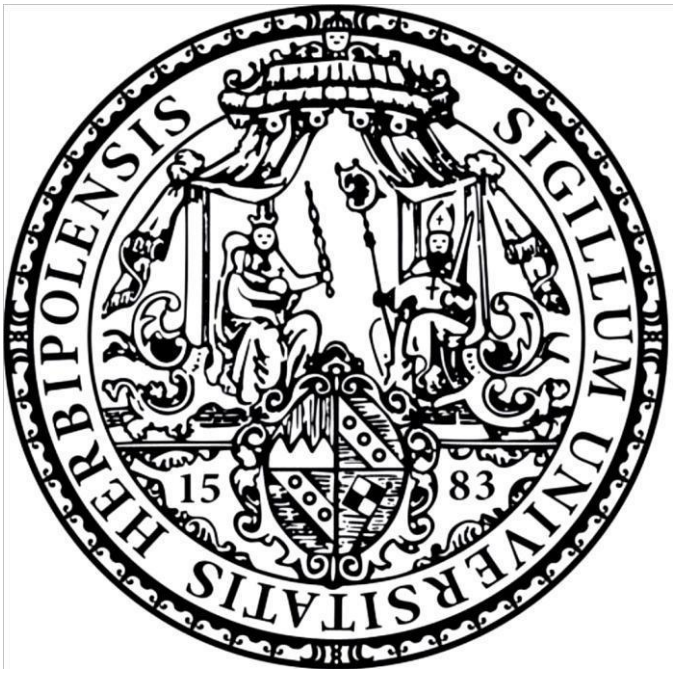
Functional properties and chemical constituents of eight underutilized Ghanaian legumes



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DEDICATION

To the memory of my parents, Nana Kwesi Kray V (known in private life as Paul Kwesi Eshun) and Mary Otoo. May you find peace, wherever you are.

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Abbreviations

AAS	Atomic absorption spectrophotometry
ACN	Acetonitrile
ADP	Adenosine-5´-diphosphate
AI	Adequate intake
ALA	Alpha linolenic acid
ATP	Adenosine-5´-triphosphate
BD	Bulk density
BCA	Biochanin A
BCA-GLU	Sissotrin
c	Concentration
CAL	Calycosin
C.c. pro	Processed *Cajanus cajan* flour
C.c. raw	Raw *Cajanus cajan* flour
C.e. pro	Processed *Canavalia ensiformis* flour
C.e. raw	Raw *Canavalia ensiformis* flour
C.g. pro	Processed *Canavalia gladiata* flour
C.g. raw	Raw *Canavalia gladiata* flour
CXP	Cell Exit Potential
DAD	Diode Array Detector
DAI	Daidzein
DAI-GLU	Daidzin

D.g. raw	Raw *Dialium guineense* flour
DNA	Deoxyribonucleic acid
DP	Declustering potential
ESI	Electrospray ionization
F-6-P	D-fructose-6-phosphate
FA	Fatty acid
FAME	Fatty Acid Methyl Ester
FAO	Food and Agriculture Organization of the United Nations
FC	Foam Capacity
FID	Flame Ionization Detector
FOR	Formononetin
FOR-GLU	Ononin
FS	Foam Stability
Gal-DH	Galactose dehydrogenase
G-6-P	D-glucose-6-phosphate
G6P-DH	Glucose-6-phosphate dehydrogenase
GC	Gas Chromatography
GEN	Genistein
GEN-GLU	Genistin
GLY	Glycitein
GLY-GLU	Glycitin

HPLC	High Performance Liquid Chromatography
IF	Isoflavone
IRI	Irilon
IS	Internal Standard
L-DOPA	L-3,4-dihydroxyphenylalanine
LA	Linoleic acid
LGC	Least Gelation Concentration
LOB	Limit of Blank
LOD	Limit of Detection
LOQ	Limit of Quantitation
MeOH	Methanol
MoH	New Zealand Ministry of Health
M.p. pro	Processed *Mucuna pruriens* flour
M.p. raw	Raw *Mucuna pruriens* flour
MRM	Multiple Reaction Monitoring
MS	Mass Spectrometry
MTBE	Methyl-tert-butylether
MUFA	Monounsaturated fatty acid
m/z	Masse/charge ratio
NAD	Nicotineamide adenine dinucleotide
NADPH	Nicotineamide adenine dinucleotide phosphate
NCD	Non-Communicable Diseases
NHMRC	National Health and Medical Research Council of Australia

OAC	Oil Absorption Capacity
o.c.	on column
ORO	Orobol
P.b. pro	Processed *Parkia biglobosa* flour
P.b. raw	Raw *Parkia biglobosa* flour
PGI	Phosphoglucoseisomerase
P.l. pro	Processed *Phaseolus lunatus* flour
P.l. raw	Raw *Phaseolus lunatus* flour
PRA	Pratensein
pro	processed
PRU	Prunetin
PRU-GLU	Prunitrin
PSE	Pseudobaptigenin
PSE-GLU	Rothindin
PUFA	Polyunsaturated fatty acid
R/2	Half Range
rel.tR	Relative retention time
RNA	Ribonucleic acid
S/N	Signal to noise ratio
SCFA	Short chain fatty acid
SFA	Saturated fatty acid
SP	Swelling Power
TMSH	Trimethylsulfonium hydroxide
tR	Retention time

UHPLC	Ultra High Performance Liquid Chromatography
UNFA	Unsaturated fatty acids
UV	Ultraviolett
6-MF	6-Methxyflavone
USAID	United States Agency for International Development
V.s. pro	Processed *Vigna subterranea* flour
V.s. raw	Raw *Vigna subterranea* flour
WAC	Water absorption capacity
WHO	World Health Organization

1 Introduction

Developing countries (Ghana inclusive) are not able to produce enough food and of the right nutritional quality to meet daily needs (Aletor & Aladetimi, 1989). In Ghana, the dearth of food supply is such that Ghana imports rice, wheat, maize, sorghum and other food products (Ministry of Food and Agriculture of Ghana, 2010). For rice for instance, Ghana imported an average of 409,000 Mt worth US$168 million between 2006 and 2008 (Ministry of Food and Agriculture of Ghana, 2010). To conserve resources for importation of food into Ghana and to create employment for its teeming unemployed young men and women, there is the need to substitute some of these imported products with local production. This calls for a study to be conducted into the potentials of some underutilized plants in Ghana for possible use as alternative sources of food. Properly harnessing and utilizing the underutilized plants may help assist to reduce poverty, hunger and undernourishment in Ghana. Some of the underutilized plants in Ghana are legumes.

In tropical countries, legumes are important major sources of protein from plant sources (Mazahib et al., 2013). They are good sources of essential amino acids (Mazahib et al., 2013), vitamins (Olalekan & Bosede, 2010), calories and carbohydrates, with starch being the most abundant carbohydrate (Aguilera et al., 2009). The industrial application of legumes depends on knowledge of their nutritional importance and functional properties (Mazahib et al., 2013). Although Ghana abounds in a variety of legumes, most of them are underutilized in food preparations because they have been inadequately investigated to come out with their potential. Some of the underutilized legumes in Ghana are *Cajanus cajan, Canavalia ensiformis, Canavalia gladiata, Dialium guineense Willd, Mucuna pruriens var. utilis, Parkia biglobosa, Phaseolus lunatus and Vigna subterranea* (Aboagye et al., 2007). Various works have been done on these legumes as reported in the literature but the bulk of the work are on legumes which are found in other countries apart from Ghana. To fill the existing gap, this study looked into the functional properties (for raw and processed flours of *Cajanus cajan, Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus Vigna subterranea* and raw flour of *Dialium guineense*), fat content and fatty acid distribution (for raw and processed flours of *Cajanus cajan*, *Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus Vigna subterranea* and raw flour of *Dialium guineense*), lower molecular weight carbohydrates (raffinose, sucrose, glucose and fructose) (for raw and processed flours of *Cajanus cajan, Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus*

Vigna subterranea and raw flour of *Dialium guineense*), mineral nutrients (for raw and processed flours of *Cajanus cajan, Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus Vigna subterranea* and raw flour of *Dialium guineense*), cyanide levels (for raw and processed flours of *Cajanus cajan, Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus Vigna subterranea* and raw flour of *Dialium guineense*), isoflavone content (for raw and processed flours of *Cajanus cajan*, *Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus Vigna subterranea* and raw flour of *Dialium guineense*) of these underutilized legume seeds (but fruits in the case of *Dialium guineense*) with regards to those from Ghana. In addition to these, the study also looked into the crude protein and starch contents of the raw and processed flours of *Canavalia gladiata, Parkia biglobosa* and *Vigna subterranea*. The results of this study may help to popularize these legumes for the successful exploitation of their potentials to help assist in reducing hunger, malnutrition and poverty in Ghana.

1.1 The Nutrition Situation in Ghana

Ghana is situated in West Africa along the Coast of the gulf of Guinea. It is bordered to the West by Ivory Coast, to the East by Togo and to the north by Burkina Faso. It is has a coastline of more than 565 km and a total land area of 238 538 km^2 (FAO, 2009). Ghana is part of the developing countries experiencing the double burden of malnutrition. The term malnutrition covers two broad groups of conditions. One is undernutrition - which includes stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and micronutrient deficiencies (a lack of important vitamins and minerals); the other condition is overweight, obesity and diet-related diseases (such as heart disease, stroke, diabetes and cancer) (WHO, 2016). There is a high prevalence of both undernutrition and overweight/obesity in Ghana (USAID, 2018). The problem of malnutrition in Ghana cuts across age groups, gender and social status. According to the Ghana Statistical Service et al. (2015), nearly 1 in every 5 children under five years in Ghana are stunted and 2 out of 3 children are anaemic. Ghana Statistical Service et al. (2015) continues that forty two per cent (42%) of women aged 15-49 are anaemic. According to USAID (2018), anaemia is a significant health problem in Ghana. According to University of Ghana et al. (2017), close to 50% of non-pregnant women are iodine deficient. Close to one-fifth of men and children between the ages 6-59 months have vitamin A deficiency in Ghana (Steiner-Asiedu, 2019; University of Ghana et al., 2017) and among non-pregnant women aged 15-49 years, 1.5% are vitamin A deficient

(Wegmüller, et al., 2020). Seven percent (7%) of women of reproductive age are deficient in vitamin B12 and more than 50% suffer from folate deficiency (Steiner-Asiedu, 2019). According to the Ghana Statistical Service et al. (2015), 5% of Ghanaian children are wasted and 11% are underweight. Steiner-Asiedu (2019) found out from her study that 32.2% of Ghanaian men are hypertensive. In Ghana, 6% of women are thin (BMI<18.5 Kg/m^2), 10% of men are thin (BMI<18.5 Kg/m^2), 40% of women are overweight/obese (BMI≥25.0 Kg/m^2) and 16% of men are overweight/obese (BMI≥25.0 Kg/m^2) (Ghana Statistical Service et al., 2015). According to the findings of Ghana Statistical Service et al. (2015), overweight/obesity increased with increasing household wealth for both men and women. There is the need to address this rise in overweight/obesity as this can lead to increases in Non-Communicable Diseases (NCDs) such as diabetes, hypertension and cardiovascular conditions (USAID, 2018). A high intake of dietary fibre, mainly from whole-grain products, reduces the risk of obesity, type 2 diabetes mellitus, dysliproteinaemia, cardiovascular disease and colorectal cancer at various extent (Hauner et al., 2012). There is the need to increase the availability and consumption of local foods (such as underutilized local legumes). This may augment the effort aimed at reducing the double burden of malnutrition as this may help in meeting the nutrients needs of the poor while at the same time reducing NCDs like hypertension and diabetes due to their high fibre content.

According to Government of Ghana (2013), young children and women are the most affected by undernutrition in Ghana, which impairs children's immune systems and places them at much greater risk of illness and death. Micronutrient deficiencies, especially of iron, iodine, and vitamin A, are of great concern and these continue to affect the health and development for all age groups in Ghana (Government of Ghana, 2013). Deficiency of iron, coupled with high malaria burden contributes to very high incidence of anaemia, particularly in women and children in Ghana (Government of Ghana, 2013). Iodine deficiency disorders (IDD) are high in Ghana and many households do not use adequately iodized salt in meal preparation. According to Chirawura et al. (2015), an estimated 120, 000 children born every year in Ghana are at risk of intellectual impairment as a result of iodine deficiency. Iodine deficiency increases the risk of still births and miscarriages in pregnant women and can results in cretinism and goitre (Ghana Health Service, 2007). In Ghana, 40% of all deaths that occur before age five are related to malnutrition (Ghana Statistical Service et al., 2005).

1.2 Legumes

Leguminous plants belong to the family Fabaceae (or Leguminosae). The family is divided into three sub-families: Papilionoideae, Mimosoideae and Caesalpinioideae (Eleni, 2014). Members of the Papilionoideae are mainly herbaceous, often annual plants, which grow throughout the world, from the tropics to high mountainous and cool regions. Most of the important legumes in human diets belong to this sub-family, amounting to about two-thirds of the Leguminosae species. Mimosoideae consist of mainly small trees and shrubs of the semi-arid tropics and subtropical regions, whereas Caesalpinioideae are mainly trees of tropical regions (Eleni, 2014). Legumes are noted for their ability to fix atmospheric nitrogen into the soil, thereby reducing fertilizer cost for farmers and gardeners who grow these plants (Oke, 2014). It is estimated that about 88% of legume species can form nitrogen-fixing nodules with rhizobia and this is responsible for up to 80% of the biological fixation of nitrogen in agricultural settings (de la Peña & Pueyo, 2012). After cereals, legumes are the most important food source (Maphosa & Jideani, 2017). In the developing world, legumes are known to offer food proteins and are generally grown under risk-prone marginal lands with low input (Saxena et al., 2010). The seeds of legumes contain as high as 20 to 50% protein, which generally runs above twice the level found in cereal grains and significantly more than the level in conventional root crops (E. A. Akande et al., 2014). The high amount of protein in legumes can be attributed to their association with activities of nitrogen-fixing bacteria in the roots of legumes; these bacteria converts nitrogen gas into ammonium which is incorporated into protein synthesis by the legume (Maphosa & Jideani, 2017). Legumes therefore play a major role in overcoming protein-calorie malnutrition in developing countries, where scarcity of animal proteins prevails. Edible legumes are also rich in other nutritional components such as essential minerals, unsaturated fatty acids and vitamins (Bamidele & Akanbi, 2013). They have abundant carbohydrates, high fibre, low fat and possess high concentration of polyunsaturated fatty acids (Gabriel et al., 2011). They have significant amount of resistant starch, making them one of the least glycaemic sources of carbohydrates (Eleni, 2014). The rate of digestion of starch from legumes is slower when compared to that of cereals and tubers (Maphosa & Jideani, 2017). Consuming legumes regularly may thus play a considerable role in reducing risk associated with Type 2 Diabetes Mellitus (Bielefeld et al., 2020). In addition to their health benefits, legumes are low-cost dietary source of protein and micronutrients (Huebbe & Rimbach, 2020). Most legumes contain only small amounts of fat (less than 3%) with oleic and linoleic acids being the main

unsaturated fatty acids, and palmitic acid the saturated fatty acid (Eleni, 2014). Legumes and cereals have complementary nutritional effects and consuming them together fulfils the need of balanced protein (Ghadge et al., 2008). The low amount of sulphur containing amino acids in legume proteins results in increased retention of calcium because hydrogen ions which results from the breakdown of sulphur containing amino acids cause bones to demineralize resulting in the excretion of calcium in the urine, thus it is not a completely negative factor (Maphosa & Jideani, 2017). Legumes contain bioactive compounds which have antioxidant properties and these compounds play useful roles in preventing some cancers, heart diseases, osteoporosis and other degenerative diseases (Maphosa & Jideani, 2017).

The major conventional legumes which are soya beans (*Glycine max*) and groundnut (*Arachis hypogaea*) have seen increased demands which has given rise to disproportionate increase in their prices (Nwaoguikpe et al., 2011). Exploitation of non-conventional legumes may help reduce the problems of food security, help agricultural development, help self-dependence and enhance the economy of developing countries (Bamidele & Akanbi, 2013) such as Ghana. Poor digestibility in the raw state and having flatulence factors in addition to some antinutritional factors make legume seeds underutilized (Ragab et al., 2010). Different individual traditional processing or combinations of the different traditional processing reduce the antinutritional factors and improve nutrients bioavailability (Ragab et al., 2010). How efficient processing might affect composition of nutrients and to which extent it will decrease antinutritional factors are still important issues to be studied (Ragab et al., 2010). Utilizing the bioactive compounds of legumes and fine tuning of their concentration to the level to serve as nutraceuticals is one of the major challenges of research in food technology (Sridhar & Niveditha, 2014). Diets based on legumes can results in healthy, longer life because the dietary components promote health (Maphosa & Jideani, 2017). For vegetarians, legumes serve as sources of high protein meat substitute (Maphosa & Jideani, 2017). Legumes lack gluten proteins and may serve as wheat alternatives for people who suffer from coeliac disease and gluten intolerance (Alviola & Monterde, 2018).

The legumes in this study are *Cajanus cajan* which belongs to the subfamily Papilionoideae (Kumar et al., 2017), *Canavalia ensiformis* which belongs to the subfamily Papilionoideae (Leon et al., 1989), *Canavalia gladiata* which belongs to the subfamily Papilionoideae (Moreno et al., 2004), *Diallium guineense* which belongs to the subfamily Caesalpiniaceae (Oni, 2013), *Mucuna*

pruriens which belongs to the subfamily Papilionoideae (Lampariello et al., 2012), *Parkia biglobosa* which belongs to the subfamily Mimosoidae (Soetan et al., 2014), *Phaseolus lunatus* which belongs to the subfamily Papilionoideae (Mercado-Ruaro & Delgado-Salinas, 2000) and *Vigna suterranea* which belongs to the subfamily Papilionoideae (Mohammed et al., 2016). In Ghana, seeds of *Cajanus cajan*, *Canavalia ensiformis*, *Canavalia gladiata*, *Mucuna pruriens*, *Phaseolus lunatus* and *Vigna suterranea* are occasionally consumed after boiling. The boiled seeds are used in stews and soups to substitute or complement meat or fish. An adult normally consumes three ladles of the beans weighing about 300 g at a sitting. For *Diallium guineense*, the fruit pulp are eaten when they are dry. An amount of 100 g of the fruit pulp of *Dialium guineense* can be eaten at a sitting by an adult. For *Parkia biglobosa*, the seeds are roasted and ground for use as a beverage or are fermented and used in stews and soups. An amount of 100 g of the roasted seed can be ground and used as a beverage or an amount of 15 g of the fermented seeds of *Parkia biglobosa* can be used in 3.5 L of soup.

It is envisaged that underutilized legumes such as the ones under this study could be sources of good quantities of undiscovered bioactive compounds that can potentially be employed in producing therapeutic, affordable, functional foods (Maphosa & Jideani, 2017).

1.2.1 Pigeonpea (*Cajanus cajan*)

Cajanus cajan (seeds shown in Plate 1 and plant shown in Plate 2) commonly called pigeonpea in English contain high levels of protein and the important amino acids methionine, lysine and tryptophan (Oke, 2014). The traditional pigeonpea cultivars and most landraces are tall and take around 180-280 days to mature (Saxena et al., 2010). It is an erect woody and annual perennial shrub predominantly grown in tropical and subtropical regions (Nanna et al., 2013). The pigeon pea plant provides several benefits to the soil such as fixing atmospheric nitrogen, adding organic matter and micro nutrients and breaking hard plough pan with its long tap root (Saxena et al., 2010). Numerous nodules are present on roots and these nodules contain Rhizobium bacteria, which fix atmospheric nitrogen (Ghadge et al., 2008). The pigeonpea plant can be grown successfully in a wide range of soil types and is capable of producing reasonable quantities of nutritive food even in the degraded soils and with minimum external inputs (Saxena et al., 2010). The fruit of the pigeonpea is a pod containing the seeds which are 3 to 5 in number. The fully grown seeds of pigeonpea when, harvested green before losing their green colour, are used as

fresh, frozen, or canned vegetable. Its broken seeds, skin, and pod walls are fed to domestic animals and the dry stems are used as domestic wood fuel (Saxena et al., 2010). Pigeonpea seeds contain some antinutritional factors. These antinutritional facors include oligosaccharides (raffinose and verbascose), polyphenols (phenols and tannins), phytolectins and enzyme inhibitors (trypsin, chymotrypsin and amylase) (Saxena et al., 2010). Pigeonpea is wonderfully rich in protein, making it an ideal supplement to traditional cereal-, banana- or tuber-based diets of most Africans which are generally protein-deficient (Odeny, 2007). The protein content is comparable with those in well-known legumes like cowpea and groundnut (Fasoyiro et al., 2010) with the crude protein content ranging between 16.59 and 29.00% (Adamu et al., 2015; O. J. Adebowale & Maliki, 2011; K. E. Akande et al., 2016; K. E. Akande et al., 2010; Bamidele & Akanbi, 2013; Okpala & Mamah, 2001; Singh et al., 2018). It is also a rich source of carbohydrates, vitamins and mineral elements (Odeny, 2007). Due to its high protein, minerals, vitamins and carbohydrates content, wide adoption of pigeonpea in Africa could play a useful role in food security, balanced diet and alleviation of poverty as an estimated 30% of children under the age of five in sub-Saharan Africa are reportedly underweight due to deficiencies in energy and nutrients (Odeny, 2007).

Plate 1: Seeds of *Cajanus cajan*

Plate 2: *Cajanus cajan* plant

1.2.2 Jack bean (*Canavalia ensiformis*)

Canavalia ensiformis (seeds shown in Plate 3 and plant shown in Plate 4) is known as the Jack bean in English. It is adapted to a wide range of environmental conditions and has the ability to produce relatively high yields of seeds having high protein content under adverse climatic and environmental conditions (Leon et al., 1989). It has deep penetrating root system which enables it to withstand very dry conditions and therefore has a great potential in regions with marginal soils and unfavourable climates which are not suitable for the more common legumes (M. A. Akpapunam & S. Sefa-Dedeh, 1997). Though it is one of the under exploited tropical dry beans, it is widely distributed, being cultivated in Africa, Asia, the West Indies, Latin America and India

(Marimuthu & Gurumoorthi, 2013). It has been used as high protein food crop by the native people of South-Western USA, Mexico, Central American countries, Brazil, Peru, Ecuador and the West Indies for many centuries (Lawal & Adebowale, 2005). Mature jack bean seeds are white in colour with a dark brown hilum and yellowish cream cotyledons contained in woody pods which measure up to 30 cm long and 2.5 cm across (M. A. Akpapunam & S. Sefa-Dedeh, 1997). Jack bean is high in essential amino acid lysine (5.73 g/16 g N), although, fairly low in methionine (Ajeigbe et al., 2012). *Canavalia ensiformis* is used as a cover crop, and the roasted seeds are ground to prepare a coffee-like drink (Rajaram & Janardhanan, 1992).

Plate 3: Seeds of *Canavalia ensiformis*

Plate 4: *Canavalia ensiformis* plant

1.2.3 Sword bean (*Canavalia gladiata*)

Canavalia gladiata (seeds shown in Plate 5 and plant shown in Plate 6) is known in English as the Sword bean. In Ghana, the seeds are called "Adua Nkrante." Sword beans are one of many underutilized but exceptionally productive, large-seeded tropical legumes (Ekanayake et al., 2007). It grows well on poor soils where most crops fail due to excellent adaptability to extreme climatic conditions, yielding about 4600 kg seeds per hectare with crude protein content of about 22-29 percent (Akinmutimi et al., 2008). Each pod which is about 30 cm long and 5 cm wide contains 10-14 seeds which are elliptical in shape and about 3 cm long (A. S. Abitogun & G. K. Oso, 2014). The amino acid profile of the mature seed compares well with that of the reference protein (casein) (Ekanayake et al., 2001). It is relatively fast growing and usually produces a crop in 3–4 months (K. O. Adebowale et al., 2006). In western countries, sword beans are used as cover crop, and the roasted seeds are ground to prepare a coffee-like drink (Rajaram & Janardhanan, 1992).

Plate 5: Seeds of *Canavalia gladiata*

Plate 6: *Canavalia gladiata* plant

1.2.4 Velvet tamarind (*Dialium guineense*)

Dialium guineense (fruits shown in Plate 7 and tree shown in Plate 8) is known in English as the velvet tamarind. *Dialium guineense* is a tall, tropical, fruit bearing tree (Niyi, 2014). The tree is 30 m high and has a densely leafy crown (Osanaiye et al. 2013). The tree is a hard wood that is economically valuable for furniture (Ogungbenle, 2015). The fruits and leaves are used for food and fodder and the wood and roots are utilized for timber and charcoal (Ajiboye & Sani, 2015). In Ghana, the fruits are called "Yooyi" by the Gas and "Akosua Tuntum" by the Akans. The pod of velvet tamarind contains the seed and sweet sour juicy pulp that is used to sweeten foods (Niyi, 2014). When mature, the fruit dries up while the pod becomes stiff and brittle (Ogungbenle & Ebadan, 2014). When the fruit is dry, it is plucked directly from the tree and de-shelled manually to obtain the fruit pulp which also contain one to three seeds. The fruit pulp is red in colour and is eaten raw in Ghana and the seeds are discarded. The pulp can be canned for marketing (Niyi, 2014) or processed into products such as cake or juice (Ayessou et al., 2014), jelly, jam and non-alcoholic beverages (Onwuka & Nwokorie, 2006). The fruit is high in ascorbic acid (Obasi et al., 2013) which is an anti-scurvy vitamin. The fruit pulp has a high carbohydrate content and can be employed for citric acid production using microorganisms that would naturally ferment it, especially fungi (Ajiboye & Sani, 2015). The stem of the plant is used as chewing stick (indigenous tooth brush) in Ghana. The plant contains saponins which presumably add to the cleaning effect and inhibit growth of microorganisms on the teeth (Okwu & Ekeke, 2003). The bark of the plant is used in medicine for naso-pharyngeal infection, stomach troubles while the leaves are used for eye and heart treatment, and pulmonary troubles (Okerulu et al., 2015).

Plate 7: Fruits of *Dialium guineense*

Plate 8: *Dialium guineense* tree

1.2.5 Velvet beans (*Mucuna pruriens*)

Mucuna pruriens (seeds shown in Plate 9 and plant shown in Plate 10) is a weak stemmed, hairy annual climber growing up to about 8 m long, having trifoliate leaves, dark purple flowers and pods with irritant hairs (Agbede & Aletor, 2005). It is called the velvet bean in English. The plant grows pods about 12 cm long that contain about 7 seeds of varied colouration from beige to brown and black, and also striped ones (Tavares et al., 2015). In Ghana, the seeds are known as "Adua Apea." In many tropical countries, *Mucuna pruriens* is valuable only as green manure or cover crop (Nwaoguikpe et al., 2011) which has also enabled the biological control of weeds, pests and diseases, while it acts to influence the composition and activity of the soil biota, particularly the earthworms (Avendaño-Yáñez et al., 2014). It has a high concentration of L-DOPA (3,4-dihydroxy L-phenylalanine) (4–7%) and is a commercial source of this substance used in the treatment of Parkinson's disease (Lampariello et al., 2012). The trichomes of pods are used for deworming, decoction of root to contain delirium, root powder as a diuretic and anti-inflammatory agent and the paste of fresh root is used in the treatment of lymphedema (Kalidass & Mahapatra, 2014).

The protein level of the seeds range between 25 and 27 percent (Okot et al., 2000). The nutritional value of this protein is however limited by the presence of antinutritional factors such as L-DOPA, protease inhibitors, amylase inhibitors, lectins, saponins, phytates, alkaloids, tannins, etc (Gurumoorthi et al., 2013; Misra & Wagner, 2004; Nyirenda et al., 2003; Siddhuraju & Becker, 2001a; Siddhuraju et al., 1996; Vijayambika et al., 2010). The most notorious of the antinutrional factors in *Mucuna pruriens* is L-DOPA which causes nausea and vomiting (Nyirenda et al., 2003). L-DOPA, though has pharmaceutical properties, is toxic when ingested by monogastrics (Huisden, 2008). The seed powder of *Mucuna pruriens* has been found to show anti-Parkinsonism effects which are probably due to the presence of L-DOPA (Misra & Wagner, 2004). This means

investigations should be directed towards the selection of germplasms with low L-DOPA for human consumption, while germplasms with high L-DOPA should be selected for pharmaceutical purposes.

Plate 9: Seeds of *Mucuna pruriens*

Plate 10: *Mucuna pruriens* plant

1.2.6 African Locust Bean (*Parkia biglobosa*)

The African Locust bean tree (*Parkia biglobosa*) (seeds shown in Plate 11 and tree shown in Plate 12) is a perennial tree legume. These trees are not normally cultivated but can be seen growing on their own in Ghana. The tree ranges in height from 7 m to 20 m and bears a large crown with branches that spread wide (Sackle & Emmanuel, 2013). The tree is a good source of timber and is useful in making pestles, mortars, bows, hoe handles, etc (Ihegwuagu et al., 2009). The plant is able to withstand drought because of its deep taproot (Builders, 2014). The seeds of the tree are covered with a hard, leathery, brown–to–black coat which can only be removed by boiling and pounding or scrubbing with sand (Aremu et al., 2015). The fermented seeds are called "dawadawa" in Ghana. "Dawadawa" which is rich in protein and fat (Builders, 2014) is black in colour with a strong smell.

Plate 11: Seeds of *Parkia biglobosa*

Plate 12: *Parkia biglobosa* tree

1.2.7 Lima beans (*Phaseolus lunatus*)

Phaseolus lunatus (seeds shown in Plate 13 and plant shown in Plate 14) is known in English as Lima beans. Lima beans are twining vines herbaceous bushes, perennial in nature, but usually grown as annual, even in the tropics (Messou et al., 2015). The pod of the Lima bean is flat, oblong and slightly curved, averaging about three inches in length with two to four flat kidney-shaped seeds (K.T. Adegbehingbe, 2013). Like other grain legumes, Lima bean is an important source of vegetable protein and it also improves soil fertility (S. R. Akande & Balogun, 2007). Lima beans consist of good source of both soluble fibre and insoluble fibre and high quality protein (Krishnaveni et al., 2014). In Ghana, the beans are called "Apatram."

Plate 13: Seeds of *Phaseolus lunatus*

Plate 14: *Phaseolus lunatus* plant

1.2.8 Bambara groundnut (*Vigna subterranea*)

Vigna subterranea (seeds shown in Plate 15 and plant shown in Plate 16) is an annual legume with small pods (pod is 1.5 cm long), round or slightly oval shaped and wrinkled with mostly one or sometimes two seeds (Elemam, 2010). It is called Bambara groundnut (named after the Bambara tribe of Mali) in English. The plant has a strong well-developed tap root and a short lateral stem on which the leaves are borne (Mabhaudhi, 2012). The plant ripens its pods underground (Oyeleke et al., 2012). The plant makes little demand on the soil and is drought resistant (Oyeleke et al., 2012). It is a nitrogen-fixing legume and therefore contributes to the maintenance of soil fertility (Ngo et al., 2015) which is important for resource poor farmers who may otherwise not be able to afford inorganic fertilizers (Mabhaudhi, 2012). The seeds of Bambara groundnut contain 63% carbohydrate, 19% proteins and 6.5% fat (Tsoata et al., 2015). In Ghana, the seeds are called "Aboboi."

Plate 15: Seeds of *Vigna subterranea*

Plate 16: *Vigna subterranea* plant

1.3 Functional properties

Legumes are nutritious foods and substituting animal protein for legumes arises from the knowledge of the functional properties of the seed flour of the legumes (O. J. Adebowale & Maliki, 2011). Processing legumes into flours is one way of adding value to increase the range of uses of legumes. The functional properties help in assessing the potential of flours in the food formulation industries. Functional properties of flours are influenced by the components of the flour such as carbohydrates, proteins, fats and oils, moisture, fibre, ash and other ingredients or food additives added to the flour and the structure of these components (Awuchi et al., 2019). These functional properties include bulk density, foaming, gelation, solubility and swelling power, water and oil absorption capacities, etc (Appiah, 2011; Mubaiwa et al., 2018; Tattiyakul et al., 2007; Tiwari et al., 2008).

Bulk density (BD) gives a measure of the mass relative to the space occupied by a food substance (Appiah, 2011). The higher the bulk density, the heavier the flour (Appiah et al., 2011) and the denser the packaging material required to package it (Awuchi et al., 2019). Heavier flours have large mass per unit volume and therefore occupy less space. This means flours with low bulk densities would occupy greater space and therefore would require more packaging material per unit weight. Table 1 presents the results of search for literature values for bulk density of the legume flours under study.

Table 1: Results of search for literature values of BD (g/ml) of legume flours. ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	0.27 – 0.69	Onimawo and Akpojovwo (2006), Mbaeyi-Nwaoha and Onweluzo (2013)	0.80	O. J. Adebowale and Maliki (2011)
Canavalia ensiformis	0.87	Ojo and Ade-Omowaye (2015)	ND	
Canavalia gladiate	ND		ND	
Dialium guineense	0.44	Obasi et al. (2013)	ND	
Mucuna pruriens	0.54	Y. A. Adebowale et al. (2005)	ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	0.66 – 0.83	Yellavila et al. (2015)	ND	
Vigna subterranea	0.52 – 0.71	Falade and Adebiyi (2015), Aremu et al. (2007)	ND	

Food foams usually consist of a gas (air) droplets dispersed in and surrounded by a liquid containing a soluble surfactant (Kinsella & Melachouris, 1976). Foaming capacity (FC) is the increase in volume upon the introduction of air or a gas into the slurry of a given food or its dispersion and foaming stability (FS) refers to the ability of the foam formed to retain its maximum volume over time (Ojo & Ade-Omowaye, 2015). Protein is the main constituent responsible for

foaming (Awuchi et al., 2019) and the foam capacity and stability depend on the interfacial film formed by proteins, which maintain air bubbles in suspension and slows down the rate of coalescence (Du et al., in press). The higher the foam capacity and stability, the better the foam enhancing ability of the flour (Appiah, Asibuo, et al., 2011). Flours with high foam capacities and stabilities will therefore be useful aerating agents in products such as bread and sponge cakes. Table 2 presents the results of search for literature values for foaming capacity of the legume flours under study.

Table 2: Results of search for literature values of FC (%) of legume flours, ND = No data available

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	25.00 – 68.00	Okpala and Mamah (2001), Oshodi and Ekperigin (1989)	8.16	O. J. Adebowale and Maliki (2011)
Canavalia ensiformis	3.70	Ojo and Ade-Omowaye (2015)	ND	
Canavalia gladiata	ND		ND	
Dialium guineense	30.00 – 43.50	Obasi et al. (2013), Ogungbenle and Ebadan (2014)	ND	
Mucuna pruriens	19.20 – 53.00	Y. A. Adebowale et al. (2005), Ahenkora et al. (1999), Bhat et al. (2008)	4.00	Ahenkora et al. (1999)
Parkia biglobosa	45.00	Abey and Abey (2016)	ND	
Phaseolus lunatus	18.67 – 35.30	Granito et al. (2007), Oshodi and Adeladun (1993), Yellavila et al. (2015)	8.30	Granito et al. (2007)
Vigna subterranea	7.90 – 18.37	Aremu et al. (2007), Falade and Adebiyi (2015), Falade and Nwajei (2015)	ND	

Table 3 presents the results of search for literature values for foam stability of the legume flours under study.

Table 3: Results of search for literature values of FS (%) of legume flours, ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	20.00	Oshodi and Ekperigin (1989)	2.45	O. J. Adebowale and Maliki (2011)
Canavalia ensiformis	1.85	Ojo and Ade-Omowaye (2015)	ND	
Canavalia gladiata	ND		ND	
Dialium guineense	62.20 – 111.00	Obasi et al. (2013), Ogungbenle and Ebadan (2014)	ND	
Mucuna pruriens	10.00 – 61.00	Y. A. Adebowale et al. (2005), Ahenkora et al. (1999), Bhat et al. (2008)	ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	8.80 – 23.20	Oshodi and Adeladun (1993)	ND	
Vigna subterranea	98.10 – 98.40	Aremu et al. (2007)	ND	

Least gelation concentration (LGC) is an index of gelation (Appiah, 2011). It measures the minimum amount of flour that is needed to form a gel in a measured volume of water (Ohizua et al., 2017). Thus, flours with high gelling abilities are those with lower LGC values. Gelation links

the macromolecular chains, resulting in the formation of a branched polymeric structure whose solubility depends on the chemical properties of the starting materials (Awuchi et al., 2019). The higher the gelling ability of the flour, the more useful is the flour in products such as puddings and sauces which require thickening and gelling (Appiah, Oduro et al., 2011; Joshi, 2012).

Table 4 presents the results of search for literature values for LGCs of the legume flours under study.

Table 4: Results of search for literature values of LGC (% w/v) of legume flours, ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	4.00 – 12.00	Onimawo and Akpojovwo (2006), Mbaeyi-Nwaoha and Onweluzo (2013), Olalekan and Bosede (2010), Oshodi and Ekperigin (1989)	ND	
Canavalia ensiformis	4.00	Olalekan and Bosede (2010)	ND	
Canavalia gladiata	ND		ND	
Dialium guineense	17.00	Ogungbenle and Ebadan (2014)	ND	
Mucuna pruriens	16.00	Bhat et al. (2008)	ND	
Parkia biglobosa	8.00	Abey and Abey (2016)	ND	

Table 4 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Phaseolus lunatus	6.00 – 12.00	Granito et al. (2007), Oshodi and Adeladun (1993)	ND	
Vigna subterranea	12.00 – 14.00	Aremu et al. (2007)	ND	

Oil absorption capacity (OAC) is the ability of food material to absorb oil (Ohizua et al., 2017). The higher the OAC, the better the ability of the flour to absorb oil for food products in which oil imbibition is desired (Appiah, Asibuo, et al., 2011). Such products include cakes, pancakes, doughnuts and sausages. High OAC in flours make them suitable as flavour enhancers in food systems (Appiah, Asibuo, et al., 2011). Hydrophobic proteins play the main role in the absorption of oil, the mechanism of which is through capillary action (Du et al., in press). Legume flours that exhibit higher OAC likely contain a higher amount of available non-polar side chains in their protein molecules (Du et al., in press). The mechanism of oil absorption often involves capillary interactions in the food matrix which allows the retention of the oil absorbed (Awuchi et al., 2019).

Table 5 presents the results of search for literature values for OACs of the legume flours under study.

Table 5: Results of search for literature values of OAC (g/g) of legume flours, ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	0.90 – 2.66	Acevedo et al. (2017), Mbaeyi-Nwaoha and Onweluzo (2013), Okpala and Mamah (2001), Olalekan and Bosede (2010), Onimawo and Akpojovwo (2006), Oshodi and Ekperigin (1989)	1.11	Acevedo et al. (2017)
Canavalia ensiformis	0.10 – 1.18	Acevedo et al. (2017), Ojo and Ade-Omowaye (2015), Olalekan and Bosede (2010)	1.63	Acevedo et al. (2017)
Canavalia gladiata	ND		ND	
Dialium guineense	1.62	Ogungbenle and Ebadan (2014)	ND	
Mucuna pruriens	0.76 – 2.25	Y. A. Adebowale et al. (2005), Ahenkora et al. (1999)	0.86	Ahenkora et al. (1999)

Table 5 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Parkia biglobosa	ND		ND	
Phaseolus lunatus	0.80 – 0.92	Granito et al. (2007), Oshodi and Adeladun (1993)	0.60	Granito et al. (2007)
Vigna subterranea	0.86 – 2.82	Acevedo et al. (2017), Aremu et al. (2007), Falade and Adebiyi (2015)	ND	

Flour solubility is the quantity of flour that dissolves in solution, often with water as the solvent (Awuchi et al., 2019). The water solubility of flours is an index of solubility of its molecules (Yellavila et al., 2015). The extent of solubility of flour in a specific solvent is usually measured as the saturation concentration, at which point addition of addition more solutes does not increase the concentration of the solution but rather starts the precipitation of excess amount of solute (Awuchi et al., 2019). The higher the solubility, the more digestible the flour (Appiah, Oduro, et al., 2011) which may potentially make the flour excellent for infant formula and food (Awuchi et al., 2019). A product with higher solubility will permit better digestibility. This is very important in the feeding of infants during weaning from lactose-based milk diet to starch and protein-based diets.

Table 6 presents the results of search for literature values for solubilities of the legume flours under study.

Table 6: Results of search for literature values of solubility (g/g) of legume flours, ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	ND		ND	
Canavalia ensiformis	ND		ND	
Canavalia gladiata	0.36	Ekanayake et al. (2006)	ND	
Dialium guineense	ND		ND	
Mucuna pruriens	ND		ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	ND		ND	
Vigna subterranea	ND		ND	

Swelling power (SP) gives an indication of the increase in the volume of flour after absorbing water (Ojo & Ade-Omowaye, 2015). The higher the SP, the better the ability of the flour to swell to improve the consistency of food. High SP is important in products such as noodles.

Table 7 presents the results of search for literature values for SPs of the legume flours under study.

Table 7: Results of search for literature values of swelling power of legume flours, ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	ND		0.07	O. J. Adebowale and Maliki (2011)
Canavalia ensiformis	ND		ND	
Canavalia gladiata	ND		ND	
Dialium guineense	ND		ND	
Mucuna pruriens	ND		ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	ND		ND	
Vigna subterranea	ND		ND	

Water absorption characteristics represent the ability of a product to associate with water under limiting water conditions such as in doughs and pastes (Giami, 1993) and an indication of the amount of water available for gelatinization (Edema et al., 2005). Imbibing water is important in foods such as sausages, custards and doughs (Jagannadham & Parimalavalli, 2015). Imbibition of water enable bakers to add more water to doughs in order to improve handling characteristics and maintain freshness in bread.

Table 8 presents the results of search for literature values for Water absorption capacity (WAC) (ml/g) of the legume flours under study.

Table 8: Results of search for literature values of WAC (ml/g) of legume flours, ND = No data available.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	1.00 – 7.50	Acevedo et al. (2017), Mbaeyi-Nwaoha and Onweluzo (2013), Okpala and Mamah (2001), Olalekan and Bosede (2010), Onimawo and Akpojovwo (2006), Oshodi and Ekperigin (1989)	1.42 – 1.74	Acevedo et al. (2017), O. J. Adebowale and Maliki (2011)
Canavalia ensiformis	0.29 – 1.50	Acevedo et al. (2017), Ojo and Ade-Omowaye (2015), Olalekan and Bosede (2010)	2.99	Acevedo et al. (2017)
Canavalia gladiata	2.30	Ekanayake et al. (2006)	ND	
Dialium guineense	2.38 – 2.50	Obasi et al. (2013), Ogungbenle and Ebadan (2014)		
Mucuna pruriens	1.40 – 2.17	Y. A. Adebowale et al. (2005), Ahenkora et al. (1999), Bhat et al. (2008)	1.56	Ahenkora et al. (1999)
Parkia biglobosa	2.62 – 3.80	Abey and Abey (2016), Sankhon et al. (2014)	ND	

Table 8 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Phaseolus lunatus	0.88 – 1.42	Granito et al. (2007), Oshodi and Adeladun (1993), Yellavila et al. (2015)	2.40	Granito et al. (2007)
Vigna subterranea	0.45 – 2.40	Aremu et al. (2007), Falade and Adebiyi (2015), Falade and Nwajei (2015)	ND	

1.4 Food constituents

1.4.1 Fats and fatty acids

Fats and oils are important food source for man and represent the highest source of energy per unit weight that man can consume (Asuquo et al., 2012). Fat carries fat-soluble vitamins and other solutes (sterols, carotenoids, squalene), acts as a storage form of energy (depot fat), and serves as an insulator (Beare-Rogers et al., 2001). Fats and oils supply fatty acids. The fatty acids composition of plant species has nutritional, biochemical and technological importance (Scrob et al., 2013). In evaluating the nutritional quality of oils, fatty acid composition occupies a special place because of the fact that certain fatty acids are linked to hyperlipidemic and cholesterolemic effects in the body (Ezeagu et al., 2005). Fatty acids composition of vegetable oils is formed by a mixture of saturated fatty acids (SFAs) and unsaturated fatty acids (UNFAs); fatty acids (FAs) are classified mostly according to the presence or absence of double bonds as saturated (SFAs—without double bonds), monounsaturated (MUFAs—with one double bond) and polyunsaturated fatty acids (PUFAs—with two or up to six double bonds) (Orsavova et al., 2015). UNFAs can exist in a *cis*- or *trans*-configuration. The former configuration is found in most naturally occurring UNFAs, the latter configuration is the result of technology processing, such as hydrogenation (Orsavova et al., 2015). In cis-FAs, the two hydrogen atoms on the carbon-carbon double bond are on the same side of the double bond but in trans-FAs, the two hydrogen atoms on the double bond

are on the opposite sides of the double bond (White, 2009). SFAs are very stable but UNFAs are susceptible to oxidation with oxidation susceptibility increasing with increasing number of double bonds (Rustan & Drevon, 2005). UNFAs should therefore be kept away from oxidants and compounds which give rise to formation of free radicals (Rustan & Drevon, 2005). Saturated and trans fats consumption is harmful to human health and can increase the cardiovascular risks and coronary heart disease in consumers (Carrillo et al., 2017; White, 2009).

Palmitic acid (C16:0) is the most common SFA in animals, plants and microorganisms (Rustan & Drevon, 2005). Stearic acid (C18:0) is a major FA in animals but in most plants, it is a minor component (Rustan & Drevon, 2005). The most common monoenoic FA in plants and animals is oleic acid (C18:1 n-9c) (Rustan & Drevon, 2005). In plant lipids, linoleic acid (C18:2 n-6c) is a major FA (Rustan & Drevon, 2005).

Linoleic acid (LA) and alpha-linolenic acids (ALA) are two traditionally recognized essential fatty acids (EFAs) (Bradbury, 2011). LA and ALA are parent compounds of the omega- 6 (n-6) and omega-3 (n-3) families of essential fatty acids (Beare-Rogers et al., 2001). The EFAs are a necessary part of the human diet because the body has no biochemical pathway to produce these molecules on its own (White, 2009). The omega-6 fatty acids are sometimes described as ω 6 fatty acids. The pattern of cis-double bond is methylene (CH_2) interrupted and starts at the sixth carbon atom from the methyl (CH_3) end (Beare-Rogers et al., 2001). Examples of these fatty acids are linoleic acid, γ-linolenic acid and arachidonic acid. The omega-3 fatty acids are sometimes described as ω 3 fatty acids. The pattern of cis double bonds is methylene (CH_2) interrupted and starts at the third carbon from the methyl (CH_3) end (Beare-Rogers et al., 2001). Examples of these fatty acids are ALA, Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA). The essential ω 3 and ω 6 fatty acids are important for the growth and development of foetus, particularly for the central nervous system, affecting visual acuity and cognitive function (Rustan & Drevon, 2005). Lack of EFAs promotes skin inflammation and delays healing of wounds (Rustan & Drevon, 2005).

Table 9 (9a to 9h) presents the results of search for literature values for fatty acids of the legume flours under study.

Table 9a: FA profile (% total FA) of fatty acids from literature for *Cajanus cajan*

Fatty acid	Raw flour	
	Range of values	References
C8:0	0.50	Oshodi et al. (1993)
C12:0	0.10	Oshodi et al. (1993)
C14:0	0.20 – 0.31	Ade-Omowaye et al. (2015), Oshodi et al. (1993)
C16:0	21.40 – 33.62	Ade-Omowaye et al. (2015), Jayadeep et al. (2009), Oshodi et al. (1993), Spoladore and Teixeira (1987)
C16:1	0.30	Oshodi et al. (1993)
C18:0	1.20 – 7.60	Ade-Omowaye et al. (2015), Jayadeep et al. (2009), Oshodi et al. (1993), Spoladore and Teixeira (1987)
C18:1 n-9c	1.60 – 13.72	Ade-Omowaye et al. (2015), Jayadeep et al. (2009), Oshodi et al. (1993), Spoladore and Teixeira (1987)
C18:2 n-6c	35.75 – 58.90	Ade-Omowaye et al. (2015), Jayadeep et al. (2009), Oshodi et al. (1993), Spoladore and Teixeira (1987)
C20:1 n9	0.20 – 0.26	Ade-Omowaye et al. (2015), Oshodi et al. (1993)
C18:3 n3	3.90 – 20.34	Ade-Omowaye et al. (2015), Jayadeep et al. (2009), Oshodi et al. (1993), Spoladore and Teixeira (1987)
C22:0	1.31	Ade-Omowaye et al. (2015)
C22:1 n9	2.50	Oshodi et al. (1993)

Table 9b: FA profile (% total FA) of fatty acids from literature for *Canavalia ensiformis*

Fatty acid	Raw flour	
	Range of values	References
C12:0	0.12 – 0.20	Gaydou et al. (1992), Siddhuraju and Becker (2001b)
C14:0	0.40 – 0.51	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Siddhuraju and Becker (2001b)
C16:0	14.80 – 21.77	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C16:1	2.02 – 9.44	Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C17:1	0.11	Siddhuraju and Becker (2001b)
C18:0	1.40 – 7.37	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C18:1 n-9c	35.36 – 54.20	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C18:2 n-6t	0.03	Siddhuraju and Becker (2001b)
C18:2 n-6c	7.40 – 30.11	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C20:0	0.70 – 1.08	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994)
C20:1 n9	1.18 – 2.40	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994)
C18:3 n3	5.09 – 13.26	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C21:0	0.07	Siddhuraju and Becker (2001b)

Table 9b continued

Fatty acid	Raw flour	
	Range of values	References
C20:2	0.24	Siddhuraju and Becker (2001b)
C22:0	0.30 – 1.97	Gaydou et al. (1992), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b)
C22:1 n9	0.18 – 3.00	Gaydou et al. (1992), Siddhuraju and Becker (2001b)
C23:0	0.16	Siddhuraju and Becker (2001b)
C22:2	0.03	Siddhuraju and Becker (2001b)
C24:0	1.60 – 2.00	Ade-Omowaye et al. (2015), Gaydou et al. (1992), Siddhuraju and Becker (2001b)
C24:1 n9	0.06	Siddhuraju and Becker (2001b)
**C22:4 n6*	0.04	Siddhuraju and Becker (2001b)
**C22:5 n3*	0.45	Siddhuraju and Becker (2001b)
**C26:0*	0.58	Siddhuraju and Becker (2001b)

Table 9c: FA profile (% total FA) of fatty acids from literature for *Canavalia gladiata*

Fatty acid	Raw flour	
	Range of values	References
C12:0	0.17 – 0.21	Siddhuraju and Becker (2001b)
C10:0	0.16	Siddhuraju and Becker (2001b)
C14:0	0.55 – 0.72	Siddhuraju and Becker (2001b)
C16:0	16.71 – 47.27	Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)
C16:1	2.52 – 2.79	Siddhuraju and Becker (2001b)
C17:1	0.25 – 0.31	Siddhuraju and Becker (2001b)

Table 9c continued

Fatty acid	Raw flour	
	Range of values	References
C18:0	0.82 – 11.03	Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)
C18:1 n-9c	22.47 – 53.40	Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)
C18:2 n-6t	0.04	Siddhuraju and Becker (2001b)
C18:2 n-6c	10.74 – 22.27	Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)
C20:0	0.76 – 0.78	Siddhuraju and Becker (2001b)
C20:1 n9	1.01 – 1.35	Siddhuraju and Becker (2001b)
C18:3 n3	2.68 – 8.49	Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)
C20:2	0.16 – 1.24	Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)
C22:0	0.45 – 0.48	Siddhuraju and Becker (2001b)
C22:1 n9	0.17 – 0.18	Siddhuraju and Becker (2001b)
C23:0	0.15 – 0.15	Siddhuraju and Becker (2001b)
C24:0	1.19 – 1.53	Siddhuraju and Becker (2001b)
C24:1 n9	0.07 – 0.11	Siddhuraju and Becker (2001b)
**C22:4 n6*	0.04 – 0.08	Siddhuraju and Becker (2001b)
**C22:5 n3*	0.63	Siddhuraju and Becker (2001b)
**C26:0*	0.63 – 1.05	Siddhuraju and Becker (2001b)

Table 9d: FA profile (% total FA) of fatty acids from literature for *Dialium guineense*

Fatty acid	Raw flour	
	Range of values	References
C12:0	11.90	Ogungbenle (2014)
C14:0	10.80	Ogungbenle (2014)
C16:0	0.76	Ogungbenle (2014)
C18:0	1	Ogungbenle (2014)
C18:1 n-9c	1.02	Ogungbenle (2014)
C18:2 n-6c	0.27	Ogungbenle (2014)

Table 9e: FA profile (% total FA) of fatty acids from literature for *Mucuna pruriens*

Fatty acid	Raw flour	
	Range of values	References
C16:0	20.00 – 20.16	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C16:1	1.72	Siddhuraju et al. (1996)
C18:0	3.84 – 12.29	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C18:1 n-9c	14.28 – 28.71	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C18:2 n-6c	37.14 – 44.48	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C20:0	1.80 – 2.54	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C18:3 n3	3.28 – 5.31	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C22:0	0.73 – 0.94	Ezeagu et al. (2005), Siddhuraju et al. (1996)
C16:1 n9	0.1	Ezeagu et al. (2005)

Table 9f: FA profile (% total FA) of fatty acids from literature for *Parkia biglobosa*

Fatty acid	Raw flour	
	Range of values	References
C14:0	3.70	Aremu, Ibrahim, et al. (2015)
C16:0	9.40 – 25.15	Aremu, Ibrahim, et al. (2015), J. A. Cook et al. (2000), Glew et al. (1997)
C16:1	7.72	Aremu, Ibrahim, et al. (2015)
C17:0	1.49	Aremu, Ibrahim, et al. (2015)
C18:0	7.40 – 18.25	Aremu, Ibrahim, et al. (2015), J. A. Cook et al. (2000), Glew et al. (1997)
C18:1 n-9c	12.26 – 23.85	Aremu, Ibrahim, et al. (2015), J. A. Cook et al. (2000), Glew et al. (1997)
C18:2 6 n-6c	11.19 – 60.98	Aremu, Ibrahim, et al. (2015), J. A. Cook et al. (2000), Glew et al. (1997)
C20:0	1.77 – 3.56	Aremu, Ibrahim, et al. (2015), J. A. Cook et al. (2000), Glew et al. (1997)
C18:3 n3	0.80 – 1.37	Aremu, Ibrahim, et al. (2015), J. A. Cook et al. (2000), Glew et al. (1997)
C22:0	0.49	Aremu, Ibrahim, et al. (2015)
C22:1 n9	12.92	Aremu, Ibrahim, et al. (2015)
C20:4 n6	2.72	Aremu, Ibrahim, et al. (2015)
C24:0	0.15	Aremu, Ibrahim, et al. (2015)

Table 9g: FA profile (% total FA) of fatty acids from literature for *Phaseolus lunatus*

Fatty acid	Raw flour	
	Range of values	References
C12:0	0.06	Ologhobo and Fetuga (1983)
C14:0	0.18 – 1.90	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983)
C14:1	0.26	Ologhobo and Fetuga (1983)
C16:0	13.80 – 26.30	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983), Vijayakumari et al. (1993)
C16:1	1.91 – 11.90	Ezeagu and Ibegbu (2010), Ologhobo and Fetuga (1983), Vijayakumari et al. (1993)
C17:0	0.4	Gaydou et al. (1983)
C18:0	3.49 – 7.77	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983), Vijayakumari et al. (1993)
C18:1 n-9c	5.95 – 22.56	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983), Vijayakumari et al. (1993)
C18:2 n-6c	23.42 – 47.90	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983), Vijayakumari et al. (1993)
C20:0	0.66 – 4.53	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983)
C20:1 n9	0.10 – 0.70	Gaydou et al. (1983), Ologhobo and Fetuga (1983)
C18:3 n3	7.85 – 22.10	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983), Vijayakumari et al. (1993)
C22:0	0.37 – 1.58	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983)
C22:1 n9	1.26	Ologhobo and Fetuga (1983)

Table 9g continued

Fatty acid	Raw flour	
	Range of values	References
C24:0	1.41 – 2.00	Ezeagu and Ibegbu (2010), Gaydou et al. (1983), Ologhobo and Fetuga (1983)
C18:1 n-7	1.70 – 3.47	Ezeagu and Ibegbu (2010), Gaydou et al. (1983)

Table 9h: FA profile (% total FA) of fatty acids from literature for *Vigna subterranea*

Fatty acid	Raw flour	
	Range of values	References
C14:0	0.71 – 0.27	Ade-Omowaye et al. (2015)
C16:0	20.57 – 23.27	Ade-Omowaye et al. (2015), Aremu et al. (2013), Yao et al. (2015)
C16:1	0.30	Yao et al. (2015)
C17:0	0.70	Yao et al. (2015)
C18:0	7.12 – 7.92	Ade-Omowaye et al. (2015), Yao et al. (2015)
C18:1 n-9c	7.54 – 22.61	Ade-Omowaye et al. (2015), Aremu et al. (2013), Yao et al. (2015)
C18:2 n-6c	34.04 – 43.71	Ade-Omowaye et al. (2015), Aremu et al. (2013), Yao et al. (2015)
C20:0	<1.00 – 2.07	Ade-Omowaye et al. (2015), Aremu et al. (2013), Yao et al. (2015)
C20:1 n9	0.31 – 0.55	Ade-Omowaye et al. (2015), Aremu et al. (2013), Yao et al. (2015)
C18:3 n3	1.30 – 3.07	Ade-Omowaye et al. (2015), Yao et al. (2015)
C20:2	0.07	Yao et al. (2015)
C22:0	<1.00 – 5.41	Ade-Omowaye et al. (2015), Aremu et al. (2013), Yao et al. (2015)

Table 9h continued

Fatty acid	Raw flour	
	Range of values	References
C20:4 n6	0.05	Yao et al. (2015)
C24:0	1.05 – 1.86	Ade-Omowaye et al. (2015), Yao et al. (2015)

1.4.2 Carbohydrates

1.4.2.1 Starch

Starch which is produced as a reserve carbohydrate in plants is a major energy supply for humans the world over (Bertoft, 2017). Starch is found in the chloroplast of the leaves and amylopasts of storage structures like seeds and tubers (Wang et al., 1998). It is the only food polysaccharide occuring naturally which the intrinsic enzymes of the human gastrointestinal tract can digest (Topping et al., 2003). Granules of starch is made up almost entirely of two major polysaccharides, amylose and amylopection, both of which consists of α-(1, 4)-linked D-glucose interconnected through α-(1, 6)-glucosidic linkages (Bertoft, 2017). Although the main role of starch is its inclusion in the diet as a high-calorie food source, it is also used in food manufacturing because it improves the functional properties of foods such as gelling and pasting (Wang et al., 1998). Starch as a polysaccharide has to be split into its monosaccharide units before it can be absorbed by humans (Aller et al., 2011). Starch is a glucose polymer (Magallanes-Cruz et al., 2017) and often contains more than 100,000 glucose units (Quezada-Calvillo et al., 2007). Starch is not normally absorbed by the small intestine and the need for digestion through hydrolysis to the monosaccharides constituting it is very important for utilization of starch (Holmes, 1971). The monosaccharide in starch is glucose. Humans and animals store glucose from starch in the form of glycogen. Many cells in the body (e.g. the red blood cells) prefer glucose as a source of energy and glycogen breaks down quickly to produce glucose when energy is needed by the body cells.

Table 10 presents the results of search for literature values for starch in the legume flours under study.

Table 10: Results of search for literature values of starch (g/100 g) of legume flours. Values with asterisk (*) are on dry weight basis, ND = No data found

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	20.65	Ade-Omowaye et al. (2015)	*39.50 – 41.70	Apata (2008)
Canavalia ensiformis	25.05 – 33.25	Ade-Omowaye et al. (2015), Siddhuraju and Becker (2001b)	*32.8	Apata (2008)
Canavalia gladiata	29.16 – 34.61	Siddhuraju and Becker (2001b), Spoladore and Teixeira (1987)	ND	
Dialium guineense	ND		ND	
Mucuna pruriens	ND		ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	67.72	Ezeagu and Ibegbu (2010)	*40.30 – 44.60	Apata (2008), Ologhobo and Fetuga (1988)
Vigna subterranea	11.50 – 50.20	Ade-Omowaye et al. (2015), Yao et al. (2015)	*40 – 41.20	Apata (2008)

1.4.2.2 Raffinose, sucrose, glucose and fructose

Raffinose is a trisaccharide containing galactose linked by α (1→6) bond to the glucose unit of sucrose. Its formula is $C_{18}H_{32}O_{16}$ (Chuang, 1970). It is indigestible to humans and monogastric animals (Valentine et al., 2017). Raffinose contains the α-galactosidic linkage which is not digestible by humans (Apata, 2008) as the appropriate endogenous enzymes, α-galactosidases are lacking (Bravo et al., 1999). Raffinose therefore reaches the colon where it is fermented to produce short chain fatty acids (SCFA), CO_2, H_2 and, in some individuals, CH_4 (Bravo et al., 1999).

Because they produce these gases and cause flatulence that can lead to stomach discomfort, abdominal rumblings, cramps, pain and diarrhea (Kannan et al., 2018), they are considered as antinutrients (Emire, 2005). On the other hand, raffinose has been found to significantly increase beneficial microbiota *Bifidobacterium* and decreasing fecal putrefactive products such as p-cresol, indole and succinic acid (Kruger et al., 2017). Therefore, removal of or reduction of the amount of raffinose in food before consumption should depend on the purpose for which the food is supposed to serve – either to improve the beneficial bacteria population in which case much of the raffinose should remain or to reduce the flatulence factor in which case much of the raffinose should be removed. Raffinose is the most abundant oligosaccharide in the plant world after sucrose, occurring in high concentrations in dormant leguminous seeds in amounts equal to or greater than the amount of sucrose and some other plant storage organs (Chuang, 1970).

Table 11 presents the results of search for literature values for raffinose in the legume flours under study.

Table 11: Results of search for literature values of raffinose (g/100 g) of legume flours. Values with asterisk (*) are on dry weight basis, ND = No data found

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	*0.46 – 0.50	Apata (2008)	*0.40 – 0.45	Apata (2008)
Canavalia ensiformis	0.34 – 0.86	Revilleza et al. (1990)	*0.51	Apata (2008)
Canavalia gladiata	0.91 – 1.53	Revilleza et al. (1990), Vadivel et al. (2010)	0.62	Vadivel et al. (2010)
Dialium guineense	ND		ND	
Mucuna pruriens	1.12 – 1.40	Revilleza et al. (1990)	ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	0.93 – 1.11	Revilleza et al. (1990)	*0.56 – 2.23	Apata (2008), Ologhobo and Fetuga (1983)
Vigna subterranea	*0.22 – 0.27	Apata (2008)	*0.53 – 0.61	Apata (2008)

Sucrose is a disaccharide made up of one molecule of glucose and one molecule of fructose. Its chemical formula is $C_{12}H_{22}O_6$. It is the major transport form of assimilates in plants (Ciereszko, 2018). It is the major product of photosynthesis in many higher plants and is transported from the source tissue through the phloem to various sink tissues to support plant growth, development and reproduction (de Maria Felix et al., 2009).

Table 12 presents the results of search for literature values for sucrose in the legume flours under study.

Table 12: Results of search for literature values of sucrose (g/100 g) of legume flours. Values with asterisk (*) are on dry weight basis, ND = No data found

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	*2.01 – 2.25	Apata (2008)	*1.75 – 1.82	Apata (2008)
Canavalia ensiformis	1.49 – 2.47	Revilleza et al. (1990)	*1.87	Apata (2008)
Canavalia gladiate	2.57	Revilleza et al. (1990)	ND	
Dialium guineense	2.95	Ayessou et al. (2014)	ND	
Mucuna pruriens	2.37 – 2.60	Revilleza et al. (1990)	ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	1.68 – 2.02	Revilleza et al. (1990)	1.19 – 1.44	Apata (2008), Ologhobo and Fetuga (1983)
Vigna subterranea	*3.02 – 3.76	Apata (2008)	*1.42 – 1.74	Apata (2008)

Glucose also called dextrose is a monosaccharide (simple sugar). It is the major free sugar circulating in the blood of higher animals. Its chemical formula is $C_6H_{12}O_6$. It is the source of energy in cell function, and the regulation of its metabolism is of great importance.

Table 13 presents the results of search for literature values for glucose in the legume flours under study.

Table 13: Results of search for literature values of glucose (g/100 g) of legume flours. Values with asterisk (*) are on dry weight basis, ND = No data found

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	*0.09 – 0.14	Apata (2008)	*0.05 – 0.09	Apata (2008)
Canavalia ensiformis	*0.1	Apata (2008)	*0.08	Apata (2008)
Canavalia gladiata	ND		ND	
Dialium guineense	17.65	Ayessou et al. (2014)	ND	
Mucuna pruriens	ND		ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	*0.07 – 0.09	Apata (2008), Ologhobo and Fetuga (1983)	*0.04 – 0.06	Apata (2008), Ologhobo and Fetuga (1983)
Vigna subterranea	*0.09 – 0.13	Apata (2008)	*0.04 – 0.05	Apata (2008)

Fructose also called fruit sugar is a monosaccharide and an isomer of glucose. Its chemical formula is thus $C_6H_{12}O_6$. The most apparent sensory property of sugars such as glucose, fructose and sucrose is their sweetness (Zaitoun et al. 2018). At equal molarity, glucose is only 74% as sweet as sucrose to the human palate (VandenLangenberg et al., 2012). Fructose is 30% sweeter than sucrose and is considered as the sweetest natural sugar in the world (Mejia-Barajas et al., 2018).

Table 14 presents the results of search for literature values for fructose in the legume flours under study.

Table 14: Results of search for literature values of fructose (g/100 g) of legume flours. Values with asterisk (*) are on dry weight basis, ND = No data found

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	*0.29 – 0.40	Apata (2008)	*0.18 – 0.28	Apata (2008)
Canavalia ensiformis	*0.24	Apata (2008)	*0.13	Apata (2008)
Canavalia gladiata	ND		ND	
Dialium guineense	15.9	Ayessou et al. (2014)	ND	
Mucuna pruriens	ND		ND	
Parkia biglobosa	ND		ND	
Phaseolus lunatus	*0.40 – 0.82	Apata (2008), Ologhobo and Fetuga (1983)	*0.21 – 0.60	Apata (2008), Ologhobo and Fetuga (1983)
Vigna subterranea	*0.84 – 0.90	Apata (2008)	*0.36 – 0.49	Apata (2008)

1.5 Ash and Minerals

Ash refers to the inorganic residue which remains after either ignition or complete oxidation of organic matter in a foodstuff (Afify et al., 2017). Ash content represents the total mineral content in foods and ashing is the first step in preparing a food sample for specific elemental analysis. Minerals together with vitamins make up micronutrients. Micronutrient deficiencies are a major public health problem in many developing countries, with infants and pregnant women especially at risk (Batra & Seth, 2002). The micronutrients are needed in small quantities. The vitamins are organic in nature but the minerals are inorganic. Minerals are inorganic substances usually required in small amounts from less than 1 to 2500 mg per day, depending on the mineral; they are present in all body tissues and fluids and their presence is necessary for the maintenance of certain physicochemical processes which are essential to life (Soetan et al., 2010). Mineral nutrients

represents about 5-6% of the total body weight (Celep et al., 2017). Some of the minerals important in human nutrition are calcium, magnesium, sodium, potassium, iron, zinc, copper and manganese. Antinutritional factors in plants can affect the absorption and availability of some minerals by humans and animals (Soetan et al., 2010). There is therefore the need for adequate processing to reduce the antinutritional factors in plants used as human foods and animal feeds.

Mineral elements play important roles in health and diseased conditions of humans (Soetan et al., 2010). For instance iron deficiency causes varying degrees of impairment in cognitive performance, lowered work capacity, lowered immunity to infections, and pregnancy complications (Batra & Seth, 2002). Maternal iron deficiency is associated with low birth weight, premature delivery, and a host of perinatal complications, especially haemorrhage with children born to such mothers being more likely to have low iron stores and suffer from impaired physical and cognitive development, and to have suboptimal immune systems (Bailey et al., 2015). Iron functions in haemoglobin in the transport of oxygen. Table 15 presents the results of search for literature values for iron in the legume flours under study.

Table 15: Results of search for literature values of iron (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	2.54 – 36.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), R.A. Oloyo (2002), Oloyo (2004), Oshodi et al. (1993), Sangronis and Machado (2007)	4.43 – 5.32	Apata and Ologhobo (1994), R.A. Oloyo (2002)
Canavalia ensiformis	3.51 – 18.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b), V. Vadivel and K. Janardhanan (2001)	4.43 – 5.21	Agbede and Aletor (2005), Apata and Ologhobo (1994)

Table 15 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Canavalia gladiata	3.42 – 45.20	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	5.03	A.S. Abitogun and G.K. Oso (2014)
Dialium guineense	2.63 – 1910.00	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Ogungbenle (2015), Oladejo (2009)	ND	
Mucuna pruriens	7.90 – 11.87	Agbede and Aletor (2005), Kala and Mohan (2010), Mugendi et al. (2010)	7.22	Agbede and Aletor (2005)

Table 15 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Parkia biglobosa	0.10 – 3.40	Aremu, Awala, et al. (2015), Ijarotimi and Keshinro (2012), G. Oboh and Ekperigin (2004), Olakunle and Adebola (2012), Sankhon et al. (2014)	ND	
Phaseolus lunatus	2.09 – 16.90	Adeparusi (2001), Akpapunam (1985), Apata and Ologhobo (1994), Granito et al. (2007), Kathirval and Kumudha (2011), Meredith and Thomas (1982)	5.06 – 11.43	Akpapunam (1985), Apata and Ologhobo (1994), Granito et al. (2007)
Vigna subterranea	1.69 – 18.51	Amarteifio et al. (2006), Mazahib et al. (2013), Ndidi et al. (2014), Olaleye et al. (2013), Oyeleke et al. (2012)	1.58 – 3.87	Mazahib et al. (2013), Ndidi et al. (2014)

Copper is necessary for normal biological activities of amino-oxides and tyrosinase enzymes which are required for the catalytic conversion of tyrosine to melanin, the vital pigment located beneath the skin, which protects the skin from dangerous radiation (Hashmi et al., 2007). Clinical disorders associated with copper deficiencies include anaemia, bone disorders, neonatal ataxia, depigmentation and abnormal growth of hair, fur or wool, impaired growth and reproductive performance, heart failure and gastrointestinal disturbances (Soetan et al., 2010). Table 16 presents the results of search for literature values for copper in the legume flours under study.

Table 16: Results of search for literature values of copper (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	0.96 – 56.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), R.A. Oloyo (2002), Oloyo (2004), Oshodi et al. (1993), Sangronis and Machado (2007)	0.99 – 1.12	Apata and Ologhobo (1994), R.A. Oloyo (2002)
Canavalia ensiformis	0.44 – 26.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b), V. Vadivel and K. Janardhanan (2001)	0.62 – 2.02	Agbede and Aletor (2005), Apata and Ol oghobo (1994)

Table 16 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Canavalia gladiata	0.68 – 5.51	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	3.41	A.S. Abitogun and G.K. Oso (2014)
Dialium guineense	0.67 – 15.10	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Oladejo (2009)	ND	
Mucuna pruriens	0.40 – 5.49	Agbede and Aletor (2005), Ahenkora et al. (1999), Kala and Mohan (2010), Mugendi et al. (2010)	0.40 – 1.75	Agbede and Aletor (2005), Ahenkora et al. (1999)
Parkia biglobosa	0.08 – 4.15	Aremu, Awala, et al. (2015), Ijarotimi and Keshinro (2012)	ND	

Table 16 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Phaseolus lunatus	0.33 – 9.67	Adeparusi (2001), Apata and Ologhobo (1994), Kathirval and Kumudha (2011), Meredith and Thomas (1982)	0.47 – 0.68	Apata and Ologhobo (1994)
Vigna subterranea	0.28 – 4.61	Amarteifio et al. (2006), Mazahib et al. (2013), Ndidi et al. (2014)	0.17 – 3.05	Mazahib et al. (2013), Ndidi et al. (2014)

Manganese is involved in glycoprotein and proteoglycan synthesis and is a component of mitochondrial superoxide dismutase (Soetan et al., 2010). It is required for proper immune function, regulation of blood sugar and cellular energy, reproduction, digestion, bone growth, blood coagulation, and hemostasis and defence against reactive oxygen species (Aschner & Erikson, 2017). It is also needed for the synthesis of acid mucopolysaccharides, such as chondroitin sulphate, to form the matrices of bones and egg shells (Soetan et al., 2010). The beneficial effects of manganese are due to the incorporation of the metal into metalloproteins; the functions carried out by manganese metalloproteins include oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases (Aschner & Erikson, 2017). Table 17 presents the results of search for literature values for manganese in the legume flours under study.

Table 17: Results of search for literature values of manganese (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	1.30	Oshodi et al. (1993)	ND	
Canavalia ensiformis	1.0 – 7.05	Agbede and Aletor (2005), Mohan and Janardhanan (1994), Vadivel and Janardhanan (2005)	5.69	Agbede and Aletor (2005)
Canavalia gladiata	0.23 – 2.20	Mohan and Janardhanan (1994), Vadivel and Janardhanan (2005)	ND	
Dialium guineense	2.13 – 2.50	Jacob et al. (2016), Oladejo (2009)	ND	
Mucuna pruriens	1.80 – 20.30	Agbede and Aletor (2005), Kala and Mohan (2010), Vadivel and Janardhanan (2005)	0.42	Agbede and Aletor (2005)
Parkia biglobosa	0.60 – 5.16	Aremu, Awala, et al. (2015), Ijarotimi and Keshinro (2012), Sankhon et al. (2014)	ND	
Phaseolus lunatus	4.75 – 0.82	Kathirval and Kumudha (2011)	ND	

Table 17 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Vigna subterranea	2.90 – 10.46	Mazahib et al. (2013), Ndidi et al. (2014), Oyeleke et al. (2012)	1.88 – 3.01	Ndidi et al. (2014)

Zinc is present in the body as a co-factor for enzymes such as arginase and diaminase and takes part in the synthesis of DNA, proteins and insulin (Hashmi et al., 2007). It is a constituent of many enzymes like lactate dehydrogenase, alcohol dehydrogenase, glutamic dehydrogenase, alkaline phosphatase, carbonic anhydrase, carboxypeptidase, superoxide dismutase, retinene reductase, DNA and RNA polymerase (Soetan et al., 2010). It is essential for the normal functioning of the cell including protein synthesis, carbohydrate metabolism, cell growth and cell division (Hashmi et al., 2007). Zinc is needed for tissue repair and wound healing, plays a vital role in protein synthesis and digestion, and is necessary for optimum insulin action (Soetan et al., 2010). Zinc deficiency manifests itself as retardation of growth, anorexia, lesions of skin and appendages, impaired development and function of reproductive organs (Hashmi et al., 2007). Table 18 presents the results of search for literature values for zinc in the legume flours under study.

Table 18: Results of search for literature values of zinc (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	3.56 – 154.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), Oshodi et al. (1993), Sangronis and Machado (2007)	3.17 – 3.54	Apata and Ologhobo (1994)

Table 18 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Canavalia ensiformis	1.10 – 158.00	Agbede and Aletor (2005), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b)	2.49 – 81.10	Agbede and Aletor (2005), Apata and Ologhobo (1994)
Canavalia gladiata	1.37 – 72.01	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	64.01	A.S. Abitogun and G.K. Oso (2014)
Dialium guineense	0.53 – 118.00	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Ogungbenle (2015), Oladejo (2009)	ND	

Table 18 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Mucuna pruriens	2.05 – 939.00	Agbede and Aletor (2005), Ahenkora et al. (1999), Kala and Mohan (2010), Mugendi et al. (2010)	9.40 – 826.00	Agbede and Aletor (2005), Ahenkora et al. (1999)
Parkia biglobosa	0.40 – 2.55	Bello and Abdu (2011), Ijarotimi and Keshinro (2012), G. Oboh and Ekperigin (2004), Sankhon et al. (2014)	ND	
Phaseolus lunatus	0.19 – 7.00	Adeparusi (2001), Apata and Ologhobo (1994), Granito et al. (2007), Kathirval and Kumudha (2011)	2.59 – 3.91	Apata and Ologhobo (1994), Granito et al. (2007)
Vigna subterranea	1.39 – 25.60	Amarteifio et al. (2006), Mazahib et al. (2013), Ndidi et al. (2014), Olaleye et al. (2013)	3.50 – 20.98	Mazahib et al. (2013), Ndidi et al. (2014)

Calcium is essential for such processes as structural support, cell adhesiveness, mitosis, blood coagulation, muscle contraction and glandular secretion (Miller & Anderson, 1999). The skeleton serves as the calcium reserve, and at the same time provides support and strength for the mechanical activities of the body (Heaney, 2006). Calcium is involved in the regulation of nerve and muscle function, blood coagulation, muscle contraction, normal transmission of nerve

impulses, neuromuscular excitability, membrane permeability and activation of enzymes such as adenosine triphosphatase (ATPase), succinic dehydrogenase, lipase (Soetan et al., 2010). In children, calcium deficiency causes rickets due to insufficient calcification by calcium phosphate of the bones leading to soft bones and bone deformity by the body weight (Soetan et al., 2010). Calcium deficiency causes osteomalacia (a generalized demineralization of bones) in adults and affects the dentition of both children and adults (Soetan et al., 2010). Table 19 presents the results of search for literature values for calcium in the legume flours under study.

Table 19: Results of search for literature values of calcium (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	65.00 – 167.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), R.A. Oloyo (2002), Oloyo (2004), Oshodi et al. (1993), Sangronis and Machado (2007)	95.00 – 118.00	Apata and Ologhobo (1994), R.A. Oloyo (2002)
Canavalia ensiformis	18.00 – 600.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b), V. Vadivel and K. Janardhanan (2001)	105.00 – 400.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994)

Table 19 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Canavalia gladiata	206.00 – 520.00	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	390.00	A.S. Abitogun and G.K. Oso (2014)
Dialium guineense	40.00 – 4410.00	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Ogungbenle (2015), Oladejo (2009)	ND	
Mucuna pruriens	38.00 – 659.00	Agbede and Aletor (2005), Ahenkora et al. (1999), Kala and Mohan (2010), Mugendi et al. (2010)	300.00 – 410.00	Ahenkora et al. (1999)

Table 19 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Parkia biglobosa	0.11 – 10.75	Aremu, Awala, et al. (2015), Bello and Abdu (2011), Ijarotimi and Keshinro (2012), G. Oboh and Ekperigin (2004), Olakunle and Adebola (2012), Sankhon et al. (2014)	ND	
Phaseolus lunatus	61.60 – 720.88	Adeparusi (2001), Akpapunam (1985), Apata and Ologhobo (1994), Granito et al. (2007), Kathirval and Kumudha (2011), Meredith and Thomas (1982)	59.00 – 106.23	Akpapunam (1985), Apata and Ologhobo (1994), Granito et al. (2007)
Vigna subterranea	`15.06 – 256.56	Amarteifio et al. (2006), Mazahib et al. (2013), Ndidi et al. (2014), Olaleye et al. (2013), Oyeleke et al. (2012)	12.09 – 196.90	Mazahib et al. (2013), Ndidi et al. (2014)

Magnesium is an active component of several enzyme systems in which thymine pyrophosphate is a cofactor and also activates pyruvic acid carboxylase, pyruvic acid oxidase, and the condensing enzyme for the reactions in the citric acid cycle (Soetan et al., 2010). It is an essential nutrient that is involved in many key metabolic reactions such as energy production, glycolysis, and the

synthesis of nucleic acids and proteins (Costello et al., 2016). Magnesium is also necessary for structural function of proteins, nucleic acids or mitochondria and is required for DNA and RNA synthesis, and for both aerobic and anaerobic energy production—oxidative phosphorylation and glycolysis—either indirectly as a part of magnesium-ATP complex, or directly as an enzyme activator (Gröber et al., 2015). Table 20 presents the results of search for literature values for magnesium in the legume flours under study.

Table 20: Results of search for literature values of magnesium (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	80.86 – 200.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), R.A. Oloyo (2002), Oloyo (2004), Oshodi et al. (1993), Sangronis and Machado (2007)	66.98 – 180.00	Apata and Ologhobo (1994), R.A. Oloyo (2002)
Canavalia ensiformis	63.16 – 400.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b), V. Vadivel and K. Janardhanan (2001)	120.00 – 440.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994)

Table 20 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Canavalia gladiata	65.53 – 540.00	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	280.00	A.S. Abitogun and G.K. Oso (2014)
Dialium guineense	25.20 – 1180.00	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Ogungbenle (2015), Oladejo (2009)	ND	
Mucuna pruriens	8.80 – 430.12	Agbede and Aletor (2005), Kala and Mohan (2010), Mugendi et al. (2010)	250.00	Agbede and Aletor (2005)

Table 20 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Parkia biglobosa	0.22 – 21.06	Aremu, Awala, et al. (2015), Bello and Abdu (2011), Ijarotimi and Keshinro (2012), G. Oboh and Ekperigin (2004), Olakunle and Adebola (2012), Sankhon et al. (2014)	ND	
Phaseolus lunatus	150.00 – 308.88	Adeparusi (2001), Apata and Ologhobo (1994), Granito et al. (2007), Kathirval and Kumudha (2011), Meredith and Thomas (1982)	100.00 – 206.25	Apata and Ologhobo (1994), Granito et al. (2007)
Vigna subterranea	20.90 – 347.15	Amarteifio et al. (2006), Ndidi et al. (2014), Olaleye et al. (2013), Oyeleke et al. (2012)	65.30	Ndidi et al. (2014)

Sodium is the principal cation in extracellular fluids (Soetan et al., 2010). It is involved in the regulation of plasma volume and acid-base balance, maintenance of osmotic pressure of the body fluids, preservation of normal irritability of muscles and cell permeability, activation of nerve and muscle function, maintenance of membrane potentials, transmission of nerve impulses and the absorptive processes of monosaccharides, amino acids, pyrimidines, and bile salts (Soetan et al., 2010). High dietary sodium has been implicated in cardiovascular and renal disorders and is, therefore, often discouraged in patients/subjects who suffer from or are prone to hypertension

(Soetan et al., 2010). Table 21 presents the results of search for literature values for sodium in the legume flours under study.

Table 21: Results of search for literature values of sodium (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	4.00 – 220.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), Oshodi et al. (1993)	1.0 – 3.00	Apata and Ologhobo (1994)
Canavalia ensiformis	7.00 – 1670.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b), V. Vadivel and K. Janardhanan (2001)	4.00 – 1510.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994)

Table 21 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Canavalia gladiata	21.30 – 1580.00	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	1730.00	A.S. Abitogun and G.K. Oso (2014)
Dialium guineense	10.00 – 4710.00	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Ogungbenle (2015), Oladejo (2009)	ND	
Mucuna pruriens	64.32 – 2210.00	Agbede and Aletor (2005), Kala and Mohan (2010), Mugendi et al. (2010)	1440.00	Agbede and Aletor (2005)
Parkia biglobosa	1.43 – 12.87	Aremu, Awala, et al. (2015), Bello and Abdu (2011), Ijarotimi and Keshinro (2012), G. Oboh and Ekperigin (2004), Sankhon et al. (2014)	ND	

Table 21 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Phaseolus lunatus	1.43 – 12.87	Adeparusi (2001), Akpapunam (1985), Apata and Ologhobo (1994), Kathirval and Kumudha (2011), Meredith and Thomas (1982)	4.00 – 6.30	Akpapunam (1985), Apata and Ologhobo (1994)
Vigna subterranea	11.66 – 135.30	Amarteifio et al. (2006), Mazahib et al. (2013), Ndidi et al. (2014), Olaleye et al. (2013), Oyeleke et al. (2012)	7.20 – 23.27	Mazahib et al. (2013), Ndidi et al. (2014)

Potassium is the principal cation in intracellular fluid and functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle and cell membrane function (Soetan et al., 2010). Increased potassium intake lowers blood pressure, and this effect has been consistent in both hypertensive and normotensive populations (Lanham-New et al., 2012). Evidence suggests that potassium may be effective in reducing stroke and could help in the prevention of chronic kidney damage (Lanham-New et al., 2012). It is essential for the maintenance of cellular osmolality and homeostasis (Kianifard & Chopra, 2018). Table 22 presents the results of search for literature values for potassium in the legume flours under study.

Table 22: Results of search for literature values of potassium (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	85.40 – 1941.00	Amarteifio et al. (2002), Apata and Ologhobo (1994), Olalekan and Bosede (2010), Oshodi et al. (1993)	1100.00 – 1330.00	Apata and Ologhobo (1994)
Canavalia ensiformis	220.00 – 2456.14	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994), Mohan and Janardhanan (1994), Olalekan and Bosede (2010), Siddhuraju and Becker (2001b), V. Vadivel and K. Janardhanan (2001)	450.00 – 620.00	Agbede and Aletor (2005), Ajeigbe et al. (2012), Apata and Ologhobo (1994)
Canavalia gladiata	920.00 – 2216.31	A.S. Abitogun and G.K. Oso (2014), Arinathan et al. (2003), Mohan and Janardhanan (1994), Siddhuraju and Becker (2001b), Vadivel and Janardhanan (2005)	400.00	A.S. Abitogun and G.K. Oso (2014)

Table 22 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Dialium guineense	260.00 – 12400.00	Ayessou et al. (2014), Gnansounou et al. (2014), Jacob et al. (2016), Ogungbenle (2015), Oladejo (2009)	ND	
Mucuna pruriens	125.00 – 2250.48	Agbede and Aletor (2005), Kala and Mohan (2010), Mugendi et al. (2010)	120.00 – 1240.00	Agbede and Aletor (2005)
Parkia biglobosa	2.23 – 230.00	Aremu, Awala, et al. (2015), Bello and Abdu (2011), Ijarotimi and Keshinro (2012), G. Oboh and Ekperigin (2004), Sankhon et al. (2014)	ND	
Phaseolus lunatus	690.00 – 1892.00	Adeparusi (2001), Akpapunam (1985), Apata and Ologhobo (1994), Kathirval and Kumudha (2011), Meredith and Thomas (1982)	661.50 – 1290.00	Akpapunam (1985), Apata and Ologhobo (1994)

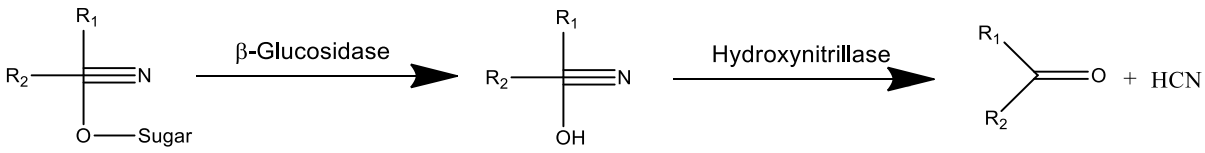
Table 22 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Vigna subterranea	50.24 – 2200.00	Amarteifio et al. (2006), Mazahib et al. (2013), Ndidi et al. (2014), Olaleye et al. (2013), Oyeleke et al. (2012)	38.70 – 186.10	Mazahib et al. (2013), Ndidi et al. (2014)

1.6 Cyanide

Cyanide is a potent and rapidly-acting asphyxiant which prevents tissue utilization of oxygen by inhibiting the cellular respiratory enzyme, cytochrome oxidase (Egekeze & Oehme, 1980). They are widely distributed among common plants in the form of cyanogenic glycosides, which hydrolyze to form hydrogen cyanide (HCN) (Egekeze & Oehme, 1980). Cyanogenic glycosides (a group of nitrile containing plant secondary compounds) in food materials release hydrogen cyanide when chewed or digested (Bolarinwa et al., 2016). The toxicity of cyanogenic glycosides and their derivatives is dependent on the release of hydrogen cyanide and cyanide toxicity can occur in animals including humans at doses between 0.5 and 3.5 mg HCN per kilogram body weight (Bolarinwa et al., 2016). This means the smaller the body size, the greater the risk of cyanide toxicity upon exposure to cyanide. Symptoms of mild cyanide poisoning include headache, nausea, metallic taste, drowsiness, dizziness, anxiety, mucous membrane irritation and hyperpnoea (Beasley & Glass, 1998). In severe cases, progressive coma, convulsions and cardiovascular collapse with shock and pulmonary oedema can develop, with a fatal outcome (Beasley & Glass, 1998). The toxicity of cyanogenic glycosides is associated with their ability to be hydrolyzed either spontaneously or in the presence of enzyme to produce cyanide as end products of their hydrolysis and, therefore, toxic levels of cyanogenic glycosides are estimated in terms of the quantity of cyanide generated following hydrolysis (Bolarinwa et al., 2016). The cyanide ions inhibit several enzyme systems, depress growth by interference with certain essential amino acids and utilization of associated nutrients (Soetan & Oyewole, 2009). Cyanogenic glycosides are amongst most important components of plant defence systems and mediate

interactions of plants with insects (Ganjewala et al., 2010). For legumes, cyanogenic glycoside is one of the potential toxic constituent (Nwaogu & Emejulu, 2010) and consuming cyanogenic glycoside even at very low concentration can cause iodine deficiency leading to goitre (Enechi et al., 2014). There is therefore the need to adequately process food materials to remove the cyanide before consumption. Cyanogenic glycoside consist of an aglycon and a sugar moiety (Appenteng et al., 2021). The chemical equation for the release of cyanide from cyanogenic glycoside during enzymatic hydrolysis is shown below:

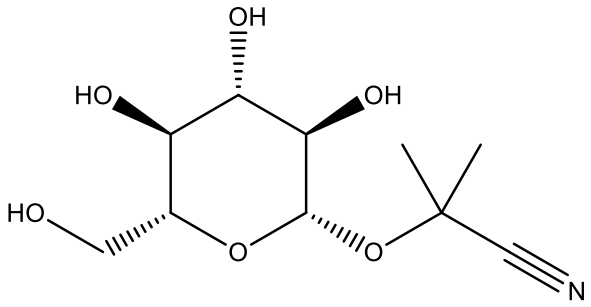


Cyanogenic glycoside

Cyanohydrin

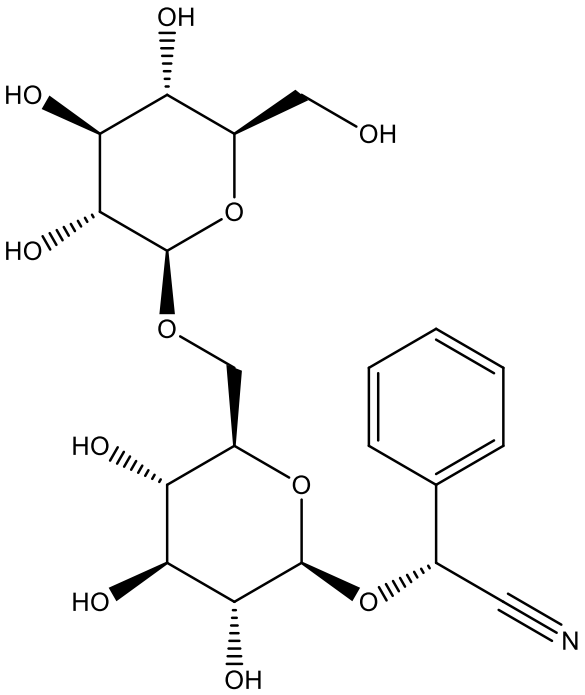
R = H: Aldehyde
R = Alkyl: Ketone

Some cyanogenic glycosides found in plant tissues are linamarin, amygdalin and dhurrin (Appenteng et al., 2021). The structural formulas of these cyanogenic glycosides are shown below.



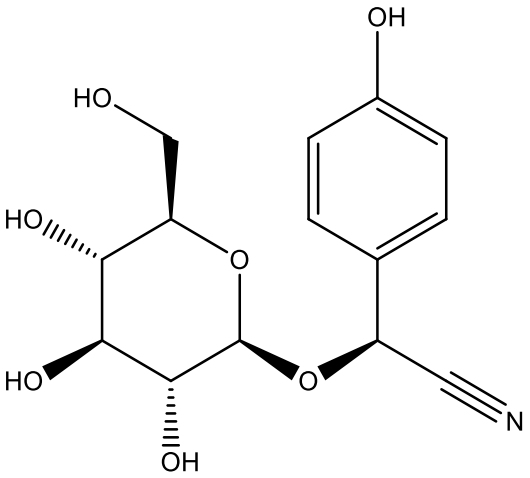
2-methyl-2-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxypropanenitrile

Linamarin



(2R)-2-phenyl-2-[(2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-[[(2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxymethyl]oxan-2-yl]oxyacetonitrile

Amygdalin



(2S)-2-(4-hydroxyphenyl)-2-[(2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyacetonitrile
Dhurrin

Table 23 presents the results of search for literature values for cyanide in the legume flours under study.

Table 23: Results of search for literature values of cyanide (mg/100 g) of legume flours. ND = No data found.

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Cajanus cajan	4.05 – 39.66	Aja et al. (2015), Iorgyer et al. (2009), Onwuka (2006)	1.35 – 11.88	Iorgyer et al. (2009), Onwuka (2006)
Canavalia ensiformis	3.45 – 11.20	Agbede and Aletor (2005), Ajeigbe et al. (2012), M.A. Akpapunam and S. Sefa-Dedeh (1997)	0.43 – 4.44	Agbede and Aletor (2005), Ajeigbe et al. (2012)
Canavalia gladiata	0.31 – 19.50	Otori and Mann (2014), Tresina and Mohan (2012)	ND	
Dialium guineense	0.68 – 338.00	Dike (2010), Ogungbenle (2015)	ND	
Mucuna pruriens	0.24 – 223.00	Agbede and Aletor (2005), Daffodil et al. (2016), Vijayakumari et al. (1996), Nwaoguikpe et al. (2011), Ogudoro et al. (2014), Olaniyi et al. (2014), Tuleun et al. (2008)	0.66 – 217.00	Agbede and Aletor (2005), Vijayakum-ari et al. (1996), Nwaoguikpe et al. (2011), Ogudoro et al. (2014)

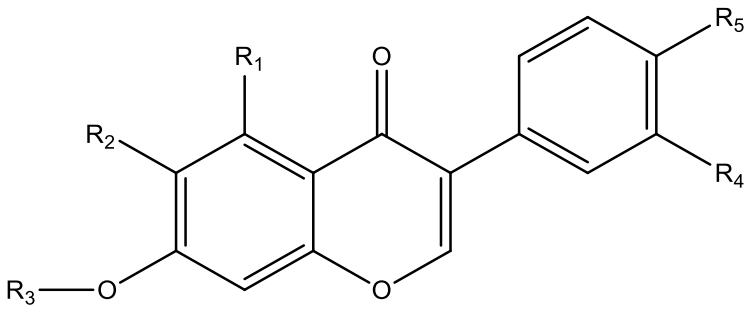
Table 23 continued

Legume	Raw flour		Processed flour	
	Range of values	References	Range of values	References
Parkia biglobosa	0.51	G. Oboh and Ekperigin (2004)	ND	
Phaseolus lunatus	0.06 – 7.01	K.T. Adegbehingbe (2014), K.T. Adegbehingbe et al. (2014), Adeparusi (2001), Granito et al. (2007)	4.36	Granito et al. (2007)
Vigna subterranea	19.70	Ndidi et al. (2014)	3.87	Ndidi et al. (2014)

1.7 Isoflavones (IFs)

Isoflavones are phytoestrogens and similar to 17-β-estradiol in chemical structure which act as oestrogen agonists or antagonists depending on the endocrine oestrogenic levels (Ko, 2014). They are bioflavonoids and soy is the richest source of these compounds by far (Ogbuewu et al. 2010). The main isoflavones are genistein, daidzein, glycetein, biochanin A and formononetin (Messina, 2014; Ogbuewu, Omede, et al., 2010). Actions of isoflavones are rather complex due to the fact that there is a large number of variables such as chemical structures and mechanisms (Ko, 2014). They have nevertheless become a focus of interest due to positive health benefits on many diseases, especially prevention of hormone-related cancers, cardiovascular disease, osteoporosis, and adverse postmenopausal symptoms, and improvement of physiological condition such as maintaining cognitive function (Ko, 2014). Isoflavones are often present as the glucoside conjugate (such as daidzin and genistin) which undergo metabolic transformation in the gut to the bioactive aglycones (daidzein and genistein) (Cederroth & Nef, 2009). The former molecules are called glucones (glycones) because they have the glucose molecules attached to them and the latter molecules are called aglucones because the glucose molecules have been removed (Ogbuewu, Omede, et al., 2010). Some glucones and their aglucones are as follows (the aglucones are in

bracket): daidzin (daidzein), genistin (genistein), glycitin (glycitein), ononin (formononetin) and sissotrin (Biochanin A) (Islam et al., 2014; Ogbuewu, Omede, et al., 2010). The general chemical structure for isoflavones is shown below.



R_1, R_2, R_3, R_4 and R_5 for the various isoflavones are shown below.

Chemical structure	Isoflavone (Abbreviation)	R_1	R_2	R_3	R_4	R_5
Aglycon	Biochanin A (BCA)	OH	H	H	H	OCH_3
	Calycosin (CAL)	H	H	H	OH	OCH_3
	Daidzein (DAI)	H	H	H	H	OH
	Formononetin (FOR)	H	H	H	H	OCH_3
	Genistein (GEN)	OH	H	H	H	OH
	Glycitein (GLY)	H	OCH_3	H	H	OH
	Irilon (IRI)	OH	O-	CH_2-	H	OH
	Orobol (ORO)	OH	H	H	OH	OH
	Pratensein (PRA)	OH	H	H	OH	OCH_3
	Prunetin (PRU)	OH	H	CH_3	H	OH
	Pseudobaptigenin (PSE)	H	H	H	CH_2-	O-
Glycoside	Daidzin (DAI-GLU)	H	H	Glu	H	OH
	Genistin (GEN-GLU)	OH	H	Glu	H	OH
	Glycitin (GLY-GLU)	H	OCH_3	Glu	H	OH
	Ononin (FOR-GLU)	H	H	Glu	H	OCH_3
	Prunetin (PRU-GLU)	OH	H	CH_3	H	O-Glu
	Rothindin (PSE-GLU)	H	H	Glu	CH_2-	O-
	Sissotrin (BCA-GLU)	OH	H	Glu	H	OCH_3

2 Objectives

2.1 General objective

To determine the potential of these underutilized legumes to help alleviate the problems of poverty, hunger and malnutrition among the vulnerable group of the Ghanaian population. The underutilized legumes in this study are pigeonpea (*Cajanus cajan*), jack bean (*Canavalia ensiformis*), sword bean (*Canavalia gladiata*), velvet tamarind (*Dialium guineense*), velvet beans (*Mucuna pruriens*), African Locust bean (*Parkia biglobosa*), Lima bean (*Phaseolus lunatus*) and Bambara groundnut (*Vigna subterranea*).

2.2 Specific objectives

1. To determine the functional properties of the flours of the underutilized legumes to be able to predict the functional roles they could play in food products.
2. To determine the fat content and fatty acid distribution in the flours of the underutilized legumes.
3. To determine the starch and sugar (raffinose, sucrose, D-glucose and D-fructose) profiles in the flours of the underutilized legumes.
4. To determine the ash and mineral nutrients (calcium, magnesium, sodium, potassium, iron, zinc, copper and manganese) concentrations in the flours of the underutilized legumes.
5. To determine the amount of bound cyanide in the underutilized legumes.
6. To determine the isoflavone profiles in the flours of the underutilized legumes.
7. To determine the protein content of the underutilized legumes.

3 Materials and Methods

3.1 Source of samples and laboratory analyses

The legume samples were obtained from Ejura in the Ejura-Sekyedumase Municipality in the Ashanti region of Ghana. The municipality is located within longitudes 1°5″W and 1°39″ W and latitudes 7°9″ N and 7°36″N with a land area of about 1340.1 km^2 (Ghana Statistical Service, 2014). Mean monthly temperatures range between 21-30°C (Yeboah, 2013). Annual rainfall in the municipality varies between 1,200 mm and 1,500 mm with very high relative humidity during the rainy season, recording 90% in its peak in June and 55% in February (Ghana Statistical Service, 2014). The municipal capital, Ejura is at an altitude of about 228 m (Aikins et al., 2016). Plate 17 shows a map of the location of Ejura-Sekyedumase in the Ashanti region of Ghana.

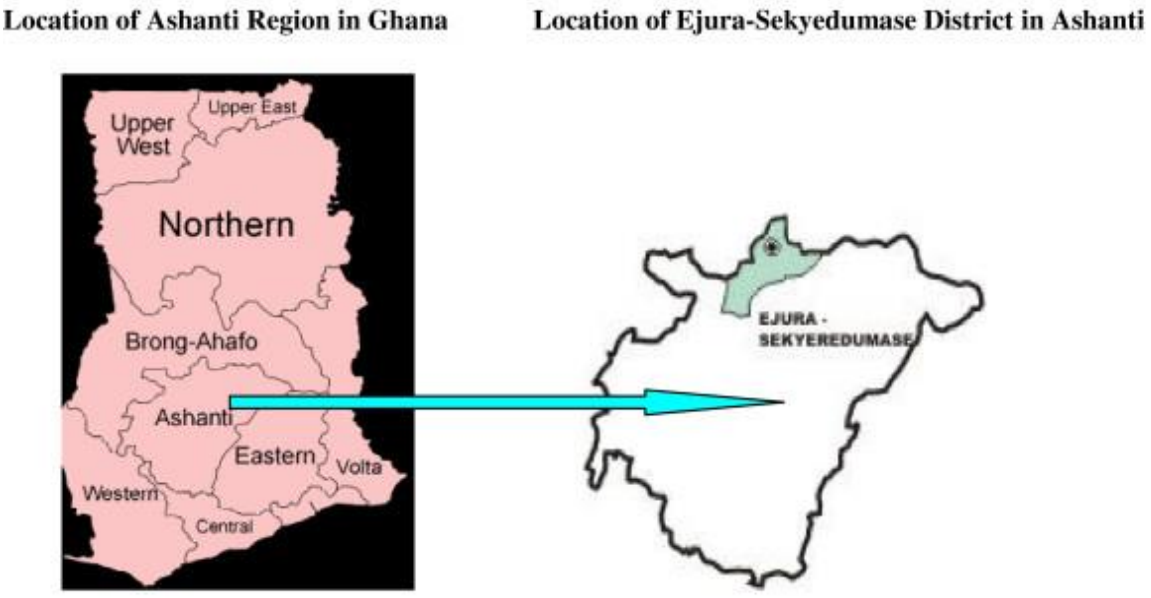


Plate 17: Map showing the location of Ejura-Sekyedumase in the Ashanti region of Ghana

Source: Duku et al. (2010).

3.1.1 Drying of legume seeds and fruits

Mature, healthy legume seeds (fruits in the case of *Dialium guineense*) were dried in a solar dryer (35-40°C) for seven consecutive days to constant weight.

3.1.2 Preparation of raw legume flours

3.1.2.1 Preparation of raw flours of *Cajanus cajan, Mucuna pruriens, Parkia biglobosa, Phaseolus lunatus* and *Vigna subterranea*

The dried legume seeds were milled with a Hammer Mill (Reitsch KG, 5657 Haan, West Germany) into flour.

3.1.2.2 Preparation of raw flours of *Canavalia ensiformis* and *Canavalia gladiata*

The seed coat of the dried legume seeds were manually removed and the dehulled seeds were milled with a Hammer Mill (Reitsch KG, 5657 Haan, West Germany) into flour.

3.1.2.3 Preparation of raw flour of *Dialium guineense*

After drying the fruits in the solar dryer to constant weight, the fruit pulp was manually separated from the shell (husk) and the seeds. The fruit pulp was milled with a Hammer Mill (Reitsch KG, 5657 Haan, West Germany) into flour.

3.1.3 Preparation of processed legume flours

3.1.3.1 Preparation of processed flours of *Cajanus cajan, Mucuna pruriens, Phaseolus lunatus* and *Vigna subrterranea*

Dried seeds were boiled in tap water for 4 hours with a seed to water ratio of 1:10 (w/v). Water was first brought to boil in an iron cooking pot, then the seeds were poured into the boiling water and allowed to come back to boil before timing was commenced. After boiling, the water was discarded and the seeds were dried in a solar dryer for 7 consecutive days to constant weight. The dried seeds were then milled with a Hammer Mill (Reitsch KG, 5657 Haan, West Germany) into flour.

3.1.3.2 Preparation of processed flours of *Canavalia ensiformis* and *Canavalia gladiata*

Dried seeds were boiled in tap water for 4 hours with a seed to water ratio of 1:10 (w/v). Water was first brought to boil in a cooking pot, then the seeds were poured into the boiling water and allowed to come back to boil before timing was commenced. After boiling, the water was discarded. The testae of the seeds were then peeled off with the hands and the dehulled seeds were dried in a solar dryer for 7 consecutive days to constant weight. The dried dehulled seeds were then milled with a Hammer Mill (Reitsch KG, 5657 Haan, West Germany) into flour.

3.1.3.3 Preparation of processed flour of *Parkia biglobosa*

Dried seeds were roasted in an iron cooking pot for 20 minutes with a hot plate. The seeds were stirred during the roasting to ensure uniform roasting temperature for all the seeds. After roasting,

the seeds were allowed to cool and then milled with a Hammer Mill (Reitsch KG, 5657 Haan, West Germany) into flour.

3.1.4 Determination of functional properties

3.1.4.1 Determination of Bulk Density (BD)

Bulk density was determined by the method of Okaka and Potter (1979). An amount of 50 g flour sample was measured and put into a 100 ml measuring cylinder. The cylinder was tapped continuously in the palms of the hands until there was no more change in volume of the flour in the cylinder. The bulk density was calculated as the weight of flour (g) divided by the volume of flour (ml).

3.1.4.2 Determination of Foam Capacity (FC)

This was determined by the method of Chinma et al. (2008). A one gram (1 g) flour sample was whipped with 100 ml distilled water in an Alaska blender (at speed II) for 5 min. The mixture was poured into a 250 ml graduated cylinder and the volume of foam at 30 s after whipping was taken as the foam capacity. The percent foam capacity was calculated as:

$$\%\text{Foam capacity} = \frac{(\text{volume after whipping} - \text{volume before whipping})}{\text{volume before whipping}} \text{ X } 100$$

3.1.4.3 Determination of Foam Stability (FS)

Foam stability was determined by the method of Chinma et al. (2008). A one gram (1 g) flour sample was whipped with 100 ml distilled water in an Alaska blender (at speed II) for 5 min. The mixture was poured into a 250 ml graduated cylinder. The volume of foam over 0-120 min is taken as foam stability for the respective time periods 30, 60, 90 and 120 min. The percent foam stability was calculated as:

$$\%\text{Foam stability} = \frac{\text{foam volume at 2 h after whipping}}{\text{initial foam volume}} \text{ X } 100$$

3.1.4.4 Determination of Least Gelation Concentration (LGC)

Least gelation concentration was determined by the method of Prinyawiwatkul et al. (1997). Suspensions of 1-25% flour (w/v at 1% increment) were made in 5 ml deionized water. The slurries

were heated in screw-capped test tubes at in a thermostatically regulated temperature water bath (Model SW 22, Julabo Labortechnik GmbH, Seelbach, Germany) at 92°C with intermittent stirring. After 1 h of heating, the test tubes were immediately cooled in tap water for 30 s and then in ice water for 5 min. The tubes were then held at a temperature of 4°C for 3 h. The minimum concentration at which the sample remained at the bottom of the tube when the tube was inverted was recorded as the least gelation concentration.

3.1.4.5 Determination of Oil Absorption Capacity (OAC)

This was determined by the method of Beuchat (1977). Two grams (2 g) of flour sample was combined with 10 ml of refined peanut oil (density = 0.91 g/ml) in a 26 ml centrifuge tube. The slurry was stirred occasionally with a glass rod over a 30 min period at 24°C. The slurry was centrifuged at 15000 x g for 20 min in an ultracentrifuge (L8-60M Ultracentrifuge, Serial number 6F 901, Beckman, USA) and the volume of decanted oil was measured. The weight of oil retained per gram of flour (OAC) was calculated as:

$$\text{OAC} = \frac{\text{density of refined peanut oil x volume of refined peanut oil retained}}{\text{weight of flour}}$$

3.1.4.6 Determination of Solubility

This was determined by the method of Tattiyakul et al. (2007). An amount of 0.3 g (m_s) of flour was measured and dispersed in 10 ml of deionized water. The dispersion was heated under mild agitation at 80°C for 30 min in a thermostatically regulated temperature water bath (Model SW 22, Julabo Labortechnik GmbH, Seelbach, Germany). The gelatinized dispersion was centrifuged (Hettlich Zentrifugen, Typ 1000, Tuttlingen, Germany) at 2970 x g for 15 min. The supernatant was decanted and dried at 100°C in an oven (Memmert 8192, Memmert GmbH Co. KG, Schwabach, Germany) until a constant weight (m_o) was obtained. The solubility was calculated as:

Solubility (g of dissolved solids/g flour) = $\frac{m_0}{m_s}$.

3.1.4.7 Determination of Swelling Power (SP)

This was determined by the method of Tattiyakul et al. (2007). An amount of 0.3 g (m_s) of flour was measured and dispersed in 10 ml of deionized water. The dispersion was heated under mild agitation at 80°C for 30 min in a thermostatically regulated temperature water bath (Model SW 22, Julabo Labortechnik GmbH, Seelbach, Germany). The gelatinized dispersion was centrifuged (Hettlich Zentrifugen, Typ 1000, Tuttlingen, Germany) at 2970 x g for 15 min. The supernatant was decanted and weight of swollen granules (m_{sw}) was measured. The decanted supernatant was dried at 100°C in an oven (Memmert 8192, Memmert GmbH Co. KG, Schwabach, Germany) until a constant weight (m_o) was obtained. The swelling power was calculated as:

$$\text{Swelling power (g/g flour)} = \frac{msw}{mo(1-solubility)}$$

3.1.4.8 Determination of Water Absorption Capacity (WAC)

This was determined by the method of Beuchat (1977). Two grams (2 g) of flour sample was combined with 10 ml of deionized water in a 26 ml centrifuge tube. The slurry was stirred occasionally with a glass rod over a 30 min period at 24°C. The slurry was centrifuged (L8-60M Ultracentrifuge, Serial number 6F 901, Beckman, USA) at 15000 x g for 20 min and the volume of decanted water was measured. The milliliters of water retained per gram flour sample (WAC) was calculated as:

$$\text{WAC} = \frac{\text{volume of water retained}}{\text{weight of flour}}$$

3.1.5 Determination of Crude fat content

Crude fat content was determined by extraction of acid-hydrolysed legume samples in a Sohxlet extractor with petroleum ether. A 250 ml quickfit round bottom flask was washed and dried in an oven (Memmert 8192, Memmert GmbH Co. KG, Schwabach, Germany) to constant weight. The flour sample was weighed into a muslin thimble and inserted into the extraction column of the Sohxlet apparatus with the condenser connected. Two hundred millilitres (200 ml) of the extracting solvent (petroleum ether, boiling point 40-60˚C) was poured into the round bottom flask and fitted into the extraction unit. The flask was then heated with the aid of electrothermal heater. Losses of solvent due to heating were checked with the aid of the condenser so that it cooled and refluxed the evaporated solvent. After extraction, the thimble was removed and the solvent salvaged by

evaporating (Büchi Rotavapor R-200, Büchi Labortechnik GmbH, Germany) it from the fat in the flask. The flask containing the fat and residual solvent was dried in an oven (Memmert 8192, Memmert GmbH Co. KG, Schwabach, Germany) at 105˚C for 30 min. It was then cooled in a desiccator and weighed. The percent fat obtained was expressed as a percentage of the initial weight of the sample using the formula

$$\% \text{ Crude fat } = \frac{\text{weight of fat X } 100}{\text{weight of flour}}$$

3.1.6 Determination of fatty acid (FA) distribution

The method here is from the Doctoral Thesis of Maryam Mahdiani in 2017 at the Chair of Food Chemistry, University of Wuerzburg (Quantitative analysis of fatty acids, cholesterol and oxidation products thereof in human breast adipose tissues). Methyl esters were prepared from the extracted fat. An amount of fat (0.01 g) was dissolved in Methyl tert-butyl ether (MTBE) (1.0 ml). The mixture was diluted 10 fold with MTBE. Fifty microliters (50 µL) of Trimethyl sulfonium hydroxide (TMSH) was added to 1.0 ml of the diluted sample. The mixture was shaken for effective mixing to convert the FAs into their corresponding fatty acid methyl esters (FAMEs). The FAMEs were analyzed by gas chromatography by injection (Agilent 7683 Autosampler, Agilent Technologies® Deutschland GmbH, Böblingen, Germany) of 1 µL sample into an instrument equipped with a flame ionization detector (FID) (Agilent 6890 GC Series plus, Agilent Technologies® Deutschland GmbH, Böblingen, Germany). The injector temperature was 260°C. The flow of Helium as carrier gas was 1 ml/min. The initial temperature of the oven was 140°C. It ramped to 230°C at a heating rate of 3°C/min. It was kept at 230°C for 5 min and then it was increased by 1°C per min to 240°C. It remained at this temperature for 20 min. The temperature of the FID was 260°C. Detection was carried out at a hydrogen flow rate of 40 ml/min, an air flow rate of 450 ml/min and a nitrogen flow of 45 ml/min. For integration of FAs peak areas, the Agilent ChemStation software (G1701DA) was used. The FA peaks were identified by comparing with Supelco 37 Component FAME Standard Mix. Co-chromatography was used to confirm the identity of the FAs in the samples. Two co-chromatographic analyses: one with 1 µL of mixture of sample and 37 component FAME Mix (0.5 µL FAME Mix + 0.5 µL sample) and other 1 µL mixture of sample and 37 component FAME Mix (0.3 µL FAME Mix + 0.7 µL sample) were manually injected into the GC-FID with the same conditions as described for the sample analyses.

3.1.7 Determination of sugars in legume flours

Sugars (raffinose, sucrose, D-glucose and D-fructose) concentrations in the legume flours (both raw and processed) were determined by enzymatic methods. Legume flour was extracted with deionized water in a water bath at 60°C and clarification was done by the addition of Carrez-I solution, Carrez-II solution and 0.1 M sodium hydroxide solution. After cooling to room temperature, the mixture was filtered, and the filtrate was subjected to enzymatic analysis using enzyme kits (R-Biopharm AG, D-64297 Darmstadt, Germany).

3.1.7.1 Prepration of Carrez I solution

Approximately 3.60 g of potassium hexacyanoferrate (II) trihydrate, $K_4[Fe(CN)_6].3H_2O$ was dissolved in deionized water to form a 100 ml solution.

3.1.7.2 Prepration of Carrez II solution

Approximately 23 g of zinc acetate dihydrate, $Zn(CH_3COO)_2.2H_2O$ was dissolved in deionized water to form a 100 ml solution.

3.1.7.3 Prepration of 0.1 M NaOH solution

An amount (4 g) of NaOH was dissolved in deionized water to form a 1 L solution.

3.1.7.4 Prepration of positive control solution for sugar analyses

Approximately 0.0700 g of raffinose pentahydrate, 0.2000 g of sucrose, 0.0600 g of fructose and 0.0250 g of glucose were dissolved together in a deionized water to form a solution of volume 100 ml.

3.1.7.5 Preparation of D-galactose solution (internal standard for raffinose determination)

Approximately 0.5000 g of D-galactose was dissolved in deionized water to form a solution of volume 100 ml.

3.1.7.6 Samples preparation for sugar analyses

Approximately 5.0 g of the legume flour (approximately 1.0 g in the case of *Dialium guineense*) was weighed into a 100 ml volumetric flask and heated with approximately 50 ml of deionized water in a thermostatically controlled temperature water bath (M12 T, Lauda 3803, Germany) at 60°C for 30 min. The mixture was occasionally shaken gently. For clarification, 5 ml of Carrez I solution was added followed by 5 ml of Carrez II solution and 10 ml of 0.1 M NaOH solution. After each addition, the solution was gently shaken for effective mixing. The mixture was cooled to room temperature and made up to the mark (100 ml) with deionized water. The solution was

filtered and the supernatant was used for the analyses of sugars. The extracts were analysed on the same day.

3.1.7.7 Rafinose content determination in flours

Raffinose was determined by the enzymatic analyses method of Boehringer Mannheim/R-Biopharm for raffinose in foodstuffs. The enzyme kit (R-Biopharm AG, D-64297 Darmstadt, Germany) contained the following: Bottle 1 with approx. 320 mg lyophilizate, consisting of: citrate buffer, pH approx. 4.5; NAD, approx. 28 mg, bottle 2 with approx. 1.6 ml suspension -galactosidase, approx. 36 U, bottle 3 with approx. 34 ml solution, consisting of: potassium diphosphate buffer, pH approx. 8.6 and bottle 4 with approx. 1.6 ml suspension -galactose dehydrogenase, approx. 30 U. Contents of bottles 2, 3 and 4 were used as received. Content of bottle 1 was dissolved in 8.0 ml of millipore water and used for the analyses. The pipetting scheme below was used for the determination of raffinose.

Pipette into cuvettes	Blank Raffinose sample	Raffinose sample	Positive control for raffinose
Solution 1	50 µL	50 µL	50 µL
Sample solution	-	*v (sample)	-
Suspension 2	12.5 µL	12.5 µL	12.5 µL
Positive control	-	-	25 µL
Millipore water	25 µL	-	-
Mix and incubate for 15 min at 20-25°C. Add:			
Solution 3	250 µL	250 µL	250 µL
Millipore water	500 µL	**v (water)	500 µL
Mix, read absorbances of the solutions after approx. 2 min (A_1). Start reaction by addition of:			
Suspension 4	12.5 µL	12.5 µL	12.5 µL
Mix, wait until the reaction has stopped (approx. 20 min) and read absorbances of the solutions (A_2). Add			
D-galactose (0.5 g/L)	12.5 µL	12.5 µL	12.5 µL
Mix, wait until the reaction has stopped (approx. 20 min) and read absorbances of the solutions (A_3).			

*v (sample): v (C.c. raw) = 50 µL, v (C.e. raw) = 525 µL, v (C.g. raw) = 30 µL, v (D.g. raw) = 525 µL, v (M.p. raw) = 30 µL, v (P.b. raw) = 30 µL, v (P.l. raw) = 50 µL, v (V.s. raw) = 100 µL, v (C.c. pro) = 525 µL, v (C.e. pro) = 525 µL, v (C.g. pro) = 100 µL, v (M.p. pro) = 100 µL, v (P.b. pro) = 30 µL, v (P.l. pro) = 100 µL, v (V.s. pro) = 525 µL.

**v(water): v (water for C.c. raw) = 475 µL, v (water for C.e. raw) = 0 µL, v (water for C.g. raw) = 495 µL, v (water for D.g. raw) = 0 µL, v (water for M.p. raw) = 495 µL, v (water for P.b. raw) = 495 µL, v (water for P.l. raw) = 475 µL, v (water for V.s. raw) = 425 µL, v (water for C.c. pro) = 0 µL , v (water for C.e. pro) = 0 µL, v (water for C.g. pro) = 425 µL, v (water for M.p. pro) =

425 µL, v (water for P.b. pro) = 495 µL, v (water for P.l. pro) = 425 µL, v (water for V.s. pro) = 0 µL.

The following equations were used to calculate the amount of raffinose in g per 100 g of the legume flour sample:

$$\text{Raffinose concentration } \left(\frac{\text{g}}{\text{l}}\right) = \frac{\text{VxMWx}\Delta\text{A}}{\varepsilon\text{xdxvx1000}} \quad (1)$$

Here V = final volume at the end of the reaction (0.85 ml)

v = volume of sample taken (ml)

MW = molecular weight of substance being analysed (g/mol)

d = light path (cm)

ε = extinction coefficient of NADH at 340 nm = 6.3 [l x $mmol^{-1}$ x cm^{-1}]

$\Delta A = (A_2 - A_1)_{sample} - (A_2 - A_1)_{blank}$

$$\text{Amount of Raffinose in flour } (g/100g) = \frac{\text{raffinose concentration } \left(\frac{\text{g}}{\text{l}}\right) x100}{\text{weight of sample per litre } (\frac{\text{g}}{\text{l}})} \quad (2)$$

The recovery of D-galactose solution used as internal standard was calculated using the following equations:

$$\text{D} - \text{galactose concentration } \left(\frac{\text{g}}{\text{l}}\right) = \frac{\text{VxMWx}\Delta\text{A}}{\varepsilon\text{xdxvx1000}} \quad (3)$$

Here V = final volume at the end of the reaction (0.8625 ml)

v = volume of D-galactose sample solution taken (0.125 ml)

MW = molecular weight of substance being analysed (g/mol)

d = light path (cm)

ε = extinction coefficient of NADH at 340 nm = 6.3 [l x $mmol^{-1}$ x cm^{-1}]

$\Delta A = (A_3 - A_2)$

$$\%\text{Recovery (D} - \text{galactose)} = \frac{\text{concentration from enzymatic analysis x 100}}{\text{concentration from weight and volume measurement}} \quad (4)$$

The recovery for the positive control solution (external standard) was calculated as follows:

$$\%\text{Recovery (Positive control)} = \frac{\text{concentration from enzymatic analysis x 100}}{\text{concentration from weight and volume measurement}} (5)$$

The principle behind the determination of raffinose is as follows:

At a pH of 4.6, α-galactosidase hydrolyzes Raffinose to D-galactose and sucrose.

(1) Raffinose + H_2O $\xrightarrow{\alpha \text{ - galactosidase}}$ D-galactose + sucrose

D-Galactose is oxidized by nicotinamide adenine dinucleotide (NAD) to D-galactonic acid in the presence of the enzyme galactose dehydrogenase (Gal-DH).

(2) D-galactose + NAD^+ $\xrightarrow{\text{Gal-DH}}$ D-galactonic acid + NADH + H^+

The amount of NADH formed in the above reaction is stoichiometric to the amount of raffinose. The increase in NADH was determined by means of its light absorption at 340 nm.

3.1.7.8 Sucrose, D-glucose and D-fructose determination in flours

Sucrose, D-glucose and D-fructose were determined enzymatically by the method of Boehringer Mannheim/R-Biopharm method of analysis of sucrose, D-glucose and D-fructose in foodstuffs. D-glucose concentration is determined before and after the enzymatic hydrolysis of sucrose; D-fructose is determined subsequently to the determination of D-glucose. The enzyme kit (R-Biopharm AG, D-64297 Darmstadt, Germany) contained the following: Bottle 1 with approx. 0.5 g lyophilizate, consisting of citrate buffer, pH approx. 4.6; β-fructosidase, approx. 720 U, bottle 2 with approx. 7.2 g powder mixture, consisting of: triethanolamine buffer, pH approx. 7.6; NADP, approx. 110 mg; ATP, approx. 260 mg; magnesium sulfate, bottle 3 with approx. 1.1 ml suspension, consisting of hexokinase, approx. 320 U; glucose-6-phosphate dehydrogenase, approx. 160 U, bottle 4 with approx. 0.6 ml phosphoglucose isomerase suspension, approx. 420 U, bottle 5 with sucrose assay control material for assay control purposes and bottle 6 with D-glucose assay control solution for assay control purposes. Contents of bottles 3 and 4 were used as

received. Content of bottle 1 was dissolved with 10 ml millipore water and the content of bottle 2 was dissolved with 45 ml millipore water and used for the analyses. The pipetting scheme below was used for the determination of sucrose.

Pipette into cuvettes	Blank sucrose sample	Sucrose sample	Positive control for sucrose
Solution 1 Sample solution Positive control	50 µL - -	50 µL *v (sample) -	50 µL - 50 µL
Mix, incubate for minimum 15 min at 20-25°C. Addition of:			
Solution 2 millipore water	250 µL 450 µL	250 µL **v (water)	250 µL 400 µL
Mix, read absorbances of the solutions after approx. 3 min (A_1). Add:			
Suspension 3	5 µL	5 µL	5 µL
Mix, wait (approx. 10-15 min) and read absorbances of the solutions (A_2).			

*v (sample): v (C.c. raw) = 30 µL, v (C.e. raw) = 30 µL, v (C.g. raw) = 30 µL, v (D.g. raw) = 30µL, v (M.p. raw) = 30 µL, v (P.b. raw) = 30 µL, v (P.l. raw) = 30 µL, v (V.s. raw) = 30 µL, v (C.c. pro) = 400 µL, v (C.e. pro) = 450 µL, v (C.g. pro) = 30 µL, v (M.p. pro) = 450 µL, v (P.b. pro) = 30 µL,
v (P.l. pro) = 400 µL, v (V.s. pro) = 200 µL.

**v(water): v (water for C.c. raw) = 420 µL, v (water for C.e. raw) = 420 µL, v (water for C.g. raw) = 420 µL, v (water for D.g. raw) = 420 µL, v (water for M.p. raw) = 420 µL, v (water for P.b. raw) = 420 µL, v (water for P.l. raw) = 420 µL, v (water for V.s. raw) = 420 µL, v (water for C.c. pro) = 50 µL , v (water for C.e. pro) = 0 µL, v (water for C.g. pro) = 420 µL, v (water for M.p. pro) = 0 µL, v (water for P.b. pro) = 420 µL, v (water for P.l. pro) = 50 µL, v (water for V.s. pro) = 250 µL.

For the determination of sucrose for all raw flours, all the samples solutions were diluted by a factor of 4 except *Dialium guineense* sample solution which was diluted by a factor of 5. For the processed flours, the *Parkia biglobosa* sample solution was diluted by a factor of 4 but all the other flour sample solutions were not diluted. The positive control solution was diluted by a factor of 4 for all determinations. The following equations were used to calculate the amount of sucrose in g per 100 g of the legume flour sample:

$$\text{Sucrose concentration } \left(\frac{g}{l}\right) = \frac{VxMWx\Delta A}{\varepsilon xdxvx1000} \qquad (1)$$

Here V = final volume at the end of the reaction (0.755 ml)

v = volume of sample taken (ml)

MW = molecular weight of substance being analysed (g/mol)

d = light path (cm)

ε = extinction coefficient of NADH at 340 nm = 6.3 [l x $mmol^{-1}$ x cm^{-1}]

$\Delta A = ((A_2 - A_1)_{sample} - (A_2 - A_1)_{blank})_{sucrose\ sample} - (A_2 - A_1)_{sample} - (A_2 - A_1)_{blank})_{D\text{-}glucose/D\text{-}fructose\ sample})$

$$\text{Amount of sucrose in flour } \left(\frac{g}{100g}\right) = \frac{\text{sucrose concentration } \left(\frac{g}{l}\right) x100}{\text{weight of sample per litre } \left(\frac{g}{l}\right)} \qquad (2)$$

The recovery for the positive control solution (external standard) was calculated as follows:

$$\%\text{Recovery (Positive control)} = \frac{\text{concentration from enzymatic analysis x 100}}{\text{concentration from weight and volume measurement}} \qquad (3)$$

For D-glucose and D-fructose, the pipetting scheme used is shown below:

Pipette into cuvettes	Blank D-glucose/D-fructose sample	D-glucose/D-fructose sample	Positive control
Solution 1 Sample solution Positive control	- - -	- * v (sample) -	- - 50 µL
Incubate for minimum 15 min at 20-25°C. Add:			
Solution 2 Millipore water	250 µL 500 µL	250 µL ** v (water)	250 µL 450 µL
Mix, read absorbances of the solutions after approx. 3 min (A_1). Start reaction by addition of:			
Suspension 3	5 µL	5 µL	5 µL
Mix, wait for completion of the reaction (approx. 10-15 min) and read absorbances of the solutions (A_2). Add			
Suspension 4	5 µL	5 µL	5 µL
Mix, read absorbances of the solutions after 10-15 min (A_3). Add			
0.5 g/L D-glucose		12.5 µL	12.5 µL
Mix, read absorbances of the solutions after 10-15 min (A_4).			

*v (sample): v (C.c. raw) = 150 µL, v (C.e. raw) = 300 µL, v (C.g. raw) = 450 µL, v (D.g. raw) = 30µL, v (M.p. raw) = 450 µL, v (P.b. raw) = 30 µL, v (P.l. raw) = 450 µL, v (V.s. raw) = 300 µL, v (C.c. pro) = 400 µL, v (C.e. pro) = 450 µL, v (C.g. pro) = 30 µL, v (M.p. pro) = 450 µL, v (P.b. pro) = 30 µL, v (P.l. pro) = 400 µL, v (V.s. pro) = 200 µL.

**v(water): v (water for C.c. raw) = 350 µL, v (water for C.e. raw) = 200 µL, v (water for C.g. raw) = 50 µL, v (water for D.g. raw) = 470 µL, v (water for M.p. raw) = 50 µL, v (water for P.b. raw) = 470 µL, v (water for P.l. raw) = 50 µL, v (water for V.s. raw) = 200 µL, v (water for C.c. pro) = 100 µL , v (water for C.e. pro) = 50 µL, v (water for C.g. pro) = 470 µL, v (water for M.p. pro) = 50 µL, v (water for P.b. pro) = 470 µL, v (water for P.l. pro) = 100 µL, v (water for V.s. pro) = 300 µL.

For the determination of D-glucose for all flours, no sample solution was diluted (except raw *Dialium guineens*e sample solution which was diluted by a factor of 5). The positive control solution was diluted by a factor of 4. The following equations were used to calculate the amount of D-glucose in g per 100 g of the legume flour sample:

$$\mathrm{D-glucose\ concentration}\left(\frac{\mathrm{g}}{\mathrm{l}}\right)=\frac{\mathrm{VxMWx\Delta A}}{\varepsilon \mathrm{xdxvx1000}} \qquad (1)$$

Here V = final volume at the end of the reaction (0.755 ml)

v = volume of sample taken (ml)

MW = molecular weight of substance being analysed (g/mol)

d = light path (cm)

ε = extinction coefficient of NADH at 340 nm = 6.3 [l x $mmol^{-1}$ x cm^{-1}]

$\Delta A = (A_2 - A_1)_{sample} - (A_2 - A_1)_{blank}$

$$\text{Amount of D} - \text{glucose in flour } (g/100g) = \frac{\text{D} - \text{glucose concentration } \left(\frac{\text{g}}{\text{l}}\right) x100}{\text{weight of sample per litre } \left(\frac{\text{g}}{\text{l}}\right)} \quad (2)$$

The recovery for the positive control solution (external standard) was calculated as follows:

$$\%\text{Recovery (Positive control)} = \frac{\text{concentration from enzymatic analysis x 100}}{\text{concentration from weight and volume measurement}} (3)$$

For the determination of D-fructose for all flours, no sample solution was diluted (except raw *Dialium guineens*e sample solution which was diluted by a factor of 5). The positive control solution was diluted by a factor of 4. The following equations were used to calculate the amount of D-fructose in g per 100 g of the legume flour sample:

$$\text{D} - \text{fructose concentration } \left(\frac{\text{g}}{\text{l}}\right) = \frac{\text{VxMWx}\Delta\text{A}}{\varepsilon\text{xdxvx1000}} \quad (1)$$

Here V = final volume at the end of the reaction (0.76 ml)

v = volume of sample taken (ml)

MW = molecular weight of substance being analysed (g/mol)

d = light path (cm)

ε = extinction coefficient of NADH at 340 nm = 6.3 [l x $mmol^{-1}$ x cm^{-1}]

$\Delta A = (A_3 - A_2)_{sample} - (A_3 - A_2)_{blank}$

$$\text{Amount of D} - \text{fructose in flour } (g/100g)$$

$$= \frac{\text{D} - \text{fructose concentration } \left(\frac{\text{g}}{\text{l}}\right) x100}{\text{weight of sample per litre } (\frac{\text{g}}{\text{l}})} \qquad (2)$$

The recovery of D-glucose solution used as internal standard was calculated using the following equations:

$$\text{D} - \text{glucose concentration } \left(\frac{\text{g}}{\text{l}}\right) = \frac{\text{VxMWx}\Delta\text{A}}{\varepsilon\text{xdxvx1000}} \qquad (3)$$

Here V = final volume at the end of the reaction (0.7725 ml)

v = volume of D-glucose solution taken (0.125 ml)

MW = molecular weight of substance being analysed (g/mol)

d = light path (cm)

ε = extinction coefficient of NADH at 340 nm = 6.3 [l x $mmol^{-1}$ x cm^{-1}]

$\Delta A = (A_4 - A_3)$

$$\%\text{Recovery (D} - \text{glucose)}$$

$$= \frac{\text{concentration from enzymatic analysis x 100}}{\text{concentration of the D} - \text{glucose solution in enzyme kit}} (4)$$

The recovery for the positive control solution (external standard) was calculated as follows:

$$\%\text{Recovery (Positive control)} = \frac{\text{concentration from enzymatic analysis x 100}}{\text{concentration from weight and volume measurement}} (5)$$

3.1.7.9. Determination of D-glucose content before inversion

At a pH of 7.6, the enzyme hexokinase (HK) catalyzes the phosphorylation of D–glucose by adenosine-5'-triphosphate (ATP) with the simultaneous formation of adenosine-5'-diphosphate (ADP) and D - glucose-6-phosphate (G-6-P).

(1) D-glucose + ATP $\xrightarrow{\text{HK}}$ G-6-P + ADP

In the presence of glucose-6-phosphate dehydrogenase (G6P-DH), the D–glucose-6-phosphate (G-6-P) formed is specifically oxidized by nicotinamide-adenine dinucleotide phosphate (NADP) to D-gluconate-6- phosphate with the formation of reduced nicotinamide-adenine dinucleotide phosphate (NADPH).

(2) G-6-P + $NADP^+$ $\xrightarrow{\text{G6P-DH}}$ D-gluconate-6-phosphate + NADPH + H^+

The NADPH formed in this reaction is stoichiometric to the amount of D–glucose and was measured by means of its light absorbance at 340 nm.

3.1.7.10 Determination of D-fructose content

HK also catalyzes the phosphorylation of D-fructose to D-fructose-6-phosphate (F-6-P) with the aid of ATP.

(1) D-fructose + ATP $\xrightarrow{\text{HK}}$ F-6-P + ADP

On completion of reaction (3), D-Fructose-6-phosphate is converted to D-glucose-6-phosphate by the action of phosphoglucoseisomerase (PGI).

(2) F-6-P $\xrightarrow{\text{PGI}}$ G-6-P

The reaction then follows the same sequence as G-6-P in reaction (2) for the D-glucose determination. The amount of NADPH formed here is stoichiometric to the amount of D-fructose and was measured by means of its light absorbance at 340 nm.

3.1.7.11 Determination of sucrose content

At a pH of 4.6, sucrose is hydrolysed to D-glucose and D-fructose by the enzyme β-fructosidase (invertase).

$$\text{Sucrose} + H_2O \xrightarrow{\beta\text{-fructosidase}} \text{D-glucose} + \text{D-fructose}$$

The determination of D-glucose after inversion (total D-glucose) is carried out as described for the determination of D-glucose. The sucrose content is calculated from the difference of the D-glucose concentrations before and after enzymatic inversion.

3.1.8 Determination of Ash content

The method here is from the Master Thesis of Ingo Fohmann in September 2018 at the Chair of Food Chemistry, University of Wuerzburg (Bestimmung der Mineralstoffgehalte von rohen und prozessierten Leguminosenmehlen aus Ghana). Crucibles were cleaned with 6 M HCl and Millipore water and heated for 30 min in a muffle furnace (M110, Serien-Nr. 8190, Memmert GmbH + Co. KG, Schwabach) to dry (550°C). The crucibles were allowed to cool in a desiccator. After repeated heating, cooling and weighing to obtain constant weights for the crucibles, the samples were measured (5 g) into the crucibles. The crucibles and their contents were heated for 30 min on a pre-ashing equipment (SVD95P, Serien-Nr. 2590213, Harry Gestigkeit GmbH, Düsseldorf Germany) and then placed inside the pre-ashing equipment until no more smoke was detected. The samples were then placed inside a muffle furnace pre-heated to 550 ± 10°C for 3 h. The crucibles were removed from the muffle furnace after 3 h, allowed to cool and the content of each crucible was moistened with 2 ml Millipore water. The crucibles and their contents were heated again on the pre-asher. This was followed by a second ashing step for 2 h in a muffle furnace (pre-heated to 550 ± 10°C). The crucibles were removed from the muffle furnace and allowed to cool in a desiccator. For ash determination, the crucibles and their contents were weighed. The final weight of the sample (ashed sample) was expressed as a percentage of the initial weight of the sample (un-ashed sample). Recovery experiments to assess the correctness of the ash content determination were conducted simultaneously with the ash determination using processed *Cajanus cajan* flour, raw *Canavalia ensiformis* flour, processed *Canavalia ensiformis* flour, raw *Parkia biglobosa* flour and raw *Dialium guineense* flour. The same procedure for the determination of the ash in legume flour samples was followed for the recovery experiment. In the recovery experiment 2.5 g of each of the mentioned flours were weighed and to each flour, an amount of sea sand which

corresponds to the amount of ash in the 2.5 g of flour was added. The sea sand weights for the recovery of the ash content are shown in Appendix 2A.

3.1.9 Mineral nutrients determination

The method here is from the Master Thesis of Ingo Fohmann in September 2018 at the Chair of Food Chemistry, University of Wuerzburg (Bestimmung der Mineralstoffgehalte von rohen und prozessierten Leguminosenmehlen aus Ghana). To quantify the mineral contents of the samples, an external calibration is used which contains all analytes in suitable concentration. The ash is dissolved in HCl and transferred to a volumetric flask (50 ml). The sample solution is diluted individually for each element to the desired concentration within the concentration range of the calibration, which is measured along with the sample dilutions. Five millilitres (5 ml) of HCl (6 M) taken with a measuring pipet is added to the ash and the solutions are heated on the pre-asher (Typ SVD95P, Serien-Nr. 2590213, Harry Gestigkeit GmbH, Düsseldorf). By repeated rinsing of the dishes with HCl (6 M), the residue is transferred quantitatively into a 50 ml volumetric flask. Two-point five millilitres (2.5 ml) of La / Cs / HCl (5.0062 g La_2O_3 + 10.0000 g CsCl + 75 ml HCl/ 100 ml Millipore water) solution are added to the volumetric flask and the volumetric flask was made up to the mark with Millipore water. The solution is allowed to stand overnight so that existing soot particles can settle. The solutions which were not clear were filtered through an ashless round filter. Thereafter, the samples were individually diluted for each element to the desired concentration within the concentration range of the calibration, which is measured along with the sample dilutions. The dilution is done with with La / Cs / HCl blank solution (25.0310g La_2O_3 + 50.00g CsCl + 375 ml HCl/500 ml Millipore water + 9500 ml Millipore water). The solutions were then injected into the air-acetylene flame of the atomic absorption spectrometer (AAS) (UNICAM 969 AA, Solaar series) and measured. The mineral-specific settings made are listed in Appendix 2B.

The mineral-independent settings for the atomic absorption spectrophotometer are listed in appendix 2 C.

Concentrations of the calibration standards used for sample measurement and recovery measurements of the minerals are shown in appendix 2D.

Recovery experiments to assess the correctness of the mineral nutrients determination were conducted simultaneously with the mineral nutrients determination in the legume flour samples. The legume flours used in the recovery experiments were processed *Cajanus cajan* flour, raw *Canavalia ensiformis* flour, processed *Canavalia ensiformis* flour, raw *Parkia biglobosa* flour and raw *Dialium guineense* flour. The same procedure for the determination of the minerals in legume flour samples was followed for the recovery experiment. In the recovery experiment 2.5 g of each of the mentioned flours were weighed and to each flour, 5 ml standard solution which contain the same mass of minerals as the average content in the 2.5 g of the flour was added. The preparation of the standards is shown in appendix 2E.

3.1.10 Cyanide determination

The method here is from the Master Thesis of Anna-Maria Kirsch in September 2018 at the Chair of Food Chemistry, University of Wuerzburg (Etablierung einer Methode zur Quantifizierung von cyanogenen Glycosiden in Mehlen von Leguminosen ghanaischer Herkunft).

3.1.10.1 Preparation of $AgNO_3$ standard solution (0.01 N)

To prepare the 0.01 N $AgNO_3$ solution, a 0.1 N solution was diluted by a factor of 10. For 250 ml of the diluted solution, a 25 ml of the 0.1 N solution was measured using a volumetric pipette and poured into a 250 ml volumetric flask and made to the mark with deionised water. In every 7 to 10 days the solution was freshly prepared and the titer was determined. The solution was stored in an amber glass bottle protected from light.

3.1.10.2 Preparation of $AgNO_3$ solution (0.02 N)

A 0.1 N $AgNO_3$ solution was diluted by a factor of 5. For 250 ml of the diluted solution, a 50 ml of the 0.1 N $AgNO_3$ solution was measured using a volumetric pipette and poured into a 250 ml volumetric flask and made to the 250 ml mark with deionised water. The solution was stored in an amber glass bottle protected from light.

3.1.10.3 Preparation of Ammonium iron (III) sulphate indicator solution

Saturated ammonium iron (III) sulphate solution is the amount of the chemical in 25 ml deionised water, measured with a measuring cylinder, dissolved until after a slight shaking nothing more dissolves and a sediment is formed. This corresponds to about 31 g Ammonium iron (III) sulphate.

3.1.10.4 Preparation of cyanide standard solution

A certified cyanide solution with a concentration of 1 g/L was used as the starting material. It was diluted by a factor of 10. For the preparation of 250 ml cyanide standard solution, 25 ml was pipetted into a 250 ml volumetric flask. It was then filled with deionised water up to the calibration mark. The concentration of the standard solution thus obtained was 3.84 mmol / L.

3.1.10.5 Preparation of dextrin solution (2%)

About 1 g of dextrin was weighed out and dissolved in 49 ml deionised water that was previously measured with a pipette.

3.1.10.6 Preparation of iron sulphate solution

To dispose of the cyanide, it is to be complexed to hexacyanoferrate using iron sulphate. For 100 ml of this solution, about 1 g of iron sulphate was weighed out and dissolved in deionised water and made up to the 100 ml mark.

3.1.10.7 Preparation of fluorescein solution

About 25 mg of fluorescein was weighed out and transferred into a 25 ml volumetric flask and dissolved in ethanol. Then it was made up to the calibration mark with ethanol.

3.1.10.8 Preparation of HNO_3 solution (5 N)

A concentrated 65% solution was used to prepare the 5 N HNO_3. A 17.3 ml solution of 65% HNO_3 was measured and transferred into a 50 ml volumetric flask, which was already half filled with deionised water. After cooling the solution in an ice bath, the content of the volumetric flask was diluted with deionised water up to the calibration mark.

3.1.10.9 Preparation of Potassium iodide solution (10%)

For about 50 ml of the solution, 5 g of KI was weighed out and dissolved in 45 ml of deionised water that previously was measured using a measuring cylinder.

3.1.10.10 Preparation of Sodium chloride original titer solution (0.05 M)

For the sodium chloride original titer solution, NaCl is first dried at 110°C until the mass is constant. Then 0.2952 g of it was weighed out into a 100 ml volumetric flask. Deionised water was added to dissolve the NaCl. After this, more deionised water was added up to the 100 ml mark.

3.1.10.11 Preparation of Sodium hydroxide solution (1 M)

About 39.997 g of NaOH pellets were dissolved in a 1 L volumetric flask in an ice bath and the flask was finally made up to the calibration mark with deionised water.

3.1.10.12 Preparation of Sodium hydroxide solution (3.6 M)

The 3.6 M sodium hydroxide solution is produced in the same way as the 1 M NaOH solution, but here 143.99 g of NaOH was weighed.

3.1.10.13 Preparation of Phenol red solution

An amount (0.1 g) of phenol red was weighed and dissolved in ethanol (100 ml) which was measured using a measuring cylinder.

3.1.10.14 Preparation of Phosphoric acid (0.1 M)

A concentrated 85% phosphoric acid served as the basis for 0.1 M phosphoric acid. From this, a pipette was used to measure 6.7 ml into deionised water in a 1 L volumetric flask with the phosphoric acid forming about one-third of the volume of this solution. This was then filled up to the calibration mark with deionised water.

3.1.10.15 Preparation of Phosphate buffer

About 9.6 g of sodium dihydrogen phosphate was weighed and dissolved in deionised water in a beaker. The pH was adjusted to 5.9 with NaOH before the solution was transferred into a 1 L volumetric flask and made up to the calibration mark with deionised water.

3.1.10.16 Preparation of Sulphuric acid (4 M)

For the sulphuric acid, a dilution was made from 95-97% sulphuric acid. For this purpose, 225 ml H_2SO_4 was measured with a measuring cylinder and transferred into deionised water in a 1 L volumetric flask in an ice bath with the sulphuric acid forming about one-third of the volume of this solution. After cooling down to room temperature this was made up to the calibration mark with deionised water.

3.1.10.17 Titre setting of the standard 0.01 N $AgNO_3$ solution

The titre of $AgNO_3$ was determined by the ratio of the actual concentration to the expected concentration after titration with 0.05 M NaCl solution. Here 2 ml of the NaCl solution was measured into a 100 ml volumetric flask and four drops of fluorescein (drawn with a Pasteur pipette) was added. This was then diluted with as much distilled water so that the magnetic stirrer was completely covered with liquid. This was then titrated against the 0.01 N $AgNO_3$ solution in a burette to the end point where a slight pink precipitate is observed.

3.1.10.18 Blank Titration

For the blank value, everything except the sample is used and the same procedure is followed as for the samples.

3.1.10.19 Measurement of Limit of detection (LOD) and Limit of quantitation (LOQ) for cyanide determination

Different volumes of the cyanide standard solution (3.84 mmol/L): 1.0 ml (3.84 µmol), 2.0 ml (7.68 µmol) and 3.0 ml (11.52 µmol) were titrated against 0.01 N $AgNO_3$ with 10% KI as the indicator. After determining the blanks, the mean blank value and standard deviation of the blanks were used to determine the Limit of Blank (LOB) by the equation below:

$$LOB = mean_{blank} + 1.654.sd_{blank}$$

Here sd_{blank} is the standard deviation of the blank. The LOD was calculated using the equation below:

$$LOD = LOB + 1.654.sd_{lcs}.$$

Here sdl_{cs} = standard deviation of the concentration of the standard cyanide solution with the lowest concentration of cyanide (i.e. 1.0 ml = 3.84 µmol cyanide solution).

After calculation, the LOD obtained was 2.52 µmol per 15 g sample (15 g sample was the approximate quantity of flour used for the cyanide determination) and this gives 16.80 µmol per 100 g or 0.44 mg per 100 g. Data generated for the calculation of the LOD are shown in appendix 3.

The recovery of the cyanide standard solution of volume 1.0 ml (3.84 µmol) differed significantly ($p \leq 0.05$) from the recoveries of the cyanide standard solutions of volumes 2.0 ml (7.68 µmol) and 3.0 ml (11.52 µmol). The recovery of the cyanide standard solution of volume 1.0 ml (3.84 µmol) had a mean of 68.9% which is far below 100% with a standard deviation of 12.2%. On the other hand, there was no significant difference between the recoveries of the cyanide solutions of volume 2.0 ml (7.68 µmol) and 3.0 ml (11.52 µmol). Cyanide solution of volume 2.0 ml (7.68 µmol) had a recovery of 95.5% with a standard deviation of 4.4% while the cyanide solution of volume 3.0 ml (11.52 µmol) had a recovery of 92.7% with a standard deviation of 6.2%. Therefore the lower

value of 7.68 µmol per 15 g of sample was defined as the LOQ. For 100 g per sample, 7.68 µmol CN per 15 g sample becomes 51.2 µmol CN per 100 g sample or 1.3 mg CN per 100 g sample.

3.1.10.20 Analyses of cyanide content of legume flours

Approximately 15 g of flour was weighed directly into a 250 ml round bottom flask. It was mixed with 30 ml of 0.1 M H_3PO4, then 30 ml of 4 M H_2SO_4 was added. Residual samples remaining at the edges were removed using deionised water flushed in the flask. This was then connected to the Soxhlet apparatus and heated at full reflux for 75 min. Four samples, as well as one positive control and blank, were treated simultaneously. After a cooling time of about 1 h, the contents of the flask were transferred quantitatively to a 250 ml Kjeldahl flask. The flask was rinsed twice with deionised water and the washings were added to the content of the Kjedahl flask. An amount (0.5 ml) of silicone antifoam agent was pipetted into each Kjeldahl flask before it was connected to the steam distillation. Now, about 80 ml of a 3.6 M NaOH solution was added. This mixture was allowed to stand for 10 min for the reaction. Subsequently, the distillation was started. The distillation time was 5 min, with a steam output of 100% set. The distillate was collected into a 250 ml Erlenmeyer flask containing 40 ml of 1 M NaOH. Distillation was carried out twice for 5 min each with fresh water to rinse the solids from the apparatus. After completion of the distillation, the receiver flask was removed from the apparatus. In each of these flasks, 1 ml of concentrated NH_3 solution was added followed by the addition of 1 ml 10% KI solution. The mixture was then titrated against 0.01 N $AgNO_3$ from a 10 ml burette. From the consumed volume of the mixture to $AgNO_3$ solution, the amount of cyanide was then calculated using the equation below:

$$n(CN) = \frac{v(AgNO_3) \text{ in ml.} 2. C(AgNO_3). t}{1000}$$

Here

$$t = \frac{\text{concentration of } AgNO_3 \text{prepared (0.01N)}}{\text{Concentration of } AgNO_3 \text{after titration with 0.05 M NaCl}}$$

In order to confirm the results obtained by acid hydrolysis regarding the cyanide contained in the flours, an internal standard was used. For this purpose, two flours were selected as representatives. There is an example in which the cyanide content is below LOD, the other over LOQ. In both

cases, amygdalin is used as the internal standard. In the case of the cyanide content under LOD, 15 g of flour amygdalin having a molar mass of 11.5 µmol is added, which is in the range of the LOQ. In the other flour, the amount of cyanide contained in 15 g of flour was used. Amygdalin was used and not linamarin because the method employed led to better recovery for amydalin.

3.1.11 Determination of isoflavones (IFs)

The method here is from the Master Thesis of Johanna Schmitt in October 2018 at the Chair of Food Chemistry, University of Wuerzburg (Übertragung und Optimierung einer bestehenden Methode zur Quantifizierung von Isoflavonen in Nahrungsergänzugsmitteln mittels HPLCDAD auf die Matrix von verschiedenen Leguminosenmehlen aus Ghana und Identifizierung der Isoflavone mittels UHPLC-MS/MS).

3.1.11.1 Extraction of Isoflavones (IFs) from legume flour samples

One gram (1 g) sample was weighed into a 15 ml plastic tube and 40 µl internal standard (IS) was pipetted into it. The sample was then mixed with 10 ml of 50% Acetonitrile (ACN) and extracted for 2 h in an ultrasonic bath. After extraction, the suspension was vortexed and shaken. The solution was centrifuged at 5000 rpm for 10 min and the supernatant was removed. The removed supernatant was stored at -20°C in a freezer. The solution was then centrifuged at 5000 rpm and the supernatant was passed through a 0.45 µm filter in a centrifuge tube. The ACN of the sample solution was evaporated at 30 mbar. The aqueous phase was frozen at -20°C and freeze-dried overnight. The residue after freeze drying was dissolved in 3 ml ACN, centrifuged at 5000 rpm for 5 minutes and the supernatant removed. The removed supernatant was evaporated to dryness at 30 mbar, and 250 µl of 10% ACN was added to the residue and centrifuged at 14.8 g / min for 10 min. The clear liquid was removed and 1.5 ml of 75% ACN was added to the remaining extraction residue, slurried using a vortexer and centrifuged for 5 min at 5000 rpm. The extractant was removed by means of a Pasteur pipette. The extractants were combined and stored at -20°C. This was used for analyses of IFs in the legume flours.

3.1.11.2 Flow medium for IFs determination

For the HPLC-DAD, 0.1% formic acid in Acetonitrile and 0.1% formic acid in Millipore water were prepared. The 0.1% formic acid in acetonitrile was prepared by adding 1.0 ml formic acid (with a 1.0 ml graduated pipette) to 500 ml of ACN in a 1000 ml volumetric flask. The volumetric flask was then filled to the 1000 ml mark with ACN and shaken.

The 0.1% formic acid in Millipore water was prepared by adding 1.0 ml formic acid (with a 1.0 ml graduated pipette) to 500 ml of Millipore water was in a 1000 ml volumetric flask. The volumetric flask was then filled with Millipore water to the 1000 ml mark and shaken.

For the UHPLC-MS/MS, 0.1% formic acid in methanol and 0.1% formic acid in Mass Sepectrometer (MS) grade water were prepared. The 0.1% formic acid in methanol was prepared by adding 0.5 ml formic acid (with a 1.0 ml graduated pipette) to some amount of MS grade methanol in a 500 ml volumetric flask. The volumetric flask was then filled to the 500 ml mark with MS grade MeOH and shaken.

The 0.1% formic acid in MS grade water was prepared by adding 0.5 ml formic acid (with a 1.0 ml graduated pipette) to some amount of MS grade water in a 500 ml volumetric flask. The volumetric flask was then filled to the 500 ml mark with MS grade water and shaken.

3.1.11.3 Mixed solvents for IFs determination

Mixed solvents with ACN

10% ACN	90 ml Millipore water + 10 ml ACN
50% ACN	50 ml Millipore water + 50 ml ACN
75% ACN	25 ml Millipore water + 75 ml ACN

Mixed solvent with MeOH

80% MeOH	20 ml Millipore water + 80 ml MeOH

3.1.11.4 Other solutions for IFs determination

BCA solution 1330 ng / µg

BCA (3183) µg dissolved in 1198 ml ACN (2660 ng / µl) was diluted by a factor of 2 (1330 ng / µl). It was stored in the freezer at -20°C.

DAI solution 249.70 ng / µg

DAI (999) µg dissolved in 2000 ml ACN (499.50 ng / µl) was diluted by a factor of 2 (249.70 ng / µl). It was stored in the freezer at -20°C.

DAI-GLU solution 107.82 ng / µg

DAI-GLU (300 µg) dissolved in 1390 µl ACN (215.64 ng / µl) was diluted by a factor of 2 (107.82 ng / µl). It was stored in the freezer at -20°C.

FOR solution 336 ng / µg

FOR (336) µg dissolved in 1000 µl ACN (336 ng / µl). It was stored in the freezer at -20°C.

FOR solution 712.89 ng / µg

FOR (2994) µg dissolved in 2100 µl ACN (1425.71 ng / µl) was diluted by a factor of 2 (712.89 ng / µl). It was stored in the freezer at -20 ° C.

GEN solution 711.61 ng / µg

GEN (1520 µg) dissolved in 1068 µl ACN (1423.22 ng / µl) was diluted by a factor of 2 (711.61 ng / µl). It was stored in the freezer at -20°C.

GEN-GLU solution 150.36 ng / µg

GEN-GLU (412 µg) dissolved in 1370 µl ACN (300.72 ng / µl) was diluted by a factor of 2 (150.36 ng / µl). It was stored in the freezer at -20°C.

Naringenin solution 15.52 ng / µg

Naringenin (489) µg dissolved in 1500 µl 80% MeOH (326.00 ng / µl) was diluted (75/1575) (15.52 ng / µl). It was stored in the freezer at -20°C.

6-methoxyflavone (6-MF) solution 254 ng / µg

6-methoxyflavone (703 µg) dissolved in 1500 µl ACN (468.6 ng / µl) was diluted (81/1500) (254 ng / µl). It was stored in the freezer at -20°C.

3.1.11.5 HPLC Methods

Agilent 1100-DAD

For the chromatographic separation of the IFs, the qualitative and quantitative extract analysis, an HP Agilent Series 1100 DAD system with degasser, quaternary pump and Autosampler was used.

Detection was at 260 nm using Diode Array Detection (DAD). The recording and the data were analyzed using the ChemStation software.

HPLC Method:

Column: Phenomenex Synergi Max-RP-HPLC column (150 x 2.0 mm; 4 µm particle size).

Injection volume: 10 µl

Flow medium: Eluent A (Millipore water with 0.1% formic acid) and Eluent B (ACN with 0.1% formis acid).

Flow rate: 0.5 ml/min

Oven temperature: 40°C.

Gradient

Time (min)	0	8	9	38	63	65	68	70	80
Eluent A (%)	10	14	17	25	39	50	50	10	10
Eluent B (%)	90	86	83	75	61	50	50	90	90

Detection: 260 nm

3.1.11.6 UHPLC-ESI-MS/MS

To confirm the peak assignment of the IFs from the qualitative extract analysis, the IFs from the legume flours were fractionated on the HPLC-DAD and analyzed using UHPLCMS / MS coupled with an electrospray ion source in negative mode. The UHPLC system consists of a Shimadzu Nexera X2 UHPLC system with degasser, two binary pumps coupled with an ABSciex 5500 QTrap hybrid system consisting of triple quadrupole and linear ion trap with a TurboVTM ion source with TurboIonspray® probe for electrospray ionization and an autosampler with a temperature of 4°C. The data was recorded and analyzed using the Analyst software. The mass / charge (m / z) of the IF transitions and the substance-specific parameters are listed in appendix 4A.

UHPLC Method:

Column: Phenomenex Kinetex C18 column (100 x 3.0 mm; 2.6 µm particle size).

Injection volume: 10 µl

Flow medium: Eluent A (Millipore water with 0.1% formic acid) and Eluent B (MeOH with 0.1% formic acid).

Flow rate: 0.3 ml/min

Oven temperature: 40°C.

Gradient

Time (min)	0	7	17	25	27	29	37.99	38
Eluent A (%)	97	70	60	0	0	97	97	stopped
Eluent B (%)	3	30	40	100	100	3	3	

MS parameter

Parameter	Setting
Polarity	negative
Temperature	550°C
Ionization voltage	-4000 V
Atomizer gas	40 psi
Turbo gas	80 psi
Curtain gas	35 psi

Measurement mode: Multiple reaction monitoring mode (MRM-mode)

3.1.11.7 Determination of the retention times (tR) of the IFs and review of the method for the chromatographic separation of IFs

To determine the relative retention times and to check the method for chromatographic separation of the IFs on high performance liquid chromatography (HPLC) coupled with a diode array detector (DAD), the individual references are measured individually and then as a mixture. The injection volume was 10 µl. The mass on column (m.o.c) should be the same in the individual references and the mixture. The pipetting scheme for reference mixture 1 is shown in appendix 4B.

3.1.11.8 Qualitative analyses of the IFs

The flours were processed and injected into the HPLC-DAD using the HPLC method and measured. Using the added IS (6-MF), the relative Retention times (tR) of the IFs in the flours were determined. The peak allocation was based on the comparison of this relative tR with those of the individual references.

The isoflavone pattern of eight legume seeds / fruits was analyzed qualitatively, and the influence of the processing on the isoflavone pattern of seven of these legume flours was compared to their respective raw flours. First the relative retention times (rel. tR) of the individual references were determined and the chromatographic separation of the isoflavones checked on the HPLC-DAD. The workup was then adapted to the sample material. Furthermore, these were first analyzed qualitatively on the HPLC-DAD. Selected IFs were then isolated from the flours on the HPLC-DAD and these were identified on the UHPLC-MS / MS on the basis of specific m / z ratio in the MRM mode. The quantification of selected IFs in the processed legume flours of *Cajanus cajan*, *Parkia biglobosa* and *Vigna subterranea* was carried out on the HPLC-DAD using standard addition.

Eighteen (18) isoflavone references and the internal standard were baseline separated in the reference mix. Thus chromatographic separation was confirmed. To determine the rel. tR of the IFs, these were measured individually with added IS (6-MF) using HPLC-DAD. To calculate the rel. tR of the individual references, the absolute retention times of the individual references were divided by the absolute retention time of the internal standard (6-MF) (Appendix 4C).

3.1.11.9 Identification of the IFs using UHPLC-MS

In the qualitative extract analysis, the IFs of the leguminous flours were determined based on their rel. tR and assigned their peak. In order to verify the qualitatively assigned peaks, these were analyzed using the UHPLC-MS / MS method. Firstly, selected individual references of 18 IFs were measured with the respective specific m / z ratio. The specific transitions were used to identify the IFs in the samples and to compare the tR of the individual reference to the sample. An acceptance range of 1.0% was determined by the tR. An IF in this area is considered identified. The IF isolated on the HPLC-DAD were measured on the UHPLC-MS / MS and compared with the references. Pipetting scheme for the dilution of the reference isoflavones BCA, DAI, DAI-GLU, FOR, GEN, GEN-GLU, GLY, PRA and PRU for measurement on the UHPLC-MS / MS is shown in appendix 4D. The solvent used was 10% ACN.

BCA was identified using the two specific m / z ratios of 283/268 and 283/239 in *Cajanus Cajan*, *Canavalia gladiata*, *Dialium guineense*, *Mucuna pruriens* and *Parkia biglobosa*. In addition, BCA eluted in the sample measurements at the same time as in the reference measurement. The peak assignment was thus confirmed using MS. In *Cajanus Cajan*, *Parkia biglobosa* and *Vigna*

subterranea, DAI was identified on the basis of the m / z ratio of 253/133 and 253/223 and the tR of 20.0 min, from which DAI deviate from the samples by a maximum of 0.5% . DAI was not identified in the samples *Canavalia ensiformis* (299.9 fmol o.c.), *Dialium guineense* (1298.0 fmol o.c.) and *Mucuna pruriens* (904.7 fmol o.c.). DAI-GLU was confirmed in *Vigna subterranea* with an m / z ratio of 415/253 and the injected peak solution eluted at the same time as the reference. In *Cajanus cajan* (150.1 fmol o.c.), *Canavalia ensiformis* (720.5 fmol o.c.) *Canavalia gladiata* (300.2 fmol o.c.), *Mucuna pruriens* (680.4 fmol o.c.) and *Phaseolus lunatus* (299.3 fmol o.c.), DAI-GLU was not clearly identified by MS. In the *Cajanus Cajan* and *Mucuna pruriens* leguminous flours, FOR was determined using the m / z ratio of 266.9 / 252 and 266.9 / 223 and the tR of 24.0 min in the reference, of which the samples were only 0.04% deviated. The IF GEN was confirmed on the basis of the m / z ratio of 268/133 and 268/159 in the legume flours *Cajanus cajan*, *Canavalia ensiformis*, *Mucuna pruriens* and *Vigna subterranea*. The samples deviated from the reference tR by 0.3%. GEN was not confirmed in the *Parkia biglobosa* flour (7807.9 fmol o.c.). In *Cajanus cajan* and *Mucuna pruriens,* the IF GEN-GLU was identified by the m / z ratio of 431/269 and the tR of 14.2 min. However, this was not found in the flours *Canavalia ensiformis* (2628.4 fmol o.c.), *Canavalia gladiata* (531.9 fmol o.c.), *Parkia biglobosa* (7507.0 fmol o.c.) and *Phaseolus lunatus* (1171.0 fmol o.c.). In the three leguminous flours (*Mucuna pruriens*, *Phaseolus lunatus* and *Vigna subterranea*), PRA deviated from the tR by 3.5%. Thus the peak in the three leguminous flours was not identified as PRA. However, it is very likely that all three contain the same substance, as they differ by only 0.3% in tR. In the samples (*Canavalia ensiformis* and *Canavalia gladiata*), it is presumably the IF GLY, as this only differed by 0.9% from the tR at the m / z ratio of 283/268. In the two samples *Cajanus cajan* and *Parkia biglobosa*, instead of the IF GLY, it is a different substance that has the same m / z ratio. This deviates from the tR of the reference by 5.0%. Appendix 4E shows the isolated IFs from the legume flour samples with their m/z ratio.

To identify the IFs from the samples, the IF peaks in the processed and the raw legume flours were isolated on the HPLC-DAD. To isolate the IF peaks, the corresponding peaks of the IFs were collected at the detector exit. After that, ACN in the isolated peak solutions were evaporated at 30 mbar and the aqueous fraction frozen at -20°C and freeze-dried overnight. Until they were used, the dry IF fractions were kept in the freezer at -20°C. The dry IF fractions were then diluted to approx. 150 fmol with 10% ACN (MS grade) and measured with the method for UHPLC-MS /

MS. For the IF which could not be detected at this concentration, 300 fmol o.c. or higher concentrations on the LC-MS / MS in MRM mode were used (pipetting scheme is in appendix 4F). The assessment of the quantity of IFs is based on an area comparison of the Sample IF with the reference IF from the qualitative determination.

3.1.11.10 Quantifying the IFs in the legume flours

The IF BCA, DAI, DAI-GLU, GEN, GEN-GLU and FOR in the processed flours of *Cajanus cajan*, *Vigna subterranea* and *Parkia biglobosa* were quantified.

3.1.11.11 Preliminary tests for calibration

External calibration and internal standard (IS)

Forty microlitres (40 µl) of a 10 ng / µl naringenin solution or apigenin solution was added to 40 µl 6-MF and the solvent was evaporated at 30 mbar. The residue was dissolved in 100 µl 10% ACN and injected into the HPLC-DAD and the tR determined.

For *Cajanus cajan*, calibration stock solutions from BCA, DAI, DAI-GLU, GEN and GEN-GLU were produced (Appendix 4G1). The calibration stock solution for *Parkia biglobosa* consisted of BCA, DAI, GEN and GEN-GLU (Appendix 4G2). The calibration stock solution for *Vigna subterranea* consisted of DAI, DAI-GLU, GEN and GEN-GLU (appendix 4G3).

3.1.11.12. Quantification of IFs in processed *Cajanus cajan*

The quantification of IF in *Cajanus cajan* was done using standard addition. For this purpose, the created calibration stock solution 1 from BCA, DAI, DAI-GLU, FOR, GEN and GEN-GLU were pipetted and added to the sample (appendix 4H1). *Cajanus cajan* was determined without internal standard (6-MF) since 6-MF is overlaid by other peaks in this sample. Additionally a blank and a reference with the concentration of calibration point 3 were always measured. After adding the calibration solution, the samples were processed (appendix 4I).

3.1.11.13 Quantification of IFs in processed *Parkia biglobosa*

IFs in *Parkia biglobosa* were quantified using standard addition. For this purpose, the created calibration stock solution 3 from BCA, DAI, GEN and GEN-GLU were pipetted and added to the sample (appendix 4H2). In addition, an internal standard (6-MF) was added. A blank and a reference with the concentration from calibration point 3 were also measured. After adding the calibration solution, the samples were processed (appendix 4I).

3.1.11.14 Quantification of IFs in processed *Vigna subterranea*

The quantification IFs of *Vigna Subterranea* was carried out using standard addition. For this purpose, the created calibration stock solution 2 from DAI, DAI-GLU, GEN and GEN-GLU were pipetted into and added to the sample (appendix 4H3). In addition, an internal standard (6-MF) was added. A blank and a reference with the concentration from calibration point 3 were also measured. After adding the calibration solution, the samples were processed (appendix 4I).

3.1.12 Determination of Crude protein content

Nitrogen was determined by the Kjedahl method [Bachelor Theses of Robin Maier in March 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, halbfett, arm an Natrium), Tobias Jaud in March 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, vollfett, lactosefrei), Julia Lai in March 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, halbfett. Reich an Calcium, Kalium und Eisen), Johanna Schmitt in September 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, vollfett. Reich an Calcium, Kalium und Eisen), Sina Junger in September 2017 (Analyse sowie lebensmittelchemische, -technologische und warenkundliche Beurteilung eines Kichererbsenmehls, sojafrei) and Leonie Schwarz in September 2017 (Analyse sowie lebensmittelchemische, -technologische und warenkundliche Beurteilung eines gerösteten Kichererbsenmehls, lactosefrei)] at the Chair of Food Chemistry, University of Wuerzburg.

The percent nitrogen (%N) was calculated using the equation below:

$$\%\, N = \frac{V(HCl) * c(HCl) * M(N)}{sample\ weight\ (g)} * 100$$

Where V(HCl) = volume (in litres) of HCl used in titration, c(HCl) = concentration of HCl in mol/dm^3, M(N) = Molar mass of nitrogen atom.

The crude protein content was obtained by multiplying the percent nitrogen (%N) by a factor of 6.25.

3.1.13 Determination of starch content

The starch content of the sample was determined by means of polarimetry[Bachelor Theses of Robin Maier in March 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, halbfett, arm an Natrium), Tobias Jaud in March 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, vollfett, lactosefrei), Julia Lai in March 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, halbfett. Reich an Calcium, Kalium und Eisen), Johanna Schmitt in September 2016 (Analyse sowie lebensmittelchemische, -technologische und -warenkundliche Beurteilung eines Sojamehls, vollfett. Reich an Calcium, Kalium und Eisen), Sina Junger in September 2017 (Analyse sowie lebensmittelchemische, - technologische und warenkundliche Beurteilung eines Kichererbsenmehls, sojafrei) and Leonie Schwarz in September 2017 (Analyse sowie lebensmittelchemische, -technologische und warenkundliche Beurteilung eines gerösteten Kichererbsenmehls, lactosefrei)] at the Chair of Food Chemistry, University of Wuerzburg.

The method consists of two separate determinations. The principle of the method is that a test portion is treated with dilute hydrochloric acid, then the solubilized starch is gelatinized and partially hydrolysed. The total optical rotation of the clarified solution is determined. Correction is made for the optical rotation caused by other substances which are soluble in 40% ethanol and optically active after treatment with dilute hydrochloric acid. The optical rotation of the resulting solution is measured by polarimetry.

The starch content (S) was calculated using the equation below:

$$S\left(\frac{g}{100g}\right) = \frac{100 * \Delta\alpha * 100}{\alpha\,{}^{20}_{D} * l * m}$$

Here, $\alpha\,{}^{20}_{D}$ = specific optical rotation (for other types of starch = 184.0)

l = length of the polarimeter tube in dm

m = weight (sample) in g

Δα = αH – αB, where

αH = angle of rotation in the main experiment and αB = angle of rotation of substances solube in 40% ethanol..

4 Results

4.1 Functional properties results

Functional properties of flours determine the functional roles the flours will play in various food products. The functional properties evaluated were bulk density (BD), foam capacity (FC), foam stability (FS), least gelation concentration (LGC), oil absorption capacity (OAC), solubility (SBL), swelling power (SP) and water absorption capacity (WAC). The data generated will help determine the potential application of these legume flours in various food products. The results of the functional properties of the raw flours of studied legumes are shown in Table 24 below.

Table 24: Functional properties of raw legume flours. Values are means ± standard deviation of three independent determinations. Values in the same column with different superscript letters differ significantly (ANOVA with Tukey mean comparison, $p \leq 0.05$).

	Functional properties of raw legume flours			
Legume	BD (g/ml)	FC (%)	FS (%)	LGC (% w/v)
Pigeonpea	0.97 ± 0.01^{a}	28.05 ± 1.14^{a}	78.87 ± 0.71^{d}	19.00 ± 1.00^{b}
Jack bean	0.88 ± 0.01^{c}	17.49 ± 1.14^{b}	89.44 ± 0.96^{c}	13.67 ± 0.58^{c}
Sword bean	0.79 ± 0.01^{e}	10.45 ± 2.26^{c}	91.14 ± 1.63^{bc}	8.67 ± 0.58^{d}
Velvet tamarind	0.61 ± 0.01^{g}	1.32 ± 0.57^{d}	99.68 ± 0.56^{a}	22.00 ± 1.00^{a}
Velvet beans	0.90 ± 0.01^{b}	17.00 ± 2.99^{b}	93.30 ± 1.61^{b}	12.67 ± 0.58^{cd}
African Locust bean	0.64 ± 0.01^{f}	7.19 ± 1.13^{c}	93.91 ± 1.02^{b}	11.33 ± 0.58^{d}
Lima bean	0.97 ± 0.01^{a}	20.92 ± 1.13^{b}	91.35 ± 0.90^{bc}	13.00 ± 1.00^{cd}
Bambara groundnut	0.84 ± 0.01^{d}	9.15 ± 1.13^{c}	92.22 ± 1.00^{bc}	23.67 ± 0.57^{a}

Table 24 continued

	Functional properties of raw legume flours			
Legume	OAC (g/g)	SBL (g/g)	SP (g/g)	WAC (ml/g)
Pigeonpea	0.20 ± 0.03^{f}	0.18 ± 0.04^{de}	5.56 ± 0.65^{d}	2.02 ± 0.03^{a}
Jack bean	0.67 ± 0.05^{c}	0.26 ± 0.02^{c}	6.65 ± 0.43^{cd}	2.03 ± 0.03^{a}
Sword bean	0.82 ± 0.05^{b}	0.24 ± 0.02^{cd}	8.94 ± 0.12^{b}	1.78 ± 0.03^{bc}
Velvet tamarind	1.11 ± 0.03^{a}	0.54 ± 0.02^{a}	7.30 ± 0.31^{c}	1.27 ± 0.03^{e}
Velvet beans	0.50 ± 0.05^{d}	0.14 ± 0.02^{e}	5.70 ± 0.27^{d}	1.70 ± 0.05^{cd}
African Locust bean	0.35 ± 0.05^{e}	0.18 ± 0.02^{de}	5.88 ± 0.04^{d}	1.62 ± 0.03^{d}
Lima bean	0.24 ± 0.02^{ef}	0.51 ± 0.03^{ab}	11.15 ± 1.14^{a}	1.85 ± 0.05^{b}
Bambara groundnut	0.18 ± 0.05^{f}	0.44 ± 0.02^{b}	9.59 ± 0.49^{b}	1.15 ± 0.05^{f}

Table 25 below shows the results of the functional properties of the flours which were prepared from the boiled seeds of the studied legumes.

Table 25: Functional properties of flours prepared from boiled legume seeds. Values are means ± standard deviation of three independent determinations. Values in the same column with different superscript letters differ significantly (ANOVA with Tukey mean comparison, $p \leq 0.05$).

	Functional properties of legume flours prepared from boiled seeds			
Legume	BD (g/ml)	FC (%)	FS (%)	LGC (% w/v)
Pigeonpea	0.95 ± 0.01^{a}	3.27 ± 1.13^{ab}	96.85 ± 1.07^{ab}	> 25
Jack bean	0.88 ± 0.01^{b}	2.31 ± 1.14^{b}	97.75 ± 1.10^{a}	> 25
Sword bean	0.83 ± 0.01^{c}	5.61 ± 1.14^{a}	94.69 ± 1.02^{b}	> 25
Velvet beans	0.81 ± 0.01^{cd}	1.65 ± 1.14^{b}	98.39 ± 1.10^{a}	> 25
Lima bean	0.94 ± 0.01^{a}	3.63 ± 1.14^{ab}	96.51 ± 1.06^{ab}	> 25
Bambara groundnut	0.84 ± 0.01^{c}	1.65 ± 1.14^{b}	98.39 ± 1.1^{a}	> 25

Table 25 continued

	Functional properties of legume flours prepared from boiled seeds			
Legume	OAC (g/g)	SBL (g/g)	SP (g/g)	WAC (ml/g)
Pigeonpea	0.68 ± 0.05^{c}	0.11 ± 0.02^{b}	6.34 ± 0.27^{ab}	2.40 ± 0.05^{c}
Jack bean	1.05 ± 0.05^{a}	0.16 ± 0.02^{b}	6.38 ± 0.17^{ab}	2.85 ± 0.05^{a}
Sword bean	1.00 ± 0.05^{ab}	0.22 ± 0.02^{a}	6.07 ± 0.31^{bc}	2.58 ± 0.03^{b}
Velvet beans	1.02 ± 0.05^{a}	0.14 ± 0.02^{b}	5.71 ± 0.26^{c}	2.38 ± 0.06^{cd}
Lima bean	0.89 ± 0.03^{b}	0.19 ± 0.02^{a}	6.87 ± 0.18^{a}	2.42 ± 0.03^{c}
Bambara groundnut	0.74 ± 0.05^{c}	0.12 ± 0.02^{b}	5.84 ± 0.09^{bc}	2.13 ± 0.06^{d}

4.1.1 Bulk density (BD) results

Significant differences ($p \leq 0.05$, adjusted) were observed among the bulk densities of the raw legume flours (Table 24). There were also significant differences ($p \leq 0.05$, adjusted) in bulk densities among the legume flours which were obtained from the boiled seeds (Table 25).

While processing (boiling) resulted in significant ($p \leq 0.05$, adjusted) decreases in the bulk densities of velvet beans and Lima beans, it resulted in significant ($p \leq 0.05$, adjusted) increase in the bulk

density of sword bean. The bulk densities of pigeonpea, Jack bean and Bambara groundnut were not significantly ($p>0.05$, adjusted) affected (Table 26).

Table 26: Two-sample t-tests for bulk densities of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p\leq0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted)
Pigeonpea	0.97 ± 0.01^{a}	0.95 ± 0.01^{a}	0.1422
Jack bean	0.88 ± 0.01^{a}	0.88 ± 0.01^{a}	1
Sword bean	0.79 ± 0.01^{b}	0.83 ± 0.01^{a}	0.0106
Velvet beans	0.90 ± 0.01^{a}	0.81 ± 0.01^{b}	0.0016
Lima bean	0.97 ± 0.01^{a}	0.94 ± 0.01^{b}	0.031
Bambara groundnut	0.84 ± 0.01^{a}	0.84 ± 0.01^{a}	0.8433

Roasting significantly ($p\leq0.05$) increased the BD of African Locust bean seed flour (Table 27). The roasting process might have resulted in a reduction in the porosity of the flour leading to the increase in BD. Onimawo and Akpojovwo (2006) also reported an increase in the BD of pigeon pea after toasting.

Table 27: Two sample t-test for BD of raw African Locust bean seed flour and flour prepared from the roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p\leq0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	0.64 ± 0.01^{b}	0.67 ± 0.01^{a}	0.0031

BD values obtained from this study were higher than the values of 0.62 (Siddiq et al., 2009) for wheat flour.

Boiling did not significantly ($p>0.05$) affect the BD of pigeonpea seed flour (Table 26). The BD values obtained were higher than that obtained by Onimawo and Akpojovwo (2006) and Mbaeyi-Nwaoha and Onweluzo (2013) who obtained BD values of 0.27 and 0.69 g/ml respectively for raw

pigeonpea seed flour. The values obtained from this study are also higher than the value of 0.8 g/ml obtained by O. J. Adebowale and Maliki (2011) for flour from the cotyledon of boiled pigeonpea containing sodium chloride (1g/kg seed).

There was no change in the BD of jack bean flour after processing (boiling) (Table 26). The BD value obtained in this study is higher than the value of 0.85 g/ml reported by Benítez et al. (2013) but close to the value of 0.87 g/ml reported by Ojo and Ade-Omowaye (2015).

Boiling led to a significant increase ($p \leq 0.05$) in the BD of sword bean seed flour (Table 26). The BD value obtained for flour from the boiled seeds is close to 0.85 g/ml for jack bean from Cuba reported by Benítez et al. (2013).

The BD value obtained in this work (Table 24) for velvet tamarind is greater than the value of 0.44 g/ml obtained by Obasi et al. (2013) for velvet tamarind fruit pulp from Nigeria.

There was a significant difference ($p \leq 0.05$) in bulk densities between raw velvet beans seed flour and the flour prepared from boiled seeds (Table 26). The bulk density values obtained in this work are higher than 0.57 g/ml obtained by Y. A. Adebowale et al. (2005).

The raw seed flour for *Parkia biglobosa* was significantly lower ($p \leq 0.05$) in BD than the roasted seed flour (Table 27).

The BD of raw Lima bean seed flour differed significantly ($p \leq 0.05$) from the flour obtained from the boiled seeds (Table 26). The bulk density values obtained in this study are higher than that obtained by Yellavila et al. (2015) (0.66 - 0.83 g/ml).

Boiling had no effect on the BD of *Vigna subterranea* seed flour (Table 26). The BD value obtained in this work is higher than the values of 0.56 - 0.57, 0.52 – 0.59 and 0.58 – 0.71 g/ml reported by Falade and Adebiyi (2015), Aremu et al. (2007) and Falade and Nwajei (2015) respectively.

4.1.2 Foam capacity (FC) results

Hydrothermal treatment led to a reduction in the foaming abilities of the seed flours (Table 28). A similar reduction in foaming ability was observed for the roasted seed flour of African Locust bean (Table 29). Similar observations of reduced foaming ability due to heat processing have been reported for cowpea flour by Giami (1993), African bread fruit kernel flour by Akubor et al. (2000)

and yam bean by Obatolu et al. (2007). FC values from this study were lower than that of wheat flour (33.7%) as reported by Siddiq et al. (2009).

Table 28: Two sample t-tests for the foam capacity of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p \leq 0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted)
Pigeonpea	28.05 ± 1.14^{a}	3.27 ± 1.13^{b}	0.0001
Jack bean	17.49 ± 1.14^{a}	2.31 ± 1.14^{b}	0.0001
Sword bean	10.45 ± 2.26^{a}	5.61 ± 1.14^{b}	0.0297
Velvet beans	17.00 ± 2.99^{a}	1.65 ± 1.14^{b}	0.0035
Lima bean	20.92 ± 1.13^{a}	3.63 ± 1.14^{b}	0.0002
Bambara groundnut	9.15 ± 1.13^{a}	1.65 ± 1.14^{b}	0.0035

Table 29: Two sample t-test for foam capacity of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	7.19 ± 1.13^{a}	1.65 ± 1.14^{b}	0.004

The FC of the raw seed flour of pigeonpea was significantly higher ($p \leq 0.05$) than the boiled seed flour (Table 28). The FC value of raw seed flour of pigeonpea obtained in this study is slightly higher than the value of 25% obtained by Okpala and Mamah (2001) but far lower than the results obtained by Oshodi and Ekperigin (1989) (68%). The FC for the boiled seed flour of pigeonpea in this study (Table 28) was lower than the value obtained by O. J. Adebowale and Maliki (2011) (8.16%).

The raw seed flour of jack bean exhibited a significantly higher ($p \leq 0.05$) FC than the boiled seed flour (Table 28). The value of FC for raw seed flour (Table 28) obtained in this study is far higher than 3.7% as reported by Ojo and Ade-Omowaye (2015). The boiled seed flour of jack bean

exhibited a slightly lower FC value (Table 28) than the value for raw seed flour reported by Ojo and Ade-Omowaye (2015) (3.7%).

The raw seed flour of sword bean had a significantly higher ($p \leq 0.05$) FC than the boiled seed flour (Table 28). Velvet tamarind fruit flour exhibited the least foaming ability among the legume flours. The FC of velvet tamarind obtained in this study (Table 24) is far lower than that the FC values of 30 and 43.5% respectively reported by Obasi et al. (2013) and Ogungbenle and Ebadan (2014).

The flour from the boiled seeds of velvet beans exhibited a significantly lower ($p \leq 0.05$) FC than the flour from the raw seeds. The FC value for the raw seed flour of velvet beans in this study (Table 28) is close to the FC value of raw velvet beans seed flour (19.2%) as reported by Y. A. Adebowale et al. (2005) but far lower than the values of 39.37 and 53% respectively reported by Bhat et al. (2008) and Ahenkora et al. (1999). The FC value for the boiled seed flour of velvet beans in this study is slightly lower than the FC value of 4% for boiled seed flour reported by Ahenkora et al. (1999).

The raw seed flour of African Locust bean was significantly higher ($p \leq 0.05$) in foaming ability than the roasted seed flour (Table 29). The FC values obtained in this study fall far below the FC value of 45% obtained by Abey and Abey (2016) for raw seed flour of African Locust bean.

The flour from the raw seeds of Lima beans had a significantly greater ($p \leq 0.05$) FC than the flour from the boiled seeds (Table 28). The FC value for raw seed flour of Lima beans obtained in this study falls slightly below the range of FC values (22.9 – 29.1%) reported by Oshodi and Adeladun (1993) but lies within the range of FC values (18.67 – 22.13%) obtained by Yellavila et al. (2015). The FC value for the raw flour of Lima beans from this study, however, falls far below the FC value for raw Lima bean seed flour obtained by Granito et al. (2007) (35.3%). The FC value of the flour from the boiled Lima beans in this study falls below that of the boiled seed flour obtained by Granito et al. (2007) (8.3%).

Boiling resulted in a significant ($p \leq 0.05$) reduction in the FC of the flours of Bambara groundnut seeds (Table 28). The raw seed flour of Bambara groundnuts exhibited a FC value falling within the range of values (7.9 – 9.9%) obtained by Aremu et al. (2007). However, the FC value for the raw seed flour of Bambara groundnuts falls slightly below the range of values reported by Falade and Nwajei (2015) (9.49 – 18.26%) and Falade and Adebiyi (2015) (10.78 – 18.37%). The flour

from the boiled Bambara groundnut seeds in this study exhibited a FC value far below the range of values obtained for raw seed flours by Aremu et al. (2007), Falade and Nwajei (2015) and Falade and Adebiyi (2015).

4.1.3 Foam stability (FS) results

There were significant differences ($p \leq 0.05$) among the foam stabilities of the raw legume flours (Table 24). There were also significant differences ($p \leq 0.05$) in foam stabilities among the legume flours which were prepared from boiled seeds (Table 25). Foam stability values from this study for all the legume flours (78.87 – 99.68%) were higher than that the value of 21.2 % for wheat flour obtained by Siddiq et al. (2009).

The stability of the foam from the raw seed flour of pigeonpea was significantly lower ($p \leq 0.05$) than the foam from the boiled seed flour (Table 30). This observation is similar to that of Obatolu et al. (2007) who, though, observed a reduction in FC of yam bean flour after heat treatment reported that the foams from the flours of heat-treated seeds were more stable than the raw seed flour. The FS for raw pigeonpea seed flour obtained from this study is far higher than that reported by Oshodi and Ekperigin (1989) (20%). The boiled seed flour of pigeonpea from this study also had far higher FS than the results reported by O. J. Adebowale and Maliki (2011) (2.45%).

The FS of the raw seed flour of jack bean was less than that of the boiled seed flour (Table 30). Obatolu et al. (2007) reported a similar effect of heat on the FS of yam bean flours. The FS values obtained in this study for raw and boiled seed flours of jack bean are far higher than the FS value reported for raw its seed flour by Ojo and Ade-Omowaye (2015) (1.85%).

The boiled seed flour of sword bean had a higher FS than its raw seed flour (Table 30). This agrees with the observation of Obatolu et al. (2007) for yam bean flour. Contrary results of effect of thermal processing on foam stabilities have been reported for cowpea by Giami (1993) and mung bean by Del Rosario and Flores (1981).

The FS of velvet tamarind (Table 24) obtained in this study is far higher than what was reported by Ogungbenle and Ebadan (2014) (62.2%) but compares favourably with the results of Obasi et al. (2013) (111%).

The boiled seed flour of velvet beans exhibited a higher FS than its raw seed flour (Table 30). This finding agrees with what was reported by Obatolu et al. (2007) for yam bean flour. On the contrary, Giami (1993) and Del Rosario and Flores (1981), respectively, reported a reducing effect of heat treatment on foam stabilities of seed flours of cowpea and mung bean. The results of FS of raw seed flour of velvet beans in this study is far higher than the results obtained by Y. A. Adebowale et al. (2005) (61%), Bhat et al. (2008) (60.33%) and Ahenkora et al. (1999) (10%). The boiled seed flour of velvet beans also exhibited a higher FS than the boiled seed flour of velvet beans reported by Ahenkora et al. (1999) (9%).

The roasted seed flour of African Locust bean formed a foam which was more stable than its raw seed flour (Table 31), corroborating the observation of Obatolu et al. (2007) for yam bean flour. This is however contrary to the observation of the effect of thermal processing on the seed flours of cowpea as reported by Giami (1993) and mung bean as reported by Del Rosario and Flores (1981).

Flour from the boiled seeds of Lima beans formed a more stable foam than the flour from the raw seeds (Table 30). Thermal processing has been reported to lead to the formation of more stable foam for yam bean by Obatolu et al. (2007). This is however contrary to the observation of Giami (1993) and Del Rosario and Flores (1981) for cowpea and mung bean flours respectively. The FS values for raw and boiled seed flours in this study are far higher than the range of values (8.8 – 23.2%) reported by Oshodi and Adeladun (1993) for raw seed flours of Lima bean.

Boiled seed flour of Bambara groundnuts formed a more stable foam than raw seed flour (Table 30). The same observation has been reported for yam bean by Obatolu et al. (2007). This is contrary to that of cowpea and mung bean as reported by Giami (1993) and Del Rosario and Flores (1981) respectively. The FS values for the raw and boiled seed flours in this study compare favourably with the range of values (98.1 – 98.4%) obtained by Aremu et al. (2007) for raw seed flours of Bambara groundnuts.

Table 30: Two sample t-tests for the foam stability of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p \leq 0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted
Pigeonpea	78.87 ± 0.71^{b}	96.85 ± 1.07^{a}	0.0001
Jack bean	$89.44\| \pm 0.96^{b}$	97.75 ± 1.10^{a}	0.003
Sword bean	91.14 ± 1.63^{b}	94.69 ± 1.02^{a}	0.0329
Vekvet beans	93.30 ± 1.61^{b}	98.39 ± 1.10^{a}	0.0213
Lima bean	91.35 ± 0.90^{b}	96.51 ± 1.06^{a}	0.0091
Bambara groundnut	92.22 ± 1.00^{b}	98.39 ± 1.10^{a}	0.0079

Table 31: Two sample t-test for foam stability of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	93.87 ± 0.99^{b}	98.39 ± 1.10^{a}	0.0061

4.1.4 Least Gelation Concentration (LGC) results

Heat treatment led to a reduction in the gelling abilities of the flours. For all boiled seed flours, no gel was formed up to a concentration of 25% (w/v). Prinyawiwatkul et al. (1997) reported that heat treatment led to an increment in the LGC of cowpea flour from 10% to 15% (w/v). The least gelation concentrations of raw seed flours of jack bean, velvet beans, African Locust bean and Lima beans are close to that of 14% w/v for wheat flour reported by Siddiq et al. (2009). While the raw seed flour of Sword bean exhibited a lower LGC than wheat flour, raw seed flours of pigeonpea and Bambara groundnuts, and roasted seed flour of African Locust bean exhibited a higher LGC than wheat flour. Raw fruit flour of velvet tamarind also had a higher LGC than the value of 14% for wheat flour reported by Siddiq et al. (2009).

The boiled seed flour of pigeonpea did not form a gel up to a concentration of 25% (w/v) (Table 25). The LGC of raw seed flour of pigeonpea obtained in this study (Table 24) is higher than the results for raw seed flours reported by Onimawo and Akpojovwo (2006) (4% w/v),

Mbaeyi-Nwaoha and Onweluzo (2013) (4% w/v), Olalekan and Bosede (2010) (6% w/v) and Oshodi and Ekperigin (1989) (12% w/v).

The boiled seed flour of jack beans did not form a gel up to a concentration of 25% (w/v) (Table 25). The LGC for the raw seed flour (Table 24) is higher than the result obtained by Olalekan and Bosede (2010) (4% w/v).

The raw sword bean seed flour exhibited the lowest LGC among the studied legume flours (Table 24). The boiled seed flour did not form a gel up to a concentration of 25% (w/v) (Table 25). The value obtained for the raw seed flour is close to the LGC of sword bean starch as reported by K. O. Adebowale et al. (2006) (10%).

The raw fruit flour of velvet tamarind exhibited a higher LGC (Table 24) than the result obtained by Ogungbenle and Ebadan (2014) (17% w/v).

The boiled seed flour of velvet beans did not form a gel up to a concentration of 25% (w/v) (Table 25). The LGC for the raw seed flour in this study (Table 24) is lower than the LGC value reported by Bhat et al. (2008) (16% w/v).

The LGC of the roasted seed flour of African Locust bean was significantly higher ($p \leq 0.05$) than that of its raw seed flour (Table 32). The LGC of the raw seed flour in this study is slightly higher than that reported by Abey and Abey (2016) (8% w/v).

The boiled seed flour of Lima beans did not form a gel up to 25% (w/v) (Table 25). The LGC of its raw seed flour in this study (Table 24) is far higher than the results obtained by Granito et al. (2007) (6% w/v) but falls slightly above the range of values (8 – 12%) reported by Oshodi and Adeladun (1993).

The boiled seed flour of Bambara groundnuts did not form a gel up to a concentration of 25% (w/v) (Table 25). The LGC of the raw seed flour in this study (Table 24) is far higher than the range of values obtained by Aremu et al. (2007) (12 – 14% w/v) for raw Bambara groundnut seed flour.

Table 32: Two sample t-test for least gelation concentration of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	11.33 ± 0.58^{b}	19.67 ± 0.58^{a}	0.0001

4.1.5 Oil Absorption Capacity (OAC) results

Flours obtained from the hydrothermally treated seeds held more oil than their corresponding raw flours (Table 33). Roasted African Locust bean seed flour also held more oil than the raw seed flour (Table 34). For pigeonpea and Bambara groundnut, both the raw and boiled seed flours recorded lower OAC than the value of 0.75 g/g for wheat flour from the USA as reported by Siddiq et al. (2009). Raw seed flours of jack bean, velvet beans, African Locust beans and Lima bean also recorded OAC values below the value of wheat flour (0.75 g/g) as reported by Siddiq et al. (2009). The boiled seed flours of jack bean, velvet beans and Lima bean, and the roasted seed flour of African Locust bean recorded OAC values higher than wheat flour from the USA (0.75 g/g) as reported by Siddiq et al. (2009), but the values fell within the range of values for wheat flour from Greece reported by Protonotariou et al. (2014) (0.78 – 1.09 g/g). Velvet tamarind fruit flour recorded a higher OAC than wheat flour from the USA (0.75 g/g) as reported by Siddiq et al. (2009). The OAC of velvet tamarind fruit flour is however close to that of wheat flour from Greece reported by Protonotariou et al. (2014) (0.78 - 1.09 g/g).

Table 33: Two sample t-tests for the oil absorption capacity of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p \leq 0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted)
Pigeonpea	0.20 ± 0.03^{b}	0.68 ± 0.05^{a}	0.0005
Jack bean	0.67 ± 0.05^{b}	1.05 ± 0.05^{a}	0.0021
Sword bean	0.82 ± 0.05^{b}	1.00 ± 0.05^{a}	0.0071
Velvet beans	0.50 ± 0.05^{b}	1.02 ± 0.05^{a}	0.004
Lima bean	0.24 ± 0.02^{b}	0.89 ± 0.03^{a}	<0.0001
Bambara groundnut	0.18 ± 0.05^{b}	0.74 ± 0.05^{a}	0.0006

Table 34: Two sample t-test for oil absorption capacity of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	0.35 ± 0.05^{b}	0.88 ± 0.03^{a}	0.0001

The OAC of the boiled seed flour of pigeonpea was significantly higher ($p \leq 0.05$) and 3.4 times that of its raw seed flour (Table 33). The values obtained in this study are lower than the results for raw pigeonpea seed flours reported by Oshodi and Ekperigin (1989) (0.9 g/g), Acevedo et al. (2017) (1.11 g/g), Okpala and Mamah (2001) (1.25 g/g), Olalekan and Bosede (2010) (1.48 g/g), Onimawo and Akpojovwo (2006) (2.5 g/g) and Mbaeyi-Nwaoha and Onweluzo (2013) (2.66 g/g). Acevedo et al. (2017) reported an OAC value of 1.11 g/g for boiled pigeonpea seed flour. This value is also higher than the results obtained for pigeonpea seed flours in this study.

The boiled seed flour of jack beans held more oil (1.57 times) than its raw seed flour (Table 33). The raw seed flour of jack beans in this study recorded a higher OAC than the results reported by Ojo and Ade-Omowaye (2015) (0.1 g/g). It, however, recorded a lower OAC than the results reported by Olalekan and Bosede (2010) (1.14 g/g) and Acevedo et al. (2017) (1.18 g/g). The OAC of the boiled seed of jack beans flour from this study is slightly lower than the results for raw seed

flour reported by Olalekan and Bosede (2010). Acevedo et al. (2017) in their study of some Argentine legumes obtained OAC values of 1.18 and 1.63 g/g for raw seed flour of pigeonpea and boiled seed flour of pigeonpea respectively. These values are higher than the values for both raw and boiled seed flours in this study.

The boiled seed flour of sword beans had a significantly higher ($p \leq 0.05$) OAC than its raw seed flour (Table 33). K. O. Adebowale et al. (2006) reported the OAC of sword bean seed starch as 2.9 g/g. This value is higher than the values obtained from the raw and boiled seed flours in this study.

Among the raw flours, only velvet tamarind held more oil than its own weight (Table 24). The value obtained in this work for raw velvet tamarind flour is lower than the value reported by Ogungbenle and Ebadan (2014) (1.62 g/g).

The boiled seed flour of velvet beans significantly ($p \leq 0.05$) held more oil than its raw seed flour (Table 33). The OAC values obtained for raw and boiled seed flours of velvet beans in this study are lower than that of the raw seed flours of velvet beans from Nigeria (2.25 g/g) reported by Y. A. Adebowale et al. (2005). Ahenkora et al. (1999) in their study of velvet beans seed flour reported OAC values of 0.76 and 0.86 g/g for the raw and boiled seed flours respectively. These values reported by Ahenkora et al. (1999) are close to the values obtained in this work.

The OAC of the roasted seed flour of African Locust bean was significantly higher ($p \leq 0.05$) than that of its raw seed flour (Table 34). Boiling significantly ($p \leq 0.05$) increased the OAC of Lima bean seed flour (Table 33). The OAC of raw seed flour obtained in this work falls below the results reported by Granito et al. (2007) (0.8 g/g) and Oshodi and Adeladun (1993) (0.82 – 0.92 g/g). The boiled seed flour in this work had a higher OAC than the value of 0.6 g/g reported by Granito et al. (2007) for hydrothermally treated seed flour of Lima bean.

There was a significant difference ($p \leq 0.05$) between the oil absorption capacities of the raw and boiled seed flours of Bambara groundnuts, with the boiled seed flour recording the higher value (Table 33). Both raw and boiled seed flours of Bambara groundnuts recorded lower oil absorption capacities than the results for raw seed flour reported by Falade and Adebiyi (2015) (0.86 – 0.88 g/g), Aremu et al. (2007) (1.4 g/g) and Falade and Nwajei (2015) (2.29 – 2.82 g/g).

4.1.6 Solubility (SBL) results

Except for velvet beans which exhibited the same SBL for both the raw and the hydrothermally treated seed flours, the other legumes which were subjected to hydrothermal treatment exhibited a reduction in SBL (Table 35). Roasted seed flour of African Locust bean also exhibited a lower SBL than the raw seed flour (Table 36).

Table 35: Two sample t-tests for the solubility of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p \leq 0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted)
Pigeonpea	0.18 ± 0.04^{a}	0.11 ± 0.02^{a}	0.1753
Jack bean	0.26 ± 0.02^{a}	0.16 ± 0.02^{b}	0.0243
Sword bean	0.24 ± 0.02^{a}	0.22 ± 0.02^{a}	0.4682
Velvet beans	0.14 ± 0.02^{a}	0.14 ± 0.02^{a}	1
Lima bean	0.50 ± 0.03^{a}	0.19 ± 0.02^{b}	0.0007
Bambara groundnut	0.44 ± 0.02^{a}	0.12 ± 0.02^{b}	0.0003

Table 36: Two sample t-test for solubility of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	0.18 ± 0.01^{a}	0.14 ± 0.02^{a}	0.0927

No significant difference ($p > 0.05$) was found between the SBL values of the raw and boiled seed flours of pigeonpea, even though the raw flour was more soluble (Table 35). For jack beans, the raw seed flour exhibited higher SBL than the boiled seed flour. The difference in SBL values was significant ($p \leq 0.05$) (Table 35). The raw seed flour of sword beans exhibited a higher SBL than the boiled seed flour but the difference in SBL values was not significant ($p > 0.05$) (Table 35). The SBL of velvet tamarind fruit flour is presented (Table 24). Velvet tamarind fruit flour exhibited a higher SBL than both raw and fermented pulp flour of *Artocarpus altilis* as reported by Appiah, Oduro, et al. (2011) (0.12 and 0.07 g/g for raw and fermented *Artocarpus altilis* flours

respectively). There was no difference between the SBL values for the raw and boiled seed flours of velvet beans (Table 35). The raw seed flour of African Locust bean exhibited a higher SBL than its roasted seed flour but the difference in SBL values was not significant ($p>0.05$) (Table 36). The raw seed flour of Lima beans exhibited a higher SBL than the boiled seed flour. The difference in SBL values was significant ($p\leq0.05$) (Table 35). The raw seed flour of Bambara groundnuts exhibited a higher SBL than the boiled seed flour. The difference in SBL values was significant ($p\leq0.05$) (Table 35).

4.1.7 Swelling Power (SP) results

The SP values of the raw seed flours ranged between 5.56 and 11.15 with Lima bean swelling most and pigeonpea having the least ability to swell (Table 24). For the boiled seed flours, Lima bean recorded the highest swelling power and velvet beans recorded the least swelling power value (Table 25).

The boiled seed flour of pigeonpea exhibited a higher SP than its raw seed flour but there was no significant difference ($p>0.05$) between them (Table 37). For jack beans, the raw seed flour had a higher SP than the boiled seed flour but the difference was not significant ($p>0.05$) (Table 37). For sword beans, the raw seed flour had a higher SP than the boiled seed flour. The difference in SP values was significant ($p\leq0.05$) (Table 37). The SP of velvet tamarind obtained in this work (Table 24) falls slightly below the range of SP values of some cereal flours (7.77, 8.11 and 9.90 g/g for commercial grades of rice, wheat and maize flours respectively) reported by Noitang et al. (2009). The boiled seed flour of velvet beans had a slightly higher SP than its raw seed flour. The difference in SP values was not significant ($p>0.05$) (Table 37). For the African Locust bean, the raw seed flour had a higher swelling ability than the roasted seed flour. The difference in SP values was significant ($p\leq0.05$) (Table 38). The raw seed flour of Lima beans swelled more than the boiled seed flour and the difference in their SP values was significant ($p\leq0.05$) (Table 37). The raw seed flour of Bambara groundnut exhibited a higher SP than the boiled seed flour. There was a significant difference between the SP values of the raw and boiled seed flours of Bambara groundnuts ($p\leq0.05$) (Table 37).

Table 37: Two sample t-tests for the swelling power of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p \leq 0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted)
Pigeonpea	5.56 ± 0.65^{a}	6.34 ± 0.07^{a}	0.3905
Jack bean	6.65 ± 0.43^{a}	6.38 ± 0.17^{a}	0.7544
Sword bean	8.94 ± 0.12^{a}	6.07 ± 0.31^{b}	0.0007
Velvet beans	5.70 ± 0.27^{a}	5.71 ± 0.26^{a}	0.9889
Lima bean	11.15 ± 1.14^{a}	6.87 ± 0.18^{a}	0.0825
Bambara groundnut	9.59 ± 0.49^{a}	5.84 ± 0.09^{b}	0.0221

Table 38: Two sample t-test for swelling power of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
Parkia biglobosa	5.88 ± 0.05^{a}	5.55 ± 0.13^{b}	0.0228

4.1.8 Water Absorption Capacity (WAC) results

The raw legume flours exhibited significant differences ($p \leq 0.05$) in their water absorption capacities (Table 24). There was similar observation for the flours obtained from the boiled seeds (Table 25). Boiling led to a significant increase ($p \leq 0.05$) in the water absorption capacities of the legume flours (Table 39). Increment in WAC as a result of heat treatment has been reported by Acevedo et al. (2017) for pigeonpea (1 – 1.74 ml/g), Hyacinth bean (1.25 – 2.37 ml/g) and jack bean (1.5 – 2.99 ml/g). WAC values obtained from this study were higher than the values of 0.85 ml/g obtained by Siddiq et al. (2009) and 0.68 – 0.95 ml/g reported by Protonotariou et al. (2014) for wheat flours.

The WAC of flour from the boiled seeds of pigeonpea was significantly higher ($p \leq 0.05$) than that of its raw seed flour (Table 39). The WAC value of raw seed flour of pigeonpea is lower than the results reported by Onimawo and Akpojovwo (2006) (4.4 g/ml) and Mbaeyi-Nwaoha and Onweluzo (2013) (7.5 ml/g) but higher than the results reported by Okpala and Mamah (2001)

(1.5 ml/g), Oshodi and Ekperigin (1989) (1.38 ml/g) and Acevedo et al. (2017) (1 ml/g). The result is however close to the value of 1.9 ml/g obtained by Olalekan and Bosede (2010). The WAC value for flour from boiled seeds of pigeonpea is higher than that reported by O. J. Adebowale and Maliki (2011) (1.42 ml/g) and Acevedo et al. (2017) (1.74 ml/g).

Heat treatment led to an improvement in the WAC of jack bean seed flour. The difference between the water absorption capacities of the raw flour and flour from the boiled seeds was significant ($p \leq 0.05$) (Table 39). The WAC values obtained from this study are higher than that reported by Ojo and Ade-Omowaye (2015) (0.29 ml/g), Olalekan and Bosede (2010) (1.28 ml/g) and Acevedo et al. (2017) (1.5 ml/g) for raw jack bean seed flour. The WAC value for the flour obtained from boiled seeds of jack bean is lower than that reported by Acevedo et al. (2017) (2.99 ml/g).

The flour obtained from boiled seeds of sword beans exhibited a higher WAC than the raw seed flour and the difference between them was significant ($p \leq 0.05$) (Table 39). For velvet tamarind fruit pulp flour, the WAC obtained in this work (Table 24) is lower than the values reported by Obasi et al. (2013) (2.5 ml/g) and Ogungbenle and Ebadan (2014) (2.38 ml/g).

The raw seed flour and the flour obtained from boiled seeds of velvet beans showed a significant difference ($p \leq 0.05$) in water absorption capacities (Table 39). The raw seed flour of velvet beans has a WAC that is close to the value of 1.5 ml/g reported by Y. A. Adebowale et al. (2005) but lower than the value of 2.17 ml/g reported by Bhat et al. (2008).

Roasting increased the WAC of the African Locust bean seed flour, with the roasted seed flour exhibiting a significantly higher ($p \leq 0.05$) value than the raw seed flour (Table 40). The water absorption capacities for both raw and roasted seed flours of African Locust bean in this study are lower than the results of raw flours reported by Sankhon et al. (2014) (2.62 ml/g) and Abey and Abey (2016) (3.8 ml/g).

The WAC of the flour obtained from the boiled seeds of Lima beans was significantly higher ($p \leq 0.05$) in comparison with the raw seed flour (Table 39). Comparatively, the WAC value for raw seed flour of Lima beans obtained in this work is higher than the results reported by Yellavila et al. (2015) (0.88 – 1.41 ml/g), Oshodi and Adeladun (1993) (1.3 – 1.42 ml/g) and Granito et al. (2007) (1.3 ml/g). The WAC of the flour of Lima beans obtained from the boiled seeds is close to the results reported by Granito et al. (2007) (2.4 ml/g).

WAC of Bambara groundnut was significantly different ($p \leq 0.05$) between the flour from the boiled seeds and the raw seed flour (Table 39). Falade and Adebiyi (2015) reported lower values of WAC (0.45 – 0.58 ml/g) for raw seed flours of Bambara groundnuts than the results obtained in this work. The value of WAC of the raw seed flour of Bambara groundnuts from this work is, however, lower than what other workers such as Falade and Nwajei (2015) (1.62 – 2.38 ml/g) and Aremu et al. (2007) (2 – 2.4 ml/g) reported. The WAC of the Bambara groundnut flour obtained from the boiled seeds falls within the range of water absorption capacities of raw seed flours reported by Falade and Nwajei (2015) and Aremu et al. (2007).

Table 39: Two sample t-tests for the water absorption capacity of raw legume seed flours and flours prepared from boiled seeds. Values are means ± standard deviation of three independent determinations. Values in the same row with different superscript letters differ significantly ($p \leq 0.05$).

	Method of processing		p-value
Legume flour	Raw	Processed (boiling)	p-value (adjusted)
Pigeonpea	2.02 ± 0.03^{b}	2.40 ± 0.05^{a}	0.0003
Jack bean	2.03 ± 0.03^{b}	2.85 ± 0.05^{a}	0.0001
Sword bean	1.78 ± 0.03^{b}	2.58 ± 0.03^{a}	<0.0001
Velvet beans	1.70 ± 0.05^{b}	2.38 ± 0.06^{a}	0.0002
Lima bean	1.85 ± 0.05^{b}	2.42 ± 0.03^{a}	0.0002
Bambara groundnut	1.15 ± 0.05^{b}	2.13 ± 0.06^{a}	0.0001

Table 40: Two sample t-test for water absorption capacity of raw African Locust bean seed flour and flour prepared from roasted seeds. Values are means ± standard deviation of three independent determinations. Means with different superscript letters indicate significant difference ($p \leq 0.05$).

	Method of processing		
Legume flour	Raw	Processed (roasting)	p-value
African Locust bean	1.62 ± 0.03^{b}	2.07 ± 0.03^{a}	<0.0001

4.2 Crude fats results

Crude fat was determined by extraction of acid-hydrolysed samples in a Sohxlet extractor with petroleum ether. The total crude fat was determined by gravimetry.

African Locust bean had the highest crude fat content (13.81% in raw seed flour and 14.31% in roasted seed flour) followed by Bambara groundnut (6.78% in raw seed flour and 7.31% in boiled seed flour). The other legume flours recorded less than 5% crude fat content (Table 41). Similar results of less than 5% oil content were obtained by Gaydou et al. (1983) for Lima bean (0.8%), O. J. Adebowale and Maliki (2011) for pigeonpea (2.74%) and Otori and Mann (2014) for sword bean (3.60%). The crude fat content of Bambara groundnut (6.78 – 7.31%) is far higher than the value of 1.4% for Ivorian Bambara groundnut (Yao et al., 2015) but compares favourably with a Nigerian variety of Bambara groundnut (7.15%) (K. E. Akande et al., 2009). The crude fat content of African Locust bean fell within the range of crude fat values of African Locust bean from Nigeria (8.32 – 17.42%) (Ikootobong et al. 2013).

Table 41: Crude fat yield (%) of legume flours. ***Values are means ± standard deviation of tripilicate determinations, **values are means ± R/2 of double determination, *values are for single determination. Values in the same row with different superscript letters are significantly different. n.d. = not determined (processed flour was not generated).

Legume	Raw Flour	Processed flour
Pigeonpea	*1.81	*1.82
Jack bean	*2.66	*2.60
Sword bean	***0.65 ± 0.02^{b}	***1.77 ± 0.01^{a}
Velvet tamarind	*2.70	n.d.
Velvet beans	*1.51	*2.98
African Locust bean	***13.81 ± 0.25^{a}	***14.21 ± 0.09^{a}
Lima bean	*2.04	*1.51
Bambara groundnut	**6.78 ± 0.15^{b}	***7.31 ± 0.04^{a}

The reductions in the crude fat contents of Jack bean and Lima bean are in agreement with the observations of Omenna et al. (2016) for cowpea, Onyeike and Oguike (2003) for groundnut and Olanipekun et al. (2015) for kidney beans. Boiling might have led to loss of structural integrity leading to the loss of crude fat (Onyeike & Oguike, 2003) for jack bean and Lima bean in this study. In sword bean, velvet beans and Bambara groundnuts, the increments in the crude fat contents upon boiling might be due to greater losses of other nutrients such as carbohydrates and proteins which then will lead to increase in percentage of the crude fat content even though there might be losses of crude fat as well during the boiling. For example, there was a 2.57% reduction in crude protein content of sword bean flour after hydrothermal treatment. For Bambara groundnut, there was a 6.19% reduction in the starch content after hydrothermal treatment. The increases in

the crude fat content of flours of sword bean and Bambara groundnut were statistically significant ($p \leq 0.05$).

Roasting led to a slight but statistically insignificant increase ($p > 0.05$) in the crude fat content of African Locust bean flour.

4.3 Fatty acids (FAs) results

The FA peaks were identified by comparing with the retention times of Supelco 37 Component FAME Standard Mix (Appendix 1P). The composition and the chromatogram for the Supelco 37 Component FAME Standard Mix is shown in Fig 1. The FA chromatograms for the legume flours and their retention times are shown in appendices 1A to 1O and the percent composition of the FAs in the FA mixture are shown in appendices 1Q to 1S.

Co-chromatographic analyses confirmed a total of eight (8) different FAs in the legume flours. All the 8 FAs were detected in African Locust bean seed flour. In jack bean and sword bean, four (4) FAs were detected. In the other five legumes, five (5) FAs were detected.

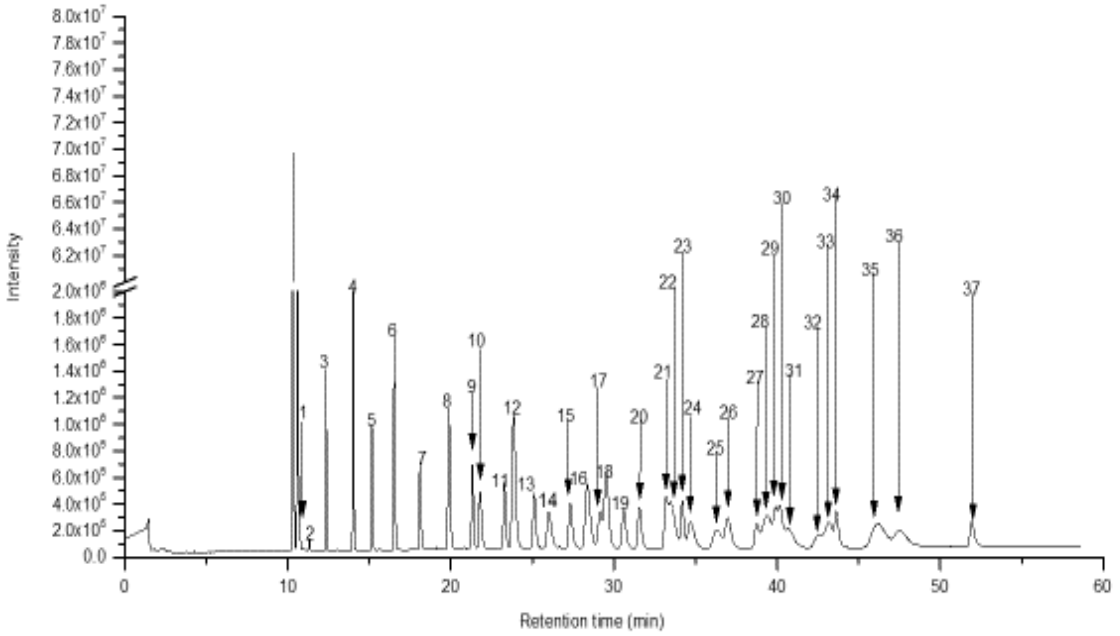


Fig 1: Chromatogram of Supelco 37 Component FAME Mix on SP 2560 column. 1 = C4:0, 2 = C6:0, 3 = C8:0, 4 = C10:0, 5 = C11:0, 6 = C12:07 = C13:0, 8 = C14:0, 9 = C14:1, 10 = C15:0, 11 = C15:1, 12 = C16:0, 13 = C16:1, 14 = C17:0, 15 = C17:1, 16 = C18:0, 17 = C18:1 n9t, 18 = C18:1 n9c, 19 = C18:2 n6t, 20 = C18:2 n6c, 21 = C20:0, 22 = C18:3 n6, 23 = C20:1 n9, 24 = C18:3 n3,25 = C21:0, 26 = C20;2, 27 = C22:0, 28 = C20:3 n6, 29 = C22:1 n9, 30 = C20:3 n3, 31 = C23:0, 32 = C20:4 n6, 33 = C22:2, 34 = C24:0, 35 = C20:5 n3, 36 = C24:1 n9, 37 = C22:6 n3.

Data on the FA profile of the legume flours (Fig. 2) show that the dominant SFA in the legume flours was palmitic acid (C16:0). Oleic acid (C18:1 n-9c) and linoleic acid (C18:2 n-6c) were the dominant UNFAs except in raw and processed Lima bean seed flours where the dominant UNFAs were linoleic acid and cis-11-Eicosenoic acid and raw jack bean seed flour where the dominant UNFAs were oleic acid and cis-11-Eicosenoic acid.

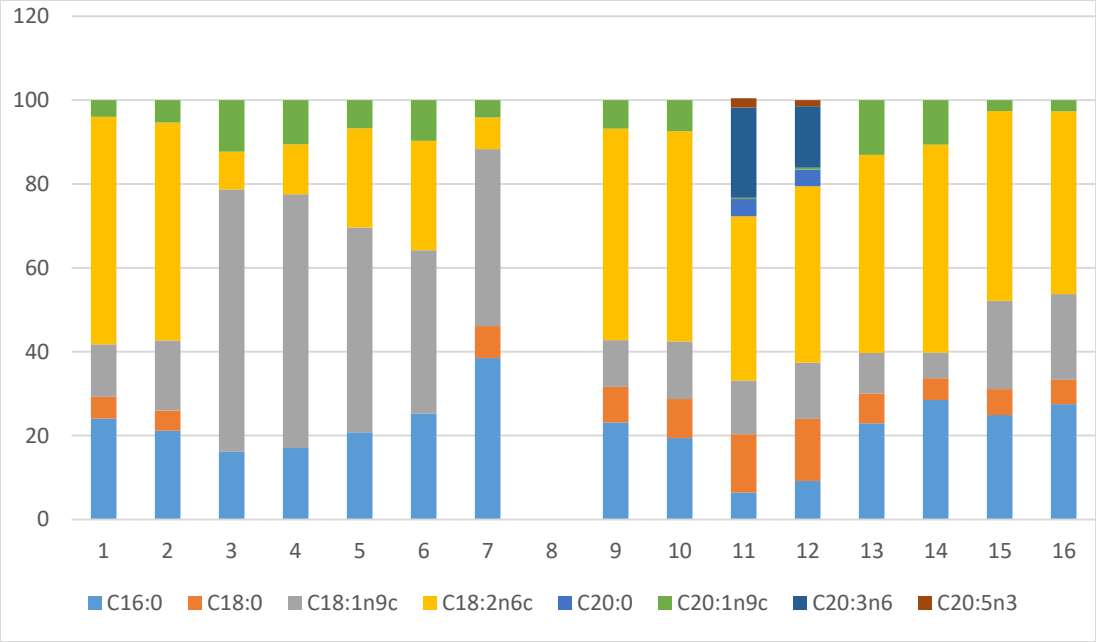


Fig 2: Fatty acid profile (% of total fatty acids of legume flours) 1 = raw pigeonpea, 2= processed pigeonpea, 3 = raw jack bean, 4 = processed jack bean, 5 = raw sword bean, 6 = processed sword bean, 7 = raw velvet tamarind, 8 = processed velvet tamarind, 9 = raw velvet bean, 10 = processed velvet bean, 11 = raw African Locust bean, 12 = processed African Locust bean, 13 = raw Lima bean, 14 = processed Lima bean, 15 = raw Bambara groundnut, 16 = processed Bambara groundnut.

The FA profile of the legume flour reveal that the FAs detected in the raw flours were the same FAs which were detected in the processed flour for each legume. The legume oils showed a high degree of unsaturation. Except for velvet tamarind fruit flour which recorded a total UNFA content of 53.83%, all the other legume flours recorded a total UNFA content of more than 60%.

The distribution of the FAs in the raw legume flours according to saturation and unsaturation shows that total SFAs ranged between 16.14% in jack bean seed flour and 46.17% in velvet tamarind fruit flour, total MUFAs ranged between 13.15% in African Locust bean seed flour and 74.84% in jack bean seed flour and total PUFAs ranged between 7.59% in velvet tamarind fruit flour and 62.80% in African Locust bean seed flour (appendix 1T).

The distribution of the FAs in the processed legume flours according to saturation and unsaturation shows that total SFAs ranged between 17.08% in jack bean seed flour and 33.72% in Lima bean seed flour, total MUFAs ranged between 13.92% in African Locust bean seed flour and 71.02%

in jack bean seed flour and total PUFAs ranged between 11.90% in jack bean seed flour and 58.11% in African Locust bean seed flour (appendix 1T).

4.4 Carbohydrates content results

4.4.1 Starch content results

Data for starch content was generated for both raw and processed flours of sword bean seeds, African Locust bean seeds and Bambara groundnut seeds (Table 42). The amounts of starch obtained for sword bean seed flour in this study (48.14 g/100 g for raw flour and 49.14 g/100 g for processed flour) are higher than what is reported by K. O. Adebowale et al. (2006) (31.00 g/100 g flour), Spoladore and Teixeira (1987) (34.61 g/100 g flour) and Siddhuraju and Becker (2001b) (29.16-29.65 g/100 g flour) but close to the value of 44.00 g starch/100 g flour reported by Ekanayake et al. (2006). In this study, African Locust bean seed flours recorded starch values (11.75% for both raw and processed flours) far below that reported by Sankhon et al. (2014) (44.14%). The starch content of Bambara groundnut seed flours (48.18% for raw flour and 45.20% for processed flour) is far higher than that reported by Ade-Omowaye et al. (2015) (11.5 – 11.7%) but close to the value of 50.2% obtained by Yao et al. (2015). While sword bean and African Locust bean seed flours showed no significant differences ($p>0.05$) in the starch content of their raw and processed flours, there was a significant difference ($p\leq0.05$) in starch content between the raw and processed flours of Bambara groundnut.

Table 42: Starch content (%) of flours of sword bean, African Locust bean and Bambara groundnut. *Values are means ± R/2 of double determinations, **values are means ± standard deviation of triplicates determinations.

Legume	Raw flour	Processed flour
Sword bean	*48.14 ± 0.80[a]	**49.14 ± 0.79[a]
African Locust bean	**11.75 ± 0.31[a]	**11.75 ± 0.30[a]
Bambara groundnut	*48.18 ± 0.65[a]	**45.20 ± 0.99[b]

4.4.2 Sugar content results

Sugar (raffinose, sucrose, D-glucose and D-fructose) concentrations in the legume flours (both raw and processed) were determined by enzymatic methods. Legume flour was extracted with

deionized water in a water bath at 60°C and clarification was done by the addition of Carrez-I-solution, Carrez-II- solution and sodium hydroxide solution. After cooling to room temperature, the mixture was filtered, and the filtrate was subjected to enzymatic analysis using an enzyme kit from Boehringer Mannheim.

4.4.2.1 Raffinose content results

The results of the concentration of raffinose in the legume flours (Table 43) shows that raffinose ranged between 0.033 % in processed jack bean flour to 1.409 % in raw velvet bean flour.

Table 43: Raffinose concentration in legume flours (g/100 g flour). Values are means of duplicate determinations. R = range, n.d. = not determined because no processed flour was generated.

	Raw flour		Processed flour		% Reduction of raffinose by processing
Legume flour	Mean	R/2	Mean	R/2	
Pigeonpea	0.640	0.010	0.039	0.002	93.91
Jack bean	0.165	0.015	0.033	0.002	80.00
Sword bean	1.372	0.021	0.192	0.005	86.01
Velvet tamarind	0.277	0.013	n.d.	n.d.	n. d.
Velvet beans	1.409	0.022	0.202	0.005	85.66
African Locust bean	1.406	0.015	1.294	0.016	7.97
Lima bean	0.840	0.010	0.393	0.017	53.21
Bambara groundnut	0.222	0.015	0.060	0.009	79.97

Raffinose was reduced to various extents in the legumes as a results of heat treatment (Table 43). The reductions were between 53.21 % in Lima beans to 93.91 % in pigeonpea for the hydrothermally treated flours. For African Locust beans, there was a 7.97 % reduction of raffinose in the roasted flour.

4.4.2.2 Sucrose content results

The results of the sucrose content of legume flours (Table 44) shows that sucrose ranged between 0.036 % in processed jack bean seed flour and 3.808 % in raw sword bean seed flour.

Table 44: Sucrose concentration in legume flours (g/100 g flour). Values are means of duplicate determinations. R = range, n.d. = not determined because no processed flour was generated.

	Raw flour		Processed flour	
Legume flour	Mean	R/2	Mean	R/2
Pigeonpea	1.439	0.033	0.075	0.003
Jack bean	1.528	0.012	0.036	0.005
Sword bean	3.808	0.006	0.355	0.035
Velvet tamarind	<6.715	0.042	n.d.	n.d.
Velvet beans	2.398	0.102	0.125	0.004
African Locust bean	2.480	0.040	2.158	0.140
Lima bean	1.238	0.045	0.069	0.010
Bambara groundnut	3.156	0.156	0.169	0.010

Sucrose was also reduced to various extents in the legumes as a results of heat treatment. The reductions were between 90.68 % in sword bean and 97.64 % in jack bean for the hydrothermally treated flours. For African Locust bean, there was a 12.98 % reduction of sucrose in the roasted flour.

4.4.2.3 D-glucose content results

The results of the concentration of D-glucose in the legume flours (Table 45) shows that D-glucose ranged between 0.012 % in processed velvet beans flour and 12.477 % in raw velvet tamarind fruit flour.

Table 45: D-glucose concentration in legume flours (g/100 g flour). Values are means of duplicate determinations. R = range, n.d. = not determined because no processed flour was generated.

	Raw flour		Processed flour	
Legume flour	Mean	R/2	Mean	R/2
Pigeonpea	0.038	0.002	0.013	0.001
Jack bean	0.036	0.001	0.015	0.005
Sword bean	0.050	0.001	0.808	0.003
Velvet tamarind	12.477	0.078	n.d.	n.d.
Velvet beans	0.023	0.001	0.012	0.002
African Locust bean	0.765	0.016	0.466	0.015
Lima bean	0.054	0.003	0.026	0.006
Bambara groundnut	0.075	0.006	0.041	0.010

D-glucose was reduced to various extents in pigeonpea, jack bean, velvet beans, African Locust bean, Lima beans and Bambara groundnuts as a results of heat treatment. However, for sword bean, there was an increment in the concentration of D-glucose by 1516 % after hydrothermal treatment. The reduction of D-glucose in the other legume flours were between 45.33 % in Bambara groundnuts and 65.79 % in pigeonpea for the hydrothermally treated flours. For African Locust bean, there was a 39.08 % reduction of D-glucose in the roasted flour.

4.4.2.4 D-fructose content results

The results of the concentration of D-fructose in the legume flours (Table 46) shows that D-fructose ranged between 0.011 % in processed velvet beans flour to 10.528 % in raw velvet tamarind fruit flour.

Table 46: D-fructose concentration in legume flours (g/100 g flour). Values are means of duplicate determinations. R = range, n.d. = not determined because no processed flour was generated.

	Raw flour		Processed flour	
Legume flour	Mean	R/2	Mean	R/2
Pigeonpea	0.032	0.001	0.013	0.001
Jack bean	0.024	0.002	0.018	0.002
Sword bean	0.011	0.001	0.162	0.001
Velvet tamarind	10.528	0.504	n.d.	n.d.
Velvet beans	0.016	0.002	0.011	0.001
African Locust bean	0.528	0.013	0.205	0.005
Lima beans	0.039	0.002	0.021	0.001
Bambara groundnuts	0.060	0.003	0.033	0.002

D-fructose was reduced to various extents in pigeonpea, jack bean, velvet beans, African Locust bean, Lima beans and Bambara groundnuts as a results of heat treatment. However, for sword bean, there was an increment in the concentration of D-fructose by 63.64 % after hydrothermal treatment. The reduction of D-fructose in the other legume flours were between 25.00 % in jack beans and 59.38 % in pigeonpea for the hydrothermally treated flours. For African Locust bean, there was a 61.17 % reduction of D-fructose in the roasted flour.

4.5 Ash content results

African Locust bean had the highest ash content (5.55% in raw seed flour and 6.43% in roasted seed flour). The other legume flours recorded less than 5% crude ash content (Tables 47). Ash

content ranged from 1.40% in raw velvet tamarind fruit flour to 6.43% in flour obtained from roasted African Locust beans. Boiling led to a reduction in the ash content of all the legumes. Roasting led to an increment in the ash content of African Locust beans (Table 47).

Table 47: Ash content (%) of raw and processed legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust beans which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	3.80 ± 0.30^{b}	2.45 ± 0.05^{ab}	0.0289
*Jack beans	2.77 ± 0.13^{de}	2.08 ± 0.04^{c}	0.0050
*Sword beans	2.63 ± 0.11^{e}	2.37 ± 0.08^{ab}	0.0304
Velvet tamarind	1.54 ± 0.12^{f}	n. d.	n. d.
*Velvet beanss	3.28 ± 0.13^{c}	2.54 ± 0.05^{a}	0.0050
**African Locust beans	5.55 ± 0.04^{a}	6.43 ± 0.50^{a}	0.0932
*Lima beans	3.49 ± 0.28^{bc}	2.49 ± 0.14^{ab}	0.0156
*Bambara groundnuts	3.14 ± 0.17^{cd}	2.26 ± 0.12^{b}	0.0072

4.6 Mineral nutrients contents results

4.6.1 Calcium content results

The calcium content ranged between 46.45 in processed Bambara groundnuts flour and 559.02 mg/100g in raw African Locust bean flour (Table 48).

Table 48: Calcium content (mg/100g) of raw and processed legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	136.28 ± 7.35^{c}	167.79 ± 8.27^{a}	0.0393
*Jack bean	155.29 ± 7.09^{b}	159.27 ± 4.36^{a}	0.4547
*Sword bean	79.49 ± 3.20^{d}	98.63 ± 2.46^{d}	0.0071
Velvet tamarind	50.81 ± 1.79^{e}	n. d.	n. d.
*Velvet beans	129.33 ± 5.23^{c}	115.53 ± 5.99^{b}	0.1584
**African Locust bean	559.02 ± 10.13^{a}	489.40 ± 4.76^{b}	0.0004
*Lima beans	73.83 ± 3.18^{d}	68.88 ± 3.46^{e}	0.4259
*Bambara groundnut	50.15 ± 2.61^{e}	46.45 ± 2.70^{f}	0.4259

While boiling led a reduction in the calcium content of velvet beans, Lima beans and Bambara groundnuts, it led to an increment in the calcium content of pigeonpea, jack beans and sword beans (Table 48). For African Locust bean, there was a reduction in the calcium content after roasting (Table 48).

4.6.2 Magnesium content results

The magnesium content ranged between 27.20 in raw velvet tamarind flour and 268.69 mg/100g in roasted African Locust bean flour (Table 49).

Table 49: Magnesium content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	106.55 ± 4.20^{c}	89.34 ± 3.34^{b}	0.0154
*Jack beans	110.60 ± 3.20^{c}	92.55 ± 1.19^{ab}	0.0031
*Sword beans	92.56 ± 1.34^{c}	91.13 ± 0.94^{b}	0.2037
Velvet tamarind	27.20 ± 0.89^{d}	n. d.	n. d.
*Velvet beans	112.42 ± 1.63^{c}	93.27 ± 2.03^{ab}	0.0013
**African Locust bean	267.09 ± 7.40^{a}	268.69 ± 1.07^{a}	0.7458
*Lima beans	106.04 ± 2.42^{c}	75.85 ± 4.56^{c}	0.0027
*Bambara groundnuts	150.33 ± 20.62^{b}	99.21 ± 0.98^{a}	0.1000

Boiling led to a reduction in the magnesium content of all the legume flours (Table 49). Roasting led to an increment in the magnesium content of African Locust bean (Table 49).

4.6.3 Sodium content results

The sodium content in raw sword bean flour was below the limit of detection (LOD). For the other flours, the sodium content ranged between 0.52 in raw Lima beans flour and 18.93 mg/100g in roasted African Locust bean flour (Table 50).

Table 50: Sodium content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	0.61 ± 0.10^{c}	6.39 ± 0.39^{a}	0.0001
*Jack bean	1.79 ± 0.38^{bc}	6.65 ± 0.39^{a}	0.0003
*Sword bean	<LOD	2.73 ± 0.22^{c}	n. d.
Velvet tamarind	3.44 ± 0.28^{b}	n. d.	n. d.
*Velvet beans	2.85 ± 0.29^{bc}	4.47 ± 0.35^{b}	0.0068
**African Locust bean	18.28 ± 1.08^{a}	18.93 ± 1.39^{a}	0.5618
*Lima bean	0.52^{c}	3.05 ± 0.33^{c}	n. d.
*Bambara groundnuts	2.06 ± 1.83^{bc}	2.59 ± 0.20^{c}	0.6661

All the flours which were obtained after hydrothermal treatment (boiling) had a higher sodium content than their corresponding raw flours (Table 50). Also, the sodium content which was below the LOD in raw sword bean flour increased to 2.73 mg/100 g in the sword bean flour obtained after hydrothermal treatment. Roasting led to a slight increment in the sodium content of African Locust bean (Table 50).

4.6.4 Potassium content results

The potassium content of the legume flours ranged from 599.12 mg/100 g in raw velvet tamarind flour to 1525.69 mg/100 g in raw pigeonpea flour (Table 51).

Table 51: Potassium content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed flour	p-value (adjusted)
*Pigeonpea	1525.69 ± 77.09^{a}	856.23 ± 26.57^{bc}	0.0006
*Jack bean	1152.75 ± 99.31^{b}	699.32 ± 14.52^{d}	0.0043
*Sword bean	1028.63 ± 46.60^{c}	890.98 ± 18.00^{ab}	0.0177
Velvet tamarind	599.12 ± 34.96^{d}	n. d.	n. d.
*Velvet beans	1225.03 ± 105.22^{b}	937.62 ± 24.22^{a}	0.0177
**African Locust bean	1030.07 ± 71.58^{c}	1065.73 ± 22.30^{a}	0.4564
*Lima bean	1317.06 ± 22.23^{b}	915.52 ± 19.30^{ab}	0.0001
*Bambara groundnuts	1212.50 ± 18.59^{bc}	809.77 ± 26.73^{c}	0.0001

All the legumes which were given hydrothermal treatment recorded a significant reduction ($p \leq 0.05$) in their potassium content (Table 51). Roasting led to an increment in the potassium content of African Locust bean, but the increment was not significant ($p > 0.05$) (Table 51).

4.6.5 Iron content results

Iron content ranged between 2.83 mg/100 g in raw sword bean flour and 491.97 mg/100 g in roasted African Locust bean flour (Table 52).

Table 52: Iron content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	4.56 ± 0.24^{b}	5.72 ± 0.34^{a}	0.0344
*Jack bean	3.27 ± 0.06^{b}	4.27 ± 0.20^{b}	0.0056
*Sword bean	2.83 ± 0.31^{b}	6.28 ± 0.17^{a}	0.0004
Velvet tamarind	3.11 ± 0.13^{b}	n. d.	n. d.
*Velvet beans	7.23 ± 0.14^{b}	6.59 ± 0.24^{a}	0.0479
**African Locust bean	315.61 ± 39.35^{a}	491.97 ± 145.76^{a}	0.1131
*Lima bean	4.55 ± 0.06^{b}	5.63 ± 0.76^{ab}	0.2654
*Bambara groundnut	3.03 ± 0.18^{b}	3.20 ± 0.02^{c}	0.2654

While boiling led to increment in the iron content of pigeonpea, jack bean, sword bean, Lima beans and Bambara groundnuts, it led to a reduction in the iron content of *Mucuna pruriens* (Table 52). Roasting led to an increment in the iron content of African Locust bean (Table 52).

4.6.6 Copper content results

Copper content of the legume flours ranged from 0.37 mg/100 g in raw Lima beans flour to 1.90 mg/100 g in velvet beans flour (both raw flour and flour from boiled seeds) (Table 53).

Table 53: Copper content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	1.30 ± 0.1^{b}	1.14 ± 0.18^{b}	1.0000
*Jack bean	0.69 ± 0.1^{de}	0.70 ± 0.04^{c}	1.0000
*Sword bean	0.57 ± 0.06^{ef}	0.64 ± 0.05^{cd}	1.0000
Velvet tamarind	0.92 ± 0.13^{cd}	n. d.	n. d.
*Velvet beans	1.90 ± 0.17^{a}	1.90 ± 0.17^{a}	1.0000
**African Locust bean	1.19 ± 0.12^{c}	1.22 ± 0.10^{a}	0.7332
*Lima bean	0.37 ± 0.05^{f}	0.39 ± 0.03^{d}	1.0000
*Bambara groundnuts	0.50 ± 0.01^{ef}	0.50 ± 0.02^{cd}	1.0000

While there was a reduction in the copper content of pigeonpea after boiling, there were increments in the copper contents of jack beans, sword beans, and Lima beans after boiling. Velvet beans and Bambara groundnuts did not show any difference in their copper content after hydrothermal treatment (Table 53). Roasting led to a slight increment in the copper content of African Locust bean (Table 53).

4.6.7 Manganese content results

The content of manganese in the legume flours varied between 0.86 mg/100 g in jack beans and 15.37 mg/100 g in roasted African Locust bean flour (Table 54).

Table 54: Manganese content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	1.46 ± 0.01^{de}	1.57 ± 0.06^{b}	0.1990
*Jack bean	0.86 ± 0.03^{g}	0.87 ± 0.03^{f}	0.8008
*Sword bean	1.13 ± 0.09^{fg}	1.05 ± 0.03^{e}	0.4298
Velvet tamarind	5.07 ± 0.19^{b}	n. d.	n. d.
*Velvet beans	2.09 ± 0.04^{c}	2.37 ± 0.04^{a}	0.0045
**African Locust bean	14.20 ± 0.21^{a}	15.37 ± 0.41^{a}	0.0116
*Lima beans	1.69 ± 0.04^{d}	1.46 ± 0.01^{c}	0.0045
*Bambara groundnuts	1.28 ± 0.03^{ef}	1.17 ± 0.03^{d}	0.0645

While there were reductions in the contents of manganese in sword bean, Lima beans and Bambara groundnuts after boiling, there were increments in the contents of manganese in pigeonpea, jack bean and velvet beans after boiling (Table 54). There was an increment in the manganese content of African Locust bean after roasting (Table 54).

4.6.8 Zinc content results

The content of zinc in the legume flours varied between 0.63 mg/100 g in raw velvet tamarind flour to 3.95 mg/100 g in raw pigeonpea flour (Table 55).

Table 55: Zinc content (mg/100g) of raw legume flours. Values are means ± standard deviation of three independent determinations. Means with different superscript letters along the column (This does not include African Locust bean which was analysed separately because the processed flour was given a different treatment) indicate significant difference ($p \leq 0.05$) (one-way ANOVA, Tukey), n. d. = not determined. For legume names with asteriks (*), the processed flour was obtained by boiling and for the legume name with a double astriks (**), the processed flour was obtained by roasting. The indicated adjusted p-values were obtained after two sample t-test (here again, African Locust bean was not added during the adjustment but was treated separately because of the different treatment to obtain its processed flour).

Legume	Raw legume flour	Processed legume flour	p-value (adjusted)
*Pigeonpea	3.95 ± 0.15^{a}	3.87 ± 0.24^{a}	1.0000
*Jack bean	1.60 ± 0.06^{d}	1.81 ± 0.20^{b}	0.4785
*Sword bean	1.76 ± 0.19^{cd}	2.54 ± 0.52^{b}	0.3489
Velvet tamarind	0.63 ± 0.13^{e}	n. d.	n. d.
*Velvet beans	2.99 ± 0.26^{b}	3.49 ± 0.26^{a}	0.3489
**African Locust bean	3.25 ± 0.51^{ab}	3.50 ± 0.65^{a}	0.6224a
*Lima beans	1.96 ± 0.17^{cd}	1.98 ± 0.19^{b}	1.0000
*Bambara groundnuts	2.03 ± 0.34^{c}	3.97 ± 0.08^{a}	0.0039

Apart from *pigeonpea*, in which there was a reduction in the content of zinc after hydrothermal processing, all the other legumes which were subjected to hydrothermal processing (jack bean, sword bean, velvet beans, Lima beans and Bambara groundnuts) recorded increments in their zinc contents (Table 55). There was a slight increment in the zinc content of African Locust bean after roasting (Table 55).

4.7 Results of levels of bound cyanide in legumes

With the exception of raw sword bean flour and raw Bambara groundnuts flour, the cyanide levels (released from the employed method) in all the raw flours were below the limit of quantification (LOQ) (51.2 µmol/100g flour) (Table 56). Raw flour of sword bean and raw flour of Bambara groundnuts recorded cyanide levels of 1.69 mg/100 g and 2.94 mg/100 g respectively. Raw flours of sword bean and Bambara groundnuts did not differ significantly ($p > 0.05$) in released cyanide from each other. While the released cyanide in Bambara groundnuts differed significantly ($p \leq 0.05$) from the released cyanide content in the other legume flours, the released cyanide in raw sword bean did not differ significantly ($p > 0.05$) from the released cyanide in the other legume flours.

Table 56: Levels of releasable cyanide (mg/100g) of raw legume flours. Values with asterisk are means ± standard deviation of three independent determinations. Values with double asterisk are means of two independent determinations. Means with different superscript letters along the column indicate significant difference ($p \leq 0.05$), n. d. = not determined.

Legume	Raw legume flour	Processed legume flours
Pigeonpea	*0.58 ± 0.56^{b} (<LOQ)	**0 (<LOD)
Jack bean	*0.46 ± 0.37^{b} (<LOQ)	**0.13 (<LOD)
Sword bean	*1.69 ± 0.72^{ab}	**0.14 (<LOD)
Velvet tamarind	*0.90 ± 0.48^{b} (<LOQ)	n.d.
Velvet beans	*0.04 ± 0.08^{b} (<LOQ)	**0 (<LOD)
African Locust bean	*0.71 ± 0.70^{b} (<LOQ)	**0 (<LOD)
Lima beans	*0.26 ± 0.35^{b} (<LOQ)	**0.07 (<LOD)
Bambara groundnuts	*2.94 ± 1.15^{a}	**0.21 (<LOD)

For the flours obtained from the legume seeds after processing, the cyanide contents were below the limit of detection (LOD) (16.8 µmol/100g flour) (Table 56).

4.8 Kinds of IFs in the studied legume flours

Table 57 shows which isoflavones were found in the various legume flours and which were not detectable. An isoflavone was considered undetectable if the signal to noise ratio (S/N) fell below 3.0.

Table 57: Qualitative analysis of raw and processed leguminous flours. The isoflavones marked with X were not detectable in the sample. The isoflavones marked with ✓ were detected.

	Pigeonpea		*Jack bean*		*Swordbean*		*Velvet tamarind*	*Velvet bean*		*African Locust bean*		*Lima bean*		*Bambara groundnut*	
Isoflavone	raw	pro.	raw	pro.	raw	pro.	raw	raw	pro.	raw	pro.	raw	pro.	raw	pro.
DAI-GLU	✓	✓	✓	✓	×	✓	×	✓	✓	×	×	×	✓	✓	✓
GLY-GLU	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
GEN-GLU	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
PSE-GLU	×	×	×	×	×	×	×	✓	×	×	✓	✓	✓	×	×
FOR-GLU	×	×	✓	×	✓	✓	×	×	×	✓	✓	✓	×	×	✓
DAI	✓	✓	×	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓
ORO	✓	✓	×	×	×	×	×	✓	✓	×	×	×	×	✓	✓
GLY	×	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	×	×
CAL	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	×	×
BCA-GLU	✓	✓	✓	×	×	✓	×	✓	✓	×	×	×	×	×	×
GEN	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	×	×	✓	✓
PRU-GLU	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	×	×
PRA	✓	×	×	×	×	×	×	✓	✓	×	×	✓	✓	×	✓
PSE	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
FOR	✓	✓	×	×	×	×	×	×	✓	×	×	×	×	×	×
IRI	×	×	×	×	×	×	✓	×	×	✓	✓	×	×	×	×
PRU	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	✓	×	×	×
BCA	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×

4.9 Quantification of IFs in the studied legume flours

The IFs BCA, DAI, DAI-GLU, FOR, GEN and GEN-GLU in the Ghanaian leguminous flours pigeonpea, African Locust bean and Bambara groundnuts were quantified. The flours were selected based on the size of their peak areas from the qualitative analysis by means of HPLC-DAD, in which the IFs have already been identified by means of UHPLC-MS/MS and on the basis of their IF composition. The IFs in the flours were quantified twice using Standard addition calibration on the HPLC-DAD.

4.9.1 Quantities of IFs in processed flour of pigeonpea

The quantities of the IFs DAI, DAI-GLU, GEN, GEN-GLU, FOR and BCA in processed pigeonpea seed flour are shown (Table 58).

Table 58: IF contents of processed pigeonpea seed flour after a double determination using HPLC-DAD, and mass fraction of the quantified IF.

IF	Amount (µg/100g)	R/2 (µg/100g)	Relative R/2 (%)	Mass fraction (%)
DAI	120.51	4.95	4.11	7.52
DAI-GLU	<LOD	-	-	-
GEN	529.53	22.44	4.24	33.03
GEN-GLU	<LOD	-	-	-
FOR	830.51	62.93	7.58	51.80
BCA	122.71	11.28	9.19	7.65

4.9.2 Quantities of IFs in processed flour of African Locust bean

The quantities of the IFs DAI, DAI-GLU, GEN, GEN-GLU, FOR and BCA in processed African Locust bean seed flour are shown (Table 59).

Table 59: IF contents of processed African Locust bean seed flour after a double determination using HPLC-DAD, and mass fraction of the quantified IF. n. d. = not detected.

IF	Amount (µg/100g)	R/2 (µg/100g)	Relative R/2 (%)	Mass fraction (%)
DAI	1.63	0.57	34.61	10.82
DAI-GLU	n.d.	-	-	-
GEN	n.d.	-	-	-
GEN-GLU	10.95	0.51	4.66	72.66
FOR	n.d.	-	-	-
BCA	2.49	0.57	22.89	16.52

4.9.3 Quantities of IFs in processed Bambara groundnut flour

The quantities of the IFs DAI, DAI-GLU, GEN, GEN-GLU, FOR and BCA in processed Bambara groundnuts flour are shown (Table 60).

Table 60: IF contents of processed Bambara groundnuts flour after a double determination using HPLC-DAD, and mass fraction of the quantified IF. n. d. = not detected

IF	Amount (µg/100g)	R/2 (µg/100g)	Relative R/2 (%)	Mass fraction (%)
DAI	128.29	18.44	14.37	44.12
DAI-GLU	<LOD	-	-	-
GEN	69.35	4.03	5.81	23.85
GEN-GLU	93.11	17.42	18.70	32.02
FOR	n.d.	-	-	-
BCA	n.d.	-	-	-

4.9.4 Recoveries of the quantified IFs in processed flours of pigeonpea, African Locust bean and Bambara groundnut

The recoveries of the quantified isoflavones in the processed flours of pigeonpea, African Locust bean and Bambara groundnuts are shown below (Table 61). All the recoveries were close to 100%.

Table 61: Percent recoveries of the isoflavones in the legume flour samples.

Isoflavone	Legume flour	%Recovery	R/2	Relative R/2 (%)
DAI	Pigeonpea	99.70%	2.00	2.01
DAI	African Locust bean	100.10%	2.80	2.80
DAI	Bambara groundnuts	100.20%	17.10	17.07
GEN	Pigeonpea	99.70%	2.97	2.98
GEN	Bambara groundnuts	101.90%	2.10	2.06
GEN-GLU	African Locust bean	100.00%	1.10	1.10
GEN-GLU	Bambara groundnuts	99.90%	9.30	9.31
FOR	Pigeonpea	99.74%	9.48	9.51
BCA	Pigeonpea	99.70%	6.00	6.02
BCA	African Locust bean	100.00%	3.60	3.60

4.10 Crude protein content results of legume flours

Data for crude protein (%N x 6.25) was generated for both raw and processed flours of sword beans, African Locust beans and Bambara groundnuts (Table 62). The results of crude protein content of sword beans (26.07% for raw flour and 25.40% for processed flour) fall slightly below the values obtained by Rajaram and Janardhanan (1992) (27.48%), Vadivel et al. (2010) (28.39%) and A.S. Abitogun and G.K. Oso (2014) (29.82%) but falls within the range of values reported by

Vadivel and Janardhanan (2004) (22.99 – 32.14%) for some six accessions of sword beans from India. The African Locust bean flours in this study recorded crude protein values (23.42% for raw flour and 23.19% for processed flour) close to the value of 25.89% reported by Ikootobong et al. (2013) from a certain accession of African Locust bean from Nigeria. The crude protein content of Bambara groundnuts (17.88% for raw flour and 18.48% for processed flour) is close to the value of 17.41%, 18.40%, 18.8% and 18.90% obtained by A. O. Abiodun and Adepeju (2011), Olaleye et al. (2013) ,Yao et al. (2015) and Ijarotimi et al. (2009) respectively. For sword beans and Bambara groundnuts, crude protein content of the raw and processed flours differed significantly ($p \leq 0.05$) but for African Locust beans, there was no significant difference in the crude protein content between the raw and processed flours.

Table 62: Crude protein content (%) of flours of sword bean, African Locust bean and Bambara groundnuts. *Values are means ± R/2 of duplicate determinations, **values are means ± standard deviation of triplicates determinations.

Legume	Raw flour	Processed flour
Sword beans	*26.07 ± 0.13^{a}	**25.40 ± 0.08^{b}
African Locust beans	**23.42 ± 0.16^{a}	**23.19 ± 0.43^{a}
Bambara groundnuts	*17.88 ± 0.07^{b}	**18.48 ± 0.09^{a}

5 Discussion of results

5.1 Discussion of functional properties results

Functional properties of legumes could provide useful information in developing various food products (Maphosa & Jideani, 2017). It helps to efficienly use the legume flours and helps consumers to accept them since functional properties significantly affect legume processing (Du et al., in press)

5.1.1 Discussion of Bulk Density (BD) results

Bulk density values ranged from 0.61 g/ml (velvet tamarind) to 0.97 g/ml (pigeonpea; Lima beans) in raw flours and 0.81 (velvet beans) to 0.95 g/ml (pigeonpea) for boiled seed flours. The roasted seed flour of African Locust bean recorded a significantly higher ($p \leq 0.05$) bulk density than the raw seed flour (Table 27). The bulk density of flour gives an indication of the volume of packaging material needed. The higher the bulk density, the heavier the flour. Flours with high bulk densities have smaller volumes per unit weight and therefore require less amount of packaging material per unit weight. Since raw velvet tamarind flour is the least dense of all the flours, its unit weight would occupy more space and therefore would require more packaging material. This could lead to high packaging cost in comparison with the other flours. In infant feeding, less bulk is desirable (Ibeabuchi et al., 2017). Since velvet tamarind fruit flour had the lowest bulk density, it could be the most suitable for use in weaning foods.

5.1.2 Discussion of Foam Capacity (FC) and Foam Stability (FS) results

FC is used as an index of the whipping characteristics of flours (Oraka & Okoye, 2017). Whipping helps in incorporating air and assist in aeration of products. Foaming is important in products requiring foamability such as sponge cakes. Heat treatment led to reduced foam capacities. Raw pigeonpea seed flour produced significantly ($p \leq 0.05$) more foam than all the other flours but did not produce the most stable foam within a period of 120 minutes. Rather, raw velvet tamarind fruit flour which produced the least amount of foam had the most stable foam within a period of 120 min. Even though the raw velvet tamarind flour and the processed seed flours produced more stable foams than the raw seed flours, raw velvet tamarind flours and the heat-treated flours may not be desirable for products requiring foamability (e.g. cakes) because of their very low foam capacities. For such purposes, raw seed flours may be more suitable because of their better foaming capacities.

5.1.3 Discussion of Least Gelation Concentration (LGC) results

Results of the least gelation concentrations of the flours show that the raw flours are better gel-forming agents than their corresponding heat-treated flours. LGC is important for food products requiring gelling and thickening such as sauces, puddings (Joshi, 2012) and soups. This means the raw flours could be more useful as thickening agents in sauces and puddings. The lower the LGC, the stronger the gelling ability of a flour. Among the flour samples, the raw flour of sword bean recorded the lowest LGC and could be the most useful among the samples as a thickening agent for sauces, puddings and soups. Heat treatment increased the concentration of flour required for gel formation.

5.1.4 Discussion of Oil Absorption Capacity (OAC) results

OAC gives an indication of whether the food or protein material will function well as a meat extender or analogues (Ojo & Ade-Omowaye, 2015). In ground meat formulations, doughnut, pancakes, etc, oil holding property is very important (Akubor et al., 2000). High OAC makes flours suitable in facilitating enhancement in flavour and mouth feel in food preparations (Appiah, Asibuo, et al., 2011). Flours with high OAC may be suitable for use in products like cakes which require high oil holding capacity (Joshi, 2012). Among the studied flours, raw flour of velvet tamarind recorded the highest OAC, suggesting probably of the presence of high amounts of lipophilic group of compounds in the velvet tamarind fruit pulp in comparison with the other studied flours. Velvet tamarind flour could be the most useful among the flours for products where imbibition of oil is required. Flours with low oil absorption capacities are good for deep-fried products to control oil absorption. Such flours could be used in coating food products before deep frying to prevent the food from absorbing so much oil. Since raw seed flour of pigeonpea recorded the lowest OAC, it may be the best among the studied flours to be used in coating food products like onion rings and fish before deep frying to prevent too much oil absorption by the food products. The raw seed flour of pigeonpea may be the best among the studied flours to partially replace wheat flour in dough batters to reduce oil absorption and increase the protein content of deep-fried products, making the products nutritious.

5.1.5 Discussion of Solubility (SBL) results

High solubility of flour suggests that the flour is digestible and hence suitable for infant food formulation (Appiah, Oduro, et al., 2011). Among the studied flours, raw velvet tamarind recorded

the highest solubility and may be the best among the flours for infant food formulation to enhance digestibility.

5.1.6 Discussion of Swelling Power (SP) results

Flours having good swelling capacities are primarily used for thickening of soups, sauces and gravies (Oraka & Okoye, 2017). Raw flour of Lima beans recorded the highest SP among the studied flours and may be the best among the flours to be used in food products which require swelling such as noodles.

5.1.7 Discussion of Water Absorption Capacity (WAC) results

WAC is important for flours as they swell and impart characteristics such as body thickness and viscosity (Falade & Adebiyi, 2015). It is an index of the maximum amount of water a food product can take up and retain (Ijarotimi et al., 2009). High WAC is advantageous when preparing food items like bread and sausages to maintain freshness and for easy handling (Bhat et al., 2008). Processed flour of jack beans recorded the highest WAC among the studied flours, suggesting probably of the presence of high amounts of hydrophilic compounds in the processed seed flour of jack beans in comparison with the other studied flours. Processed jack beans seed flour could be the best among the flours to be used to maintain freshness in bread and sausages.

5.2 Discussion of crude fat results

Dietary fats which are important sources of energy play a significant role in human nutrition, and modification of fat and/or fatty acid intake could have a preventive potential in nutrition-related chronic diseases that have become very frequent (Wolfram et al., 2015). Fats serve as solvents for certain taste substances and numerous odour substances. They enrich the nutritional quality and are important in food to achieve the desired texture, specific mouth feel and aroma, and a satisfactory aroma retention. Fats are also important in the transport of nutritionally essential fat-soluble vitamins (Appiah, 2011). The high fat content of African Locust bean makes it a better source of fat than the other legumes and could make it a better aroma retainer. The fat content of African Locust bean could be expressed and the characterization of the oil done to find out the uses of the oil (either as industrial oil for products such as soaps, shampoos and paints or as an edible oil or both for industrial products and edible purposes). On the other hand, the low fat content of the other legumes could be useful in the formulation of low fat diet for certain categories of people such as the obese (Oyeleke et al., 2012). According to Vorster et al. (2004),

overconsumption of fats and oils is generally linked with obesity and a wide range of NCDs especially when the consumer does not undertake physical activity.

5.3 Discussion of fatty acids (FAs) results

Fatty acids act as double-edged swords because of their role as major energy source, structural components of cell membranes, precursors of bioactive molecules, regulators of enzyme activities and gene expression on the positive side; ischaemic/reperfusion injury and heart failures on the negative side via their imbalance in their homeostasis. This depends on the dietary fatty acid supplied to the body (Sathya & Siddhuraju, 2015). Saturated and trans fats consumption is harmful to human health and can increase the cardiovascular risks and coronary heart disease in consumers (Carrillo et al., 2017; Ministry of Health of Ghana, 2009; White, 2009).

Traditional foods eaten by Ghanaians invariably had low fat content, mainly because of the fact that fat and high fat-containing foods were much more expensive than high carbohydrate-containing foods (Ministry of Health of Ghana, 2009). Some of the traditional dishes in Ghana are *Akyeke* (made from grated cassava that is fermented, and eaten with fried fish with ground pepper garnished with chopped pepper and onion), *Banku* (cooked by a proportionate mixture of fermented corn and cassava dough in hot water into a smooth, whitish consistent paste and served with a pepper sauce and fish), *Tuo zaafi* (maize dough with a little dried cassava dough cooked without salt and served with green vegetable soup made from bitter leaves or freshly pounded cassava leaves) and *kenkey* (maize dough dumpling served with pepper sauce and fish). Currently, overweight and obesity, which were considered problems only in high income countries, are now increasing in Ghana, particularly in urban towns and cities and a major contributor to this alarming trend is changing dietary patterns including the increasing consumption of westernized diets, high in fats, as well as sugars and salt (Ministry of Health of Ghana, 2009).

The results obtained in this study corroborate the results of some researchers as follows: that LA is the dominant fatty acid in pigeonpea ((Jayadeep et al., 2009); (Oshodi et al., 1993); (Ade-Omowaye et al., 2015)), velvet beans ((Ezeagu et al., 2005); (Siddhuraju et al., 1996)), African Locust bean ((J. A. Cook et al., 2000); (Glew et al., 1997)), Lima beans (Gaydou et al., 1983) and Bambara groundnuts ((Yao et al., 2015); (Ade-Omowaye et al., 2015)) and oleic acid is the

dominant fatty acid in jack beans ((Gaydou et al., 1992); (Siddhuraju & Becker, 2001b)) and sword beans ((Siddhuraju & Becker, 2001b); (Spoladore & Teixeira, 1987)) (appendix 1U). The presence of substantial amounts of Cis-11-Eicosenoic acid (between 0.32% in raw African Locust bean flour and 13.01% in raw Lima beans seed flour) and the absence of ALA acid in the legume flours is however not in agreement with studies conducted before (appendix 1U). This variation from previous studies could be due to environmental differences that affect the nutrient content or the method of analysis. In this study, co-chromatography was used to confirm the presence of the fatty acids in the legume flours but no co-chromatography was done in the research conducted by the authors mentioned.

Replacing saturated fat with unsaturated fat is far more effective in lowering the risk of coronary heart disease than simply reducing total fat consumption (Ryan et al., 2007) although unsaturation is a disadvantage with respect to the oxidative stability of the oil.. The saturated fatty acids - lauric, myristic and palmitic - elevate serum cholesterol and low-density lipoprotein (LDL) levels. Stearic acid does not have significant effect on serum cholesterol or LDL levels (Mensink, 2016). It is important to note that, lauric and myristic acids (which were not detected in the studied Ghanaian legumes) have more potential in raising total and LDL cholesterol concentrations whilst palmitic acid (found in abundance in these studied Ghanaian legumes) is less potent in that regard (S. L. Cook et al., 1997; Fattore et al., 2014; Iggman & Risérus, 2011). Trans fatty acids induce an adverse plasma lipid profile which increases the risk for coronary heart disease (Khosla & Hayes, 1996). It is worth noting that no trans fatty acid(s) was/were detected in any of the legume flours. The lower total saturated fatty acids than unsaturated fatty acids and the absence of trans fatty acids in all the legume flours suggests the potential food value of these legumes. According to EFSA, (2019a) saturated and trans fatty acids in the diet should be as low as possible. The fatty acid profiles of the legumes show that the fatty acid content in the legume flours are desirable. These days foods are not eaten only with the intention of provision of necessary nutrients and satisfaction of hunger but also to prevent nutrition-related diseases and improve the physical and mental wellbeing of the individuals (Menrad, 2003; Roberfroid, 2000). A reduction in the intake of total and saturated fat and a larger intake of polyunsaturated fatty acids at the expense of saturated fatty acids reduces the amount of LDL cholesterol in the plasma (Wolfram et al., 2015). There is the need for further investigations of these legumes for their potential use as healthy low-fat foods.

While heat processing led to reduction of palmitic acid (C16:0) and LA (C18:2 n-6c) in pigeonpea, velvet beans and Bambara groundnuts, it led to increment of these fatty acids in jack beans, sword beans, African Locust bean and Lima beans. Heat processing led to the reduction of stearic acid (C18:0) in pigeonpea, Lima beans and Bambara groundnuts but increment in the percent composition of stearic acid in velvet beans and African Locust bean. For oleic acid (C18:1 n-9c) and Cis-11-Eicosenoic acid (C20:1 n9), heat processing led to their reduction in jack bean and Lima beans but increment in pigeonpea and velvet beans. In sword beans and Bambara groundnuts, there were reductions in oleic acid and increments in Cis-11-Eicosenoic acid after heat processing but in African Locust bean, there was an increment in the oleic acid content and a reduction in the Cis-11- Eicosenoic acid content. Arachidic acid (C20:0), Cis-8, 11, 14-Eicosatrienoic acid (C20:3 n6) and Cis-5, 8, 11, 14, 17-Eicosapentaenoic acid (C20:5 n3) which were detected only in African Locust bean flours were all reduced in the roasted flour. The processing methods (boiling for pigeonpea, jack beans, sword beans, velvet beans, Lima beans and Bambara groundnuts and roasting for African Locust bean) resulted in varied deviations of the various FAs from the raw flours either by increasing or reducing the percent FA composition of the identified FAs. There is the need for further investigations aimed at optimizing the processing methods for the best FA distribution in the processed flours.

LA and ALA are the most important essential fatty acids needed for growth, physiological functions and maintenance of the body (Fathima & Mohan, 2009). These two FAs work together in competitive balance, regulating blood clotting, immune response and inflammatory processes (Aremu et al., 2017). They are also important for normal foetal development, particularly, for brain development and visual acuity (WHO/FAO, 1994). They are indispensable in the diet because humans cannot synthesise them (FAO, 2010). While LA was detected in all the legume flours, ALA was not detected in any of the legume flours. This means that ALA must be obtained from other sources in order to get all the essential fatty acids.

Polyunsaturated fatty acids (PUFA) are fatty acids with between two and six double bonds and long carbon chains of 18-22 carbon atoms (Oshodi et al., 1995). The ratio of PUFA to SFA is important in the determination of the detrimental effects of dietary fats. The higher the ratio, the more nutritionally useful the oil (Aremu et al., 2013). The ratio of PUFA to SFA ranged between

0.16 for raw velvet tamarind flour to 2.56 for raw flour of African Locust bean. Thus, healthwise, raw *Parkia biglobosa* oil could be the best among the studied flours to be used in food products.

5.4 Discussion of results of carbohydrates contents of legume flours

5.4.1 Discussion of results of starch contents of legume flours

Boiling led to a slight increase in the starch content of sword bean but a slight decrease in the starch content of Bambara groundnuts. For African Locust bean, roasting did not affect the amount of starch present in the flour. Starch is the most abundant available carbohydrate (Hardy et al., 2015), defined as the carbohydrate fraction which is digested by α-amylase in the upper gastrointestinal tract and absorbed into the portal blood mainly as glucose (Roder et al., 2005). Starch is often the main source of digestible carbohydrate in the human diet (Butterworth et al., 2011) and contributes significantly to exogenous glucose supply and the total food energy intake (Roder et al., 2005). Some starches are however resistant to digestive enzymes (Slavin & Carlson, 2014) and are called resistant starches (Sajilata et al., 2006). Based on nutritional purposes, starch can be classified into rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) (Englyst et al., 1992).

There is the need for in depth study of the starches of these legume flours as this will help in knowing the best use for these starches especially for sword beans and Bambara groundnuts which contain substantial quantities of starch. Flours with a high proportion of resistant starch will have beneficial effects in the management of diabetes and hyperlipidemia (Sankhon et al., 2014).

5.4.2 Discussion of results of sugar contents of legume flours

The sugar profiles of the legume flours except for velvet tamarind showed that sucrose is the major sugar followed by raffinose with D-glucose and D-fructose present only in very small quantities. In velvet tamarind, D-glucose and D-fructose were the major sugars with raffinose being present in small amount. The total digestible sugar content of velvet tamarind was exceptionally high and this could make it useful as ingredient in jam making. In comparison with the total digestible sugar content, the raffinose content of the velvet tamarind is relatively low and this is desirable as it could minimize the problem of indigestibility (Onyesom et al., 2005) that causes flatulence in humans.

The small amounts of the monosaccharides in most of the legumes might be due to the fact that as the beans mature, the content of monosaccharides reduces whiles complex carbohydrates such as raffinose, stachyose and sucrose increase as in the case of soya beans (Lokuruka, 2011).

5.4.2.1 Discussion of results of raffinose content of legume flours

The raffinose content in raw flour of pigeonpea was greater than the value obtained by Apata (2008). The raffinose content in raw flour of sword bean was also greater than that reported by Revilleza et al. (1990). The raffinose content in raw flour of jack beans was less than that reported by Revilleza et al. (1990). These variations could be due to genetic and environmental factors (Raja et al., 2016). The results obtained in this work is however close to the results obtained by Revilleza et al. (1990) for raw flours of velvet beans (1.409% versus 1.12 – 1.40%) and Lima beans (0.840% versus 0.93 - 1.11%).

Boiling reduced the levels of raffinose by 93.91%, 80.00%, 86.01%, 85.66%, 53.21 % and 72.97% in pigeonpea, jack beans, sword beans, velvet beans, Lima beans and Bambara groundnuts respectively. The reductions in raffinose in the legumes are consistent with the reports of Mubarak (2005) for *Phaseolus aureus* and Abdel-Gawad (1993) for *Vicia faba* L, *Lens culinaris, Phaseolus vulgaris* and *Vigna sinensis*. The reduction in raffinose might be due to solubility or leaching of the raffinose into the medium (Revilleza et al., 1990). According to Reddy et al. (1984), discarding cook water reduces the raffinose family of sugars in beans.

There was also a 7.97% reduction in raffinose in African Locust bean after roasting. A similar observation of reduced raffinose levels after roasting has been reported *in Dolichos lablab* by Revilleza et al. (1990). The observed reduction in raffinose after roasting might be probably due to non-enzymic browning reaction, oxidation of sugars or pyrolysis (Revilleza et al., 1990).

Raffinose is a flatus oligosaccharide (Onyesom et al., 2005) and it reduction after processing is thus desirable in order to reduce the concentration of flatulence producing factors. Buildup of flatus in the intestinal tract results in discomfort, abdominal rumblings, cramps, pain, diarrrhoea, etc (Reddy et al., 1984). According to Maphosa & Jideani (2017), oligosaccharides such as raffinose are prebiotic in nature and promote the growth of probiotics, which play a major role in keeping

the colon healthy. There is therefore the need to keep in mind the prebiotic nature of the oligosaccharides in legumes during processing to improve the consumer acceptability of these legumes.

5.4.2.2 Discussion of results of sucrose content of legume flours

Except for velvet tamarind, sucrose was the main sugar in all the legumes, ranging from 0.036 g/100 g in processed jack beans flour to 3.808 g/100 g in raw sword bean flour.

The sucrose content of raw flour of pigeonpea in this study lies within the range of values (1.186 – 1.666%) obtained by H. A. Oboh et al. (2000). The sucrose content in raw flour of jack beans in this work fell slightly below the range of values (1.49 – 2.47%) reported by Revilleza et al. (1990). The sucrose result obtained in this work lies within the range of values (2.37 – 2.60%) obtained by Revilleza et al. (1990) for raw flour of velvet beans.

The sucrose content in raw flour of sword beans obtained in this work was greater than that reported by Revilleza et al. (1990) (2.57%). The sucrose content in the raw flour of Bambara groundnuts was more than that reported by Mubaiwa et al. (2018) (3.09% dry weight). The sucrose content in raw flour of Lima beans was less than that reported by Revilleza et al. (1990) (1.238 versus 1.68 – 2.02%). These variations could be due to genetic and environmental factors (Raja et al., 2016).

Boiling led to decreases in the sucrose content of the legume flours. This could be due to the leaching out of sucrose into the boiling water (Apata, 2008). Boiling reduced the levels of sucrose by 94.79%, 97.64.00%, 90.68%, 94.79%, 94.43% and 94.65% in pigeonpea, jack beans, sword beans, velvet beans, Lima beans and Bambara groundnuts respectively. A study by Abdel-Gawad (1993) reported reductions in the concentration of sucrose in *Vicia faba* L, *Lens culinaris*, *Phaseolus vulgaris* and *Vigna sinensis* by 39.4%, 34.2%, 44.0% and 41.7% respectively, after cooking.

There was a 12.98% reduction of sucrose in African Locust bean after roasting. This roasting-induced decrease in the concentration of sucrose may be due to thermal degradation of the sucrose with further dehydration and polymerization reactions with reactive intermediate products (Oracz & Nebesny, 2019).

For velvet tamarind, the absorbance difference for the sucrose after the spectrophotometric analysis was less than 0.1. The exact concentration of sucrose in the velvet tamarind flour could therefore not be calculated. Using 0.1 as the absorbance value for sucrose gives 6.715 g sucrose/100 g flour for velvet tamarind. This suggests that the amount of sucrose in 100 g velvet tamarind flour is less than 6.715 g.

Sucrose provides sweetness and energy in food**.** It contributes significantly to the flavour and acceptance of legumes such as *Phaseolus vulgaris* (VandenLangenberg et al., 2012). In *Vigna unguiculata* L Walp, the sucrose concentration of the seeds is an important component of the taste (Tchiagam et al., 2011).

5.4.2.3 Discussion of results of D-glucose content of legume flours

Apart from velvet tamarind, all the legumes contained small amount of D-glucose which ranged between 0.012 g/100 g in processed *velvet beans* flour and 0.765 g/100 g in raw flour of African Locust bean.

The amount of D-glucose obtained from the velvet tamarind in this work was lower than the values of glucose reported for velvet tamarind from Senegal (17.65% after converting dry weight into wet weight) (Ayessou et al., 2014) and Nigeria (20.03%) (O. A. Abiodun et al., 2017). The differences may be due to the different geographical areas where the fruits were obtained from.

Boiling led to decreases in the D-glucose content of the pigeonpea, jack beans, velvet beans, Lima beans and Bamabara groundnuts. The reduction in the D-glucose content of the legume flours after boiling could be due to the leaching of D-glucose into the boiling water (Apata, 2008).

Boiling reduced the levels of D-glucose by 65.79%, 58.33%, 47.83%, 51.85% and 45.33% in pigeonpea, jack beans, velvet beans, Lima beans and Bambara groundnuts respectively.
The result of sword bean contrasted with the other legumes in that the results indicated an increment in the concentration of D-glucose after boiling. The increment in the D-glucose content of the sword bean after boiling could be due to heat induced hydrolysis of sucrose into monosaccharides during the cooking process. There was an increment in the D-glucose concentration by 1516% after boiling.

African Locust bean recorded a 39.08% reduction in D-glucose concentration after roasting. The roasting-induced decrease in the concentration of D-glucose could be due to thermal degradation of the D-glucose with further dehydration and polymerization reactions with reactive intermediate products (Oracz & Nebesny, 2019).

Glucose provides sweetness and energy in food**.** It contributes significantly to the flavour and acceptance of legumes such as *Phaseolus vulgaris* (VandenLangenberg et al., 2012).

5.4.2.4 Discussion of results of D-fructose content of legume flours

Except for velvet tamarind, all the legumes contained small amounts of D-fructose, varying between 0.011 g/100 g in processed velvet beans flour to 0.528 g/100 g in raw African Locust bean flour.

The amount of D-fructose obtained from the velvet tamarind in this work was lower than the value of fructose reported for velvet tamarind from Senegal (15.9% after converting dry weight into wet weight) (Ayessou et al., 2014) and Nigeria (18.01%) (O. A. Abiodun et al., 2017). The differences may be due to the different geographical areas where the fruits were obtained from.

Boiling led to decreases in the D-fructose content of the pigeonpea, jack beans, velvet beans, Lima beans and Bambara groundnuts. The reduction in the D-fructose content of the legume flours after boiling could be due to the leaching out of D-fructose into the boiling water (Apata, 2008). Boiling

reduced the levels of D-fructose by 59.38%, 25.00%, 31.25%, 46.15% and 45.00% in pigeonpea, jack beans, velvet beans, Lima beans and Bambara groundnuts respectively.

The results of sword bean differ from the other legumes in that the results showed an increment in the concentration of D-fructose after boiling. The increment in the D-fructose content of the sword bean after boiling could be due to heat induced hydrolysis of sucrose into monosaccharides during the cooking process. There was an increment in the D-fructose concentration by 63.64% after boiling. The increment in the D-fructose content of the sword bean after boiling could be due to heat induced hydrolysis of sucrose into monosaccharides during the cooking process.

African Locust bean recorded a 61.17% reduction in D-fructose concentration after roasting. The roasting-induced decrease in the concentration of D-fructose could be due to thermal degradation of the D-fructose with further dehydration and polymerization reactions with reactive intermediate products (Oracz & Nebesny, 2019).

Fructose provides sweetness and energy in food**.** It contribute significantly to the flavour and acceptance of legumes such as *Phaseolus vulgaris* (VandenLangenberg et al., 2012).

5.5 Discussion of results of Ash contents of legume flours

Ash refers to the inorganic material which is left after either ignition or total oxidation of the organic matter in a food material and it represents the total mineral content in a food material. Apart from African Locust bean, all the other legume flours recorded less than 5% ash content. The ash content of African Locust bean (5.55% for raw seeds and 6.43% for roasted seeds) compares favourably with the value of 6.51% obtained for raw seeds of African Locust bean by Aremu, Awala, et al. (2015).

Boiling reduced the levels of ash in all the legumes. The reduction in ash content after boiling suggests the overall quantity of minerals in the legumes were reduced after boiling.

5.6 Discussion of results of mineral nutrients contents of legume flours

5.6.1 Discussion of results of calcium contents of legume flours

The amounts of calcium, which functions as a constituent of teeth and bones (Jacob et al., 2016) ranged between 46.45 mg/100 g in processed Bambara groundnut flour and 559.02 mg/100 g in raw African Locust bean flour. The values of calcium obtained for these legumes are in close agreement with those obtained by Amarteifio et al. (2002) for pigeonpea, Oladejo (2009) for velvet tamarind, Apata and Ologhobo (1994) for Lima beans and Amarteifio et al. (2006) for Bambara groundnut. The calcium concentrations in jack beans and velvet beans fell within the range of values from literature (Agbede & Aletor, 2005; Ahenkora et al., 1999; Ajeigbe et al., 2012; Apata & Ologhobo, 1994 ; Kala & Mohan, 2010; Mohan & Janardhanan, 1994; Mugendi et al., 2010; Olalekan & Bosede, 2010). Whiles the concentration of calcium in sword beans from this study fell below the range of values available from literature (A.S. Abitogun & G.K. Oso, 2014; Arinathan et al., 2003; Mohan & Janardhanan, 1994; Siddhuraju & Becker, 2001b; V. Vadivel & K. Janardhanan, 2001), that of African Locust bean fell far above the range of values from literature (Aremu, Awala, et al., 2015; Bello & Abdu, 2011; Ijarotimi & Keshinro, 2012; G. Oboh & Ekperigin, 2004; Olakunle & Adebola, 2012; Sankhon et al., 2014). The differences in the amounts of calcium from previous workers might be due to genetic origin, geographical source, and the level of fertility of the soil in which the legumes were grown (Siddhuraju & Becker, 2001b).

Consumption of milk and dairy products which will ensure that there is regular supply of dietary calcium is not common among Ghanaians. Plants foods contribute the bulk of the dietary calcium in Ghana. Since only about 25-30 per cent of dietary calcium is effectively absorbed, the dietary intake has to be large enough to ensure this rate of absorption in order to avoid skeletal damage since calcium provide rigidity to the skeleton by formation of phosphate salts (FAO/WHO, 2001). In this regard African Locust bean might be very good to play such a role because of it high calcium concentration.

5.6.2 Discussion of results of magnesium contents of legume flours

Magnesium works with calcium for muscle contraction and blood coagulation (Gnansounou et al., 2014). It also plays a role in bone mineralization (A.S. Abitogun & G.K. Oso, 2014) and in allowing asthmatic patients to breath with ease by relaxing the muscles along the airway to the lungs (Jacob et al., 2016). The results of magnesium content in this study compare well with the

results obtained by Oshodi et al. (1993) for pigeonpea. The magnesium concentration in jack beans (Apata & Ologhobo, 1994 ; Mohan & Janardhanan, 1994), sword beans (Arinathan et al., 2003; Siddhuraju & Becker, 2001b), velvet tamarind (Gnansounou et al., 2014), velvet beans (Agbede & Aletor, 2005; Aremu, Awala, et al., 2015) and Bambara groundnut (Amarteifio et al., 2006; Ndidi et al., 2014) fell within the range of values from literature. While the concentration of magnesium in Lima beans in this study fell below the range of values from literature (Adeparusi, 2001; Kathirvel & Kumudha, 2011) that of African Locust bean fell far above the range of values from literature (Aremu, Awala, et al., 2015; Ijarotimi & Keshinro, 2012). These differences in the amounts of magnesium from previous workers might be due to genetic origin, geographical source, and the level of fertility of the soil in which the legumes were grown (Siddhuraju & Becker, 2001b).

The adequate intake (AI) of magnesium for various groups of people are as follows; 350 mg/day for men, 300 mg/day for women (the same amount to be taken during pregnancy and lactation), 80 mg/day for infants aged 7-11 months, 170 mg/day for children aged 1 to < 3 years, 230 mg/day for children aged 3 to < 10 years, 300 mg/day for boys aged 10 to < 18 years and 250 mg/day for girls aged 10 to < 18 years (EFSA, 2015b). The daily magnesium needs can be supplied by all the legume samples by consumption of the appropriate quantities of the legumes. For example about 375.25 g of processed velvet beans flour may be able to meet the AI for adult men but for adult women, 321.65 g of processed velvet beans flour may be able to meet their AI needs.

5.6.3 Discussion of results of sodium contents of legume flours

In comparison with previous reports of Olalekan and Bosede (2010), Agbede and Aletor (2005), A.S. Abitogun and G.K. Oso (2014), Ogungbenle (2015), Adeparusi (2001) and Oyeleke et al. (2012), the amounts of sodium in these legumes are generally low. The differences in the amounts of sodium from previous workers might be due to genetic origin, geographical source, and the level of fertility of the soil in which the legumes were grown (Siddhuraju & Becker, 2001b). The low amounts of sodium in these legumes is good for health because high dietary sodium has been implicated in cardiovascular and renal diseases (A.S. Abitogun & G.K. Oso, 2014). The low amounts of sodium in these legumes compare well with those of other workers like Apata and Ologhobo (1994) for pigeonpea, jack beans and Lima beans and Ayessou et al. (2014) for velvet tamarind. There were increases in the sodium content of the legumes which were subjected to

hydrothermal treatment. The observed increase in sodium content after hydrothermal treatment is consistent with the results of A.S. Abitogun and G.K. Oso (2014) for sword beans and Ndidi et al. (2014) for Bambara groundnut but is in contrast with the observation of other workers like Apata and Ologhobo (1994), Ajeigbe et al. (2012), A.S. Abitogun and G.K. Oso (2014) and Akpapunam (1985) who observed decreases in the sodium content of various legumes after hydrothermal treatment.

Safe and adequate consumption of sodium for various groups of individuals per day is as follows: 0.2 g for infants between 7 – 11 months, 1.1 g for children between 1-3 years, 1.3 g for children between 4-6 years, 1.7 g for children between 7-10 years, 2.0 g for children between 11-17 years and 2.0 g for adults (EFSA, 2019b). The studied legumes are very poor sources of sodium. For instance an adult may have to consume not less than 1056.52 g of processed African Locust bean flour (the flour with the highest quantity of sodium among the studied flours) before meeting his or her adequate daily sodium requirement.

5.6.4 Discussion of results of potassium contents of legume flours

Potassium was the most abundant mineral found in the legume flours. Its concentration ranged between 599.12 mg/100 g (raw flour of velvet tamarind) and 1525.69 mg/100 g (raw flour of pigeonpea). Since the potassium content of all the legumes was more than the sodium content, the sodium to potassium ratio (Na/K) is less than one for all the legumes. This further suggests that consumption of these legumes could reduce high blood pressure (Aremu, Awala, et al., 2015). The results for potassium for pigeonpea (Apata & Ologhobo, 1994 ; Oshodi et al., 1993), jack beans (Ajeigbe et al., 2012; Siddhuraju & Becker, 2001b), sword beans (A.S. Abitogun & G.K. Oso, 2014; V. Vadivel & K. Janardhanan, 2001), velvet tamarind (Agbede & Aletor, 2005; Mugendi et al., 2010) and Lima beans (Adeparusi, 2001; Granito et al., 2007) fell within the range of values from literature. While velvet tamarind (Ayessou et al., 2014) and Bambara groundnut (Amarteifio et al., 2006; Oyeleke et al., 2012) in this study recorded potassium values close to values from literature, African Locust bean recorded values far above the values obtained from literature (Aremu, Awala, et al., 2015; Bello & Abdu, 2011; Ijarotimi & Keshinro, 2012; Olakunle & Adebola, 2012). This difference in the amounts of potassium from other workers might be due to genetic origin, geographical source, and the level of fertility of the soil in which the legumes were grown (Siddhuraju & Becker, 2001b).

The AI of potassium for various groups of people are as follows; 3500 mg/day for adult men and women (the same amount to be taken during pregnancy), 750 mg/day for infants aged 7-11 months, 800 mg/day for children aged 1 to 3 years, 3500 mg/day for children aged 15 to 17 years and 4000 mg/day for lactating women (EFSA, 2016). The daily potassium needs can be supplied by all the legume samples by consumption of the appropriate quantities of the legumes. For example about 373.29 g of processed velvet beans flour may be able to meet the AI for adult men and women.

5.6.5 Discussion of results of iron contents of legume flours

Iron is important for the formation of haemoglobin (Jacob et al., 2016). The iron content of the legume flours in this study ranged from 2.83 mg/100 g in raw sword bean flour to 491.97 mg/100g in flour from roasted seeds of African Locust bean. For pigeonpea (Apata & Ologhobo, 1994 ; R.A. Oloyo, 2002; Oloyo, 2004), jack beans (Apata & Ologhobo, 1994 ; Mohan & Janardhanan, 1994), sword beans (A.S. Abitogun & G.K. Oso, 2014; Mohan & Janardhanan, 1994; Siddhuraju & Becker, 2001b), velvet tamarind (Ayessou et al., 2014; Jacob et al., 2016 ; Oladejo, 2009), velvet beans (Agbede & Aletor, 2005; Kala & Mohan, 2010 ; Mugendi et al., 2010), Lima beans (Akpapunam, 1985; Apata & Ologhobo, 1994) and Bambara groundnut (Mazahib et al., 2013; Olaleye et al., 2013), the results of iron contents are close to values from literature. Values of iron concentration for African Locust bean in this study were far above the values reported in literature (Ijarotimi & Keshinro, 2012; G. Oboh & Ekperigin, 2004; Sankhon et al., 2014). The differences in the concentrations of iron from previous workers might be due to genetic origin, geographical source, and the level of fertility of the soil in which the legumes were grown (Siddhuraju & Becker, 2001b). All the legume samples are good sources of iron judging from the recommended daily intake (RDI) range of 8-18 mg iron /day (27 mg iron/day during pregnancy) (NHMRC & MoH, 2006). For legumes iron absorption is enhanced when they are consumed in combination with foods that are rich in vitamin C (Maphosa & Jideani, 2017). Care must be taken in order not to exceed the Upper Level of Intake (UL) (20 mg/day for 0-3 years; 40 mg/day for 4-13 years; 45 mg/day for 14 years and above) (NHMRC & MoH, 2006) especially for African Locust bean which is very rich in iron. The high iron content of these legumes could potentially play a role in preventing anaemia especially in women of reproductive age (Maphosa & Jideani, 2017) and children.

The bioavailability of iron in these legumes should be studied to find out if these legumes can add significant amounts of iron to the Ghanaian diet.

5.6.6 Discussion of results of copper contents of legume flours

The concentration of copper obtained in this study was within the range of 0.37 mg/100g (raw Lima beans flour) and 1.90 mg/100g (raw and processed flours of velvet beans). Copper is part of the catalytic centre in many enzymes, especially enzymes involved in synthesis of neurotransmitters (EFSA, 2015a). The results of copper concentrations from this study compare well with that obtained by; R.A. Oloyo (2002), Oshodi et al. (1993), Sangronis and Machado (2007) and Amarteifio et al. (2002) for pigeonpea, Apata and Ologhobo (1994) and Mohan and Janardhanan (1994) for jack beans, Mohan and Janardhanan (1994) for sword beans, Oladejo (2009) and Ayessou et al. (2014) for velvet tamarind, Mugendi et al. (2010) for velvet beans, Adeparusi (2001) for Lima beans and Amarteifio et al. (2006) for Bambara groundnut. For African Locust bean the concentrations obtained for copper lies within the range of values reported in literature (Aremu, Awala, et al., 2015; Ijarotimi & Keshinro, 2012).

The AI of copper for various groups of people are as follows; 1.6 mg/day for men, 1.3 mg/day for women (to be increased by 0.2 mg/day during pregnancy and lactation), 0.4 mg/day for infants aged 7-11 months, 0.7 mg/day for children aged 1 to < 3 years, 1.0 mg/day for children aged 3 to < 10 years, 1.3 mg/day for boys aged 10 to < 18 years and 1.1 mg/day for girls aged 10 to < 18 years (EFSA, 2015a). The daily copper needs can be supplied by all the legume samples by consumption of the appropriate quantities of the legumes. For example about 84 g of velvet beans flour may be able to meet the AI for adult men but for adult women who are not pregnant or lactating, about 68 g of velvet beans flour may be able to meet their AI needs.

5.6.7 Discussion of results of manganese contents of legume flours

Manganese acts as an activator for many enzymes and supports the regulation of blood sugar levels. It works with vitamin K to enhance blood clotting (Jacob et al., 2016). The values of manganese obtained for the flours studied in this work varied from 0.86 mg/100 g (raw flour of jack beans) to 15.37 mg/100g (flour from roasted seeds of African Locust bean). The contents of manganese in this work are close to the value reported by Oshodi et al. (1993) for pigeonpea, and Otori and Mann (2014) for sword bean. While manganese concentrations in jack beans, velvet beans and Bambara groundnut fell below values reported in literature (Agbede & Aletor, 2005;

Ndidi et al., 2014; Oyeleke et al., 2012), the concentrations in velvet tamarind, African Locust bean and Lima beans fell above the values reported in literature (Ijarotimi & Keshinro, 2012; Jacob et al., 2016 ; Kathirval & Kumudha, 2011; Oladejo, 2009 ; Sankhon et al., 2014). These differences in the amounts of manganese in the mentioned legume flours from other researchers might be due to genetic origin, geographical source, and the level of fertility of the soil in which the legumes were grown (Siddhuraju & Becker, 2001b).

The AI of manganese for various groups of people are as follows; 3 mg/day for adults (pregnant and lactating women inclusive) and 0.02 – 0.50 mg/day for infants aged 7-11 months (EFSA, 2013). The daily manganese needs can be supplied by all the legume samples by consumption of the appropriate quantities of the legumes. For example about 126.58 g of processed velvet beans flour may be able to meet the AI for adult men and women.

5.6.8 Discussion of results of zinc contents of legume flours

Zinc, a trace element is important for the synthesis of protein and nucleic acid. It plays an important role during infancy and adolescence, and during recovery from illness (Jacob et al., 2016). Zinc contents of legume flours in this study ranged between 0.63 mg/100g (velvet tamarind) and 3.97 mg/100g (flour from boiled Bambara groundnut seeds). The findings of this study are in close agreement with the values reported by Apata and Ologhobo (1994) and Oshodi et al. (1993) for pigeonpea, Oladejo (2009) for velvet tamarind, Kala and Mohan (2010) for velvet beans and Ijarotimi and Keshinro (2012) for African Locust bean. The concentrations of zinc obtained for jack beans, sword beans, Lima beans and Bambara groundnut fell within the range of values in literature (Amarteifio et al., 2006; Apata & Ologhobo, 1994; Arinathan et al., 2003; Kathirvel & Kumudha, 2011; Mazahib et al., 2013; Mohan & Janardhanan, 1994).

Deficiency of zinc leads to anorexia, loss of appetitie, smell and taste and may have effect on the immune system, triggering arteriosclerosis and anaemia (Chasapis et al., 2012). Since zinc absorption is affected by the presence of ligands such as phytates, these legumes need to be effectively processed to reduce the substances that complex zinc and reduce the bioavailability of zinc.

5.7 Discussion of results of bound cyanide in legume flours

Results reveal that the legume flours contain some amounts of cyanogenic glycosides. The toxicity of cyanogenic glycosides is linked with their ability to undergo hydrolysis either spontaneously or

in the presence of enzyme to produce cyanide as end products of their hydrolysis (Bolarinwa et al., 2016). Cyanogenic glycosides break down to produce hydrogen cyanide upon hydrolysis. Hydrogen cyanide can cause both acute and chronic toxicity in humans (Food Standards Australia New Zealand [FSANZ], 2005). In addition to these, cyanide ions also cause neuropathy and death (Emire et al., 2013). Death due to cyanide poisoning can occur when the levels of cyanide consumed exceed the amount the individual can detoxify (Food Standards Australia New Zealand [FSANZ], 2005). In oral form the lethal dose for cyanide lies between 0.5 and 3.5 mg/kg body weight (Granito et al., 2007). The processing methods reduced the concentration of cyanide released from the legumes. This reduction agrees with the observation of Ajeigbe et al. (2012) and Bolarinwa et al. (2016), who reviewed several studies and reported a reduction in the cyanide content after heat treatment. The concentrations of cyanide released from the legumes after heat treatment of the seeds were below the LOD (16.8 µmol/100g flour). In addition to these, the released cyanide quantities from raw flours of velvet beans and Lima beans were also below the LOD. In raw flours of pigeonpea, jack beans, velvet tamarind and African Locust bean, cyanide levels were above the LOD, but below the LOQ (51.2 µmol / 100 g of flour). In raw flours of sword beans and Bambara groundnut, the LOQ was exceeded. Heat treatment led to zero amount of releasable cyanide from pigeonpea, velvet beans and African Locust bean. In jack beans, sword beans, Lima beans and Bambara groundnut, the levels of reduction of releasable cyanide after heat processing were 71.74%, 91.72%, 73.08% and 92.86% respectively. Further heat processing may lead to further reduction of releasable cyanide from these legumes and reduce the potential health risk in associated with their consumption.

The cyanide ion inhibits several enzyme systems, suppress growth by interfering with some essential amino acids and utilization of associated nutrients (Emire et al., 2013). For a person weighing 60 kg, he or she will have to consume 30 mg of cyanide in order to reach the minimum lethal dose of 0.5 mg kg^{-1} body (Granito et al., 2007). Assuming that the amount of released cyanide from these legumes are the same as the bound cyanide in the legumes, then a 60 kg person will have to consume 5172.41 g of raw pigeonpea flour or 6521.74 g of raw jack bean flour or 1775.15 g of raw sword bean flour or 3333.33 g of raw velvet tamarind flour or 75000 g of raw velvet beans flour or 4225.35 g of raw African Locust bean flour or 11538 g of raw Lima bean flour or 1020.41 g of raw Bambara groundnut flour to reach the minimum lethal dose. For the processed flours, a 60 kg person will have to consume 23076.92 g of jack beans or 21428.57 g of

sword beans or 42857.14 g of Lima beans or 14285.71 g of Bambara groundnut to reach the minimum lethal dose. People of small body weight may not be able to detoxify cyanide from a meal from any of these legumes when the legumes are inadequately processed to remove the cyanide. Persistent intake of these legumes without proper processing could induce adverse health effects such as konzo, tropical ataxic neuropathy, goitre and cretinism (Food Standards Australia New Zealand [FSANZ], 2005).

5.8 Discussion of results of IFs (qualitative) in legume flours

Thermal treatment had an effect on the isoflavone composition of the legume seed flours. In all the flours, thermal processing led to an increase in the area of the isoflavones present. This is in sharp contrast to the observation of Niyibituronsa et al. (2019) who observed a reduction in the isoflavone content of soya bean grains after hydrothermal treatment. Similar to this study, Jackson et al. (2002) observed increases in the aglycone content of thermally treated soya bean seeds. The increase in the aglycone content of the legume flours prepared from the thermally processed seeds may be due to the thermal degradation of the conjugate glycoside to release its aglycone (Chukwuma et al., 2007).

5.9 Discussion of results of quantities of IFs in legume flours

The quantitative results of the isoflavone content for the processed flours of pigeonpea, African Locust bean and Bambara groundnut were successfully determined. This study showed that only the processed flours of pigeonpea, African Locust bean and Bambara groundnut have isoflavone concentrations high enough to be quantified by the method used for the analysis. The IFs BCA, DAI, DAI-GLU, FOR, GEN and GEN-GLU in the Ghanaian Legumes of pigeonpea, African Locust bean and Bambara groundnut were quantified. The flours were selected based on the size of their peak areas from the qualitative analysis by means of HPLC-DAD, in which the IFs have already been identified by means of UHPLC-MS/MS and on the basis of their IF composition. The IF in the flours was quantified twice using standard addition calibration on the HPLC-DAD.

5.9.1 Discussion of results of quantities of IFs in processed flours of pigeonpea, African Locust bean and Bambara groundnut

The IFs BCA, DAI, FOR and GEN were successfully quantified in pigeonpea. In processed African Locust bean flour, the IFs BCA, DAI and GEN-GLU were successfully quantified and in Bambara groundnut, the IFs DAI, GEN and GEN-GLU were successfully quantified. The sum of the quantified isoflavones in the processed flours ranged between 15.07 µg/100 g flour in African

Locust bean and 1603.26 µg/100 g flour in pigeonpea giving a 106 fold difference between processed pigeonpea flour and processed African Locust bean flour. The percent recoveries of the isoflavones in the legume flours ranged between 99.70 and 101.90.

These Ghanaian legumes may offer a potential as sources of isoflavones, in addition to soya beans which is well known to be a relatively rich source of isoflavones (Aguiar et al., 2007). Soya bean isoflavones have been reported to have beneficial effects on human health (Chen et al., 2019; Zagrodzka et al., 2005). Some reviwers have reported no health effect of soya bean isoflavones on human health (Gómez-Zorita et al., 2020; Hwan-Hee et al., 2021; Marcello et al., 2019; Pabich & Materska, 2019; Rienks et al., 2017; Sekikawa et al., 2019). In all these studies, study populations were either from Western or Eastern countries and seldom any African country. Since Western and Eastern study populations respond differently according to epidemiological studies, there is a necessity to to evaluate the effect on Africans separately. The isoflavone content of soya bean ranges between 74500 µg/100 g and 525398 µg/100g (Azam et al., 2020). This study has provided quantitative data on the isoflavone content of some Ghanaian legumes and the data show that the isoflavone content of the studied Ghanaian legumes fall far below that of soya bean seeds, which is one of the few sources of isoflavones for human nutrition. Nevertheless, studies are needed to investigate the effect of these isoflavones in these Ghanaian legumes on humans when these legumes are consumed. The Ghanaian legumes may offer for possible utilization as functional food ingredients.

5.10 Discussion of results of crude protein contents in legume flours

While boiling led to a slight reduction in the crude protein content of sword beans, it increased the crude protein content of Bambara groundnut slightly. For African Locust bean, roasting led to a slight reduction in the crude protein content. Both in the diet and in the body, 95% of nitrogen is found in the form of proteins and 5% is found in the form of other nitrogenous substances like free amino acids, urea or nucleotide (EFSA, 2012). This means true protein forms about 95% of the total crude protein. From crude protein values obtained in this study (Table 62) processed sword bean flour may contain about 24.77% true protein, processed African Locust bean flour may contain 22.03% true protein and processed Bambara groundnut flour may contain 17.56% true protein. Comparing obtained crude protein values in this study with the crude protein value in a conventional legume such as soya bean, it is evident that the crucde protein values obtained from

this study are far lower than the crude protein values in soya beans. While Etiosa et al. (2017), reported a crude protein content of 37.69% for soya bean seed, Alamu et al. (2017), reported a range of crude protein values of between 31.78% and 35.56% for soya beans. Howver, the crude protein values obtained from the legumes in this study are far higher than those obtained from cereals and tubers. In Ghana, commonly consumed cereal crops include rice, maize, millet and sorghum. The protein content of these mentioned cereals range between 4.28% in brown rice and 10.49% in millet (Yankah et al., 2020; Durojaiye et al., 2016; Annan & Plahar, 1995). For tubers, the common ones consumed in Ghana are cassava, yam and sweet potato. The protein content of these mentioned tubers range between 1.4% in cassava and 1.6% in sweet potato (Chandrasekara & Kumar, 2016). The values of protein for these cereals and tubers suggest that comparatively, the studied legumes could potentially be good sources of protein which could be used to assist in reducing protein malnutrition. The body requires dietary proteins for tissue growth, maintenance (EFSA, 2012) and repair.

6 Potential contribution of the studied legumes to food security and alleviation of malnutrition

The study has established the functional properties, fat content and fatty acid distribution, sugar (raffinose, sucrose, D-glucose and D-fructose) profiles, mineral nutrients, cyanide content, isoflavone profiles, crude protein content (for raw and processed flours of sword bean, African Locust bean and Bambara groundnut) and starch content (for raw and processed flours of sword bean, African Locust bean and Bambara groundnut) of the studied underutilized legumes. Among the legume flours, velvet tamarind flour had the lowest bulk density and could be the most suitable for use in weaning foods even though high amount of packaging material is needed for it packaging due to its low bulk density. Velvet tamarind flour also had the highest solubility among the studied flours and, therefore, may be more digestible and hence suitable as ingredient for infant foods. For products which require foaming like sponge cakes, the raw legume flours (except raw velvet tamarind flour) rather than the processed flours may be suitable as ingredients because the processed flours had very low foam capacities. For products which require gelling and thickening such as sauces and puddings, the raw flours may be suitable as ingredients rather than the processed flours as heat treatment increased the concentration of flours needed for gel formation in all the flours obtained from the heat treated seeds. Raw seed flour of pigeonpea had the lowest oil absorption among the studied flours and may be the best among the flours to be used in coating deep fried foods to prevent too much oil absorption. For products which require swelling such as noodles, raw flour of Lima beans may be the best ingredient among the studied flours because of it high swelling power. For products which require maintenance of freshness for easy handling during preparation such as bread, processed flour of jack beans may be the best among the studied flours to be used as ingredients because of its high ability to absorb water.

Raw flour of velvet tamarind had a very high digestible sugar content and this could make it a useful ingredient in the making of jams. Flours of African Locust bean had very high calcium and magnesium contents and may be the best among the flours to provide rigidity to the skeleton and the teeth. African Locust bean flour also had a very high iron content and may be the best among the studied flours to consume to improve the level of haemoglobin in the blood. All the flours had very small amount of sodium and a very high amount of potassium. The consumption of these legumes may therefore be helpful in reducing high blood pressure. For copper, manganese and zinc, the daily needs of individuals can be supplied by the consumption of appropriate amounts of

these legumes. The legume flours released very low amounts of cyanide (from the method employed in their quantitation). Even though acute cyanide poisoning may be rare when consumption is low, there is the need to properly process these legumes to completely get rid of the cyanide to avoid the long term exposure of cyanide to those who regularly consume these legumes. With the exception of African Locust bean, all the other legumes recorded fat content less than 8%. They contained a high amounts of cis unsaturated fatty acids and no trans fatty acids. African Locust bean also had a high amount of unsaturated fatty acids with approximately 14% oil content. Because of the relatively high oil content of the African Locust bean, it may be economical to express the oil and used as cooking oil or for industrial applications. The properties of the oil of African Locust bean need to be studied to know the use to which the oil could be put to – either as a cooking oil or industrial oil for products such as soaps or both as cooking oil and for industrial uses.

This study provided quantitative data on the isoflavone content of some Ghanaian legumes (processed flours of pigeonpea, African Locust bean and Bambara groundnut). The data show that the isoflavone content of these three legume flours fall far below that of soya bean seeds, which is one of the few sources of isoflavones. There is the need to investigate the effect of these isoflavones in these Ghanaian legumes on humans when these legumes are consumed especially for Africans since much of the studies on effect of isoflavones on human health has concentrated on people from Asian and Western countries.

Apart from African Locust bean, the other legume flours could potentially serve as healthy, low fat (with a high degree of unsaturation) food. Quantities of crude protein and starch were obtained for raw and processed flours of sword bean, African Locust bean and Bambara groundnut. The obtained data point to the potential contribution of these legumes to food security and alleviation of malnutrition but more studies need to be conducted to get a clear indication of this potential.

7 Conclusion and recommendations

7.1 Conclusion

This research was a crucial research aimed at the possibility of using these legumes to contribute to food security and alleviation of malnutrition in Ghana. The study has provided the groundwork for further research and use of these legumes. If prioritized and supported, these legumes could potentially provide nutritionally healthy foods, industrial raw materials and employment. Analyses were carried out on both the raw flours of the legumes as well as the processed flours (except velvet tamarind which is eaten in the raw state without processing). Taking account of the functional properties and nutrients analyses, these legumes could be promoted for wider usage. The results could serve as a guide to food processors to depending on the desired function or the quality they want in the end product select the flours of these studied legumes. In this case farmers can go into increased cultivation of these legumes to alleviate hunger and provide extra income for themselves. The functional properties of the legume flours indicate that they could be potentially incorporated into products such as bread, cakes, biscuits, noodles, etc. This may be beneficial for a non-traditionally wheat producing country like Ghana because it will results in reduced importation of wheat flour into Ghana and conserve money. Generally low in sodium and fat, with unsaturated fatty acids (MUFA and PUFA) in the cis configuration forming more than 50% of total fatty acids, these legume flours may contribute to reducing the risk of cardiovascular diseases. With the exception of velvet tamarind, all the legumes had very low sugar content and may be nutritionally good for diabetic patients.

7.2 Recommendations

This study has been able to quantify some chemical constituents and established the functional properties of flours of these underutilized legumes in Ghana. It is recommended that the amino acids of the flours should be profiled in order to assess the protein quality of these legumes and ensure a diet that contains the qualitative and quantitative requirements of essential amino-acids. It is important to determine the bioavailability of the nutrients in these legumes using animal models. These studies should focus on the digestibility of the proteins, starch and lipids in these legumes and on the possibility of the presence of antinutrients, such as phytates, oxalates, alkaloids, tannins, protease inhibitors, lectins, etc. These legumes should be incorporated into food products such as bread, cakes, biscuits, noodles, soups and their performance investigated because the final test of functionality of ingredient that is to be used in a food systems is to incorporate it

in the food system and the behaviour of the ingredients studied. Also, further studies should be carried out on the effects of consumption of these legumes on the nutritional and health status of human beings.

Since African Locust bean has a considerable amount of oil, the properties of the oil such as viscosity, refractive index, specific gravity, percentage free fatty acid content, iodine value, saponification value, peroxide value, etc should be studied to know whether the oil could be used as cooking oil or industrial oil or both.

The effect of isoflavone consumption on the health of people from sub-Sahara Africa is rarely found in literature. It is recommended that studies should be carried out on the effect on the health of people consuming these legumes due to the isoflavones (though quantities are small in comparison with soya bean) present in these legumes

8 Summary

The aim of this study was to determine the potential of some Ghanaian underutilized legumes in helping to reduce the problems of poverty, hunger and malnutrition among the vulnerable group of the Ghanaian population. The legume samples were obtained from farmers in Ejura in the Ejura-Sekyedumase Municipality in the Ashanti region of Ghana. Flours were produced from the legumes without and with prior processing for the determination of functional properties as well as crude fat content and fatty acid profile, starch (3 legumes), sugar content, ash and mineral content, releasable cyanide, isoflavone (3 flours) and crude protein (3 legumes). The results suggest the legumes may have untapped potential. Results of the functional properties reveal that the legume flours may serve useful roles in various food products. For instance, velvet tamarind (*Dialium guineense*) flour may be useful in infant food formulation because of it high solubility and low bulk density. African Locust bean (*Parkia biglobosa*) flour had the highest fat content among the studied flours, recording a fat content of approximately 14%. It may therefore be economical to express the oil and used as edible oil or for industrial applications for products such as soaps, shampoos, paints, etc. This means the properties of the oil of African Locust bean (*Parkia biglobosa*) flour need to be studied to know the uses of the oil. Unsaturated fatty acids formed more than 50% of the fatty acids in all the legumes. This observation coupled with the low sodium content of all the legumes suggests that these legumes may be suitable for consumption to prevent cardiovascular diseases. The daily mineral needs of individuals can be met by the consumption of appropriate amounts of these legumes (For example, 375.25 g of processed velvet bean flour may be able to meet the adequate intake requirement for adult males, while for adult females 321.65 g of processed velvet bean flour may meet their adequate intake requirement. Also, consumption of 1.63 - 3.66 g of processed African Locust bean flour may be able to meet the Recommended Dietary Intake of iron which is between 8 - 18 mg/day). African Locust bean (*Parkia biglobosa*) flour had a very high calcium and magnesium content and is possibly very good for strengthening bones and teeth and, due to its comparatively high iron content, may be very good at preventing iron deficiency. Except for velvet tamarind (*Dialium guineense*), all other legumes had a very low sugar content and may therefore be suited for diabetics. Very low amounts of cyanides [ranging from 0 in processed flours of pigeonpea (*Cajanus cajan*), velvet beans (*Mucuna pruriens*) and African Locust bean (*Parkia biglobosa*) to 2.94 mg/100g in Bambara groundnuts (*Vigna subterranea*)] were released from the legume flours. The processing methods used in this study

(e.g. cooking) led to between 71-93% reduction of releasable cyanide in jack bean (*Canavalia ensiformis*), sword bean (*Canavalia gladiata*), Lima bean (*Phaseolus lunatus*) and Bambara groundnut (*Vigna subterranea*). The processing methods used in this study led to zero (0) amount of releasable cyanide in pigeonpea (*Cajanus cajan*), velvet beans (*Mucuna pruriens*) and African Locust bean (*Parkia biglobosa*). The findings point to the need to properly process these legumes to completely get rid of the cyanides to avoid long term exposure of cyanide to those who regularly consume these legumes. This study also provided quantitative data on the isoflavone content of the processed flours of pigeon pea (*Cajanus cajan*), African Locust bean (*Parkia biglobosa*) and Bambara groundnut (*Vigna subterranea*). The amounts of daidzein, genistein, daidzin and genistin in the processed flours of pigeonpea (*Cajanus cajan*), African Locust bean (*Parkia biglobosa*) and Bambara groundnut (*Vigna subterranea*) are very low compared to those in soya beans. Although the biological activities of the main soy isoflavones (daidzein and genistein) are very well studied, little is known about the effect of this class of substances on men and women in sub-Saharan Africa. Therefore, no reliable statement can be made about the effect of isoflavones in this population group. Quantitative data on the crude protein and starch content of sword bean (*Canavalia gladiata*), African Locust bean (*Parkia biglobosa*) and Bambara groundnut (*Vigna subterranea*) flours show that these legumes can potentially contribute to the prevention of malnutrition (for example due to protein deficiency). It is recommended that the bioavailability of the nutrients in the studied legume flours should be determined using animal models. There is the need for further research to be conducted on these legumes to unearth more potentials of these legumes. The proper use of these legumes will not only contribute to healthy nutrition for the Ghanaian population, but could also be of great environmental and economic benefit.

9 Zusammenfassung

Ziel dieser Studie war es, das Potenzial einiger selten genutzter ghanaischer Hülsenfrüchte zur Verringerung der Probleme von Armut, Hunger, und Unterernährung in der gefährdeten Gruppe der ghanaischen Bevölkerung zu ermitteln. Die Hülsenfruchtproben wurden von Bauern in Ejura in der Gemeinde Ejura-Sekyedumase in der Ashanti-Region in Ghana erhalten. Aus den Hülsenfrüchten wurde ohne und mit vorausgehender Prozessierung Mehle hergestellt, die für die Bestimmung der funktionellen Eigenschaften sowie Rohfettgehalt und Fettsäureprofil, Stärke (3 Leguminosen), Zuckergehalt, Asche und Mineralstoffgehalt, freisetzbares Cyanid, Isoflavon (3 Mehle) und Rohprotein (3 Legumonosen) bestimmt. Die Ergebnisse deuten darauf hin, dass die Hülsenfrüchte möglicherweise bisher ungenutztes Potenzial haben. Die Ergebnisse der funktionellen Eigenschaften zeigen, dass die Hülsenfruchtmehle in verschiedenen Lebensmittelprodukten nützliche Funktionen erfüllen können. Zum Beispiel kann Samttamarindenmehl (*Dialium guineense*) aufgrund seiner hohen Löslichkeit und geringen Schüttdichte in der Formulierung von Säuglingsnahrung nützlich sein. Afrikanisches Johannisbrotmehl (*Parkia biglobosa*) wies mit etwa 14% den höchsten Fettgehalt unter den untersuchten Mehlen auf. Es kann daher wirtschaftlich sein, das Öl auszupressen und als Speiseöl oder für industrielle Anwendungen für Produkte wie Seifen, Shampoos, Farben usw. Dies bedeutet, dass die Eigenschaften des Öls von afrikanischen Johannisbrotkernmehl (*Parkia biglobosa*) untersucht werden müssen, um die Verwendung des Öls zu kennen. Ungesättigte Fettsäuren bilden mehr als 50% der Fettsäuren in allen Hülsenfrüchten. Diese Beobachtung in Verbindung mit dem niedrigen Natriumgehalt aller Hülsenfrüchte legt nahe, dass der Verzehr dieser Hülsenfrüchte Herz-Kreislauf-Erkrankungen vorbeugen könnte. Der tägliche Mineralstoffbedarf des Einzelnen kann durch den Verzehr entsprechender Mengen dieser Hülsenfrüchte gedeckt werden (Beispielsweise können 375,25 g verarbeitetes Samtbohnenmehl in der Lage sein, den angemessene Zufuhr für erwachsene Männer zu decken, während für erwachsene Frauen 321,65 g verarbeitetes Samtbohnenmehl ihren Bedarf an einer angemessenen Zufuhr decken können. Auch der Verzehr von 1,63 - 3,66 g verarbeitetem afrikanischen Johannisbrotkernmehl kann in der Lage sein, die Empfohlene Nahrungsaufnahme von Eisen zu erreichen, die zwischen 8 - 18 mg / Tag liegen). Afrikanisches Johannisbrotmehl (*Parkia biglobosa*) hatte einen sehr hohen Kalzium- und Magnesiumgehalt und ist möglicherweise sehr gut geeignet, um Knochen und den Zähnen Festigkeit zu verleihen und kann aufgrund seines

vergleichsweise hohen Eisengehalts sehr gut zur Vorbeugung von Eisenmangel beitragen. Außer Samttamarinde (*Dialium guineense*) haben alle anderen Hülsenfrüchte einen sehr geringen Zuckergehalt und damit gut für Diabetiker geeignet. Sehr geringe Mengen an Cyanid [von 0 in verarbeitetem Mehl von Straucherbsen *(Cajanus cajan*), Samtbohnen (*Mucuna pruriens*) und Afrikanischer Johannisbrotbohne (*Parkia biglobosa*) bis zu 2,94 mg/100 g in Bambara-Erdnüssen (*Vigna subterranea*)] wurden aus dem freigesetzt Hülsenfrüchte Mehle. Werden die Hülsenfrüchte vor der Herstellung von Mehlen prozessiert (z.B. Kochen) kann die freisetzbare Cyanidmenge um 71-93% [Jackbohne (*Canavalia ensiformis*), Schwertbohne (*Canavalia gladiata*), Limabohne (*Phaseolus lunatus*) und Bambara-Erdnuss (*Vigna subterranea*)] reduziert werden. Für einen Teil der Leguminosen [Straucherbse (*Cajanus cajan*), Samtbohnen (*Mucuna pruriens*) und afrikanischer Johannisbrotbohne (*Parkia biglobosa*)] kann daraufhin in den Mehlen kein freisetzbares Cyanid mehr nachgeweisen werden. Die Ergebnisse weisen auf die Notwendigkeit hin, diese Hülsenfrüchte richtig zu verarbeiten, um die Cyanid vollständig zu beseitigen und eine langfristige Exposition von Zyaniden bei regelmäßigen Verzehr dieser Hülsenfrüchte zu vermeiden. Diese Studie lieferte auch quantitative Daten zum Isoflavongehalt der verarbeiteten Mehle von Straucherbse (*Cajanus cajan*), Afrikanischer Johannisbrotbohne (*Parkia biglobosa*) und Bambara-Erdnuss (*Vigna subterranea*). Die Mengen an daidzein, genistein, daidzin und genistin in den verarbeiteten Mehlen von Straucherbse (*Cajanus cajan*), Johannisbrot (*Parkia biglobosa*) und Bambara-Erdnuss (*Vigna subterranea*) sind im Vergleich zu denen in Sojabohnen sehr gering. Obwohl die biologischen Aktivitäten der wichtigsten Soja-Isoflavone (daidzein und genistein) sehr gut untersucht sind, ist über die Wirkung dieser Stoffklasse auf Männer und Frauen in Subsahara Afrika wenig bekannt. Daher kann über, die Wirkung der Isoflavone in dieser Bevölkrungsgruppe kein verlässliche Aussage getroffen werden. Quantitative Daten zum Rohprotein- und Stärkegehalt der Mehle von Schwertbohne (*Canavalia gladiata*), Afrikanischer Johannisbrot (*Parkia biglobosa*) und Bambara-Erdnuss (*Vigna subterranea*) zeigen, dass diese Hülsenfrüchte potenziell zur Vermeidung von Unterernährung (beispielsweise durch Proteinmangel) beitragen können. Es wird empfohlen, die Bioverfügbarkeit der Nährstoffe in den untersuchten Hülsenfruchtmehlen anhand von Tiermodellen zu bestimmen. Es besteht Bedarf an weiterer Forschung an diesen Hülsenfrüchten, um weitere Potenziale zu entdecken. Die richtige Nutzung dieser Hülsenfrüchte könnte nicht nur einen Beitrag zur gesunden Ernährung der

ghanaischen Bevölkerung leisten, sondern darüber hinaus umweltpolitisch und wirtschaftlich von großem Nutzen sein.

10 References

Abdel-Gawad, A. S. (1993). Effect of domestic processing on oligosaccharide content of some dry legume seeds *Food Chem, 46*(1), 25-31.

Abey, S., & Abey, N. O. (2016). Effects of Gamma Irradiation and cooking on the Physico-Chemical Properties of African Locust Bean (*Parkia biglobosa*) Seeds. *Food Public Health, 6*(1), 8-14. doi:10.5923/j.fph.20160601.02

Abiodun, A. O., & Adepeju, A. B. (2011). Effect of Processing on the Chemical, Pasting and Anti-Nutritional Composition of Bambara Nut (*Vigna subterranea* L. Verdc) flour *Adv J Food Sci Tech, 3*(4), 224-227.

Abiodun, O. A., Dauda, A. O., Adebisi, T. T., & Alonge, C. D. (2017). Physico-chemical, microbial and sensory properties of kunu zaki beverage sweetened with black velvet tamarind (*Dialium guineense*). *Croat J Food Sci Tech, 9*(1), 46-56. doi:10.17508/cjfst.2017.9.1.07

Abitogun, A. S., & Oso, G. K. (2014). Assesment of Processing Methods on the Chemical Composition of Sword Bean (*Canavaliagladiata*). *IOSR J Appl Chem, 7*(5 Ver II), 106-112.

Abitogun, A. S., & Oso, G. K. (2014). Assessment of Processing Methods on the chemical composition of Sword bean (*Canavalia gladiata*) *IOSR J Appl Chem, 7* (5 Ver 2), 106–112.

Aboagye, L. M., Obirih-Opareh, N., Amissah, L., & Adu-Dapaah, H. (2007). *Analysis of existing national policies and legislation that enable or inhibit the wider use of underutilized plant species for food and agriculture in Ghana*. Retrieved from Maccarese (Fiumicino), Italy:

Acevedo, B. A., Thompson, C. M. B., Foutel, N. S. G., Chaves, M. G., & Avanza, M. V. (2017). Effect of different treatments on the microstructure and functional and pasting properties of pigeon pea (*Cajanus cajan* L.), dolichos bean (*Dolichos lablab* L.) and jack bean (*Canavalia ensiformis*) flours from the north-east Argentina. *Int J Food Sci Technol, 52*(1), 222-230. doi:10.1111/ijfs.13271

Adamu, G., Ezeokoli, O., Dawodu, A., Adebayo-Oyetoro, A., & Ofodile, L. (2015). Macronutrients and Micronutrients Profile of Some Underutilized Beans in South Western Nigeria. *Int J Biochem Res Rev, 7*(2), 80-89. doi:10.9734/ijbcrr/2015/17219

Ade-Omowaye, B. I. O., Tucker, G. A., & Smetanska, I. (2015). Nutritional potential of nine underexploited legumes in Southwest Nigeria. *Int Food Res J, 22*(2), 798-806.

Adebowale, K. O., Afolabi, T. A., & Olu-Owolabi, B. I. (2006). Functional, physicochemical and retrogradation properties of sword bean (*Canavalia gladiata*) acetylated and oxidized starches. *Carbohyd Polym, 65*(1), 93-101. doi:10.1016/j.carbpol.2005.12.032

Adebowale, O. J., & Maliki, K. (2011). Effect of fermentation period on the chemical composition and functional properties of Pigeon pea (*Cajanus cajan*) seed flour. *Int Food Res J, 18*(4), 1329-1333.

Adebowale, Y. A., Adeyemi, I. A., & Oshodi, A. A. (2005). Functional and physicochemical properties of flours of six *Mucuna* species. *Afr J Biotechnol, 4*(12), 1461-1468.

Adegbehingbe, K. T. (2013). Microbiological and nutrient studies of fermented cooked Lima bean (*Phaseolus lunatus*) seeds. *Glob J Biol Agric Health Sci, 2*(2), 94-101.

Adegbehingbe, K. T. (2014). Effect of fermentation on nutrient composition and anti-nutrient contents of ground Lima bean seeds fermented with *Aspergillus fumigatus*, *Rhizopus stolonifer* and *Saccharomyces cerevisiae*. *Int J Adv Res, 2* (7), 1208-1215.

Adegbehingbe, K. T., Adetuyi, F. C., & Akinyosoye, F. A. (2014). Effect of fermentation on Nutrient and Antinutrient contents of Ground-Cooked Lima bean (*Phaseolus lunatus*) seeds using *Baciluus subtillis* and *Bacillus pumilus*. *Brit Microbiol Res J, 4* (11), 1285–1298.

Adeparusi, E. O. (2001). Effect of processing on the nutrients and anti-nutrients of lima bean (*Phaseolus lunatus* L.) flour. *Nahrung, 45* (2), 94–96.

Afify, A. S., Abdalla, A. A., Elsayed, A., Gamuhay, B., Abu- Khadra, A. S., Hassan, M., . . . Mohamed, A. (2017). Survey on the Moisture and Ash Contents in Agricultural Commodities in Al-Rass Governorate, Saudi Arabia in 2017. *Assiut J Agric Sci, 48*(6), 55-62. doi:10.21608/ajas.1999.5752

Agbede, J. O., & Aletor, V. A. (2005). Studies of the chemical composition and protein quality evaluation of differently processed *Canavalia ensiformis* and *Mucuna pruriens* seed flours. *J Food Compos Anal, 18*(1), 89-103. doi:10.1016/j.jfca.2003.10.011

Aguiar, C. L., Baptista, A. S., Alencar, S. M., Haddad, R., & Eberlin, M. N. (2007). Analysis of isoflavonoids from leguminous plant extracts by RPHPLC/DAD and electrospray ionization mass spectrometry. *Int J Food Sci Nutr, 58*(2), 116-124. doi:10.1080/09637480601149350

Aguilera, Y., Esteban, R. M., Benitez, V., Molla, E., & Martin-Cabrejas, M. A. (2009). Starch, functional properties, and microstructural characteristics in chickpea and lentil as affected by thermal processing. *J Agr Food Chem, 57*(22), 10682-10688. doi:10.1021/jf902042r

Ahenkora, K., Dadzie, M., & Osei-Bonsu, P. (1999). Composition and functional properties of raw and heat processed velvet bean *(Mucuna pruriens* (L.) DC *var utilis*) flours. *Int J Food Sci Tech, 34*(2), 131-135.

Aikins, K. A., Afriyie, J. K., Amanor, I. N., Ackah, S. M., & Bobobee, E. Y. H. (2016). Assessment of Tractor Maintenance Practices of Tractor Operators at Ejura, Ghana. *Int J Sci Eng Appl, 5*(5), 257-267.

Aja, P. M., Alum, E. U., Ezeani, N. N., Nwali, B. U., & Edwin, N. (2015). Comparative phytochemical composition of *Cajanus cajan* leaf and seed. *Int J Microbiol Res, 6* (1), 42–46.

Ajeigbe, S. O., Mohammed, A. K., Yahaya, I. A., & Oyelowo, A. O. (2012). Effect of processing techniques on levels of Minerals and antinutritional factors of *Canavalia ensiformis*. *Pak J Nutr, 11* (12), 1121 – 1124.

Ajiboye, A. E., & Sani, A. (2015). Fermentation of the fruit pulp of *Dialium guineense* (Velvet tamarind) for Citric Acid Production Using Naturally Occurring Fungi. *Int J Curr Microbiol Appl Sci, 4*(7), 432-440.

Akande, E. A., Odedeji, J. O., & Agbolade, J. O. (2014). Physical Characterization and Physicochemical Properties of Jackbean (*Canavalia ensiformis*). *Int J Eng Tech Res, 2*(8), 230-232.

Akande, K. E., Abubakar, M. M., Adegbola, T. A., & Bogoro, S. E. (2016). Nutritional composition of some unconventional plant protein sources. *J Anim Prod Res, 28*(2), 1-10.

Akande, K. E., Abubakar, M. M., Adegbola, T. A., Bogoro, S. E., & Doma, U. D. (2010). Chemical Evaluation of the Nutritive Quality of Pigeon Pea [*Cajanus cajan* (L.) Millsp.]. *Int J Poult Sci, 9*(1), 63-65.

Akande, K. E., Abubakar, M. M., Adegbola, T. A., Bogoro, S. E., Doma, U. D., & Fabiyi, E. F. (2009). Nutrient compostion and uses of bambara groundnut (*Vignia substerranea* (l.) verdcourt) *Cont J Food Sci Technol, 3,* 8-13.

Akande, S. R., & Balogun, M. O. (2007). Evaluation and heritability studies of local Lima bean (*Phaseolus lunatus* L.) cultivars from south-west Nigeria *UDO Ag. (Venezuela), 7*(1), 22-28.

Akinmutimi, A. H., Ojewola, G. S., Abasiekong, S. F., & Onwudike, O. C. (2008). Evaluation of Toasted, Cooked and Akanwu-Cooked Sword Bean Meal in Place of Soya Bean Meal in Broiler Starter Diets. *Int J Poult Sci, 7*(5), 480-486.

Akpapunam, M. A. (1985). Effects of Blanching, Soaking, and Cooking on the HCN Yields, Nitrogen, Ash, and Minerals of Lima Beans (*Phaseolus lunatus*). *J Food Sci, 50* (4), 1191–1192.

Akpapunam, M. A., & Sefa-Dedeh, S. (1997). Jack bean (*Canavalia ensiformis*): Nutrition related aspects and needed nutrition research. *Plant Food Hum Nutr, 50*(2), 93-99.

Akpapunam, M. A., & Sefa-Dedeh, S. (1997). Some physicochemical properties and antinutritional factors of raw, cooked and germinated Jack bean (*Canavalia ensiformis*). *Food Chem, 59*(1), 121–125.

Akubor, P. I., Isolokwu, P. C., Ugbane, O., & Onimawo, I. A. (2000). Proximate composition and functional properties of African breadfruit kernel and flour blends. *Food Res Int, 33*(8), 707-712.

Alamu, E. O., Therese, G., Mdziniso, P., & Bussie, M. (2017). Assessment of nutritional characteristics of products developed using soybean (*Glycine max* (L.) Merr.) pipeline and improved varieties. *Cog Food Agric, 3*:1, 1398042, DOI: 10.1080/23311932.2017.1398042

Aletor, V. A., & Aladetimi, O. O. (1989). Compositional evaluation of some cowpea yarieties and some under-utilized edible legumes in Nigeria. *Die Nahrung, 33*(10), 999-1007.

Aller, E. E. J. G., Abete, I., Astrup, A., Martinez, J. A., & van Baak, M. A. (2011). Starches, Sugars and Obesity. *Nutrients, 3*(3), 341-369.

Alviola, J. N. A., & Monterde, V. G. (2018). Physicochemical and Functional Properties of Wheat (*Triticum aestivum*) and Selected Local Flours in the Philippines. *Philipp J Sci, 147*(3), 419-430.

Amarteifio, J. O., Munthali, D. C., Karikari, S. K., & Morake, T. K. (2002). The composition of pigeon peas (*Cajanus cajan* (L.) Millsp.) grown in Botswana. *Plant Food Hum Nutr, 57* (2), 173–177.

Amarteifio, J. O., Tibe, O., & Njogu, R. M. (2006). The mineral composition of bambara groundnut (*Vigna subterranea* (L) Verdc) grown in Southern Africa. *Afr J Biotechnol, 5*(23), 2408-2411.

Annan, N. T., & Plahar, W. A. (1995). Development and quality evaluation of a soy-fortified Ghanaian weaning food. *Food Nutr Bull, 16*(3), 1-8.

Apata, D. F. (2008). Effect of cooking methods on available and unavailable carbohydrates of some tropical grain legumes. *Afr J Biotechnol, 7*(16), 2940-2945.

Apata, D. F., & Ologhobo, A. D. (1994). Biochemical evaluation of some Nigerian legume seeds. *Food Chem, 49* (4), 333–338.

Appenteng, M. K., Krueger, R., Johnson, M. C., Ingold, H., Bell, R., Thomas, A. L., & Greenlief, C. M. (2021). Cyanogenic glycoside Analysis in American Elderberry. *Molecules, 26*, 1384. https://doi.org/10.3390/molecules26051384

Appiah, F. (2011). *Nutrient composition, functional properties, digestibility and formulation of selected food products from breadfruits (Artocarpus spp. and Treculia africana).* (Phd PhD

Thesis), Kwame Nkrumah University of Science and Technology, Kumasi, Ghana., Kumasi, Ghana.

Appiah, F., Asibuo, J. Y., & Kumah, P. (2011). Physicochemical and functional properties of bean flours of three cowpea (*Vigna unguiculata* L. Walp) varieties in Ghana. *Afr J Food Sci, 5*(2), 100-104.

Appiah, F., Oduro, I., & Ellis, W. O. (2011). Functional properties of *Artocarpus altilis* pulp flour as affected by fermentation. *Agric Biol J N Am, 2*(5), 773-779. doi:10.5251/abjna.2011.2.5.773.779

Aremu, M. O., Awala, E. Y., Opaluwa, O. D., Odoh, R., & Bamidele, T. O. (2015). Effect of Processing on Nutritional Composition of African Locust Bean (*Parkia biglobosa*) and Mesquite Bean (*Prosopis africana*) Seeds. *Comm Appl Sci, 3*(1), 22-41.

Aremu, M. O., Haruna, A., Oko, O. J., & Ortutu, S. C. (2017). Fatty Acid, Phospholipid and Sterol Compositions of Breadfruit (*Artocarpus altilis*) and Wonderful Kola (*Buchholzia aoriacea*) Seeds. *Int J Sci, 6*(4), 116-123. doi:10.18483/ijSci.1260

Aremu, M. O., Ibrahim, H., Awala, E. Y., Olonisakin, A., & Oko, O. J. (2015). Effect of Fermentation on Fatty Acid Compositions of African Locust Bean and Mesquite Bean. *J Chem Eng Chem Res, 2*(10), 817-823.

Aremu, M. O., Mamman, S., & Olonisakin, A. (2013). Evaluation of fatty acids and physicochemical characteristics of six varieties of bambara groundnut (*Vigna subterranea* L. Verdc) seed oils. *Riv Ital Sostanze Gr, 90*(2), 107-113.

Aremu, M. O., Olaofe, O., & Akintayo, E. T. (2007). Functional properties of some Nigerian varieties of Legume seed flours and flour concentration effect on foaming and gelation properties. *J Food Tech, 5*(2), 109-115.

Arinathan, V., Mohan, V. R., & John De Britto, A. (2003). Chemical composition of certain tribal pulses in South India. *Int J Food Sci Nutr, 54*(3), 209-217. doi:10.1080/09637480120092026

Aschner, M., & Erikson, K. (2017). Manganese. *Adv Nutr, 8*(3), 520-521. doi:10.3945/an.117.015305

Asuquo, J. E., Etim, E. E., Ukpong, I. U., & Etuk, S. E. (2012). Extraction, Characterization and Fatty Acid Profile of *Poga oleosa* Oil. *Int J Modern Anal Sep Sci, 1*(1), 23-30.

Avendaño-Yáñez, M. L., Ortiz-Ceballos, Á. I., Sánchez-Velásquez, L. R., Pineda-López, M. R., & Meave, J. A. (2014). Synergic Effect of *Mucuna pruriens* var. Utilis (Fabaceae) and *Pontoscolex corethrurus* (Oligochaeta, Glossoscolecidae) on the Growth of *Quercus insignis* (Fagaceae) Seedlings, a Native Species of the Mexican Cloud Forest. *Open J For, 4*(1), 1-7. doi:10.4236/ojf.2014.41001

Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The functional properties of foods and flours. *Int J Adv Acad Res (Sci Tech Eng), 5*(11), 139-160.

Ayessou, N. C., Ndiaye, C., Cisse´, M., Gueye, M., Sakho, M., & Dornier, M. (2014). Nutrient composition and nutritional potential of wild fruit *Dialium guineense*. *J Food Compos Anal, 34*(2), 186-191. doi:10.1016/j.jfca.2014.01.002

Azam, M., Zhang, S., Abdelghany, A. M., Shaibu, A. S., Feng, Y., Li, Y., . . . Sun, J. (2020). Seed isoflavone profiling of 1168 soybean accessions from major growing ecoregions in China. *Food Res Int, 130*, 108957. doi:10.1016/j.foodres.2019.108957

Bailey, R. L., West, K. P., & Black, R. E. (2015). The epidemiology of global micronutrient deficiencies. *Ann Nutr Metab, 66* 22-33. doi:10.1159/000371618

Bamidele, O. P., & Akanbi, C. T. (2013). Influence of gamma irradiation on the nutritional and functional properties of pigeon pea (*Cajanus cajan*) flour. *Afr J Food Sci, 7*(9), 285-290. doi:10.5897/AJFS2013

Batra, J., & Seth, P. K. (2002). Effect of iron deficiency on developing rat brain. *Indian J Clin Biochem, 17*(2), 108-114. doi:10.1007/BF02867982

Beare-Rogers, J., Dieffenbacher, A., & Holm, J. V. (2001). Lexicon of lipid nutrition (IUPAC Technical Report). *Pure Appl Chem, 73*(4), 685-744.

Beasley, D. M. G., & Glass, W. I. (1998). Cyanide poisoning: pathophysiology and treatment recommendations. *Occup Med, 48*(7), 427-431.

Bello, A. G., & Abdu, I. (2011). Nutrient and mineral elements levels in four indigenous tree seeds in Sokoto State, Nigeria. *J Plant Breed Crop Sci, 3* (15), 396-400. doi:10.5897/JPBCS10.048

Benítez, V., Cantera, S., Aguilera, Y., Mollá, E., Esteban, R. M., Díaz, M. F., & Martín-Cabrejas, M. A. (2013). Impact of germination on starch, dietary fiber and physicochemical properties in non-conventional legumes. *Food Res Int, 50*(1), 64-69. doi:10.1016/j.foodres.2012.09.044

Bertoft, E. (2017). Understanding Starch Structure: Recent Progress. *Agronomy, 7*(3), 56.

Beuchat, L. R. (1977). Functional and Electrophoretic Characteristics of Succinylated Peanut Flour Protein. *J Agr Food Chem, 25*(2), 258-261.

Bhat, R., Sridhar, K. R., Young, C., Bhagwath, A. A., & Ganesh, S. (2008). Composition and functional properties of raw and electron beam-irradiated *Mucuna pruriens* seeds. *Int J Food Sci Technol, 43*(8), 1338-1351. doi:10.1111/j.1365-2621.2007.01617.x

Bielefeld, D., Grafenauer, S., & Rangan, A. (2020). The Effects of Legume Consumption on Markers of Glycaemic Control in Individuals with and without Diabetes Mellitus: A Systematic Literature Review of Randomised Controlled Trials. *Nutrients, 12*(7), 2123.

Bolarinwa, I. F., Oke, M. O., Olaniyan, S. A., & Ajala, A. S. (2016). A Review of Cyanogenic Glycosides in Edible Plants. In M. L. Larramendy & S. Soloneski (Eds.), *Toxicology - New Aspects to this Scientific Conundrum*: InTechOpen.

Bradbury, J. (2011). Docosahexaenoic acid (DHA): an ancient nutrient for the modern human brain. *Nutrients, 3*(5), 529-554. doi:10.3390/nu3050529

Bravo, L., Siddhuraju, P., & Saura-Calixto, F. (1999). Composition of underexploited Indian pulses. Comparison with common legumes. *Food Chem, 64*(2), 185-192.

Builders, M. I. (2014). *Parkia biglobosa* (African Locust Bean tree). *World J Pharm Res, 3*(2), 1672-1682.

Butterworth, P. J., Warren, F. J., & Ellis, P. R. (2011). Human α-amylase and starch digestion: An interesting marriage. *Starch/Stärke, 63*(7), 395–405.

Carrillo, W., Carpio, C., Morales, D., Vilcacundo, E., Álvarez, M., & Silva, M. (2017). Content of Fatty Acids in Corn (*Zea mays* L.) Oil from Ecuador. *Asian J Pharm Clin Res, 10*(8), 150-153. doi:10.22159/ajpcr.2017.v10i8.18786

Cederroth, C. R., & Nef, S. (2009). Soy, phytoestrogens and metabolism: A review. *Mol Cell Endocrinol, 304*(1-2), 30-42. doi:10.1016/j.mce.2009.02.027

Celep, G. S., Kaynar, P., & Rastmanesh, R. (2017). Biochemical functions of micronutrients. *Adv Obes Weight Manag Cont, 6*(2), 43-45. doi:10.15406/aowmc.2017.06.00147

Chasapis, C. T., Loutsidou, A. C., Spiliopoulou, C. A., & Stefanidou, M. E. (2012). Zinc and human health: an update. *Arch Toxicol, 86*(4), 521-534.

Chandrasekara, A., & Kumar, T. J. (2016). Roots and Tuber Crops as Functional Foods: A Review on Phytochemical Constituents and Their Potential Health Benefits. *Int J Food Sci, 2016,* Article ID 3631647, http://dx.doi.org/10.1155/2016/3631647

Chen, L., Teng, H., & Xiao, J. (2019). A value-added cooking process to improve the quality of soybean: Protecting its isoflavones and antioxidant activity. *Food Sci Hum Well, 8*(2), 195-201. doi:10.1016/j.fshw.2019.05.001

Chinma, C. E., Alemede, I. C., & Emelife, I. G. (2008). Physicochemical and Functional Properties of Some Nigerian Cowpea Varieties. *Pak J Nutr, 7*(1), 186-190.

Chirawurah, D., Apanga, S., & Addah, J. (2015). Assessing Iodized Salt Use in Rural Northern Ghana: A Mixed Method Approach. *Food Pub Health, 5*(3), 70-76.

Chuang, T. (1970). *Raffinose in the Sugarbeet (Beta vulgaris): I. Biosynthesis and Degradation in the Root; II. Hydrolysis in Molasses With Sweet Almond Emulsin.* (PhD), Utah State University,

Chukwuma, Y., Walker, L., Vogler, B., & Verghese, M. (2007). Changes in the Phytochemical Composition and Profile of Raw, Boiled, and Roasted Peanuts. *J Agr Food Chem, 55*(22), 9266-9273.

Ciereszko, I. (2018). Regulatory roles of sugars in plant growth and development. *Acta Soc Bot Pol, 87*(2). doi:10.5586/asbp.3583

Cook, J. A., VanderJagt, D. J., Pastuszyn, A., Mounkaila, G., Glew, R. S., Millson, M., & Glew, R. H. (2000). Nutrient and Chemical Composition of 13 Wild Plant Foods of Niger - Short Communication. *J Food Compos Anal, 13* (1), 83-92.

Cook, S. L., Konrad, S. D., Goh, Y. K., French, M. A., & Clandidnin, M. T. (1997). Palmitic acid effect on lipoprotein profiles and endogenous cholesterol synthesis or clearance in humans. *Asia Pacific J Clin Nutr, 6*(1), 6-11.

Costello, R., Wallace, T. C., & Rosanoff, A. (2016). Magnesium. *Adv Nutr, 7*(1), 199-201. doi:10.3945/an.115.008524

Daffodil, E. D., Tresina, P. S., & Mohan, V. R. (2016). Nutritional and antinutritional assessment of *Mucuna pruriens* (L.) DC var. utilis (Wall ex. Wight) Bak. Ex Burck and *Mucuna deeringiana* (Bort) Merril- An underutilized tribal pulse. *Int Food Res J, 23* (4), 1501-1513.

de la Peña, C., & Pueyo, J. (2012). Legumes in the reclamation of marginal soils, from cultivar and inoculant selection to transgenic approaches. *Agron Sustain Dev, 32*(1), 65–91.

de Maria Felix, J., Papini-Terzi, F. S., Rocha, F. R., Vêncio, R. Z. N., Vicentini, R., Nishiyama, M. Y., . . . Menossi, M. (2009). Expression Profile of Signal Transduction Components in a Sugarcane Population Segregating for Sugar Content. *Tropical Plant Biol, 2*(2), 98-109. doi:10.1007/s12042-009-9031-8

Del Rosario, R. R., & Flores, D. M. (1981). Functional Properties of Four Types of Mung Bean Flour. *J Sci Food Agr, 32*(2), 175-180.

Dike, M. C. (2010). Proximate, phytochemical and nutrient compositions of some fruits, seeds and leaves of some plant species at Umudike, Nigeria. *ARPN J Agric Biol Sci, 5*(1), 7–16.

Du, S., Jiang, H., Yu, X., & Jane, J. (in press). Physicochemical and functional properties of whole legume flour. *LWT - Food Sci Tech*, 1-6.

Duku, S., van der Zijpp, A. J., & Howard, P. (2010). Small ruminant feed systems: perceptions and practices in the transitional zone of Ghana. *J Ethnobiol Ethnomed, 6*, 11. doi:10.1186/1746-4269-6-11

Durojaiye, I. A., Drambi, U. D., & Chukwu, O. (2016). An Evaluation of Proximate Composition on Cereal Grains for Confectionery and Pasta Production. *Int Ref J Eng Sci, 5*(5), 1-6.

Edema, M. O., Sanni, L. O., & Sanni, A. I. (2005). Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. *Afr J Biotechnol, 4*(9), 911-918.

EFSA. (2012). Scientific Opinion on Dietary Reference Values for Protein. *EFSA J, 10*(2), 2557. doi:doi: 10.2903/j.efsa.2012.2557

EFSA. (2013). Scientific Opinion on Dietary Reference Values for manganese. *EFSA J, 11*(11), 3419. doi:doi:10.2903/j.efsa.2013.3419

EFSA. (2015a). Scientific Opinion on Dietary Reference Values for copper. *EFSA Journal, 13*(10), 4253. doi:10.2903/j.efsa.2015.4253

EFSA. (2015b). Scientific Opinion on Dietary Reference Values for magnesium. *EFSA J, 13*(7), 4186. doi:doi:10.2903/j.efsa.2015.4186

EFSA. (2016). Scientific opinion on dietary reference values for potassium *EFSA J, 14*(10), 4592. doi:doi:10.2903/j.efsa.2016.4592

EFSA. (2019a). Dietary reference values for the EU. Retrieved from www.efsa.europa.eu

EFSA. (2019b). Scientific Opinion on the dietary reference values for sodium. *EFSA J, 17*(9), 5778.

Egekeze, J. O., & Oehme, F. W. (1980). Cyanides and their toxicity: A literature review. *Vet Quart, 2*(2), 104-114. doi:10.1080/01652176.1980.9693766

Ekanayake, S., Jansz, E. R., Abeysekera, A. M., & Nair, B. M. (2001). Some anti-nutritional factors of mature sword beans (*Canavalia gladiata*). *Vidyodaya J Sci, 10*, 81-90.

Ekanayake, S., Nair, B. M., Asp, N., & Jansz, E. R. (2006). Effect of Processing of Sword Beans (*Canavalia gladiata*) on Physicochemical Properties of Starch. *Starch/Stärke, 58* (5), 215–222.

Ekanayake, S., Skog, K., & Asp, N.-G. (2007). Canavanine content in sword beans (*Canavalia gladiata*): analysis and effect of processing. *Food Chem Toxicol, 45*(5), 797-803. doi:10.1016/j.fct.2006.10.030

Elemam, W. M. O. (2010). *Nutritive Value of Newly Developed Bambara Groundnut (Vigna subterranea L.) Lines.* (MSc), University of Khartoum, Sudan.

Eleni, L. (2014). *Effect of some traditional processing methods on the protein content of legumes from Ghana.* (Master), Univerity of Copenhagen, Denmark.

Emire, S. A. (2005). *Influence of processing on antinutrients, raffinose family oligosaccharides and in-vitro protein digestibility of improved dry bean (Phaseolus vulgaris L.) varieties grown in Ethiopia.* (DEng), Asian Institute of Technology, Thailand.

Emire, S. A., Jha, Y. K., & Mekam, F. (2013). Role of Anti-nutritional Factors in Food Industry. *Bev Food World*, 23-28.

Enechi, O. C., Odo, C. E., & Oburu, C. S. (2014). Concentrations of anti-nutritional factors in raw edible cocoyam (*Colocasia esculenta*) leaves. *J Pharm Res, 8*(1), 38-40.

Englyst, H. N., Kingman, S. M., & Cummings, J. H. (1992). Classification and measurement of nutritionally important starch fractions. *Eur J Clin Nutr, 46*, S33-50.

Etiosa, O. R., Chika, N. B., & Benedicta, A. (2018). Mineral and Proximate Composition of Soya Bean. *Asian J Phys Chem Sci, 4*(3), 1-6.

Ezeagu, I. E., & Ibegbu, M. D. (2010). Biochemical composition and nutritional potential of Ukpa: a variety of tropical Lima beans (*Phaseolus lunatus*) from Nigeria – A short Report. *Pol J Food Nutr Sci, 60* (3), 231-235

Ezeagu, I. E., Krishna, A. G. G., & Khatoon, S. (2005). Fatty acid composition of oil from three *Mucuna* bean varieties from Nigeria – A short report. *Pol J Food Nutr Sci, 14/55*(2), 151–152.

Falade, K. O., & Adebiyi, A. O. (2015). Effect of γ-Irradiation on Cooking, Functional and Pasting Properties of Bambara Groundnut (*Vigna subterranea* [L.] Verdc.) Cultivars. *J Food Process Eng, 38*(5), 452-466. doi:10.1111/jfpe.12176

Falade, K. O., & Nwajei, C. P. (2015). Physical, proximate, functional and pasting properties of four non- and γ-irradiated Bambara groundnut (*Vigna subterranean*) cultivars. *Int J Food Sci Tech, 50*(3), 640-651. doi:10.1111/ijfs.12659

FAO. (2009). *Ghana Nutrition Profile*. FAO

FAO. (2010). *Fats and fatty acids in human nutrition: Report of an expert consultation*. Rome, Italy: FAO

FAO/WHO. (2001). *Human Vitamin and Mineral Requirements*. Rome, Italy: FAO/WHO

Fasoyiro, S. B., Akande, S. R., Arowora, K. A., Sodeko, O. O., Sulaiman, P. O., Olapade, C. O., & Odiri, C. E. (2010). Physico-chemical and sensory properties of pigeon pea (*Cajanus cajan*) flours. *Afr J Food Sci, 4*(3), 120-126.

Fathima, K. R., & Mohan, V. R. (2009). Nutritional and Antinutritional Assessment of *Mucuna atropurpurea* DC: An Underutilized Tribal Pulse. *Afr J Basic Appl Sci, 1* (5-6), 129-136.

Fattore, E., Bosetti, C., Brighenti, F., Agostoni, C., & Fattore, G. (2014). Palm oil and blood lipid-related markers of cardiovascular disease: a systematic review and meta-analysis of dietary intervention trials. *Am J Clin Nutr, 99*(6), 1331-1350. doi:10.3945/ajcn.113.081190

Food Standards Australia New Zealand [FSANZ]. (2005). *Cyanogenic glycosides in cassava and bamboo shoots: a human health risk assessment* (28). Canberra, Australia: Food Standards Australia New Zealand Retrieved from http://www.foodstandards.gov.au

Gabriel, R. A. O., Akinyosoye, F. A., & Adetuyi, F. C. (2011). Nutritional composition of *Canavalia ensiformis* (L.) (Jack beans) as affected by the use of Mould Starter Cultures for fermentation. *Trends Appl Sci Res, 6*(5), 463-471. doi:10.3923/tasr.2011.463.471

Ganjewala, D., Kumar, S., Asha, D. S., & Ambika, K. (2010). Advances in cyanogenic glycosides biosynthesis and analyses in plants: A review. *Acta Biol Szeged, 54*(1), 1-14.

Gaydou, E. M., Bianchini, J., & Ratovohery, J. V. (1983). Triterpene Alcohols, Methyl Sterols, Sterols, and Fatty Acids in Five Malagasy Legume Seed Oils. *J Agrlc Food Chem, 31*(4), 833-836.

Gaydou, E. M., Viano, J., & Bourreil, P. J. L. (1992). *Canavalia ensiformis* neutral lipids, a rich source of lupeol. *J Am Oil Chem Soc, 69*(5), 495-497. doi:10.1007/bf02540958

Ghadge, P. N., Shewalkar, S. V., & Wankhede, D. B. (2008). Effect of processing methods on qualities of instant whole legume: Pigeon pea (*Cajanus cajan* L.). *Agric Eng Int, 10*, 1-8.

Ghana Health Service. (2007). *Annual Report*. Ghana Health Service

Ghana Statistical Service. (2014). *2010 Population and Housing Census District analytical Report: Ejura Sekyedumasi Municipal*. Ghana: Ghana Statistical Service

Ghana Statistical Service, Ghana Health Service, & ICF International. (2015). *Ghana 2014 Demographic and Health Survey: Key Findings*. Rockville, Maryland, USA: UNICEF

Ghana Statistical Service, Noguchi Memorial Institute for Medical Research, & ORC Macro. (2005). *Nutrition of young children and mothers in Ghana: Findings from the 2003 Ghana Demographic and Health Survey*. Calverton, Maryland, USA: ORC Macro.

Giami, S. Y. (1993). Effect of processing on the proximate composition and functional properties of cowpea (*Vigna unguiculata*) flour. *Food Chem, 47*(2), 153-158.

Glew, R. H., VanderJagt, D. J., Lockett, C., Grivetti, L. E., Smith, G. C., Pastuszyn, A., & Millson, M. (1997). Amino Acid, Fatty Acid, and Mineral Composition of 24 Indigenous Plants of Burkina Faso. *J Food Compos Anal, 10*(3), 205–217.

Gnansounou, S. M., Noudogbessi, J. P., Yehouenou, B., Gbaguidi, A. N. M., Dovonon, L., Aina, M. P., . . . Sohounhloue, D. (2014). Proximate composition and micronutrient potentials of *Dialium guineense* wild growing in Benin. *Int Food Res J, 21*(4), 1603-1607.

Gómez-Zorita, S., González-Arceo, M., Fernández-Quintela, A., Eseberri, I., Trepiana, J., & Portillo, M. P. (2020). Scientific Evidence Supporting the Beneficial Effects of Isoflavones on Human Health. *Nutrients, 12*(12), 3853: https://doi.org/10.3390/nu12123853

Government of Ghana. (2013). *National Nutrition Policy 2014–2017*. Accra, Ghana: Ghana Government

Granito, M., Brito, Y., & Torres, A. (2007). Chemical composition, antioxidant capacity and functionality of raw and processed *Phaseolus lunatus*. *J Sci Food Agr, 87*(15), 2801-2809. doi:10.1002/jsfa.2926

Gröber, U., Schmidt, J., & Kisters, K. (2015). Magnesium in Prevention and Therapy. *Nutrients, 7*(9), 8199-8226. doi:10.3390/nu7095388

Gurumoorthi, P., Janardhanan, K., & Kalavathy, G. (2013). Improving nutritional value of velvet bean, *Mucuna pruriens* (L.) DC. var. utilis (Wall.ex.Wight) L. H. Bailey, an under-utilized pulse, using microwave technology. *Indian J Tradit Know, 12*(4), 677-681.

Hardy, K., Brand-Miller, J., Brown, K. D., Thomas, M. G., & Copeland, L. (2015). The importance of dietary carbohydrate in human evolution. *Quart Rev Biol, 90*(3), 251-268.

Hashmi, D. R., Ismail, S., & Shaikh, G. H. (2007). Assessment of the level of trace metals in commonly edible vegetables locally available in the markets of Karachi City. *Pak J Bot, 39*(3), 747-751.

Hauner, H., Bechthold, A., Boeing, H., Brönstrup, A., Buyken, A., Leschik-Bonnet, E., . . . Wolfram, G. (2012). Evidence-Based Guideline of the German Nutrition Society: Carbohydrate Intake and Prevention of Nutrition-Related Diseases. *Ann Nutr Metab, 60*, 1-58.

Heaney, R. P. (2006). Calcium Intake and Disease Prevention. *Arq Bras Endocrinol Metab, 50*(4), 685-693.

Holmes, R. (1971). Carbohydrate digestion and absorption. *J Clin Path, 24*, 10-13.

Huebbe, P., & Rimbach, G. (2020). Historical Reflection of Food Processing and the Role of Legumes as Part of a Healthy Balanced Diet. *Foods, 9*(8), 1056.

Huisden, C. M. (2008). *Detoxification, nutritive value, and anthelmintic properties of Mucuna pruriens.* (PhD), University of Florida, Florida.

Hwan-Hee, J., Young-Min, L., Jeong-Sook, C., & Oran, K. (2021). Validation of soy isoflavone intake and its health effects: a review of the development of exposure biomarkers. *Nutr Res Pract, 15*(1), 1-11.

Ibeabuchi, J. C., Okafor, D. C., Peter – Ikechukwu, A., Agunwa, I. M., Eluchie, C. N., Ofoedu, C. E., & Nwatu, N. P. (2017). Comparative study on the proximate composition, functional and sensory properties of three varieties of beans *Phaseolus lunatus*, *Phaseolus vulgaris* and *Vigna um - bellata*. *Int J Adv Eng Tech, Manag Appl Sci, 5*(1), 1-23.

Iggman, D., & Risérus, U. (2011). Role of different dietary saturated fatty acids for cardiometabolic risk. *Clin Lipidol, 6*(2), 209-223. doi:10.2217/clp.11.7

Ihegwuagu, N. E., Omojola, M. O., Emeje, M. O., & Kunle, O. O. (2009). Isolation and evaluation of some physicochemical properties of *Parkia biglobosa* starch. *Pure Appl Chem, 81*(1), 97-104. doi:10.1351/pac-con-08-01-21

Ijarotimi, O. S., & Keshinro, O. O. (2012). Comparison between the amino acid, fatty acid, mineral and nutritional quality of raw, germinated and fermented African Locust Bean (*Parkia biglobosa*) flour. *Acta Sci Pol Technol Aliment, 11*(2), 151-165.

Ijarotimi, O. S., Oyewo, M. T., & Oladeji, B. S. (2009). Chemical, functional and sensory properties of roasted bambara groundnut (*Vigna subterranean* L. Verdc) and cooking banana (*Musa* spp., ABB genome) weaning diet. *Afr J Food Sci, 3*(5), 139-146.

Ikootobong, S. U., Edak, A. U., Valentine, O. N., & Elza, C. O. (2013). Effect of processing on proximate composition, anti-nutrient status and amino acid content in three accessions of African locust bean (*Parkia biglobosa* (jacq.) benth. *Int J Food Sci Nutr, 64*(1), 94-102. doi:10.3109/09637486.2012.704903

Iorgyer, M. I., Adeka, I. A., Ikondo, N. D., & Okoh, J. J. (2009). The impact of Boiling periods on the proximate composition and level of some anti nutritional factors in pigeon pea (*Cajanus cajan*) seeds. *Prod Agric Technol J, 5* (1), 92–102. .

Islam, M. A., Punt, A., Spenkelink, B., Murk, A. J., Rolaf van Leeuwen, F. X., & Rietjens, I. M. C. M. (2014). Conversion of major soy isoflavone glucosides and aglycones in in vitro intestinal models. *Mol Nutr Food Res, 58*(3), 503-515. doi:10.1002/mnfr.201300390

Jackson, C.-J. C., Dini, J. P., Lavandier, C., Rupasinghe, H. P. V., Faulkner, H., Poysa, V., . . . DeGrandis, S. (2002). Effects of processing on the content and composition of isoflavones during manufacturing of soy beverage and tofu. *Process Biochem, 37*(10), 1117-1123.

Jacob, J. O., Mann, A., Adeshina, O. I., & Ndamitso, M. M. (2016). Nutritional composition of selected wild fruits from Minna Area of Niger State, Nigeria. *Int J Biol Biomol Agric Food Biotec Eng, 10* (1), 37–42.

Jagannadham, K., & Parimalavalli, R. (2015). Comparative study on chemical, functional and pasting properties of chickpea (non cereal) and wheat (cereal) starches. *Int Food Res J, 22*(2), 677-683.

Jayadeep, P. A., Sashikala, V. B., & Pratape, V. M. (2009). Nutrients and certain lipid soluble bioactive components in dehusked whole grains (gota) and dehusked splits (dhal) from pigeon pea (*Cajanus cajan*) and their cooking characteristics. *Int J Food Sci Nutr, 60 Suppl 4*, 273-284. doi:10.1080/09637480903099626

Joshi, A. (2012). *Functional properties of select seed flours and blackgram (Phaseolus mungo L.) storage globulin protein gene identification.* (MSc), The Florida State University.

Kala, B. K., & Mohan, V. R. (2010). Chemical composition and Nutritional evaluation of lesser known pulses of the Genus *Mucuna*. *Adv Biores, 1*(2), 105–116.

Kalidass, C., & Mahapatra, A. K. (2014). Evaluation of the proximate and phytochemical compositions of an underexploited legume *Mucuna pruriens var. utilis* (Wall ex Wight) L.H.Bailey. *Int Food Res J, 21*(1), 303-308.

Kannan, U., Sharma, R., Gangola, M. P., Sari, N., & Chibbar, R. N. (2018). Improving Grain Quality in Pulses: Strategies to Reduce Raffinose Family Oligosaccharides in Seeds. *Ekin J Crop Breed Genetic, 4*(1), 70-78.

Kathirval, P., & Kumudha, P. (2011). A comparative study on the chemical compositions of wild and cultivated germplasm of *Phaseolus lunatus* L. *Int J Appl Biol Pharm Technol, 2* (4), 296–305.

Kathirvel, P., & Kumudha, P. (2011). A comparative study on the chemical composition of wild and cultivated germplasm of *Phaseolus lunatus* L. *Int J Appl Biol Pharm, 2*(4), 296-305.

Khosla, P., & Hayes, K. C. (1996). Dietary trans-monounsaturated fatty acids negatively impact plasma lipids in humans: critical review of the evidence. *J Am Coll Nutr, 15*(4), 325-339.

Kianifard, T., & Chopra, A. (2018). A therapeutic role for potassium (K) to reduce pain and complications related to the cardiovascular system and bone in rheumatoid arthritis (RA): A clinical research perspective. *Rheum Res, 3*(1), 1-12. doi:10.22631/rr.2017.69997.1035

Kinsella, J. E., & Melachouris, N. (1976). Functional properties of proteins in foods: A survey. *Crit Rev Food Sci Nut, 7*(3), 219-280.

Ko, K. P. (2014). Isoflavones: Chemistry, analysis, functions and effects on health and cancer. *Asian Pac J Cancer Prev, 15*(17), 7001-7010. doi:10.7314/apjcp.2014.15.17.7001

Krishnaveni, M., Dhanalakshmi, R., & Nandhini, N. (2014). *Abrus precatorius, Phaseolus lunatus* seeds phytoconstituent analysis - A comparative study. *World J Pharm Res, 3*(8), 679-687.

Kruger, C., Zhou, Y., Thorsrud, B. A., Morel-Despeisse, F., & Chappuis, E. (2017). Safety evaluation of α-galacto-oligosaccharides for use in infant formulas investigated in neonatal piglets. *Toxicol Res Appl, 1*(1), 1-10. doi:10.1177/2397847317722828

Kumar, C. V. S., Naik, S. J. S., Mohan, N., Saxena, R. K., & Varshney, R. K. (2017). Botanical Description of Pigeonpea [*Cajanus cajan* (L.) Millsp.]. In R. K. Varshney, R. K. Saxena, & S. A. Jackson (Eds.), *The Pigeonpea Genome* (pp. 17-29). Patancheru, India: Springer International Publishing AG.

Lampariello, L. R., Cortelazzo, A., Guerranti, R., Sticozzi, C., & Valacchi, G. (2012). The Magic Velvet Bean of *Mucuna pruriens*. *J Tradit Complement Med, 2*(4), 331–339.

Lanham-New, S. A., Lambert, H., & Frassetto, L. (2012). Potassium. *Adv Nutr, 3*(6), 820-821. doi:10.3945/an.112.003012

Lawal, O. S., & Adebowale, K. O. (2005). Physicochemical characteristics and thermal properties of chemically modified jack bean (*Canavalia ensiformis*) starch. *Carbohyd Polym, 60*(3), 331-341. doi:10.1016/j.carbpol.2005.01.011

Leon, A., Angulo, I., Picard, M., Carré, B., Derouet, L., & Harscoat, J. P. (1989). Proximate and amino acid composition of seeds of *Canavalia ensiformis*.Toxicity of the kernel fraction for chicks. *Ann Zootech, 38*(4), 209-218.

Lokuruka, M. (2011). Effects of processing on soybean nutrients and potential impact on consumer health: an overview. *Afr J Food Agric Nutr Dev, 11*(4), 5000-5017.

Mabhaudhi, T. (2012). *Drought tolerance and water–use of selected South African landraces of taro (Colocasia esculenta l. schott) and bambara groundnut (Vigna subterranea l. verdc)* (PhD (Crop Science)), University of KwaZulu-Natal.

Magallanes-Cruz, P. A., Flores-Silva, P. C., & Bello-Perez, L. A. (2017). Starch Structure Influences Its Digestibility: A Review. *J Food Sci, 82*(9), 2016-2023.

Maphosa, Y., & Jideani, V. A. (2017). The Role of Legumes in Human Nutrition. In M. C. Hueda (Ed.), *Functional Food - Improve Health through Adequate Food*: IntechOpen.

Marcelo, C., Warwick, M., Marcelo, C., & Qayyum, R. (2019). The association between urinary genistein levels and mortality among adults in the United States. *PLoS ONE 14*(1), e0211368. https//doi.org/10.1371/journal.pone.0211368

Marimuthu, M., & Gurumoorthi, P. (2013). Physicochemical and functional properties of starches from Indian Jack bean (*Canavalia ensiformis*), an underutilized wild food legume. *J Chem Pharm Res, 5*(1), 221-225.

Mazahib, A. M., Nuha, M. O., Salawa, I. S., & Babiker, E. E. (2013). Some nutritional attributes of bambara groundnut as influenced by domestic processing. *Int Food Res J, 20* (3), 1165-1171.

Mbaeyi-Nwaoha, I. E., & Onweluzo, J. C. (2013). Functional properties of Sorghum (*S. bicolor* L.) – Pigeonpea (*Cajanus cajan*) flour blends and Storage stability of a flaked Breakfast formulated from blends. *Pak J Nutr, 12*(4), 382-397.

Mejia-Barajas, J. A., Molinero-Ortiz, E., & Sosa-Aguirre, C. R. (2018). Quick Method for Determination of Fructose-Glucose Ratio in Agave Syrup. *J Food Process Technol, 9: 710*(1). doi:10.4172/2157-7110.1000710

Menrad, K. (2003). Market and marketing of functional food in Europe. *J Food Eng, 56*(2-3), 181-188.

Mensink, R. P. (2016). *Effects of saturated fatty acids on serum lipids and lipoproteins: a systematic review and regression analysis*. Geneva, Switzerland: WHO

Mercado-Ruaro, P., & Delgado-Salinas, A. (2000). Cytogenetic studies in *Phaseolus L*. (Fabaceae). *Genet Mol Biol, 23*(4), 985-987.

Meredith, F. I., & Thomas, C. A. (1982). Amino Acid and Elemental Contents of Lima Bean Seed. *J Food Sci, 47* (6), 2021-2024.

Messina, M. (2014). Soy foods, isoflavones, and the health of postmenopausal women. *Am J Clin Nutr, 100* 423S-430S. doi:10.3945/ajcn.113.071464

Messou, T., Clément, Y. B., Benjamin, Y. N., & Kablan, T. (2015). Physical and biochemical characteristics of the Seeds white variety of *Phaseolus lunatus* (L.) consumed in south-east of Côte d'Ivoire during maturation. *Int J Agric Crop Sci, 8*(5), 713-722.

Miller, G. D., & Anderson, J. B. (1999). The role of calcium in prevention of chronic diseases. *J Am Coll Nutr, 18*(5), 371S-372S. doi:10.1080/07315724.1999.10718900

Ministry of Food and Agriculture of Ghana. (2010). *Medium Term Agriculture Sector Investment Plan (METASIP) 2011 – 2015*. Ministry of Food and Agriculture of Ghana.

Ministry of Health of Ghana. (2009). *Dietary and physical activity guidelines for Ghana*. Ministry of Health of Ghana

Misra, L., & Wagner, H. (2004). Alkaloidal constituents of *Mucuna pruriens* seeds. *Phytochemistry, 65*(18), 2565-25677. doi:10.1016/j.phytochem.2004.08.045

Mohammed, M. S., Shimelis, H. A., & Laing, M. D. (2016). Preliminary investigation of the crossing of bambara nut (*Vigna subterranea*[L.] Verdc.). *Bayero J Pure Appl Sci, 8*(2), 225-232. doi:10.4314/bajopas.v8i2.37

Mohan, V. R., & Janardhanan, K. (1994). The biochemical composition and nutrient assessment of less known pulses of the genus *Canavalia*. *Int J Food Sci Nutr, 45*(4), 255-262. doi:10.3109/09637489409166166

Moreno, F. B., Delatorre, P., Freitas, B. T., Rocha, B. A., Souza, E. P., Faco, F., . . . Cavada, B. S. (2004). Crystallization and preliminary X-ray diffraction analysis of the lectin from *Canavalia gladiata* seeds. *Acta Crystallogr D Biol Crystallogr, 60*(Pt 8), 1493-1495. doi:10.1107/S0907444904014489

Mubaiwa, J., Fogliano, V., Chidewe, C., & Linnemann, A. R. (2018). Bambara groundnut (*Vigna subterranea* (L.) Verdc.) flour: A functional ingredient to favour the use of an unexploited sustainable protein source. *PLoS One, 13*(10), e0205776. doi:10.1371/journal.pone.0205776

Mubarak, A. E. (2005). Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chem, 89*(4), 489-495. doi:10.1016/j.foodchem.2004.01.007

Mugendi, J. B., Njagi, E. N. M., Kuria, E. N., Mwasaru, M. A., Mureithi, J. G., & Apostolides, Z. (2010). Effects of processing technique on the nutritional composition and anti-nutrient content of mucuna bean (*Mucuna pruriens* L.). *Afr J Food Sci, 4*(4), 156-166.

Nanna, R. S., Banala, M., Pamulaparthi, A., Kurrat, A., & Kagithoju, S. (2013). Evaluation of Phytochemicals and Fluorescent Analysis of Seed and Leaf Extracts of *Cajanus cajan* L. *Int J Pharm Sci Rev Res, 22*(1), 11-18.

Ndidi, U. S., Ndidi, C. U., Aimola, I. A., Bassa, O. Y., Mankilik, M., & Adamu, Z. (2014). Effects of Processing (Boiling and Roasting) on the Nutritional and Antinutritional Properties of Bambara Groundnuts (*Vigna subterranea* [L.] Verdc.) from Southern Kaduna, Nigeria. *J Food Process, 2014*, 1-9. doi:10.1155/2014/472129

Ngo, N. L., Ngo, B. M., Fankem, H., Adamou, S., Kamguia, K., Ngakou, A., . . . Etoa, F. (2015). Isolation and Screening of Indigenous Bambara Groundnut (*Vigna subterranea*) Nodulating Bacteria for their Tolerance to Some Environmental Stresses. *Am J Microbiol Res, 3*(2), 65-75. doi:10.12691/ajmr-3-2-5

NHMRC, & MoH. (2006). *Nutrient Reference Values for Australia and New Zealand*. Australia: Australian National Health and Medical Research Council (NHMRC)

Niyi, O. H. (2014). Sugar, physicochemical properties and fatty acid composition of velvet tamarind (*Dialium guineense*) pulp and oil. *Eur J Biotechnol Biosci, 2*(3), 33-37.

Niyibituronsa, M., Onyango, A. N., Gaidashova, S., Imathiu, S., Uwizerwa, M., Ochieng, E. P., . . . Harvey, J. (2019). The effect of different processing methods on nutrient and isoflavone content of soymilk obtained from six varieties of soybean grown in Rwanda. *Food Sci Nutr, 7*(2), 457-464. doi:10.1002/fsn3.812

Noitang, S., Sooksai, S. A., Foophow, T., & Petsom, A. (2009). Proximate Analysis and Physico-Chemical Properties of Flour from the Seeds of the China Chestnut, *Sterculia monosperma* Ventenat. *Pak J Biol Sci, 12*(19), 1314-1319.

Nwaogu, L. A., & Emejulu, A. A. (2010). Evaluation of the toxicity of cyanogens in a commonly consumed Nigeria legume pigeon pea (Cajanus cajan) seed and its biochemical effects in rabbits. *Int J Biol Chem Sci, 4*(6), 1435-1441.

Nwaoguikpe, R. N., Braide, W., & Ujowundu, C. O. (2011). The Effects of Processing on the Proximate and Phytochemical Compositions of *Mucuna pruriens* Seeds (Velvet Beans). *Pak J Nutr, 10*(10), 947-951.

Nyirenda, D., Musukwa, M., & Jonsson, L. O. (2003). The effects of different processing methods of velvet beans (*Mucuna pruriens*) on L-DOPA content, proximate composition and broiler chicken performance. *Trop Subtrop Agroecosys, 1*(2-3), 253-260.

Obasi, N. E., Okorocha, C., & Orisakwe, O. F. (2013). Production and Evaluation of Velvet tamarind (*Dialium guineense* Wild) candy. *Eur J Food Sci Technol, 1*(1), 1-8.

Obatolu, V. A., Fasoyiro, S. B., & Ogunsunmi, L. (2007). Processing and functional properties of yam beans (*Sphenostylis stenocarpa*). *J Food Process Pres, 31*(2), 240-249.

Oboh, G., & Ekperigin, M. M. (2004). Nutritional evaluation of some Nigerian wild seeds. *Nahrung, 48*(2), 85-87. doi:10.1002/food.200200254

Oboh, H. A., Muzquiz, M., Burbano, C., Cuadrado, C., Pedrosa, M. M., Ayet, G., & Osagie, A. U. (2000). Effect of soaking, cooking and germination on the oligosaccharide content of selected Nigerian legume seeds. *Plant Food Hum Nutr, 55*(2), 97-110.

Odeny, D. A. (2007). The potential of pigeonpea (*Cajanus cajan* (L.) Millsp.) in Africa. *Nat Resour Forum, 31*(4), 297-305.

Ogbuewu, I. P., Omede, A. A., Chukwuka, O. K., Iheshiulor, O. O. M., Uchegbu, M. C., Udebuani, A. C., . . . Iloeje, M. U. (2010). The overview of the chemistry, health benefits and the potential threats associated with prolonged exposure to dietary soy isoflavones. *Int J Agric Res, 5*(12), 1084-1099.

Ogbuewu, I. P., Uchegbu, M. C., Emenalom, O. O., Okoli, I. C., & Iloeje, M. U. (2010). Overview of the chemistry of soy isoflavones, potential threats and potential therapeutic benefits. *Elec J Env Agricult Food Chem, 9*(4), 682-695.

Ogudoro, A. C., Saidu, A. N., & Kabiru, A. Y. (2014). Evaluation of the Phytochemical and anti nutrient composition of raw and processed *Mucuna pruriens* (Velvet beans). *Annals: Food Sci Technol, 15*(1), 60–69.

Ogungbenle, H. N. (2014). Sugar, physicochemical properties and fatty acid composition of velvet tamarind (*Dialium guineense*) pulp and oil. *Eur J Biotechnol Biosci, 2*(3), 33-37.

Ogungbenle, H. N. (2015). Analytical and Nutritional Evaluation of Velvet Tamarind (*Dialium guineense*) Pulps. *Am Chem Sci J, 6*(2), 69-76. doi:10.9734/acsj/2015/14678

Ogungbenle, H. N., & Ebadan, P. (2014). Nutritional Qualities and Amino Acid Profile of Velvet Tamarind (*Dalium guineense*) Pulp. *Brit Biomed Bull, 2*(1), 6-16.

Ohizua, E. R., Adeola, A. A., Idowu, M. A., Sobukola, O. P., Afolabi, T. A., Ishola, R. O., . . . Falomo, A. (2017). Nutrient composition, functional, and pasting properties of unripe cooking banana, pigeon pea, and sweetpotato flour blends. *Food Sci Nutr, 5*(3), 750-762. doi:10.1002/fsn3.455

Ojo, M. A., & Ade-Omowaye, B. I. O. (2015). Some Functional and Physical Properties of Selected Underutilized Hard-To-Cook Legumes in Nigeria. *Am J Food Sci Nutr, 2*(5), 73 - 81.

Okaka, J. C., & Potter, N. N. (1979). Physico-chemical and functional properties of cowpea powders processed to reduce beany flavor. *J Food Sci, 44*(4), 1235-1240.

Oke, D. G. (2014). Proximate and Phytochemical Analysis of *Cajanus Cajan* (Pigeon Pea) Leaves. *Chem Sci T, 3*(3), 1172-1178. doi:10.7598/cst2014.785

Okerulu, I. O., Onyema, C. T., & Agunabu, F. C. (2015). Assessment of the Phytochemicals Proximate and Elemental Composition of the Fruits of *Dialium guineese* (Icheku) *AASCIT J Chem, 2*(4), 93-96.

Okot, M. W., Sentumbwe, E. J., & Bareeba, F. B. (2000). Effects of Moist Heat and Dry Heat on the Nutritional Value of Velvet Beans (*Mucuna pruriens Var. Utilis*) for the Laying Hen. *Tanzania J. Agric. Sc, 3*(2), 123-128.

Okpala, L. C., & Mamah, E. N. (2001). Functional properties of raw and processed pigeon pea (*Cajanus cajan*) flour. *Int J Food Sci Nutr, 52*(4), 343-346.

Okwu, D. E., & Ekeke, E. (2003). Phytochemical screening and mineral composition of chewing sticks in South Eastern Nigeria. *Global J Pure Appl Sci, 9*(2), 235-238.

Oladejo, T. A. (2009). Proximate composition and micronutrient potentials of three locally available wild fruits in Nigeria *Afr J Agric Res, 4* (9), 887-892.

Olakunle, M. M., & Adebola, A. (2012). Effect of fermentation on the nutritive value and mineral composition of African Locust Beans. *Pak J Nutr, 11*(1), 11 – 13.

Olalekan, A. J., & Bosede, B. F. (2010). Comparative Study on Chemical Composition and Functional Properties of Three Nigerian Legumes (Jack Beans, Pigeon Pea and Cowpea). *J Emerg Trends in Eng Appl Sci, 1*(1), 89-95.

Olaleye, A. A., Adeyeye, E. I., & Adesina, A. J. (2013). Chemical composition of bambara groundnut (*V. subterranea* L. Verdc.) seed parts. *Bangladesh J Sci Ind Res, 48*(3), 167-178.

Olanipekun, O. T., Omenna, E. C., Olapede, O. A., Suleiman, P., & Omodara, O. G. (2015). Effect of boiling and roasting on the nutrient composition of kidney beans seed flour. *Sky J Food Sci, 4*(2), 24-29.

Olaniyi, A. P., Success, D. A., & Abimbola, O. W. (2014). Comparative Studies on Some Anti Nutritional Factors in Seeds of *Mucuna pruriens* (Velvet Beans) and *Sphenostylis stenocarpa* (African Yam Beans). *J Biol Agric Healthcare, 4* (16), 13–16.

Ologhobo, A. D., & Fetuga, B. L. (1983). Varietal differences in the Fatty acid composition of oils from Cowpea (*Vigna unguiculata*) and Lima bean (*Phaseolus lunatus*). *Food Chem, 10*(4), 267–274

Ologhobo, A. D., & Fetuga, B. L. (1988). Effects of different processes on the carbohydrates of lima bean. *Nahrung, 32*(2), 173-177.

Oloyo, R. A. (2002). Processing effects on the chemical composition and nutritional potential of the pigeon pea (*Cajanus cajan* L). *Riv Ital Sostanze Gr, 79*, 273-276.

Oloyo, R. A. (2002). Processing effects on the chemical composition and nutritional potential of the pigeon pea (*Cajanus cajan* L.). *Riv Ital Sostanze Gr, 79*, 273–276.

Oloyo, R. A. (2004). Chemical and nutritional quality changes in germinating seeds of *Cajanus cajan* L. *Food Chem, 85*(4), 497-502. doi:10.1016/s0308-8146(02)00454-5

Omenna, E. C., Olanipekun, O. T., & Kolade, R. O. (2016). Effect of boiling, pressure cooking and germination on the nutritional and antinutrients content of cowpea (*Vigna unguiculata*). *ISABB J Food and Agric Sci, 6*(1), 1-8.

Oni, P. I. (2013). Evaluation Of Silvicultural Requirements Of *Dialium Guineense* (Willd), A Neglected Indigenous Fruit In Nigeria. *Int J Eng ResTechnol, 2*(4), 1769-1780.

Onimawo, I. A., & Akpojovwo, A. E. (2006). Toasting (Dry heat) and nutrient composition, functional properties and antinutritional factors of Pigeon pea (*Cajanus cajan*) flour. *J Food Process Pres, 30*(6), 742 - 753.

Onwuka, G. I. (2006). Soaking, boiling and antinutritional factors in pigeon peas (*Cajanus cajan*) and cowpeas (*Vigna unguiculata*). *J Food Process Preserv, 30* (5), 616–630.

Onwuka, G. I., & Nwokorie, S. O. (2006). Comparative studies on the Winning Potentials of Black Tamarind, Local Grape fruit and Exotic Apple. *J Food Technol, 4*(4), 350-353.

Onyeike, E. N., & Oguike, J. U. (2003). Influence of heat processing methods on the nutrient composition and lipid characterization of groundnut (*Arachis hypogaea*) seed pastes. *Biokemistri, 15*(1), 34-43.

Onyesom, I., Enaholo, A. T., & Mordi, J. (2005). Effect of Processing Techniques on The Contents of Flatulence Factors and Emulsion Properties of Cowpea (*Vigna unguiculata*). *J Appl Sci Environ Mgt, 9*(2), 65-72.

Oracz, J., & Nebesny, E. (2019). Effect of roasting parameters on the physicochemical characteristics of high-molecular-weight Maillard reaction products isolated from cocoa beans of different *Theobroma cacao* L. groups. *Eur Food Res Tech, 245*(1), 111–128. doi:10.1007/s00217-018-3144-y

Oraka, C. O., & Okoye, J. I. (2017). Effect of heat processing treatments on the chemical composition and functional properties of Lima bean (*Phaseolus lunatus*) flour. *Am J Food Sci Nutr, 1*(1), 14-24.

Orsavova, J., Misurcova, L., Ambrozova, J. V., Vicha, R., & Mlcek, J. (2015). Fatty Acids Composition of Vegetable Oils and Its Contribution to Dietary Energy Intake and Dependence of Cardiovascular Mortality on Dietary Intake of Fatty Acids. *Int J Mol Sci, 16*(6), 12871-12890. doi:10.3390/ijms160612871

Osanaiye, F. G., Alabi, M. A., Sunday, R. M., Olowokere, T., Salami, E. T., Otunla, T. A., & Odiaka, S. C. (2013). Proximate Composition of Whole Seeds and Pulp of African Black Velvet Tamarind (*Dialium guineense*). *IOSR J Agric Vet Sci, 5*(3), 49-52.

Oshodi, A. A., & Adeladun, M. O. A. (1993). Proximate composition, some nutritionally valuable minerals and functional properties of three varieties of Lima bean (*Phaseolus lunatus* Linn.) flour. *Int J Food Sci Nutr, 43*(4), 181-186. doi:10.3109/09637489309027540

Oshodi, A. A., & Ekperigin, M. M. (1989). Functional properties of Pigeon pea (*Cajanus cajan*) flour. *Food Chem, 34*(3), 187-191.

Oshodi, A. A., Ipinmoroti, K. O., Adeyeye, E. I., & Hall, G. M. (1995). Amino and fatty acids composition of African yam bean (*Sphenostylis stenocarpa*) flour. *Food Chem, 53*(1), 1-6.

Oshodi, A. A., Olaofe, O., & Hall, G. M. (1993). Amino acid, fatty acid and mineral composition of pigeon pea (*Cajanus cajan*). *Int J Food Sci Nutr, 43*(4), 187-191. doi:10.3109/09637489309027541

Otori, A., & Mann, A. (2014). Nutritive and Anti-nutritive composition of Wild grown *Canavalia gladiata* seeds. *World J Pharm Sci, 2*(3), 213-218.

Oyeleke, G. O., Afolabi, O., & Isola, A. D. (2012). Some Quality Characteristics and Carbohydrate Fractions of Bambara Groundnut (*Vigna subterranea* L.) Seed Flour. *IOSR J Appl Chem, 2*(4), 16-19.

Pabich, M., & Materska, M. (2019). Biological Effect of Soy Isoflavones in the Prevention of Civilization Diseases. *Nutrients, 11,* 1660; doi:10.3390/nu11071660.

Prinyawiwatkul, W., Beuchat, L. R., McWatters, K. Y., & Phillips, R. D. (1997). Functional Properties of Cowpea (*Vigna unguiculata*) Flour As Affected by Soaking, Boiling, and Fungal Fermentation. *J Agr Food Chem, 45*(2), 480-486.

Protonotariou, S., Drakos, A., Evageliou, V., Ritzoulis, C., & Mandala, I. (2014). Sieving fractionation and jet mill micronization affect the functional properties of wheat flour. *J Food Eng, 134*, 24-29. doi:10.1016/j.jfoodeng.2014.02.008

Quezada-Calvillo, R., Robayo-Torres, C. C., Ao, Z., Hamaker, B. R., Quaroni, A., Brayer, G. D., . . . Nichols, B. L. (2007). Luminal Substrate ‘‘Brake’’ on Mucosal Maltase-glucoamylase Activity Regulates Total Rate of Starch Digestion to Glucose. *J Pediatr Gastroenterol Nutr, 45*(1), 32-43.

Ragab, H. I., Kijora, C., Ati, K. A. A., & Danier, J. (2010). Effect of Traditional Processing on the Nutritional Value of Some Legumes Seeds Produced in Sudan for Poultry Feeding. *Int J Poult Sci, 9* (2), 198-204.

Raja, R. B., Agasimani, S., Varadharajan, A., & Ram, S. G. (2016). Natural variability and effect of processing techniques on raffinose family oligosaccharides in pigeonpea cultivars. *Legume Res, 39*(4), 528-532. doi:10.18805/lr.v0iOF.9279

Rajaram, N., & Janardhanan, K. (1992). Nutritional and chemical evaluation of raw seeds of *Canavalia gladiata* (Jacq) DC. and *C. ensiformis* DC: The under utilized food and fodder crops in India. *Plant Food Hum Nutr, 42*(4), 329-336.

Reddy, N. R., Pierson, M. D., Sathe, S. K., & Salunkhe, D. K. (1984). Chemical, Nutritional and Physiological Aspects of Dry Bean Carbohydrates - A Review. *Food Chem, 13*(1), 25-68.

Revilleza, M. J., Mendoza, E. M., & Raymundo, L. C. (1990). Oligosaccharides in several Philippine indigenous food legumes: determination, localization and removal. *Plant Foods Hum Nutr, 40*(1), 83-93.

Rienks, J., Barbaresko, J., & Nöthling, U. (2017). Association of isoflavone biomarkers with risk of chronic disease and mortality: a systematic review and meta-analysis of observational studies. *Nutr Rev, 75*(8), 616-641.

Roberfroid, M. B. (2000). A European Consensus of Scientific Concepts of Functional Foods. *Nutrition, 16*(7-8), 689-691.

Roder, N., Ellis, P. R., & Butterworth, P. J. (2005). Starch molecular and nutritional properties: a review. *Adv Mol Med, 1*(1), 5-14.

Rustan, A. C., & Drevon, C. A. (2005). Fatty Acids: Structures and Properties. In *Encyclopedia of Life Sciences*: John Wiley & Sons, Ltd.

Ryan, E., Galvin, K., O'Connor, T. P., Maguire, A. R., & O'Brien, N. M. (2007). Phytosterol, Squalene, Tocopherol Content and Fatty Acid Profile of Selected Seeds, Grains, and Legumes. *Plant Foods Hum Nutr, 62*(3), 85-91. doi:10.1007/s11130-007-0046-8

Sackle, S. A., & Emmanuel, K. (2013). Nutritional and Sensory Analysis of *Parkia biglobosa* (Dawadawa) Based Cookies. *J Food Nutr Sci, 1*(4), 43-49. doi:10.11648/j.jfns.20130104.13

Sajilata, M. G., Singhal, R. S., & Kulkarni, P. R. (2006). Resistant Starch—A Review. *Comp Rev Food Sci Food Saf, 5*(1), 1-17.

Sangronis, E., & Machado, C. J. (2007). Influence of germination on the nutritional quality of *Phaseolus vulgaris* and *Cajanus cajan*. *LWT - Food Sci Technol, 40*(1), 116-120. doi:10.1016/j.lwt.2005.08.003

Sankhon, A., Amadou, I., Yao, W., Wang, H., Qian, H., & Sangare, M. (2014). Comparison of Physicochemical and Functional properties of flour and starch extract in different methods from Africa locust bean (*Parkia biglobosa*) seeds. *Afr J Tradit Complement Altern Med, 11*(2), 264-272. doi:10.4314/ajtcam.v11i.2.6

Sathya, A., & Siddhuraju, P. (2015). Effect of processing methods on compositional evaluation of underutilized legume, *Parkia roxburghii* G. Don (yongchak) seeds. *J Food Sci Technol, 52*(10), 6157–6169. doi:10.1007/s13197-015-1732-4

Saxena, K. B., Kumar, R. V., & Sultana, R. (2010). Quality nutrition through pigeonpea—a review. *Health, 2*(11), 1335-1344. doi:10.4236/health.2010.211199

Scrob, A., Muste, S., & Culea, M. (2013). GC/MS analysis of fatty acids in some corn inbred lines. *Romanian J. Biophys, 23*(1-2), 107-111.

Sekikawa, A., Ihara, M., Lopez, O., Kakuta, C., Lopresti, B., Higashiyama, A., … Cui, C. (2019). Effect of S-Equol and Soy Isoflavones on Heart and Brain. *Curr Cardiol Rev 15*(2), 114-135.

Siddhuraju, P., & Becker, K. (2001a). Preliminary nutritional evaluation of Mucuna seed meal (*Mucuna pruriens var. utilis*) in common carp (*Cyprinus carpio* L.) : an assessment by growth performance and feed utilisation. *Aquacult, 196*(1-2), 105–123.

Siddhuraju, P., & Becker, K. (2001b). Species/variety differences in biochemical composition and nutritional value of Indian tribal legumes of the genus Canavalia. *Nahrung, 45*(4), 224-233. doi:10.1002/1521-3803(20010801)45:4<224::AID-FOOD224>3.0.CO;2-V

Siddhuraju, P., Vijayakumari, K., & Janardhanan, K. (1996). Chemical Composition and Protein Quality of the Little-Known Legume, Velvet Bean (*Mucuna pruriens* (L.) DC.). *J Agric Food Chem, 44*(9), 2636−2641.

Siddiq, M., Nasir, M., Ravi, R., Dolan, K. D., & Butt, M. S. (2009). Effect of Defatted Maize Germ Addition on the Functional and Textural Properties Of Wheat Flour. *Int J Food Prop, 12*(4), 860-870. doi:10.1080/10942910802103028

Singh, S. K., Jadhav, P. V., Nandanwar, R. S., Patil, A. N., Wandhare, M., Naik, R. M., & Katkar, R. N. (2018). Assessment of nutritional quality parameters in selected vegetable type pigeonpea genotypes. *J Pharmacogn Phytochem, 7*(1), 1446-1450.

Slavin, J., & Carlson, J. (2014). Carbohydrates[1]. *Adv Nutr, 5*(6), 760-761.

Soetan, K. O., Akinrinde, A. S., & Adisa, S. B. (2014). Comparative studies on the proximate composition, mineral and anti-nutritional factors in the seeds and leaves of African Locust Bean (*Parkia biglobosa*). *Ann Food Sci Technol, 15*(1), 70-74.

Soetan, K. O., Olaiya, C. O., & Oyewole, O. E. (2010). The importance of mineral elements for humans, domestic animals and plants: A review. *Afr J Food Sci, 4*(5), 200-222.

Soetan, K. O., & Oyewole, O. E. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. *Afr J Food Sci, 3*(9), 223-232.

Spoladore, D. S., & Teixeira, J. P. F. (1987). Composição química das sementes de *Canavalia gladiata* D.C. *Bragantia, 46*(1), 133-139. doi:10.1590/S0006-87051987000100014

Sridhar, K. R., & Niveditha, V. R. (2014). Nutritional and bioactive potential of coastal sand dune wild legume *Canavalia maritima* (Aubl.) Thou. - An Overview. *Indian J Nat Prod Resour, 6*(2), 107-120.

Steiner-Asiedu, M. (2019). The Nutrition Landscape in Ghana: Implications on our Human Resources and National Development. Retrieved from http://ugspace.ug.edu.gh/handle/123456789/30002

Tattiyakul, J., Pradipasena, P., & Asavasaksakul, S. (2007). Taro Colocasia esculenta (L.) Schott Amylopectin Structure and Its Effect on Starch Functional Properties. *Starch - Stärke, 59*(7), 342-347. doi:10.1002/star.200700620

Tavares, R. L., Silva, A. S., Campos, A. R. N., Schuler, A. R. P., & de Souza Aquino, J. (2015). Nutritional composition, phytochemicals and microbiological quality of the legume, *Mucuna pruriens*. *Afr J Biotechnol, 14*(8), 676-682. doi:10.5897/ajb2014.14354

Tchiagam, J. B. N., Youmbi, E., Njintang, Y. N., Bell, J. M., & Maina, A. N. (2011). Generation Means Analysis of Seed Sucrose Content in Cowpea (*Vigna unguiculata* L. Walp.). *Asian J Agric Sci, 3*(6), 475-480.

Tiwari, B. K., Tiwari, U., Mohan, R. J., & Alagusundaram, K. (2008). Effect of Various Pre-treatments on Functional, Physiochemical, and Cooking Properties of Pigeon pea (*Cajanus cajan* L). *Food Sci Technol Int, 14*(6), 487-495. doi:10.1177/1082013208101023

Topping, D. L., Fukushima, M., & Bird, A. R. (2003). Resistant starch as a prebiotic and synbiotic: state of the art. *Proc Nutr Soc, 62*(1), 171-176.

Tresina, P. S., & Mohan, V. R. (2012). Comparative Assessment on the nutritional and antinutritional attributes of the underutilized legumes, *Canavalia gladiata* (JACQ.) DC, *Erythrina indica* LAM. and *Abrus precatorious* L. *Trop Subtrop Agroecosyst, 15* (3), 539-556.

Tsoata, E., Njock, S. R., Youmbi, E., & Nwaga, D. (2015). Early effects of water stress on some biochemical and mineral parameters of mycorrhizal *Vigna subterranea* (L.) Verdc. (Fabaceae) cultivated in Cameroon. *Int J Agron Agric Res, 7*(2), 21-35.

Tuleun, C. D., Carew, S. N., & Patrick, J. A. (2008). Fruit characteristics and chemical composition of some varieties of velvet beans (*Mucuna spp*) found in Benue State of Nigeria. *Livestock Res Rur Dev, 20 (10)*.

University of Ghana, GroundWork, University of Wisconsin-Madison, KEMRI-Wellcome Trust, UNICEF, Ghana Health Service, . . . USDA. (2017). *Ghana Micronutrient Survey 2017*. Accra, Ghana: UNICEF

USAID. (2018). Ghana: Nutrition Profile. Retrieved from https://www.usaid.gov

Vadivel, V., Doss, A., & Pugalenthi, M. (2010). Evaluation of nutritional value and protein quality of raw and differentially processed sword bean [*Canavalia gladiata* (jacq.) dc.] seeds. *Afr J Food Agric Nutr Dev, 10*(7), 2850 – 2865

Vadivel, V., & Janardhanan, K. (2001). Diversity in nutritional composition of wild jack bean (*Canavalia ensiformis* L. DC) seeds collected from south India. *Food Chem, 74*(4), 507-511.

Vadivel, V., & Janardhanan, K. (2004). The nutritional and antinutritional attributes of sword bean [*Canavalia gladiata* (Jacq.) DC.]: an under-utilized tribal pulse from South India. *Int J Food Sci Tech, 39* (9), 917–926.

Vadivel, V., & Janardhanan, K. (2005). Nutritional and Antinutritional Characteristics of Seven South Indian Wild Legumes. *Plant Food Hum Nutr, 60*(2), 69-75.

Valentine, M. F., De Tar, J. R., Mookkan, M., Firman, J. D., & Zhang, Z. J. (2017). Silencing of Soybean Raffinose Synthase Gene Reduced Raffinose Family Oligosaccharides and Increased True Metabolizable Energy of Poultry Feed. *Front Plant Sci, 8: 692*, 1-11. doi:10.3389/fpls.2017.00692

VandenLangenberg, K. M., Bethke, P. C., & Nienhuis, J. (2012). Patterns of Fructose, Glucose, and Sucrose Accumulation in Snap and Dry Bean (*Phaseolus vulgaris*) Pods. *HORTSCIENCE, 47*(7), 874–878.

Vijayakumari, K., Siddhuraju, P., & Janardhanan, K. (1993). Nutritional and antinutritional properties of certain underexploited legume seeds. *Int J Food Sci Nutr, 44*(3), 18-189.

Vijayakumari, K., Siddhuraju, P., & Janardhanan, K. (1996). Effect of different post-harvest treatments on antinutritional factors in seeds of the tribal pulse, *Mucuna pruriens* (L.) DC. *Int J Food Sci Nutr, 47* (3), 263-272.

Vijayambika, C., Jegadeesan, M., & Saravana, G. A. (2010). Comparative L-DOPA and anti-nutritional contents in seed materials of market samples of *Mucuna pruriens* (L.) DC. *Int J Res Ayurveda Pharm, 1* (2), 480-483.

Vorster, H. H., Nell, T. A., Kumanyika, S., & Tee, E. S. (2004). Fats and oils: towards more specific quantitative and qualitative guidelines for South Africans? *South Afr J Clin Nutr, 17*(2), 44-52.

Wang, T. L., Bogracheva, T. Y., & Hedley, C. (1998). Starch: As simple as A, B, C? *J Exp Bot, 49*(320), 481-502.

Wegmüller, R., Bentil, H., Wirth, J. P., Petry, N., Tanumihardjo, S. A., Allen, L., . . . Rohner, F. (2020). Anemia, micronutrient deficiencies, malaria, hemoglobinopathies and malnutrition in young children and non-pregnant women in Ghana: Findings from a national survey. *PLOS ONE, 15*(1), e0228258.

White, B. (2009). Dietary Fatty Acids. *Am Fam Physician, 80*(4), 345-350.

WHO. (2016). What is malnutrition? Retrieved from http://www.who.int/features/qa/malnutrition/en/

WHO/FAO. (1994). *Fats and oils in human nutrition (Report of a Joint Expert Consultation), FAO Food and Nutrition Paper 57*. Rome, Italy: WHO/FAO.

Wolfram, G., Bechthold, A., Boeing, H., Ellinger, S., Hauner, H., Kroke, A., . . . Dinter, J. (2015). Evidence-Based Guideline of the German Nutrition Society: Fat Intake and Prevention of Selected Nutrition-Related Diseases. *Ann Nutr Metab, 67*(3), 141-204.

Yankah, N., Intiful, F. D., & Tette, E. M. A. (2020). Comparative study of the nutritional composition of local brown rice, maize (obaatanpa), and millet—A baseline research for varietal complementary feeding. *Food Sci Nutr, 8*: 2692–2698.

Yao, D. N., Kouassi, K. N., Erba, D., Scazzina, F., Pellegrini, N., & Casiraghi, M. C. (2015). Nutritive Evaluation of the Bambara Groundnut Ci12 Landrace [*Vigna subterranea* (L.) Verdc. (Fabaceae)] Produced in Cote d'Ivoire. *Int J Mol Sci, 16*(9), 21428-21441. doi:10.3390/ijms160921428

Yeboah, S. (2013). *Yield gap analysis in maize production from stakeholders perspective in Ejura-Sekyedumase District of the Ashanti region of Ghana.* (MSc), Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Yellavila, S. B., Agbenorhevi, J. K., Asibuo, J. Y., & Sampson, G. O. (2015). Proximate Composition, Minerals Content and Functional Properties of Five Lima Bean Accessions. *J Food Secur, 3*(3), 69-74. doi:10.12691/jfs-3-3-1

Zagrodzka, G., Ksycińska, H., Ramza, J., & Zagrodzka, J. (2005). Chromatographic quantification of isoflavones (why and how). *Acta Chromatogr, 15*(15), 31-65.

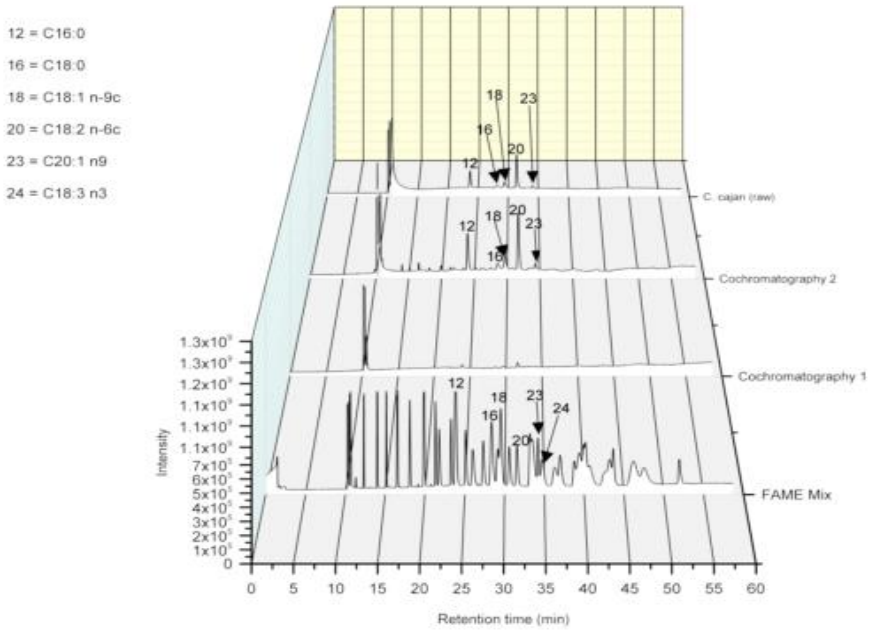
Zaitoun, M., Ghanem, M., & Harphoush, S. (2018). Sugars: Types and Their Functional Properties in Food and Human Health. *Int J Public Health Res, 6*(4), 93-99.

11 Appendices

Appendix 1

Gas chromatograms for fatty acid profiles of legume flours

1A: Gas chromatogram for raw *Cajanus cajan* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Cajanus cajan* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.69	194127	30780650	25.957
2	28.202	26261	6092480	5.138
3	29.359	67404	14648694	12.353
4	31.413	387283	62566626	52.762
5	34.044	33464	4493576	3.789

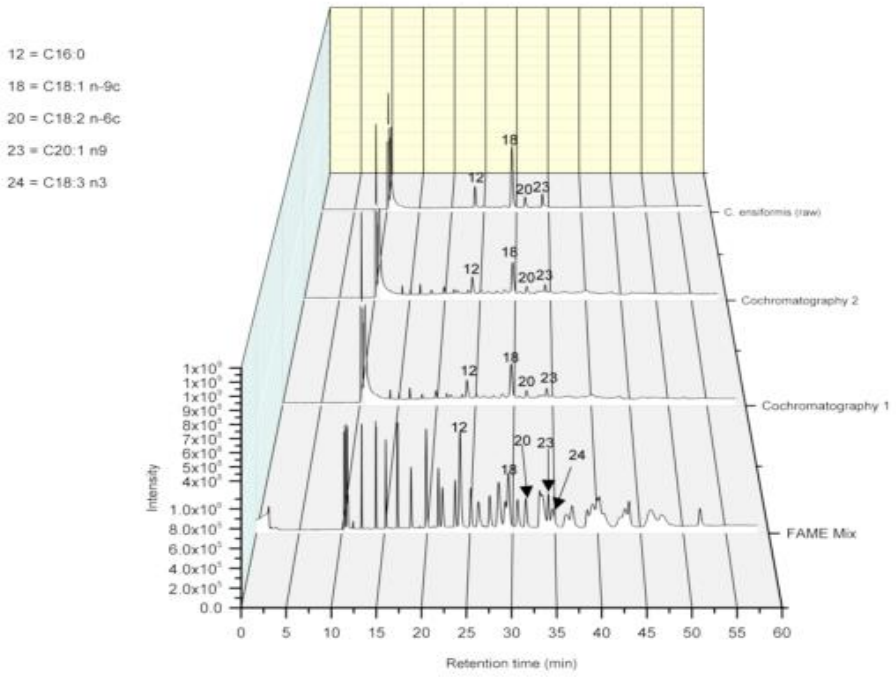
Area percent report and retention times of the fatty acid peaks in raw *Cajanus cajan* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.624	366011	46048606	23.545
2	28.086	56290	10473750	5.355
3	29.29	136289	24420074	12.486
4	31.37	814207	106742927	54.578
5	34.007	72461	7894139	4.036

Area percent report and retention times of the fatty acid peaks in raw *Cajanus cajan* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.607	347631	46717962	23.231
2	28.067	53073	10453504	5.198
3	29.279	132013	25771338	12.815
4	31.351	784794	109979170	54.688
5	33.993	69918	8182335	4.069

1B: Gas chromatogram for raw *Canavalia ensiformis* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Canavalia ensiformis* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.623	299077	44454364	16.645
2	29.314	858719	166533801	62.356
3	31.352	152895	23926334	8.959
4	34.015	192295	32154134	12.04

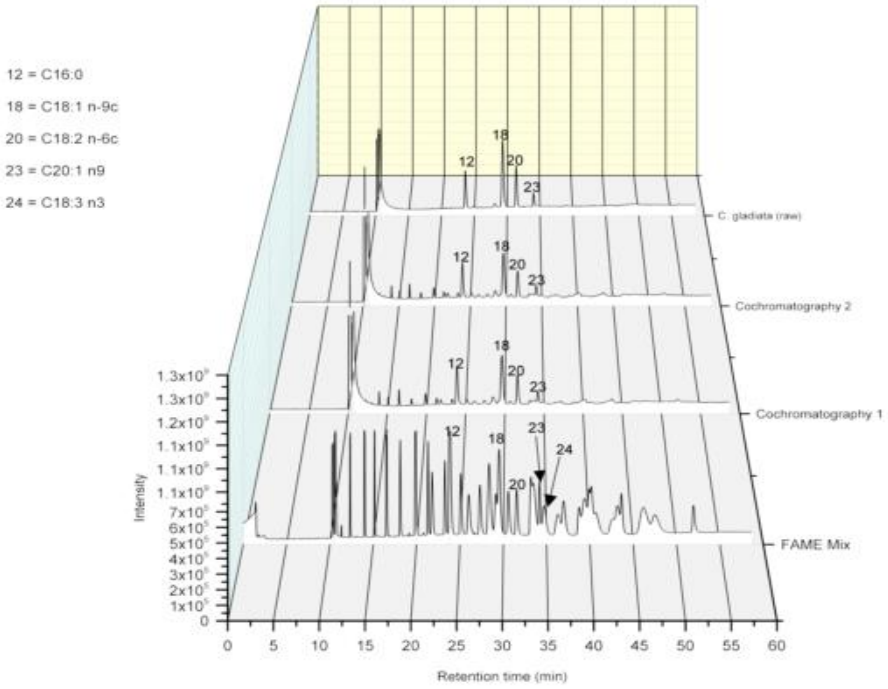
Area percent report and retention times of the fatty acid peaks in raw *Canavalia ensiformis* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.633	383148	58960864	15.901
2	29.341	1153031	232164956	62.611
3	31.379	203596	32761699	8.835
4	34.021	274769	46918403	12.653

Area percent report and retention times of the fatty acid peaks in raw *Canavalia ensiformis* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.631	298016	44223809	15.951
2	29.331	916139	174572340	62.968
3	31.367	164186	25267144	9.114
4	34.019	208583	33178290	11.967

1C: Gas chromatogram for raw *Canavalia gladiata* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Canavalia gladiata* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.63	332746	49243418	20.587
2	29.316	596181	116710106	48.791
3	31.37	367853	56512705	23.626
4	34.017	124038	16735781	6.997

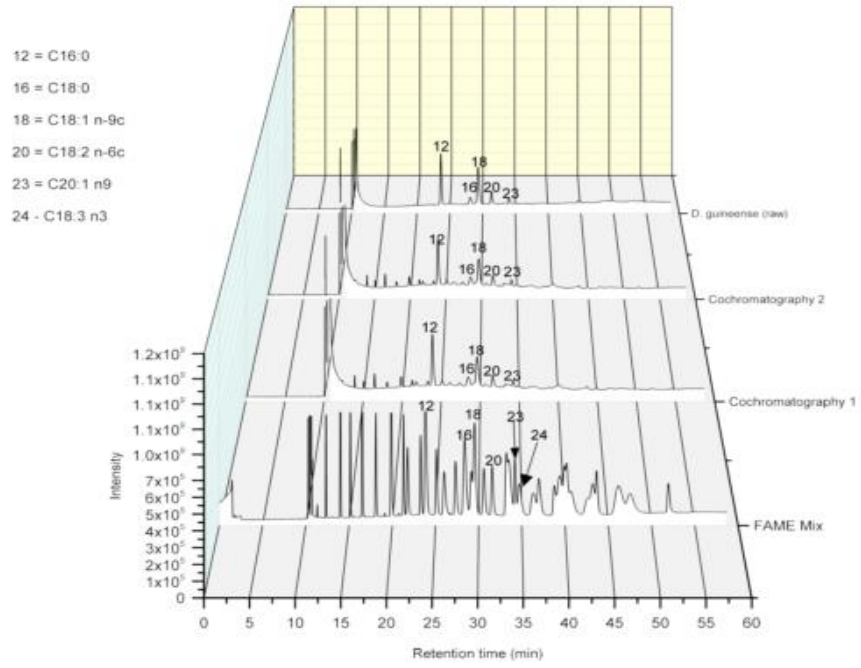
Area percent report and retention times of the fatty acid peaks in raw *Canavalia gladiata* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.642	482503	69479226	21.513
2	29.345	829064	156575050	48.482
3	31.392	510786	75786239	23.466
4	34.022	173213	21117731	6.539

Area percent report and retention times of the fatty acid peaks in raw *Canavalia gladiata* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.639	315664	45717596	20.507
2	29.318	584455	109696818	49.206
3	31.373	358580	53000176	23.774
4	34.015	118576	14518419	6.512

1D: Gas chromatogram for raw *Dialium guineense* fruit flour



Area percent report and retention times of the fatty acid peaks in raw *Dialium guineense* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.642	423841	61615138	36.909
2	28.125	59875	12684888	7.599
3	29.302	307695	69145255	41.42
4	31.362	105537	16814885	10.073
5	34.013	53983	6677522	4

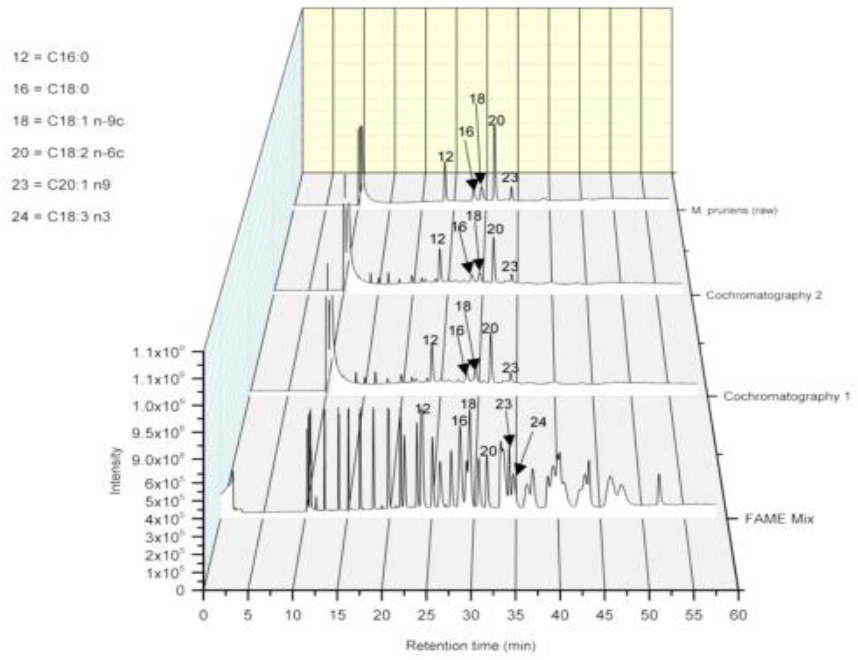
Area percent report and retention times of the fatty acid peaks in raw *Dialium guineense* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.631	316546	52190993	39.514
2	28.102	43102	10149719	7.684
3	29.318	224509	55983689	42.385
4	31.341	44819	8294176	6.28
5	34.006	38039	5464607	4.137

Area percent report and retention times of the fatty acid peaks in raw *Dialium guineense* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.639	387271	62384746	39.409
2	28.113	53437	12208563	7.712
3	29.31	274192	67066808	42.367
4	31.34	55945	10094000	6.377
5	33.997	47458	6545801	4.135

1E: Gas chromatogram for raw *Mucuna pruriens* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Mucuna pruriens* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.634	308995	51560710	21.879
2	28.114	85585	21487809	9.118
3	29.32	110286	27926399	11.85
4	31.373	682826	118986544	50.489
5	34.007	108983	15705306	6.664

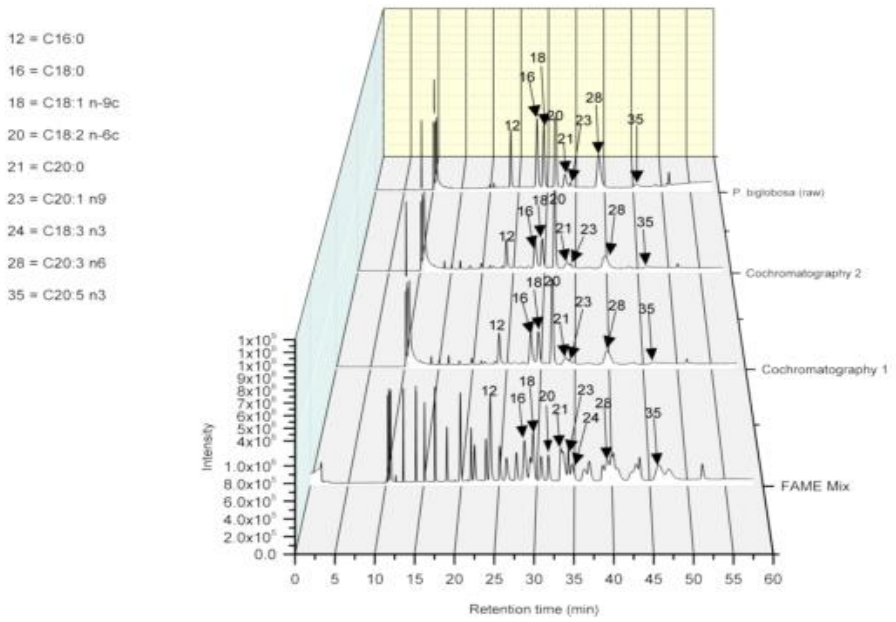
Area percent report and retention times of the fatty acid peaks in raw *Mucuna pruriens* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.645	374541	63274543	23.95
2	28.121	83935	21488113	8.133
3	29.333	113035	29004172	10.978
4	31.382	748960	132547639	50.17
5	34.017	122528	17880047	6.768

Area percent report and retention times of the fatty acid peaks in raw *Mucuna pruriens* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.646	335093	54303306	24.172
2	28.143	75130	18292704	8.142
3	29.351	99679	24471740	10.893
4	31.387	666730	112397015	50.03
5	34.02	108494	15192570	6.763

1F: Gas chromatogram for raw *Parkia biglobosa* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Parkia biglobosa* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.655	663478	120156668	7.578
2	28.261	849194	225524873	14.223
3	29.436	827565	204557407	12.901
4	31.534	3296975	653338554	41.203
5	33.195	17042	60180401	3.795
6	34.092	42542	5785692	0.365
7	39.134	506252	288938211	18.222
8	45.722	42001	27164545	1.713

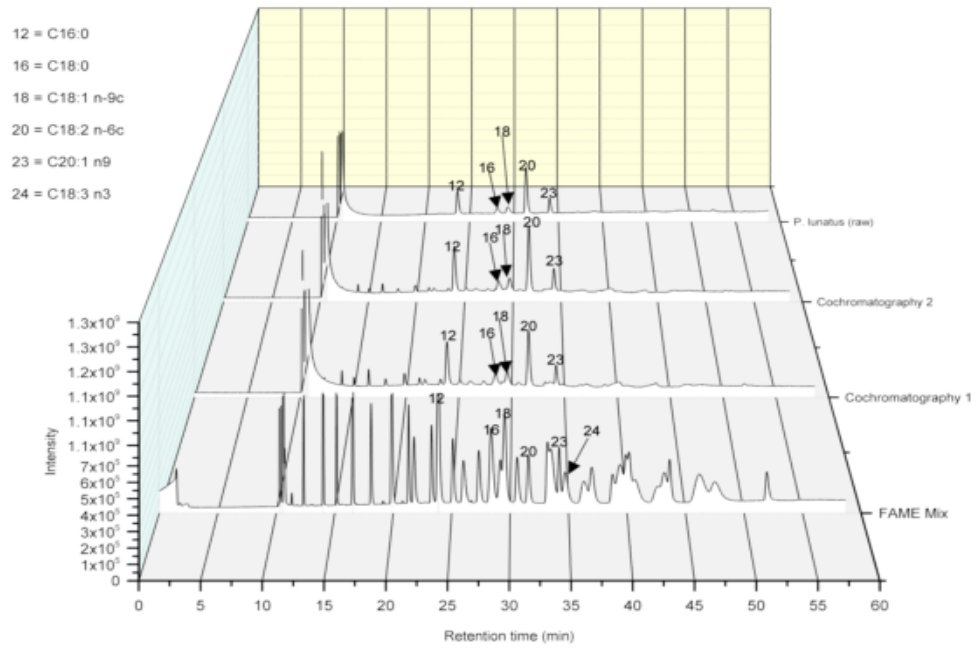
Area percent report and retention times of the fatty acid peaks in raw *Parkia biglobosa* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.652	461118	77075007	6.412
2	28.216	691361	167640898	13.946
3	29.404	678891	150456470	12.517
4	31.488	2648136	475285452	39.54
5	33.186	153592	49895490	4.151
6	34.061	33863	3816323	0.317
7	39.076	487432	250925692	20.875
8	45.727	45079	26940131	2.241

Area percent report and retention times of the fatty acid peaks in raw *Parkia biglobosa* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.65	154657	26142146	5.501
2	28.146	256162	63665031	13.397
3	29.333	261955	55723610	11.726
4	31.408	1007279	174034807	36.621
5	33.182	65364	21462150	4.516
6	34.027	12125	1321850	0.278
7	39.125	234276	120562787	25.369
8	45.721	21645	12319412	2.592

1G: Gas chromatogram for raw *Phaseolus lunatus* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Phaseolus lunatus* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.641	193277	34632117	23.004
2	28.121	47487	10817350	7.185
3	29.308	53989	13787447	9.158
4	31.369	390164	71572449	47.542
5	34.018	127363	19735955	13.11

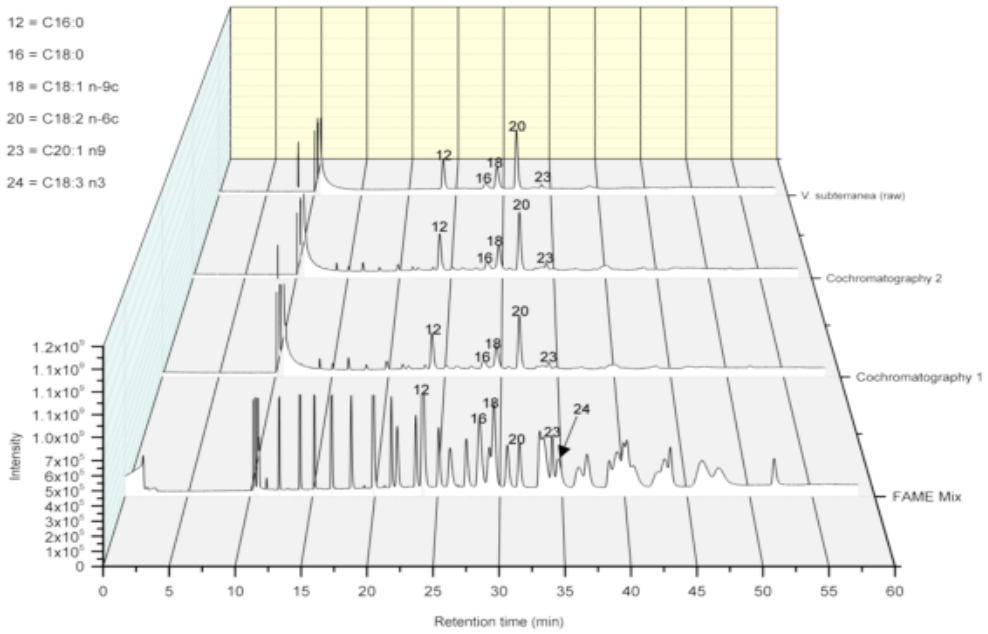
Area percent report and retention times of the fatty acid peaks in raw *Phaseolus lunatus* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.647	260983	46355630	23.554
2	28.127	62348	14016931	7.122
3	29.323	69222	17590073	8.938
4	31.383	509824	92925261	47.217
5	34.019	168104	25915854	13.168

Area percent report and retention times of the fatty acid peaks in raw *Phaseolus lunatus* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.652	170031	31193611	22.718
2	28.122	42657	9843595	7.169
3	29.3	59356	15123720	11.014
4	31.367	340439	63658798	46.361
5	34.016	110470	17490525	12.738

1H: Gas chromatogram for raw *Vigna subterranea* seed flour



Area percent report and retention times of the fatty acid peaks in raw *Vigna subterranea* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.645	272434	48466532	22.708
2	28.148	51522	13949523	6.536
3	29.307	196775	45971665	21.539
4	31.373	540528	98948269	46.361
5	34.022	37856	6095740	2.856

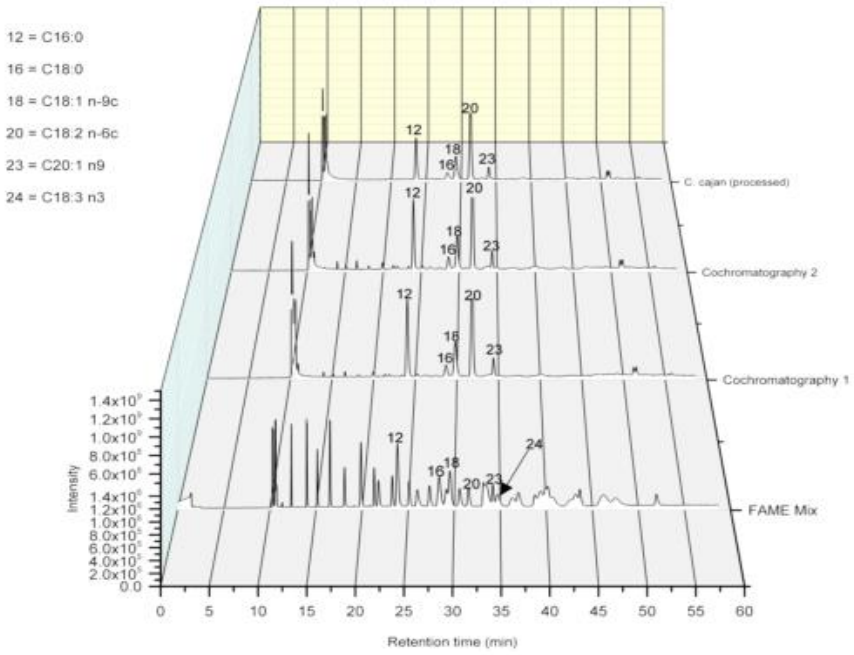
Area percent report and retention times of the fatty acid peaks in raw *Vigna subterranea* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.667	369648	69426985	25.737
2	28.138	58115	16492727	6.114
3	29.327	228073	56220107	20.841
4	31.39	624256	120879406	44.811
5	34.036	40947	6735683	2.497

Area percent report and retention times of the fatty acid peaks in raw *Vigna subterranea* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.668	363812	69473667	26.499
2	28.159	54995	15667804	5.976
3	29.34	220102	54243083	20.689
4	31.397	597436	116622450	44.482
5	34.024	38865	6170535	2.354

1I: Gas chromatogram for processed *Cajanus cajan* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Cajanus cajan* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.56	896818	159440918	21.489
2	28.043	138628	34482369	4.647
3	29.259	493283	124142129	16.731
4	31.369	2050211	384168565	51.777
5	33.966	260054	39734514	5.355

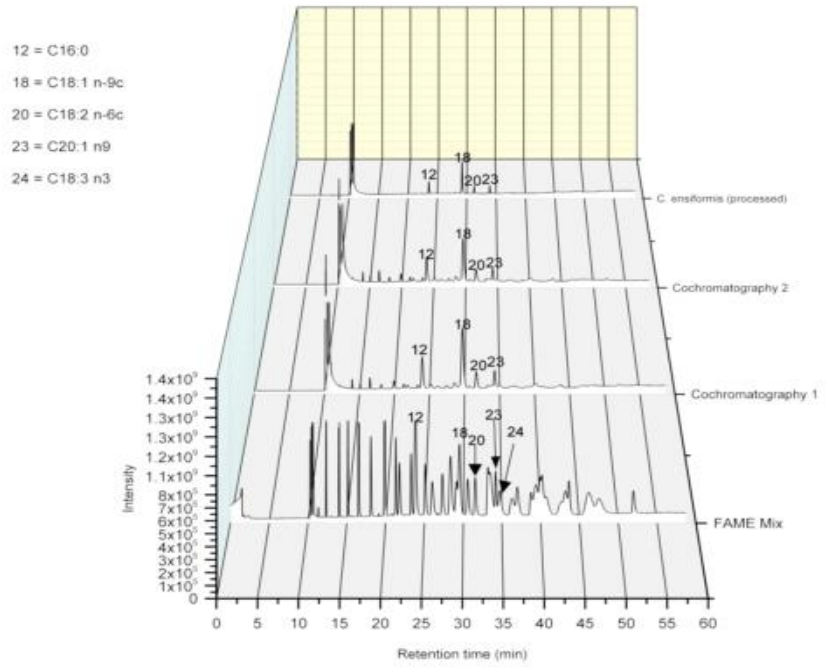
Area percent report and retention times of the fatty acid peaks in processed *Cajanus cajan* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.548	669150	123278385	21.268
2	28.013	104523	27985972	4.828
3	29.228	375938	96769052	16.695
4	31.328	1552999	301276356	51.977
5	33.948	192100	30328300	5.232

Area percent report and retention times of the fatty acid peaks in processed *Cajanus cajan* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.545	543469	93212630	21.075
2	27.999	87260	21791601	4.927
3	29.218	309682	73952563	16.72
4	31.305	1289222	230001300	52.002
5	33.941	159186	23338607	5.277

1J: Gas chromatogram for processed *Canavalia ensiformis* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Canavalia ensiformis* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.571	130676	9560391	17.605
2	29.208	340838	32366021	59.6
3	31.269	80448	6388891	11.765
4	33.92	84918	5989794	11.03

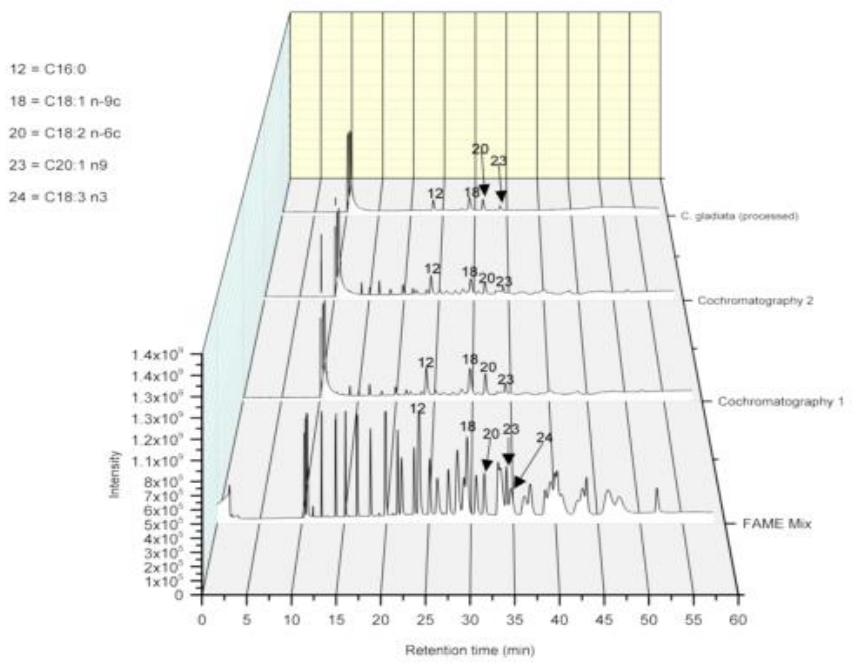
Area percent report and retention times of the fatty acid peaks in processed *Canavalia ensiformis* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.588	147055	16185848	15.85
2	29.238	437966	63023311	61.716
3	31.298	108701	12316002	12.06
4	33.959	111624	10593656	10.374

Area percent report and retention times of the fatty acid peaks in processed *Canavalia ensiformis* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.539	74324	10467619	17.997
2	29.192	194512	34896644	59.999
3	31.264	48144	6899462	11.862
4	33.923	50029	5898724	10.142

1K: Gas chromatogram for processed *Canavalia gladiata* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Canavalia gladiata* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.536	102263	16566813	25.168
2	29.168	120602	25734001	39.094
3	31.249	104563	17092175	25.966
4	33.907	45597	6432602	9.772

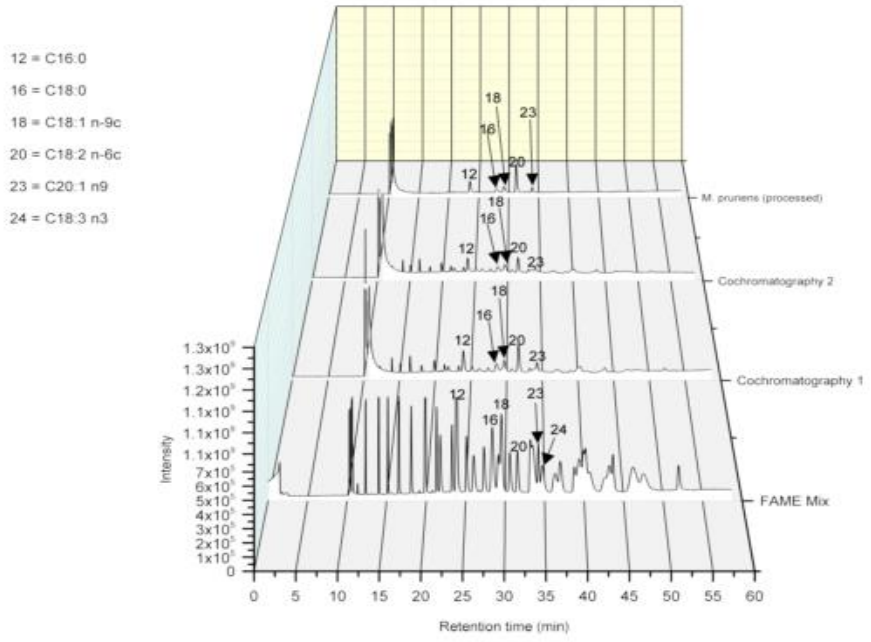
Area percent report and retention times of the fatty acid peaks in processed *Canavalia gladiata* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.526	95127	15563521	25.111
2	29.159	110234	24124873	38.925
3	31.247	97282	16388897	26.443
4	33.91	41736	5900506	9.52

Area percent report and retention times of the fatty acid peaks in processed *Canavalia gladiata* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.517	86991	15673464	25.805
2	29.16	99669	23583922	38.829
3	31.228	86568	15600208	25.684
4	33.902	37755	5881094	9.683

1L: Gas chromatogram for processed *Mucuna pruriens* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Mucuna pruriens* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.528	112289	19163363	20.09
2	27.952	33377	8733910	9.156
3	29.181	54731	12996616	13.625
4	31.246	275072	47452901	49.748
5	33.907	47867	7040339	7.381

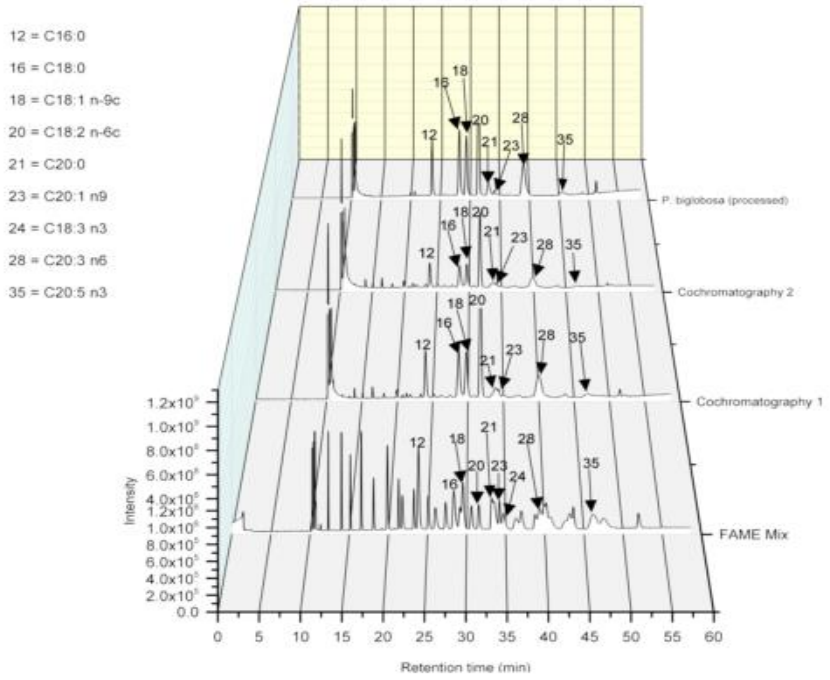
Area percent report and retention times of the fatty acid peaks in processed *Mucuna pruriens* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.526	82141	14169741	20.602
2	27.955	24350	6318465	9.187
3	29.185	38979	9149995	13.304
4	31.251	193354	34105573	49.589
5	33.918	33817	5033088	7.318

Area percent report and retention times of the fatty acid peaks in processed *Mucuna pruriens* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.559	96215	12728583	17.709
2	28.009	34997	6858859	9.543
3	29.202	53953	10277051	14.298
4	31.29	274292	36654545	50.998
5	33.946	47462	5355989	7.452

1M: Gas chromatogram for processed *Parkia biglobosa* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Parkia biglobosa* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.586	909969	131830425	8.753
2	28.185	1077614	223676840	14.851
3	29.374	976737	202238330	13.428
4	31.483	3812710	631928873	41.958
5	33.057	202936	61083602	4.056
6	34.036	61348	6904344	0.458
7	38.963	517489	224029188	14.875
8	45.493	45576	24402152	1.62

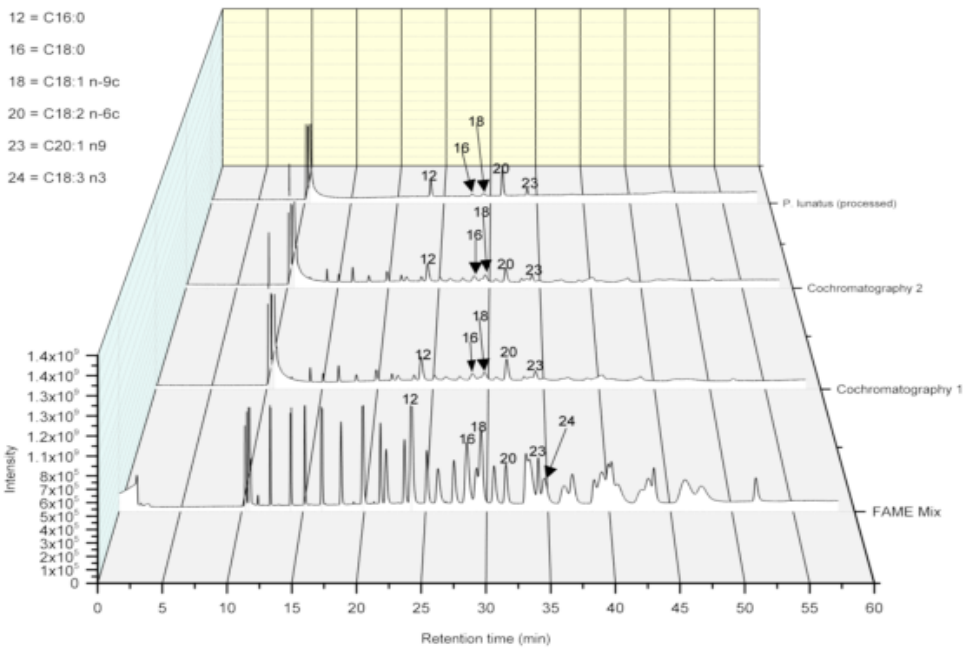
Area percent report and retention times of the fatty acid peaks in processed *Parkia biglobosa* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.586	840355	122944586	9.469
2	28.171	908343	193266356	14.884
3	29.357	849638	175032179	13.48
4	31.456	3316950	548572974	42.248
5	33.04	164550	50043107	3.854
6	34.024	52156	5878747	0.453
7	38.917	421893	186650821	14.375
8	45.473	34522	16069955	1.238

Area percent report and retention times of the fatty acid peaks in processed *Parkia biglobosa* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.603	847724	123917031	9.501
2	28.175	889964	191135127	14.654
3	29.356	843911	175829996	13.481
4	31.475	3288872	546592543	41.906
5	33.093	162465	51762820	3.969
6	34.038	52864	6178939	0.474
7	38.964	416214	189498285	14.529
8	45.444	36092	19403488	1.488

1N: Gas chromatogram for processed *Phaseolus lunatus* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Phaseolus lunatus* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.575	174916	22424394	28.999
2	28.018	21094	3899533	5.043
3	29.215	24682	4654852	6.02
4	31.291	288927	38287145	49.512
5	33.953	72306	8062861	10.427

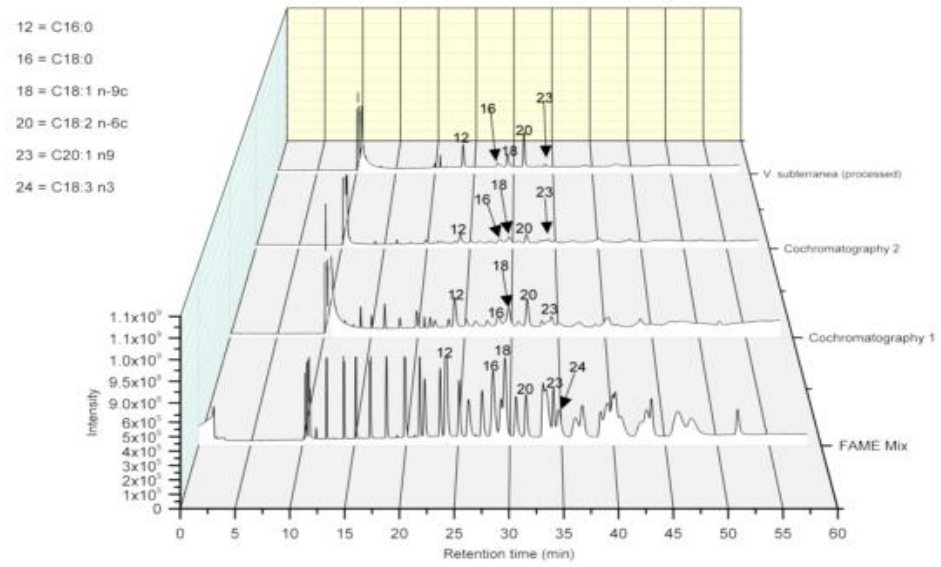
Area percent report and retention times of the fatty acid peaks in processed *Phaseolus lunatus* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.589	327852	30298044	26.935
2	28.04	48927	6359160	5.653
3	29.241	50964	7007979	6.23
4	31.324	588391	56495633	50.225
5	33.967	150489	12323885	10.956

Area percent report and retention times of the fatty acid peaks in processed *Phaseolus lunatus* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.568	233861	28156444	26.339
2	28.011	34029	5920412	5.538
3	29.214	36723	6520717	6.1
4	31.305	440516	54611847	51.087
5	33.949	109674	11689464	10.935

1O: Gas chromatogram for processed *Vigna subterranea* seed flour



Area percent report and retention times of the fatty acid peaks in processed *Vigna subterranea* flour (run 1)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.585	219772	28577411	27.807
2	28.024	34570	5983258	5.822
3	29.226	122942	20894731	20.331
4	31.308	332783	44650144	43.446
5	33.964	24959	2665497	2.594

Area percent report and retention times of the fatty acid peaks in processed *Vigna subterranea* flour (run 2)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.59	160175	22025318	27.394
2	28.037	25121	4585617	5.703
3	29.239	92287	16475839	20.492
4	31.312	249553	35158699	43.728
5	33.971	18692	2157383	2.683

Area percent report and retention times of the fatty acid peaks in processed *Vigna subterranea* flour (run 3)

Peak number	Retention time (min)	Peak height	Peak area	% composition
1	23.618	359909	47011260	27.549
2	28.075	57536	10107458	5.923
3	29.276	205089	34907901	20.456
4	31.35	552336	74157797	43.456
5	34	40965	4464421	2.616

1P: Retention time and area of fatty acids of 37-components FAME Mix

Peak number	Retention time (min)	Peak height	Peak area	Component	% composition
1	10.602	2455811	109766252	C4:0	6.461
2	10.737	186474	5311404	C6:0	0.313
3	11.337	81417	3529049	C8:0	0.208
4	12.34	1368314	49322460	C10:0	2.903
5	14.008	2075560	87925792	C11:0	5.175
6	15.157	950125	47061193	C12:0	2.77
7	16.533	1608238	97059724	C13:0	5.713
8	18.11	653071	49652120	C14:0	2.922
9	19.884	1056611	101760839	C14:1	5.989
10	21.317	634100	49606994	C15:0	2.92
11	21.785	425907	51319776	C15:1	3.021
12	23.281	501052	49180373	C16:0	2.895
13	23.846	1018954	153853061	C16:1	9.056
14	25.113	414348	51791539	C17:0	3.048
15	26.005	271689	51298775	C17:1	3.019
16	27.324	335219	51337737	C18:0	3.022
17	28.377	467439	97220430	C18:1n9t	5.722
18	29.534	444565	72695951	C18:1n9c	4.279
19	30.595	290907	48385218	C18:2n6t	2.848
20	31.564	308260	48495830	C18:2n6c	2.854
21	33.201	183500	21290138	C20:0	1.253
22	33.561	85409	15130223	C18:3n6	0.891
23	34.19	292600	33304080	C20:1n9	1.96
24	34.717	145686	34366986	C18:3n3	2.023
25	36.308	96513	26653479	C21:0	1.569
26	36.988	177920	37795689	C20:2	2.225
27	38.757	117198	17655363	C22:0	1.039
28	39.382	91857	21115399	C20:3n6	1.243
29	39.926	60061	7145722	C22:1n9	0.421
30	40.187	96234	11226893	C20:3n3	0.661
31	40.779	41445	9543670	C20:4n6	0.562
32	42.613	28880	7939033	C23:0	0.467
33	43.172	76628	14958782	C22:2	0.88
34	43.646	184172	24943083	C24:0	1.468
35	46.185	146998	71976649	C20:5n3	4.236
36	47.549	79471	33951426	C24:1n9	1.998
37	51.952	183074	33426832	C22:6n3	1.967

1Q

Fatty acid profile (% of total fatty acids of raw legume flours). Fatty acid distribution was obtained by integrating the peaks to obtain the peak areas and multiplying the peak areas by the ratio of the molecular weight of the fatty acid to the molecular weight of the fatty acid methyl ester formed from the fatty acid to obtain the actual area. The actual area was then expressed as a percentage of the total area of the fatty acid methyl esters. All values are means ± standard deviation of three independent determinations from one extraction. Values in the same column with different superscript letters differ significantly (ANOVA with Tukey mean comparisons, $p \leq 0.05$). C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 n-9c = Oleic acid, C18:2 n-6c = Linoleic acid, C20:0 = Arachidic acid, C20:1 n-9c = Cis-11-Eicosenoic acid, C20:3 n6 = Cis-8, 11, 14-Eicosatrienoic acid, C20:5 n3 = Cis-5, 8, 11, 14, 17-Eicosapentaenoic acid, n.d. = not detected.

Legume	C16:0	C18:0	C18:1 n-9c	C18:2 n-6c
Cajanus cajan	24.10 ± 1.48^{bc}	5.20 ± 0.11^{e}	12.48 ± 0.24^{e}	54.24 ± 1.08^{a}
Canavalia ensiformis	16.14 ± 0.40^{d}	n. d.	62.55 ± 0.31^{a}	9.02 ± 0.18^{f}
Canavalia gladiata	20.79 ± 0.56^{c}	n. d.	48.86 ± 0.36^{b}	23.63 ± 0.15^{e}
Dialium guineense	38.49 ± 1.47^{a}	7.68 ± 0.06^{bc}	42.13 ± 0.55^{c}	7.59 ± 2.17^{f}
Mucuna pruriens	23.20 ± 1.26^{bc}	8.41 ± 0.56^{b}	11.17 ± 0.53^{ef}	50.46 ± 0.24^{b}
Parkia biglobosa	6.47 ± 1.05^{e}	13.86 ± 0.44^{a}	12.83 ± 0.62^{e}	39.12 ± 2.37^{d}
Phaseolus lunatus	22.95 ± 0.42^{bc}	7.11 ± 0.03^{c}	9.64 ± 1.14	47.24 ± 0.16
Vigna subterranea	24.89 ± 2.01^{b}	6.22 ± 0.29^{d}	21.05 ± 0.45^{d}	45.26 ± 1.00^{c}

1Q continued

Legume	C20:0	C20:1 n-9c	C20:3 n6	C20:5 n3
Cajanus cajan	n. d.	3.98 ± 0.15^{d}	n. d.	n. d.
Canavalia ensiformis	n. d.	12.29 ± 0.32^{b}	n. d.	n. d.
Canavalia gladiata	n. d.	6.72 ± 0.27^{c}	n.d	n. d.
Dialium guineense	n. d.	4.11 ± 0.08^{d}	n. d.	n. d.
Mucuna pruriens	n. d.	6.76 ± 0.06^{c}	n.d.	n. d.
Parkia biglobosa	4.17 ± 0.36	0.32 ± 0.05^{f}	21.49 ± 3.71	2.19 ± 0.44
Phaseolus lunatus	n. d.	13.06 ± 0.23^{a}	n. d.	n. d.
Vigna subterranea	n. d.	2.58 ± 0.26^{e}	n. d.	n. d.

1R

Fatty acid profile (% of total fatty acids of legume flours from boiled seeds). Fatty acid distribution was obtained by integrating the peaks to obtain the peak areas and multiplying the peak areas by the ratio of the molecular weight of the fatty acid to the molecular weight of the fatty acid methyl ester formed from the fatty acid to obtain the actual area. The actual area was then expressed as a percentage of the total area of the fatty acid methyl esters. All values are means ± standard deviation of three technical replicates from one extraction. Values in the same column with different superscript letters differ significantly (Tukey, $p \leq 0.05$). C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 n-9c = Oleic acid, C18:2 n-6c = Linoleic acid, C20:0 = Arachidic acid, C20:1 n-9c = Cis-11-Eicosenoic acid, C20:3 n6 = Cis-8, 11, 14-Eicosatrienoic acid, C20:5 n3 = Cis-5, 8, 11, 14, 17-Eicosapentaenoic acid, n.d. = not detected.

Legume	C16:0	C18:0	C18:1 n-9c	C18:2 n-6c
Cajanus cajan	21.20 ± 0.21^{b}	4.80 ± 0.410^{c}	16.73 ± 0.02^{d}	51.95 ± 0.12^{a}
Canavalia ensiformis	17.08 ± 1.14^{c}	n. d.	60.46 ± 1.12^{a}	11.90 ± 0.15^{e}
Canavalia gladiata	25.26 ± 0.38^{a}	n. d.	38.98 ± 0.14^{b}	26.05 ± 0.38^{d}
Mucuna pruriens	19.39 ± 1.54^{bc}	9.31 ± 0.21^{a}	13.75 ± 0.51^{e}	50.13 ± 0.77^{b}
Phaseolus lunatus	28.47 ± 1.56^{a}	5.25 ± 0.32^{b}	6.09 ± 0.11^{f}	49.62 ± 0.86^{b}
Vigna subterranea	27.49 ± 0.21^{a}	5.82 ± 0.11^{b}	20.45 ± 0.08^{c}	43.59 ± 0.16^{c}

1R continued

Legume	C20:0	C20:1 n-9c	C20:3 n6	C20:5 n3
Cajanus cajan	n. d.	5.31 ± 0.06^{d}	n. d.	n. d.
Canavalia ensiformis	n. d.	10.56 ± 0.46^{a}	n. d.	n. d.
Canavalia gladiata	n. d.	9.71 ± 0.13^{b}	94.69 ± 1.02	n. d.
Mucuna pruriens	n. d.	7.42 ± 0.07^{c}	n.d.	n. d.
Phaseolus lunatus	n. d.	10.57 ± 0.39^{a}	n.d.	n. d.
Vigna subterranea	n. d.	2.65 ± 0.05^{e}	n.d.	n. d.

1S

Fatty acid profile (% of total fatty acids of roasted *Parkia biglobosa* seed flour). Fatty acid distribution was obtained by integrating the peaks to obtain the peak areas and multiplying the peak areas by the ratio of the molecular weight of the fatty acid to the molecular weight of the fatty acid methyl ester formed from the fatty acid to obtain the actual area. The actual area was then expressed as a percentage of the total area of the fatty acid methyl esters. All values are means ± standard deviation of three technical replicates from one extraction. C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 n-9c = Oleic acid, C18:2 n-6c = Linoleic acid, C20:0 = Arachidic acid, C20:1 n-9c = Cis-11-Eicosenoic acid, C20:3 n6 = Cis-8, 11, 14-Eicosatrienoic acid, C20:5 n3 = Cis-5, 8, 11, 14, 17-Eicosapentaenoic acid.

Fatty acid profile of roasted *Parkia biglobosa* seed flour

Fatty acid	Flour
C16:0	9.19 ± 0.42
C18:0	14.80 ± 0.12
C18:1 n-9c	13.46 ± 0.03
C18:2 n-6c	42.01 ± 0.18
C20:0	3.98 ± 0.10
C20:1 n9	0.46 ± 0.02
C20:3 n6	14.65 ± 0.26
C20:5 n3	1.45± 0.19

1T

Fatty acid profile according to saturation and unsaturation (% of total fatty acids of legume flours). SFA = Total saturated fatty acids, MUFA = Total monounsaturated fatty acids, PUFA = Total polyunsaturated fatty acids, 1 = raw flour, 2 = processed flour, n.p.f. = no processed flour.

Legume	SFA	MUFA	PUFA	PUFA/SFA
[1]*Cajanus cajan*	29.3	16.46	54.24	1.85
[2]*Cajanus cajan*	26.00	22.04	51.95	2.00
[1]*Canavalia ensiformis*	16.14	74.84	9.02	0.56
[2]*Canavalia ensiformis*	17.08	71.02	11.90	0.70
[1]*Canavalia gladiata*	20.79	55.58	23.63	1.14
[2]*Canavalia gladiata*	25.26	48.69	26.05	1.03
[1]*Dialium guineense*	46.17	46.24	7.59	0.16
[2]*Dialium guineense*	n.p.f.	n.p.f.	n.p.f.	n.p.f.
[1]*Mucuna pruriens*	31.61	17.93	50.46	1.60
[2]*Mucuna pruriens*	28.70	21.17	50.13	1.75
[1]*Parkia biglobosa*	24.50	13.15	62.80	2.56
[2]*Parkia biglobosa*	22.97	13.92	58.11	2.08
[1]*Phaseolus lunatus*	30.06	22.70	47.24	1.57
[2]*Phaseolus lunatus*	33.72	16.66	49.62	1.47
[1]*Vigna subterranea*	31.11	23.63	45.26	1.45
[2]*Vigna subterranea*	33.31	23.10	43.59	1.31

Appendix 2

2A: Sea sand weights for the recovery of the ash content.

Sea sand weights for the recovery of the ash content.

Legume flour	Weight of sea sand (g)
Cajanus cajan (processed)	0.0611
Canavalia ensiformis (raw)	0.0691
Canavalia ensiformis (processed)	0.0520
Parkia biglobosa (raw)	0.1389
Dialium guineense (raw)	0.0384

2B: Settings of the atomic absorption spectrophotometer for the individual minerals.

Settings of the atomic absorption spectrophotometer for the individual minerals.

Lamp	Slot	Maximum working voltage	Wavelength	Slit width of burner
Ca/Mg	2	6 mA	Ca: 422.7 nm	Ca: 0.5 nm
Ca/Mg	2	6 mA	Mg: 285.2 nm	Mg: 0.5 nm
Na/K	3	5 mA	Na: 589.0 nm	Na: 0.2 nm
Na/K	3	5 mA	K: 766.5 nm	K: 0.5 nm
Fe/Cu	1	15 mA	Fe: 248.3 nm	Fe: 0.2 nm
Fe/Cu	1	15 mA	Cu: 324.8 nm	Cu: 0.5 nm
Mn	3	15 mA	Mn: 279.5 nm	Mn: 0.2 nm
Zn	2	10 mA	Zn: 213.9 nm	Zn: 0.5 nm

2C: Mineral-independent settings of the AAS

Mineral-independent settings of the AAS

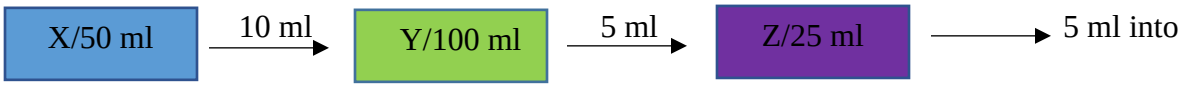
Parameter	Setting
Mode	Flame absorption
Signal	Continuous
Measurement time	4s
Repetitions	3
Burner gas	air/C_2H_2

2D: Calibration range and calibration standards of minerals used for sample measurements and recovery measurement of minerals

Calibration range and calibration standards of minerals used for sample measurements and recovery measurement of minerals

Mineral	Calibration range (mg/L)	Calibration standards (mg/L)					
		1	2	3	4	5	6
Ca	3.00 - 10.05	3.00	4.50	6.01	7.51	9.01	10.51
Mg	0.05 - 0.18	0.05	0.08	0.10	0.13	0.15	0.18
Na	0.47 - 1.65	0.47	0.71	0.94	1.18	1.42	1.65
K	0.24 - 0.83	0.24	0.35	0.47	0.59	0.71	0.83
Fe	0.62 - 2.17	0.62	0.93	1.24	1.55	1.86	2.17
Cu	0.25 - 1.00	0.25	0.38	0.50	0.63	0.75	0.88
Mn	0.33 - 1.14	0.33	0.49	0.65	0.81	0.98	1.14
Zn	0.4 - 1.4	0.40	0.60	0.80	1.00	1.20	1.40

2E: Dilution scheme for standard solution used for recovery of mineral nutrients analyses



Amount of salts and reference standard solutions added for mineral recovery experiment. The colors correspond to the respective dilution level of the dilution scheme at which the Solution is added.

Legume flour	Target weight (g) /Standard addition (ml)							
	$CaCO_3$	Mg standard	NaCl	KCl	$(NH_4)_2.FeSO_4.6H_2O$	Cu standard	$MnSO_4.H_2O$	Zn Standard
Cajanus cajan (processed)	0.0575	12	0.0446	0.2241	0.1102	16	0.0663	11
Canavalia ensiformis (raw)	0.0515	15	0.0604	0.2918	0.0609	9	0.0351	4
Canavalia ensiformis (processed)	0.0539	13	0.0458	0.1806	0.0813	9	0.0362	5
Parkia biglobosa (raw)	0.0929	18	0.0618	0.1307	0.1474	8	0.0581	4
Dialium guineense (raw)	0.3466	4	0.0239	0.1560	0.0596	13	0.0426	9

Appendix 3
Data for calculation of LOD for cyanide

A: Data from standard solution

Titre (t) = 0.9786

Blank volume = 0.2 ml for A_1 and A_2, and 0.17 ml for A_3 and A_4.

C(CN) = 3.84 mmol/L

CN solution	V($AgNO_3$) in ml	n (CN) calculated	V(CN) in ml	n(CN) expected	% Recovery	Mean % recovery
3.84 µmol						
A1	0.32	2.34	1	3.84	60.94	68.88 ± 12.22% (17.74%)
A2	0.36	3.14	1	3.84	81.77	
A3	0.32	2.94	1	3.84	76.56	
A4	0.28	2.16	1	3.84	56.25	
7.68 µmol						
A1	0.56	7.04	2	7.68	91.66	95.51 ± 4.39% (4.60%)
A2	0.6	7.82	2	7.68	101.82	
A3	0.54	7.24	2	7.68	94.27	
A4	0.54	7.24	2	7.68	94.27	
11.5 µmol						
A1	0.74	10.56	3	11.5	91.83	92.78 ± 6.17% (6.65%)
A2	0.7	9.78	3	11.5	85.04	
A3	0.72	10.8	3	11.5	93.91	
A4	0.76	11.54	3	11.5	100.35	

B: Data from blank

Blank	V ($AgNO_3$) in ml	n (CN) $_{theoretically}$ in µmol	Mean n (CN)
A1	0.18	1.76	1.70 ± 0.11
A2	0.18	1.76	
A3	0.16	1.57	

Appendix 4
4A:

MS settings for identification of different isoflavones in legume flours. Shown are MRM transitions and the substance-specific parameters collision energy (CE), Cell leakage potential (CXP) and declustering potential (DP) for the individual IF using UHPLC.

Analyte	MRM Transition (m/z ratio)	CE	CXP	DP
BCA	283 > 268	-25	-13	-30
	283 > 253	-25	-13	-30
DAI	253 > 223	-46	-11	-125
	253 > 133	-40	-9	-125
DAI-GLU	415 > 253	-30	-16	-80
FOR	266 > 252	-26	-11	-100
	266 > 223	-46	-11	-125
GEN	268 > 158	-40	-9	-190
	268 > 133	-40	-13	-190
GEN-GLU	431 > 269	-30	-16	-80
GLY	283 > 268	-25	-13	-30
	283 > 184	-25	-13	-30
PRA	299 > 284	-25	-13	-80
	299 > 177	-25	-13	-80
PRU	283 > 268	-25	-13	-30
	283 > 239	-30	-16	-80
	283 > 184	-30	-16	-80

4B:

Pipetting scheme for the preparation of a reference mixture with a volume of 1 ml. Shown are the concentrations of the reference solutions in mM, the volumes taken from them in µl and the mass on column of the analytes after injection of 10 µl of the reference mixture in ng.

Analyte	c (mM)	Volume (ul)	m.o.c. (ng)
DAI-GLU	0.02	91	8.9
GLY-GLU	0.03	87	10.6
GEN-GLU	0.02	91	8.9
PSE-GLU	0.1	42	18.2
FOR-GLU	0.1	25	10.5
DAI	0.04	79	7.7
ORO	0.2	16	8.9
GLY	0.04	297	34.4
CAL	0.1	30	8.3
BCA-GLU	0.1	25	10.9
PRU-GLU	0.1	17	7.4
GEN	0.04	65	6.3
PRA	0.1	17	5
PSE	0.1	31	8.5
FOR	0.09	43	10.5
IRI	0.4	12	14
PRU	0.1	16	4.5
BCA	0.09	16	3.9
6-MF	0.1	28	7.1

4C:

Measurement of the individual references with added internal standard. The individual references are arranged in order of increasing relative retention time.

Individual reference	Number	Absolute retention time (min)	Relative retention time (min)
DAI-GLU	1	8.63	0.14
GLY-GLU	2	10.30	0.17
GEN-GLU	3	13.41	0.22
PSE-GLU	4	18.44	0.30
FOR-GLU	5	19.73	0.32
DAI	6	20.72	0.34
ORO	7	21.83	0.36
GLY	8	23.18	0.38
CAL	9	24.43	0.40
BCA-GLU	10	31.10	0.51
GEN	11	31.94	0.52
PRU-GLU	12	34.31	0.56
PRA	13	35.09	0.60
PSE	14	40.52	0.67
FOR	15	41.23	0.68
IRI	16	49.57	0.81
PRU	17	54.90	0.92
BCA	18	55.77	0.93
6-MF	19	-	-

4D:

Pipetting scheme for the dilution of the reference isoflavones BCA, DAI, DAI-GLU, FOR, GEN, GEN-GLU, GLY, PRA and PRU for measurement on the UHPLC-MS / MS. Solvent used is 10% ACN

Reference	Ck (ng/µl)	Dilution	Cv (ng/µl)	n.o.c. (fmol)
BCA	0.39	//10 µl + 890 µl 10% ACN (Cv)	$4.33*10^{-3}$	151.27
DAI	0.77	//50 µl + 50 µl 10% ACN	$3.85*10^{-3}$	153.00
		//10 µl + 990 µl 10% ACN (Cv)		
DAI-GLU	0.89	//50 µl + 50 µl 10% ACN	$6.36*10^{-3}$	152.68
		//20 µl + 1380 µl 10% ACN (Cv)		
FOR	33.6	//10 µl + 990 µl 10% ACN	$4.20*10^{-3}$	157
		//10 µl + 790 µl 10% ACN (Cv)		
GEN	0.63	//20 µl + 980 µl 10% ACN	$4.20*10^{-3}$	155.00
		//30 µl + 66 µl 10% ACN (Cv)		
GEN-GLU	0.89	//10 µl + 50 µl 10% ACN	$6.36*10^{-3}$	147
		//10 µl + 690 µl 10% ACN (Cv)		
GLY	3.44	//10 µl + 790 µl 10% ACN	$4.3*10^{-3}$	151.00
		//10 µl + 100 µl 10% ACN (Cv)	$2.9*10^{-2}$	1008.00
GLY	3.44	//10 µl + 790 µl 10% ACN		
		//200 µl + 100 µl 10% ACN (Cv)		
PRA	0.50	//10 µl + 990 µl 10% ACN (Cv)	$5.00*10^{-3}$	167.00
PRU	0.45	//10 µl + 490 µl 10% ACN (Cv)	$9.00*10^{-3}$	316.61

4E:

IF listed alphabetically with their specifically measured m / z ratio with which the references or isolated IF from the legume flour samples were measured using UHPLC-MS and their tR (min). Samples marked with an X were identified as another substance. Samples with n.n. were undetectable.

IF	m/z	Reference	*Cajanus cajan*	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*
BCA	283/268	24.91	24.90	-	25.23	25.23
	283/269	25.09	25.03	-	25.14	25.16
DAI	253/133	20.04	20.03	n.n.	-	n.n.
	253/233	20.04	20.00	n.n.	-	n.n.
DAI-GLU	415/253	12.12	n.n.	n.n.	n.n.	-
FOR	266.9/252.0	23.98	23.97	-	-	-
	266.9/223.1	23.98	23.97	-	-	-
GEN	268/133	22.60	22.60	22.59	-	-
	268/159	22.64	22.60	n.n.	-	-
GEN-GLU	431/269	14.16	14.17	n.n.	n.n.	-
GLY	283/184	21.49	x	n.n.	n.n.	-
	283/268	21.44	x	21.63	21.61	
PRA	299.0/284.0	23.12	-	-	-	-

Appendix 4E continued

IF	m/z	Reference	Mucuna pruriens	Parkia biglobosa	Phaseolus lunatus	Vigna subterranea
BCA	283/268	24.91	24.93	25.50	-	-
	283/269	25.09	25.12	25.13	-	-
DAI	253/133	20.04	n.n.	19.96	19.97	20.02
	253/233	20.04	n.n.	19.94	19.94	20.00
DAI-GLU	415/253	12.12	n.n.	-	n.n.	12.12
FOR	266.9/252.0	23.98	23.97	-	-	-
	266.9/223.1	23.98	23.99	-	-	-
GEN	268/133	22.60	22.59	n.n.	-	22.59
	268/159	22.64	22.58	n.n.	-	22.61
GEN-GLU	431/269	14.16	14.17	n.n.	n.n.	-
GLY	283/184	21.49	n.n.	x	-	-
	283/268	21.44	n.n.	x	-	-
PRA	299.0/284.0	23.12	x	-	x	x

4F

4F (1)

Pipetting scheme for the dilutions of the IF BCA, DAI, DAI-GLU, FOR, GEN, GEN-GLU, and GLY from *Cajanus cajan* for measurement on the UHPLC-MS/MS. A solvent with 10% ACN was used.

Cajanus cajan	Dilution	n.o.c. (fmol)
BCA	//1 ml: 0.477 ng/µl //10/100:0.048 ng/µl //44/500:4.22*10^{-3} ng/µl	148.60
	Cv //1 ml: 0.069 ng/µl	157.33
DAI	//40/690: 4.00*10^{-3}	
DAI-GLU	//50 µl: 0.064 ng/µl	1537.06
FOR	//1 ml: 0.226 ng/µl //10/500: 4.2*10^{-3}ng/µl	168.49
GEN	//1 ml: 0.914 ng/µl //10/100: 0.091 ng/µl //30/500: 4.02*10^{-3} ng/µl	149.00
	//1 ml: 0.012 ng/µl	158.66
GEN-GLU	//290/500: 6.86*10^{-3} ng/µl	
GLY	//500 µl: 0.010 ng/µl	351.79

4F (2)

Pipetting scheme for the dilutions of the IF DAI, DAI-GLU, GEN, GLY and GEN-GLU from *Canavalia ensiformis* for measurement on the UHPLC-MS / MS. A solvent with 10% ACN was used.

Canavalia ensiformis	Dilution	n.o.c. (fmol)
DAI	//480 µl: $7.63*10^{-3}$ ng/µl //100 µl: 2.06 ng/µl	157.33
DAI-GLU	//100 µl: 2.06 ng/µl //10/100: 0.21 ng/µl	4956.05
GEN	//500 µl: 0.016 ng/µl	592.07
GLY	//100: 0.368 ng/µl	6301.00
GEN-GLU	//100 µl: 0.11 ng/µl	2628.39

4F (3)

Pipetting scheme for the dilutions of the IF BCA, DAI-GLU, GEN-GLU, GLY and PRU from *Canavalia gladiata* for measurement on the UHPLC-MS / MS. A solvent with 10% ACN was used.

Canavalia gladiata	Dilution	n.o.c. (fmol)
BCA	//1 ml: 0.032 ng/µl //134/500: $8.58*10^{-}$ ng/µl	301.70
DAI-GLU	//200 µl: 0.013^{-3} ng/µl //10/100: 0.21 ng/µl	300.21
GEN-GLU	//1 ml: 0.023 ng/µl	531.94
GLY	//100: 0.08 ng/µl	2937.54
PRU	//200 µl	596.37

4F (4)

Pipetting scheme for the dilutions of the IF DAI and BCA from *Dialium guineense* for measurement on the UHPLC-MS / MS. A solvent with 10% ACN was used.

Dialium guineense	Dilution	n.o.c. (fmol)
DAI	//200 µl: 0.033 ng/µl	1297.99
BCA	//1 ml: 0.019 ng/µl //90/200: $8.46*10^{-3}$ ng/µl	297.61

4F (5)

Pipetting scheme for the dilutions of the IF BCA, DAI, DAI-GLU, FOR, GEN, GEN-GLU, GLY, PRA and PRU from *Mucuna pruriens* for measurement on the UHPLC-MS/MS. A solvent with 10% ACN was used.

Mucuna pruriens	Dilution	n.o.c. (fmol)
BCA	//1 ml: 0.248 ng/µl //20/500:$9.92*10^{-3}$ ng/µl	348.98
DAI	//100 µl: 0.35 ng/µl //50/100: 0.18 ng/µl	6799.42
DAI-GLU	//50 µl: 0.24 ng/µl	5763.97
FOR	//500 µl: 0.009 ng/µl //220/500: $4.06*10^{-3}$ng/µl	151.35
GEN	//100 µl: 0.15 ng/µl	5469.00
GEN-GLU	//370 µl: $6.57*10^{-3}$ ng/µl	152.00
GLY	//500 µl: 0.006 ng/µl //360/500: $4.53*10^{-3}$ ng/µl	159.36
PRA	//1 ml: 0.389 ng/µl //10/100: 0.039 ng/µl //70/250: 0.011 ng/µl	363.69
PRU	//500 //100/200	655.73

4F (6)

Pipetting scheme for the dilutions of the IF BCA, DAI, DAI-GLU, GEN, GEN-GLU and GLY from *Parkia biglobosa* for measurement on the UHPLC-MS/MS. A solvent with 10% ACN was used.

Parkia biglobosa	Dilution	n.o.c. (fmol)
BCA	//1 ml: 0.028 ng/µl //16/500: $8.98*10^{-3}$ ng/µl	315.20
DAI	//100 µl: 0.12 ng/µl	4848.47
DAI-GLU	//370 µl: $6.32*10^{-3}$ ng/µl	151.78
GEN	//100 µl: 0.05 ng/µl	1717.59
GEN-GLU	//100 µl: 0.64 ng/µl	7507.00
GLY	//100 µl: 1.104 ng/µl //10/100: 0.11 ng/µl	3883.73

4F (7)

Pipetting scheme for the dilutions of the IF DAI-GLU, GEN-GLU, DAI and PRA from *Phaseolus lunatus* for measurement on the UHPLC-MS/MS. A solvent with 10% ACN was used.

Phaseolus lunatus	Dilution	n.o.c. (fmol)
DAI-GLU	//100 µl: 0.066 ng/µl	299.34
GEN-GLU	//100 µl: 0.065 ng/µl	1503.31
DAI	//100 µl: 0.036 ng/µl	308.06
PRA	//500 µl: 0.019 ng/µl //96/200: $8.98*10^{-3}$ ng/µl	298.94

4F (8)

Pipetting scheme for the dilutions of the IF DAI, DAI-GLU, GEN and PRA from *Vigna subterranea* for measurement on the UHPLC-MS/MS. A solvent with 10% ACN was used.

Vigna subterranea	Dilution	n.o.c. (fmol)
DAI	//300 µl: $6.27*10^{-3}$ ng/µl	150.50
DAI-GLU	//1 ml: 0.017 ng/µl	408.28
DAI	//1 ml: 0.022 ng/µl //200/500: $8.80*10^{-3}$ ng/µl	325.64
PRA	//1 ml: 0.012 ng/µl //400/500: $9.60*10^{-3}$ ng/µl	319.72

4G

4G (1)

Pipetting scheme for creating the calibration stock solution 1 for *Cajanus cajan* and its concentration after working up on the column (ng) for isoflavones determination.

Substance	Ck (ng/µl)	V (µl)	Cv (ng/µl)	In 20 µl (ng)*	m.o.c.
BCA	1330.00	50	33.25	665.00	26.6
DAI	249.75	374	46.79	935.81	37.43
DAI-GLU	107.82	43	2.32	46.47	1.86
FOR	712.89	278	99.09	1981.74	79.27
GEN	711.61	400	142.32	2846.44	113.86
GEN-GLU	150.36	49	3.68	73.68	2.95
ACN		//2000			

*Calibration point 1

4G (2)

Pipetting scheme for creating calibration stock solution 3 for *Parkia biglobosa* and its concentration after working up on the column (ng).

Substance	Ck (ng/µl)	V (µl)	Cv (ng/µl)	In 20 µl (ng)*	m.o.c.
BCA	1330.00	20	26.60	532.00	21.28
DAI	249.75	134	33.47	669.40	26.78
GEN	711.61	58	41.27	825.47	33.02
GEN-GLU	300.72	270	81.19	1623.89	65.00
ACN		//1000			

*Calibration point 1

4G (3)

Pipetting scheme for the preparation of the calibration stock solution 2 for *Vigna subterranea* and its concentration after working up on the column (ng).

Substance	Ck (ng/µl)	V (µl)	Cv (ng/µl)	In 20 µl (ng)*	m.o.c.
DAI	249.75	108	17.98	359.64	14.40
DAI-GLU	215.64	300	43.13	862.60	34.50
GEN	711.61	74	35.11	702.12	28.10
GEN-GLU	300.72	155.4	31.15	623.09	24.92
ACN		//1500			

*Calibration point 1

4H

4H (1)

Pipetting scheme of adding the calibration solution 1 by means of standard addition for the determination of IFs in *Cajanus cajan* and for the reference and the blank.

Solution	Pipetting scheme
Sample	Sample
Calibration point 1	Sample + 20 µl Calibration mixture 1
Calibration point 2	Sample + 40 µl Calibration mixture 1
Calibration point 3	Sample + 60 µl Calibration mixture 1
Calibration point 4	Sample + 80 µl Calibration mixture 1
Calibration point 5	Sample + 100 µl Calibration mixture 1
Blank IS	60 µl Calibration mixture 1
Reference	60 µl Calibration mixture 1

4H (2)

Pipetting scheme of adding the calibration solution 3 by means of standard addition using standard for the determination of IFs in *Parkia biglobosa* and for the reference and blank.

Solution	Pipetting scheme
Sample	Sample + 40 µl IS (6-MF)
Calibration point 1	Sample + 40 µl IS (6-MF) + 20 µl Calibration mixture 3
Calibration point 2	Sample + 40 µl IS (6-MF) + 40 µl Calibration mixture 3
Calibration point 3	Sample + 40 µl IS (6-MF) + 60 µl Calibration mixture 3
Calibration point 4	Sample + 40 µl IS (6-MF) + 80 µl Calibration mixture 3
Calibration point 5	Sample + 40 µl IS (6-MF) + 100 µl Calibration mixture 3
Blank IS	40 µl IS (6-MF) + 60 µl Calibration mixture 3
Reference	40 µl IS (6-MF) + 60 µl Calibration mixture 3

4H (3)

Pipetting scheme of adding the calibration solution 2 by means of standard addition for the determination of IFs in *Vigna subterranea* and for the reference and the blank.

Solution	Pipetting scheme
Sample	Sample + 40 µl IS (6-MF)
Calibration point 1	Sample + 40 µl IS (6-MF) + 20 µl Calibration mixture 2
Calibration point 2	Sample + 40 µl IS (6-MF) + 40 µl Calibration mixture 2
Calibration point 3	Sample + 40 µl IS (6-MF) + 60 µl Calibration mixture 2
Calibration point 4	Sample + 40 µl IS (6-MF) + 80 µl Calibration mixture 2
Calibration point 5	Sample + 40 µl IS (6-MF) + 100 µl Calibration mixture 2
Blank IS	40 µl IS (6-MF) + 60 µl Calibration mixture 2
Reference	40 µl IS (6-MF) + 60 µl Calibration mixture 2

4I

One gram (1 g) sample was weighed into a 15 ml plastic tube and 40 µl IS (6-MF) was pipetted into it. The sample was then mixed with 10 ml of 50% ACN and extracted for 2 hours in an ultrasonic bath. During the extraction, the suspension wass vortexed and shaken. After the extraction, the solution was centrifuged at 5000 rpm for 10 min and the supernatant was removed. The removed supernatant was placed overnight in a freezer at -20°C. The precipitated fats/proteins were centrifuged down at 5000 rpm and the supernatant was filtered through a 0.45 µm filter into a centrifuge tube. The ACN of the sample solution was evaporated at 30 mbar until there was no more solvent in the sample solution. The aqueous phase frozen at -20°C was freeze-dried overnight. The residue after freeze-drying was dissolved in 3 ml of ACN, centrifuged at 5000 rpm for 5 min and the supernatant removed. The supernatant removed was evaporated to dryness at 30 mbar, the residue after evaporation was taken up in 250 µl of 10% ACN and centrifuged at 14.8 g/min for 10 min. The extractant was removed. The remaining extraction residue was first mixed with 1.5 ml of 75% ACN, slurried using a vortexer, centrifuged for 5 min at 5000 rpm and removed using a Pasteur pipette. The residue was then slurried with 1.5 ml of ACN, centrifuged and the extractant removed. The clear liquid was used for measurement on the HPLC-DAD.

Appendix 5
Raw results

5A: Functional properties

5A1: Bulk density of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladaita*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0.96	0.88	0.8	0.61	0.91	0.64	0.97	0.84
0.97	0.88	0.79	0.61	0.91	0.65	0.97	0.84
0.97	0.89	0.79	0.6	0.89	0.64	0.96	0.85

5A2: Bulk density of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0.95	0.88	0.83	n.d.	0.81	0.68	0.94	0.83
0.95	0.88	0.82	n. d.	0.81	0.67	0.94	0.83
0.96	0.89	0.83	n.d.	0.82	0.67	0.95	0.85

5A3: Foam capacity of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
28.71	18.81	7.84	0.99	13.73	7.84	21.57	7.84
28.71	16.83	11.76	0.99	19.61	5.88	19.61	9.8
26.73	16.83	11.76	1.98	17.65	7.84	21.57	9.8

5A4: Foam capacity of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
1.96	2.97	4.95	n. d.	0.99	0.99	4.95	0.99
3.92	2.97	6.93	n. d.	2.97	0.99	2.97	0.99
3.92	0.99	4.95	n. d.	0.99	2.97	2.97	2.97

5A5: Foam stability of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
78.46	90	92.73	100	93.1	94.55	90.32	92.73
78.46	88.33	91.23	100	91.8	94.44	91.8	92.86
79.69	90	89.47	99.03	95	92.73	91.94	91.07

5A6: Foam stability of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
98.08	97.11	95.28	n. d.	99.02	99.02	95.28	99.02
96.23	97.11	93.52	n. d.	97.12	99.02	97.12	99.02
96.23	99.02	95.28	n. d.	99.02	97.12	97.12	97.12

5A7: Least gelation concentration of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
20	14	8	21	12	11	14	23
19	14	9	22	13	11	13	24
18	13	9	23	13	12	12	24

5A8: Least gelation concentration of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
> 25	> 25	> 25	n. d.	> 25	19	> 25	> 25
> 25	> 25	> 25	n. d.	> 25	20	> 25	> 25
> 25	> 25	> 25	n. d.	> 25	20	> 25	> 25

5A9: Oil absorption capacity of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0.18	0.64	0.77	1.09	0.46	0.41	0.23	0.23
0.23	0.64	0.86	1.09	0.5	0.32	0.27	0.18
0.18	0.73	0.82	1.14	0.55	0.32	0.23	0.14

5A10: Oil absorption capacity of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0.64	1.09	1	n. d.	0.96	0.86	0.91	0.77
0.73	1.05	0.96	n. d.	1.05	0.91	0.86	0.68
0.68	1	1.05	n. d.	1.05	0.86	0.91	0.77

5A11: Solubility of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0.13	0.27	0.23	0.53	0.13	0.17	0.47	0.47
0.2	0.27	0.27	0.53	0.13	0.2	0.53	0.43
0.2	0.23	0.23	0.57	0.17	0.17	0.53	0.43

5A12: Solubility of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0.1	0.17	0.23	n. d.	0.13	0.13	0.2	0.13
0.1	0.17	0.23	n. d.	0.17	0.17	0.2	0.13
0.13	0.13	0.2	n. d.	0.13	0.13	0.17	0.1

5A13: Swelling power of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
4.81	7	8.96	7	5.46	5.84	9.88	10.13
5.92	6.77	9.05	7.29	5.65	5.92	11.5	9.47
5.96	6.17	8.82	7.62	6	5.88	12.07	9.18

5A14: Swelling power of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
6.48	6.36	5.91	n. d.	5.62	5.5	6.67	5.92
6.03	6.56	6.43	n. d.	6	5.72	7	5.85
6.5	6.23	5.88	n. d.	5.5	5.42	6.95	5.74

5A15: Water absorption capacity of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
2	2	1.75	1.25	1.75	1.65	1.8	1.2
2.05	2.05	1.8	1.25	1.65	1.6	1.85	1.1
2	2.05	1.8	1.3	1.7	1.6	1.9	1.15

5A16: Water absorption capacity of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
2.45	2.85	2.6	n. d.	2.35	2.05	2.4	2.1
2.35	2.9	2.6	n. d.	2.45	2.10	2.4	2.2
2.4	2.8	2.55	n. d.	2.35	2.05	2.45	2.1

5B: Percent fatty acids distribution in legume flours (n.p. = not prepared)

5B1: C16:0 of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
25.8	16.61	20.5	36.79	21.75	7.56	22.86	22.62
23.4	15.9	21.43	39.39	23.81	6.38	23.41	25.65
23.09	15.92	20.43	39.28	24.03	5.47	22.58	26.41

5B2: C16:0 of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
21.41	17.53	25.07	n.p.	20.01	8.71	28.82	27.71
21.19	15.78	25.01	n.p.	20.52	9.42	26.76	27.30
20.99	17.92	25.70	n.p.	17.64	9.45	29.83	27.45

5B3: C18:0 of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
5.11	0	0	7.61	9.06	14.26	7.14	6.55
5.32	0	0	7.7	8.08	13.94	7.08	6.12
5.17	0	0	7.73	8.09	13.39	7.12	5.99

5B4: C18:0 of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
4.65	0	0	n.p.	9.17	14.85	5.01	5.83
4.83	0	0	n.p.	9.2	14.89	5.62	5.71
4.93	0	0	n.p.	9.55	14.66	5.13	5.93

5B5: C18:1n9c of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
12.28	62.22	48.83	41.49	11.78	12.93	9.10	21.56
12.41	62.61	48.52	42.46	10.91	12.51	8.88	20.87
12.74	62.83	49.24	42.44	10.83	11.71	10.95	20.72

5B6: C18:1n9c of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
16.75	59.62	39.13	n.p.	13.64	13.42	5.98	20.36
16.71	61.74	38.96	n.p.	13.31	13.48	6.19	20.52
16.74	60.03	38.86	n.p.	14.31	13.48	6.09	20.48

5B7: C18:2n6c of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
53	9.03	23.64	10.09	50.72	41.27	47.74	46.4
54.81	8.84	23.48	6.29	50.4	39.50	47.41	44.85
54.92	9.19	23.78	6.39	50.26	36.58	46.56	44.52

5B8: C18:2n6c of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
51.81	11.77	25.98	n.p.	49.77	41.93	49.72	43.49
52.01	12.06	26.46	n.p.	49.61	42.22	50.43	43.77
52.03	11.86	25.70	n.p.	51.01	41.88	48.72	43.50

5B9: C20:0 of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0	0	0	0	0	3.82	0	0
0	0	0	0	0	4.17	0	0
0	0	0	0	0	4.53	0	0

5B10: C20:0 of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0	0	0	n.p.	0	4.07	0	0
0	0	0	n.p.	0	3.87	0	0
0	0	0	n.p.	0	3.99	0	0

5B11: C20:1n9c of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
3.81	12.14	7.03	4.02	6.69	0.37	13.16	2.87
4.05	12.65	6.57	4.16	6.80	0.32	13.22	2.51
4.09	12.07	6.55	4.16	6.79	0.28	12.79	2.37

5B12: C20:1n9c of proceesed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladiata*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
5.38	11.08	9.82	n.p.	7.42	0.46	10.47	2.61
5.26	10.42	9.57	n.p.	7.36	0.45	11.00	2.70
5.30	10.19	9.73	n.p.	7.49	0.48	10.23	2.63

5B13: C20:3n6 of raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladaita*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0	0	0	0	0	18.09	0	0
0	0	0	0	0	20.94	0	0
0	0	0	0	0	25.44	0	0

5B14: C20:3n6 of processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladaita*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0	0	0	n.p.	0	14.93	0	0
0	0	0	n.p.	0	14.43	0	0
0	0	0	n.p.	0	14.58	0	0

5B15: C20:5n3 for raw flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladaita*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0	0	0	0	0	1.72	0	0
0	0	0	0	0	2.25	0	0
0	0	0	0	0	2.60	0	0

5B16: C20:5n3 for processed flours

Cajanus cajan	*Canavalia ensiformis*	*Canavalia gladaita*	*Dialium guineense*	*Mucuna pruriens*	*Parkia biglobosa*	*Phaseolus lunatus*	*Vigna subterranea*
0	0	0	n.p.	0	1.62	0	0
0	0	0	n.p.	0	1.24	0	0
0	0	0	n.p.	0	1.49	0	0

5C: Sugar concentrations in legume flours

5C1: Raffinose concentration (g/100g flour) in raw legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.495	0.724	0.227
Weight of sample (g/l)				49.031		
Amount of sample weighed (g)/100 ml solution				4.9031		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.495		
Sample A2				0.724		
ΔA				0.227		
Raffinose concentration (g/l)				0.309		
Amount of raffinose (g/100 g flour sample)				0.630		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.724		
Sample A3				0.989		
ΔA				0.265		
D-galactose concentration (g/L)				0.523		
% Recovery (internal standard)				101.730		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.278	0.882	0.569
Weight of sample (g/l)				49.062		
Amount of sample weighed (g)/100 ml solution				4.9062		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.311		
Sample A2				0.882		
ΔA				0.569		
Raffinose concentration (g/l)				0.074		
Amount of raffinose (g/100 g flour sample)				0.150		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.882		
Sample A3				1.145		
ΔA				0.263		
D-galactose concentration (g/L)				0.519		
% Recovery (internal standard)				100.962		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.278	0.581	0.301
Weight of sample (g/l)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.278		
Sample A2				0.581		
ΔA				0.301		
Raffinose concentration (g/l)				0.683		
Amount of raffinose (g/100 g flour sample)				1.392		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.581		
Sample A3				0.848		
ΔA				0.267		
D-galactose concentration (g/L)				0.527		
% Recovery (internal standard)				102.498		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Dialium guineense*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.279	0.487	0.206
Weight of sample (g/l)				10.118		
Amount of sample weighed (g)/100 ml solution				1.0118		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.279		
Sample A2				0.487		
ΔA				0.206		
Raffinose concentration (g/l)				0.027		
Amount of raffinose (g/100 g flour sample)				0.264		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.487		
Sample A3				0.753		
ΔA				0.266		
D-galactose concentration (g/L)				0.525		
% Recovery (internal standard)				102.114		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.402	0.713	0.309
Weight of sample (g/l)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.402		
Sample A2				0.713		
ΔA				0.309		
Raffinose concentration (g/l)				0.701		
Amount of raffinose (g/100 g flour sample)				1.430		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.713		
Sample A3				0.982		
ΔA				0.269		
D-galactose concentration (g/L)				0.531		
% Recovery (internal standard)				103.266		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.434	0.737	0.301
Weight of sample (g/l)				49.095		
Amount of sample weighed (g)/100 ml solution				4.9095		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.434		
Sample A2				0.737		
ΔA				0.301		
Raffinose concentration (g/l)				0.683		
Amount of raffinose (g/100 g flour sample)				1.391		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.737		
Sample A3				0.998		
ΔA				0.261		
D-galactose concentration (g/L)				0.515		
% Recovery (internal standard)				100.195		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.367	0.675	0.306
Weight of sample (g/l)				49.054		
Amount of sample weighed (g)/100 ml solution				4.9054		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.367		
Sample A2				0.675		
ΔA				0.306		
Raffinose concentration (g/l)				0.417		
Amount of raffinose (g/100 g flour sample)				0.849		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.675		
Sample A3				0.938		
ΔA				0.263		
D-galactose concentration (g/L)				0.519		
% Recovery (internal standard)				100.962		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.322	0.495	0.171
Weight of sample (g/l)				49.063		
Amount of sample weighed (g)/100 ml solution				4.9063		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.322		
Sample A2				0.495		
ΔA				0.171		
Raffinose concentration (g/l)				0.116		
Amount of raffinose (g/100 g flour sample)				0.237		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.495		
Sample A3				0.761		
ΔA				0.266		
D-galactose concentration (g/L)				0.525		
% Recovery (internal standard)				102.114		

Raffinose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.268	0.27		0.097	0.322	0.233
Weight of sample (g/l)				0.604		
Amount of sample weighed (g)/100 ml solution				0.0604		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.025		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.268		
Blank A2				0.27		
Sample A1				0.097		
Sample A2				0.322		
ΔA				0.223		
Raffinose concentration (g/l)				0.607		
Amount of raffinose (g/100 g flour sample)				100.523		
Addition of internal standard						
Weight of D-galactose (g/L)				0.514		
Amount of D-galactose weighed (g)/100 ml				0.0514		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.322		
Sample A3				0.596		
ΔA				0.274		
D-galactose concentration (g/L)				0.541		
% Recovery (internal standard)				105.185		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.272	0.951	0.677
Weight of sample (g/l)				49.065		
Amount of sample weighed (g)/100 ml solution				4.9065		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.497		
Sample A2				0.733		
ΔA				0.234		
Raffinose concentration (g/l)				0.319		
Amount of raffinose (g/100 g flour sample)				0.649		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.733		
Sample A3				0.997		
ΔA				0.264		
D-galactose concentration (g/L)				0.521		
% Recovery (internal standard)				100.758		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.272	0.951	0.677
Weight of sample (g/l)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.272		
Sample A2				0.951		
ΔA				0.677		
Raffinose concentration (g/l)				0.088		
Amount of raffinose (g/100 g flour sample)				0.179		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.951		
Sample A3				1.219		
ΔA				0.268		
D-galactose concentration (g/L)				0.529		
% Recovery (internal standard)				102.285		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.276	0.57	0.292
Weight of sample (g/l)				49.052		
Amount of sample weighed (g)/100 ml solution				4.9052		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.276		
Sample A2				0.57		
ΔA				0.292		
Raffinose concentration (g/l)				0.663		
Amount of raffinose (g/100 g flour sample)				1.351		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.57		
Sample A3				0.835		
ΔA				0.265		
D-galactose concentration (g/L)				0.523		
% Recovery (internal standard)				101.140		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Dialium guineense*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.276	0.507	0.229
Weight of sample (g/l)				10.245		
Amount of sample weighed (g)/100 ml solution				1.0245		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.276		
Sample A2				0.507		
ΔA				0.229		
Raffinose concentration (g/l)				0.030		
Amount of raffinose (g/100 g flour sample)				0.290		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.507		
Sample A3				0.774		
ΔA				0.267		
D-galactose concentration (g/L)				0.527		
% Recovery (internal standard)				101.903		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.413	0.715	0.3
Weight of sample (g/l)				49.075		
Amount of sample weighed (g)/100 ml solution				4.9075		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.413		
Sample A2				0.715		
ΔA				0.3		
Raffinose concentration (g/l)				0.681		
Amount of raffinose (g/100 g flour sample)				1.387		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.715		
Sample A3				0.977		
ΔA				0.262		
D-galactose concentration (g/L)				0.517		
% Recovery (internal standard)				99.995		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.435	0.744	0.307
Weight of sample (g/l)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.435		
Sample A2				0.744		
ΔA				0.307		
Raffinose concentration (g/l)				0.697		
Amount of raffinose (g/100 g flour sample)				1.420		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.744		
Sample A3				1.015		
ΔA				0.271		
D-galactose concentration (g/L)				0.535		
% Recovery (internal standard)				103.430		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.368	0.669	0.299
Weight of sample (g/l)				49.032		
Amount of sample weighed (g)/100 ml solution				4.9032		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.368		
Sample A2				0.669		
ΔA				0.299		
Raffinose concentration (g/l)				0.407		
Amount of raffinose (g/100 g flour sample)				0.830		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.669		
Sample A3				0.937		
ΔA				0.268		
D-galactose concentration (g/L)				0.529		
% Recovery (internal standard)				102.285		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.324	0.475	0.149
Weight of sample (g/l)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.324		
Sample A2				0.475		
ΔA				0.149		
Raffinose concentration (g/l)				0.101		
Amount of raffinose (g/100 g flour sample)				0.207		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.475		
Sample A3				0.744		
ΔA				0.269		
D-galactose concentration (g/L)				0.531		
% Recovery (internal standard)				102.666		

Raffinose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.265	0.267		0.096	0.324	0.226
Weight of sample (g/l)				0.607		
Amount of sample weighed (g)/100 ml solution				0.0607		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.025		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.265		
Blank A2				0.267		
Sample A1				0.096		
Sample A2				0.324		
ΔA				0.226		
Raffinose concentration (g/l)				0.615		
Amount of raffinose (g/100 g flour sample)				101.372		
Addition of internal standard						
Weight of D-galactose (g/L)				0.517		
Amount of D-galactose weighed (g)/100 ml				0.0517		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.324		
Sample A3				0.597		
ΔA				0.273		
D-galactose concentration (g/L)				0.539		
% Recovery (internal standard)				104.193		

5C2: Sucrose concentration in raw legume flours

Sucrose concentration (g/100g flour) in raw legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.423	0.552	0.126
Weight of sample (g/L)				49.031		
Amount of sample weighed (g)/100 ml solution				4.9031		
Dilution of solution				4.9031g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.568		
Glucose sample A2				0.571		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.423		
Sucrose sample A2				0.552		
ΔA				0.126		
Sucrose concentration (g/L)				0.172		
Amount of sucrose (g/100 g) sample				1.406		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.522	0.66	0.136
Weight of sample (g/L)				49.062		
Amount of sample weighed (g)/100 ml solution				4.9062		
Dilution of solution				4.9062g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.612		
Glucose sample A2				0.614		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.522		
Sucrose sample A2				0.66		
ΔA				0.136		
Sucrose concentration (g/L)				0.186		
Amount of sucrose (g/100 g) sample				1.516		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.472	0.815	0.342
Weight of sample (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				4.9045g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.617		
Glucose sample A2				0.618		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.472		
Sucrose sample A2				0.815		
ΔA				0.342		
Sucrose concentration (g/L)				0.468		
Amount of sucrose (g/100 g) sample				3.814		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Dialium guineense*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.362	0.739	0.023
Weight of sample (g/L)				10.118		
Amount of sample weighed (g)/100 ml solution				1.0118		
Dilution of solution				1.0118g/100 ml//10ml/50ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.307		
Glucose blank A2				0.309		
Glucose sample A1				0.306		
Glucose sample A2				0.661		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.362		
Sucrose sample A2				0.739		
ΔA				0.023		
Sucrose concentration (g/L)				0.031		
Amount of sucrose (g/100 g) sample				1.554		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.456	0.683	0.224
Weight of sample (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				4.9034g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.723		
Glucose sample A2				0.726		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.456		
Sucrose sample A2				0.683		
ΔA				0.224		
Sucrose concentration (g/L)				0.306		
Amount of sucrose (g/100 g) sample				2.499		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.476	0.697	0.219
Weight of sample (g/L)				49.095		
Amount of sample weighed (g)/100 ml solution				4.9095		
Dilution of solution				4.9095g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.651		
Glucose sample A2				0.653		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.476		
Sucrose sample A2				0.697		
ΔA				0.219		
Sucrose concentration (g/L)				0.299		
Amount of sucrose (g/100 g) sample				2.440		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.411	0.522	0.101
Weight of sample (g/L)				49.054		
Amount of sample weighed (g)/100 ml solution				4.9054		
Dilution of solution				4.9054g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.431		
Glucose sample A2				0.435		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.411		
Sucrose sample A2				0.522		
ΔA				0.107		
Sucrose concentration (g/L)				0.146		
Amount of sucrose (g/100 g) sample				1.193		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.367	0.667	0.297
Weight of sample (g/L)				49.063		
Amount of sample weighed (g)/100 ml solution				4.9063		
Dilution of solution				4.9063g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.367		
Glucose blank A2				0.368		
Glucose sample A1				0.464		
Glucose sample A2				0.467		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.367		
Sucrose sample A2				0.667		
ΔA				0.297		
Sucrose concentration (g/L)				0.406		
Amount of sucrose (g/100 g) sample				3.311		

Sucrose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.373	1.178	0.527
Weight of sample (g/L)				2.145		
Amount of sample weighed (g)/100 ml solution				0.2145 g/100 ml		
Dilution of solution				0.2145g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.307		
Glucose blank A2				0.309		
Glucose sample A1				0.374		
Glucose sample A2				0.538		
Sucrose blank A1				0.312		
Sucrose blank A2				0.313		
Sucrose sample A1				0.373		
Sucrose sample A2				1.178		
ΔA				0.642		
Sucrose concentration (g/L)				0.527		
Amount of sucrose (g/100 g) sample				98.223		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.415	0.548	0.132
Weight of sample (g/L)				49.065		
Amount of sample weighed (g)/100 ml solution				4.9065		
Dilution of solution				4.9065g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.561		
Glucose sample A2				0.562		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.415		
Sucrose sample A2				0.548		
ΔA				0.132		
Sucrose concentration (g/L)				0.180		
Amount of sucrose (g/100 g) sample				1.471		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.445	0.79	0.341
Weight of sample (g/L)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				4.9056g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.567		
Glucose sample A2				0.569		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.516		
Sucrose sample A2				0.656		
ΔA				0.138		
Sucrose concentration (g/L)				0.189		
Amount of sucrose (g/100 g) sample				1.539		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.445	0.79	0.341
Weight of sample (g/L)				49.052		
Amount of sample weighed (g)/100 ml solution				4.9052		
Dilution of solution				4.9052g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.614		
Glucose sample A2				0.618		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.445		
Sucrose sample A2				0.79		
ΔA				0.341		
Sucrose concentration (g/L)				0.466		
Amount of sucrose (g/100 g) sample				3.802		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Dialium guineense*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.314	0.688	0.02
Weight of sample (g/L)				10.245		
Amount of sample weighed (g)/100 ml solution				1.0245		
Dilution of solution				1.0245g/100 ml//10ml/50ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.312		
Glucose blank A2				0.313		
Glucose sample A1				0.331		
Glucose sample A2				0.685		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.314		
Sucrose sample A2				0.688		
ΔA				0.02		
Sucrose concentration (g/L)				0.027		
Amount of sucrose (g/100 g) sample				1.335		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.472	0.681	0.206
Weight of sample (g/L)				49.075		
Amount of sample weighed (g)/100 ml solution				4.9075		
Dilution of solution				4.9075g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.712		
Glucose sample A2				0.715		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.472		
Sucrose sample A2				0.681		
ΔA				0.206		
Sucrose concentration (g/L)				0.282		
Amount of sucrose (g/100 g) sample				2.296		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.465	0.692	0.226
Weight of sample (g/L)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				4.9043g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.632		
Glucose sample A2				0.633		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.465		
Sucrose sample A2				0.692		
ΔA				0.226		
Sucrose concentration (g/L)				0.309		
Amount of sucrose (g/100 g) sample				2.520		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.397	0.516	0.115
Weight of sample (g/L)				49.032		
Amount of sample weighed (g)/100 ml solution				4.9032		
Dilution of solution				4.9032g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.416		
Glucose sample A2				0.42		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.397		
Sucrose sample A2				0.516		
ΔA				0.115		
Sucrose concentration (g/L)				0.157		
Amount of sucrose (g/100 g) sample				1.283		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.363	0.634	0.269
Weight of sample (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				4.9045g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.371		
Glucose blank A2				0.372		
Glucose sample A1				0.423		
Glucose sample A2				0.425		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.363		
Sucrose sample A2				0.634		
ΔA				0.269		
Sucrose concentration (g/L)				0.368		
Amount of sucrose (g/100 g) sample				3.000		

Sucrose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.308		0.367	1.172	0.534
Weight of sample (g/L)				2.158		
Amount of sample weighed (g)/100 ml solution				0.2158 g/100 ml		
Dilution of solution				0.2158g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.312		
Glucose blank A2				0.313		
Glucose sample A1				0.372		
Glucose sample A2				0.526		
Sucrose blank A1				0.307		
Sucrose blank A2				0.308		
Sucrose sample A1				0.367		
Sucrose sample A2				1.172		
ΔA				0.651		
Sucrose concentration (g/L)				0.534		
Amount of sucrose (g/100 g) sample				98.999		

5C3: D-glucose concentration (g/100g flour) in raw legume flours

D-glucose concentration (g/100g flour) in raw legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.327	0.453	0.139
Weight of sample (g/L)				49.031		
Amount of sample weighed (g)/100 ml solution				4.9031		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.15		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.327		
Sample A2				0.453		
ΔA				0.124		
Glucose concentration (g/L)				0.018		
Amount of glucose (g/100 g) sample				0.036		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.697	0.936	0.611
Weight of sample (g/L)				49.062		
Amount of sample weighed (g)/100 ml solution				4.9062		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.697		
Sample A2				0.936		
ΔA				0.237		
Glucose concentration (g/L)				0.017		
Amount of glucose (g/100 g) sample				0.035		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.308	0.831	0.521
Weight of sample (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.308		
Sample A2				0.831		
ΔA				0.521		
Glucose concentration (g/L)				0.025		
Amount of glucose (g/100 g) sample				0.051		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Dialium guineense*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.306	0.661	0.353
Weight of sample (g/L)				10.118		
Amount of sample weighed (g)/100 ml solution				1.0118		
Dilution of solution				1.0118g/100ml// 10ml/50ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.306		
Sample A2				0.661		
ΔA				0.353		
Glucose concentration (g/L)				0.254		
Amount of glucose (g/100 g) sample				12.554		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.512	0.743	0.229
Weight of sample (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.512		
Sample A2				0.743		
ΔA				0.229		
Glucose concentration (g/L)				0.011		
Amount of glucose (g/100 g) sample				0.022		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.421	0.934	0.511
Weight of sample (g/L)				49.095		
Amount of sample weighed (g)/100 ml solution				4.9095		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.421		
Sample A2				0.934		
ΔA				0.511		
Glucose concentration (g/L)				0.368		
Amount of glucose (g/100 g) sample				0.749		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.278	0.857	0.577
Weight of sample (g/L)				49.054		
Amount of sample weighed (g)/100 ml solution				4.9054		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.278		
Sample A2				0.857		
ΔA				0.577		
Glucose concentration (g/L)				0.028		
Amount of glucose (g/100 g) sample				0.056		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.283	0.757	0.472
Weight of sample (g/L)				49.063		
Amount of sample weighed (g)/100 ml solution				4.9063		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.283		
Sample A2				0.757		
ΔA				0.472		
Glucose concentration (g/L)				0.034		
Amount of glucose (g/100 g) sample				0.069		

D-glucose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.307	0.309		0.374	0.538	0.162
Weight of sample (g/L)				0.283		
Amount of sample weighed (g)/100 ml solution				0.0283 g /100 ml		
Dilution of solution				0.0283 g/100 ml// 25 ml/100 ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.307		
Blank A2				0.309		
Sample A1				0.374		
Sample A2				0.538		
ΔA				0.162		
Glucose concentration (g/L)				0.070		
Amount of glucose (g/100 g) sample				98.874		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.322	0.455	0.132
Weight of sample (g/L)				49.065		
Amount of sample weighed (g)/100 ml solution				4.9065		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.15		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.322		
Sample A2				0.455		
ΔA				0.132		
Glucose concentration (g/L)				0.019		
Amount of glucose (g/100 g) sample				0.039		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.528	0.781	0.452
Weight of sample (g/L)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.528		
Sample A2				0.781		
ΔA				0.252		
Glucose concentration (g/L)				0.018		
Amount of glucose (g/100 g) sample				0.037		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.311	0.818	0.506
Weight of sample (g/L)				49.052		
Amount of sample weighed (g)/100 ml solution				4.9052		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.311		
Sample A2				0.818		
ΔA				0.506		
Glucose concentration (g/L)				0.024		
Amount of glucose (g/100 g) sample				0.049		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Dialium guineense*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.331	0.685	0.353
Weight of sample (g/L)				10.245		
Amount of sample weighed (g)/100 ml solution				1.0245		
Dilution of solution				1.0245g/100ml//10ml/50ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.331		
Sample A2				0.685		
ΔA				0.353		
Glucose concentration (g/L)				0.254		
Amount of glucose (g/100 g) sample				12.399		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.562	0.813	0.25
Weight of sample (g/L)				49.075		
Amount of sample weighed (g)/100 ml solution				4.9075		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.562		
Sample A2				0.813		
ΔA				0.25		
Glucose concentration (g/L)				0.012		
Amount of glucose (g/100 g) sample				0.024		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.412	0.945	0.532
Weight of sample (g/L)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.412		
Sample A2				0.945		
ΔA				0.532		
Glucose concentration (g/L)				0.383		
Amount of glucose (g/100 g) sample				0.781		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.276	0.798	0.521
Weight of sample (g/L)				49.032		
Amount of sample weighed (g)/100 ml solution				4.9032		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.276		
Sample A2				0.798		
ΔA				0.521		
Glucose concentration (g/L)				0.025		
Amount of glucose (g/100 g) sample				0.051		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.283	0.826	0.542
Weight of sample (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.283		
Sample A2				0.826		
ΔA				0.542		
Glucose concentration (g/L)				0.039		
Amount of glucose (g/100 g) sample				0.080		

D-glucose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.312	0.313		0.372	0.526	0.153
Weight of sample (g/L)				0.273		
Amount of sample weighed (g)/100 ml solution				0.0273g /100 ml		
Dilution of solution				0.0273g/100ml// 25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.312		
Blank A2				0.313		
Sample A1				0.372		
Sample A2				0.526		
ΔA				0.153		
Glucose concentration (g/L)				0.066		
Amount of glucose (g/100 g) sample				96.802		

5C4: D-fructose concentration in raw legume flours

D-fructose concentration (g/100g flour) in raw legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.453	0.558	0.104
Weight of sample/litre (g/L)				49.031		
Amount of sample weighed (g)/100 ml solution				4.9031		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.15		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.453		
Sample A3				0.558		
ΔA				0.104		
Fructose concentration (g/L)				0.015		
Amount of fructose (g/100 sample)				0.031		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.558		
Sample A4				0.851		
ΔA for internal standard				0.293		
D-glucose concentration (g/L)				0.518		
% Recovery (Internal standard)				103.563		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.936	1.116	0.179
Weight of sample/litre (g/L)				49.062		
Amount of sample weighed (g)/100 ml solution				4.9062		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.936		
Sample A3				1.116		
ΔA				0.179		
Fructose concentration (g/L)				0.013		
Amount of fructose (g/100 sample)				0.026		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.116		
Sample A4				1.381		
ΔA for internal standard				0.265		
D-glucose concentration (g/L)				0.468		
% Recovery (Internal standard)				93.666		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.831	0.936	0.104
Weight of sample/litre (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.831		
Sample A3				0.936		
ΔA				0.104		
Fructose concentration (g/L)				0.005		
Amount of fructose (g/100 sample)				0.010		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.936		
Sample A4				1.216		
ΔA for internal standard				0.28		
D-glucose concentration (g/L)				0.495		
% Recovery (Internal standard)				98.968		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.743	0.93	0.186
Weight of sample/litre (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.743		
Sample A3				0.93		
ΔA				0.186		
Fructose concentration (g/L)				0.009		
Amount of fructose (g/100 sample)				0.018		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.93		
Sample A4				1.212		
ΔA for internal standard				0.282		
D-glucose concentration (g/L)				0.498		
% Recovery (Internal standard)				99.675		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.934	1.118	0.183
Weight of sample/litre (g/L)				49.095		
Amount of sample weighed (g)/100 ml solution				4.9095		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.934		
Sample A3				1.118		
ΔA				0.183		
Fructose concentration (g/L)				0.133		
Amount of fructose (g/100 sample)				0.270		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.118		
Sample A4				1.384		
ΔA for internal standard				0.266		
D-glucose concentration (g/L)				0.470		
% Recovery (Internal standard)				94.019		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.857	1.231	0.373
Weight of sample/litre (g/L)				49.054		
Amount of sample weighed (g)/100 ml solution				4.9054		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.857		
Sample A3				1.231		
ΔA				0.373		
Fructose concentration (g/L)				0.018		
Amount of fructose (g/100 sample)				0.037		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.231		
Sample A4				1.497		
ΔA for internal standard				0.266		
D-glucose concentration (g/L)				0.470		
% Recovery (Internal standard)				94.019		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.757	1.186	0.428
Weight of sample/litre (g/L)				49.063		
Amount of sample weighed (g)/100 ml solution				4.9063		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.757		
Sample A3				1.186		
ΔA				0.428		
Fructose concentration (g/L)				0.031		
Amount of fructose (g/100 sample)				0.063		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.186		
Sample A4				1.462		
ΔA for internal standard				0.276		
D-glucose concentration (g/L)				0.488		
% Recovery (Internal standard)				97.554		

D-fructose concentration (g/100g flour) in raw legume flours (first experiment) continued

	Blank			Positive control		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.31		0.512	0.873	0.36
Weight of sample/litre (g/L)				0.634		
Amount of sample weighed (g)/100 ml solution				0.0634 g/100ml		
Dilution of solution				0.0634 g/100 ml//25 ml/100 ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.512		
Sample A3				0.873		
ΔA				0.36		
Fructose concentration (g/L)				0.156		
Amount of fructose (g/100 sample)				98.727		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.873		
Sample A4				1.165		
ΔA for internal standard				0.292		
D-glucose concentration (g/L)				0.516		
% Recovery (Internal standard)				103.209		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment)

	Blank			*Dialium guineense*		
	A2	A3	ΔA	A2	A3	ΔA
	0.309	0.310		0.661	0.942	0.280
Weight of sample/litre (g/L)				10.118		
Amount of sample weighed (g)/100 ml solution				1.0118		
Dilution of solution				1.0118 g/100 ml//10 ml/50 ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.309		
Blank A3				0.31		
Sample A2				0.661		
Sample A3				0.942		
ΔA				0.28		
Fructose concentration (g/L)				0.203		
Amount of fructose (g/100 sample)				10.024		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.942		
Sample A4				1.223		
ΔA for internal standard				0.281		
D-glucose concentration (g/L)				0.497		
% Recovery (Internal standard)				99.321		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Cajanus cajan*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.455	0.566	0.11
Weight of sample/litre (g/L)				49.065		
Amount of sample weighed (g)/100 ml solution				4.9065		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.15		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.455		
Sample A3				0.566		
ΔA				0.11		
Fructose concentration (g/L)				0.016		
Amount of fructose (g/100 g sample)				0.032		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.566		
Sample A4				0.862		
ΔA for internal standard				0.296		
D-glucose concentration (g/L)				0.523		
% Recovery (Internal standard)				104.623		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.781	0.934	0.152
Weight of sample/litre (g/L)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.781		
Sample A3				0.934		
ΔA				0.152		
Fructose concentration (g/L)				0.011		
Amount of fructose (g/100 g sample)				0.022		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.934		
Sample A4				1.207		
ΔA for internal standard				0.273		
D-glucose concentration (g/L)				0.482		
% Recovery (Internal standard)				96.494		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.818	0.943	0.124
Weight of sample/litre (g/L)				49.052		
Amount of sample weighed (g)/100 ml solution				4.9052		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.818		
Sample A3				0.943		
ΔA				0.124		
Fructose concentration (g/L)				0.006		
Amount of fructose (g/100 g sample)				0.012		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.943		
Sample A4				1.228		
ΔA for internal standard				0.285		
D-glucose concentration (g/L)				0.504		
% Recovery (Internal standard)				100.735		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Dialium guineense*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.685	0.998	0.312
Weight of sample/litre (g/L)				10.245		
Amount of sample weighed (g)/100 ml solution				1.0245		
Dilution of solution				1.0245 g/100 ml//10 ml/50 ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.685		
Sample A3				0.998		
ΔA				0.312		
Fructose concentration (g/L)				0.226		
Amount of fructose (g/100 g sample)				11.031		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.998		
Sample A4				1.281		
ΔA for internal standard				0.283		
D-glucose concentration (g/L)				0.500		
% Recovery (Internal standard)				100.028		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.813	0.959	0.145
Weight of sample/litre (g/L)				49.075		
Amount of sample weighed (g)/100 ml solution				4.9075		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.813		
Sample A3				0.959		
ΔA				0.145		
Fructose concentration (g/L)				0.007		
Amount of fructose (g/100 g sample)				0.014		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.959		
Sample A4				1.245		
ΔA for internal standard				0.286		
D-glucose concentration (g/L)				0.505		
% Recovery (Internal standard)				101.089		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.945	1.112	0.166
Weight of sample/litre (g/L)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.945		
Sample A3				1.112		
ΔA				0.166		
Fructose concentration (g/L)				0.120		
Amount of fructose (g/100 g sample)				0.245		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.112		
Sample A4				1.379		
ΔA for internal standard				0.267		
D-glucose concentration (g/L)				0.472		
% Recovery (Internal standard)				94.373		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.798	1.213	0.414
Weight of sample/litre (g/L)				49.032		
Amount of sample weighed (g)/100 ml solution				4.9032		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.798		
Sample A3				1.213		
ΔA				0.414		
Fructose concentration (g/L)				0.020		
Amount of fructose (g/100 g sample)				0.041		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.213		
Sample A4				1.486		
ΔA for internal standard				0.273		
D-glucose concentration (g/L)				0.482		
% Recovery (Internal standard)				96.494		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.826	1.213	0.386
Weight of sample/litre (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.3		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.826		
Sample A3				1.213		
ΔA				0.386		
Fructose concentration (g/L)				0.028		
Amount of fructose (g/100 g sample)				0.057		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				1.213		
Sample A4				1.491		
ΔA for internal standard				0.278		
D-glucose concentration (g/L)				0.491		
% Recovery (Internal standard)				98.261		

D-fructose concentration (g/100g flour) in raw legume flours (second experiment) continued

	Blank			Positive control		
	A2	A3	ΔA	A2	A3	ΔA
	0.313	0.314		0.522	0.892	0.369
Weight of sample/litre (g/L)				0.662		
Amount of sample weighed (g)/100 ml solution				0.0662 g/100ml		
Dilution of solution				0.0662 g/100 ml//25 ml/100 ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.313		
Blank A3				0.314		
Sample A2				0.522		
Sample A3				0.892		
ΔA				0.369		
Fructose concentration (g/L)				0.160		
Amount of fructose (g/100 g sample)				96.915		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.892		
Sample A4				1.181		
ΔA for internal standard				0.289		
D-glucose concentration (g/L)				0.511		
% Recovery (Internal standard)				102.149		

5C5: Raffinose concentration (g/100g flour) in processed legume flours

Raffinose concentration (g/100g flour) in processed legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.336	0.492	0.154
Weight of sample (g/l)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.336		
Sample A2				0.492		
ΔA				0.154		
Raffinose concentration (g/l)				0.020		
Amount of raffinose (g/100 g flour sample)				0.041		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.492		
Sample A3				0.758		
ΔA				0.266		
D-galactose concentration (g/L)				0.525		
% Recovery (internal standard)				101.130		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.411	0.529	0.116
Weight of sample (g/l)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.411		
Sample A2				0.529		
ΔA				0.116		
Raffinose concentration (g/l)				0.015		
Amount of raffinose (g/100 g flour sample)				0.031		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.529		
Sample A3				0.797		
ΔA				0.268		
D-galactose concentration (g/L)				0.529		
% Recovery (internal standard)				101.891		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.423	0.56	0.135
Weight of sample (g/l)				49.057		
Amount of sample weighed (g)/100 ml solution				4.9057		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.423		
Sample A2				0.56		
ΔA				0.135		
Raffinose concentration (g/l)				0.092		
Amount of raffinose (g/100 g flour sample)				0.187		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.56		
Sample A3				0.831		
ΔA				0.271		
D-galactose concentration (g/L)				0.535		
% Recovery (internal standard)				103.031		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.52	0.671	0.149
Weight of sample (g/l)				49.067		
Amount of sample weighed (g)/100 ml solution				4.9067		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.52		
Sample A2				0.671		
ΔA				0.149		
Raffinose concentration (g/l)				0.101		
Amount of raffinose (g/100 g flour sample)				0.207		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.671		
Sample A3				0.937		
ΔA				0.266		
D-galactose concentration (g/L)				0.525		
% Recovery (internal standard)				101.130		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.423	0.708	0.283
Weight of sample (g/l)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.423		
Sample A2				0.708		
ΔA				0.283		
Raffinose concentration (g/l)				0.642		
Amount of raffinose (g/100 g flour sample)				1.309		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.708		
Sample A3				0.971		
ΔA				0.263		
D-galactose concentration (g/L)				0.519		
% Recovery (internal standard)				99.990		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.411	0.684	0.271
Weight of sample (g/l)				49.059		
Amount of sample weighed (g)/100 ml solution				4.9059		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.411		
Sample A2				0.684		
ΔA				0.271		
Raffinose concentration (g/l)				0.184		
Amount of raffinose (g/100 g flour sample)				0.376		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.684		
Sample A3				0.946		
ΔA				0.262		
D-galactose concentration (g/L)				0.517		
% Recovery (internal standard)				99.610		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.335	0.528	0.191
Weight of sample (g/l)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.335		
Sample A2				0.528		
ΔA				0.191		
Raffinose concentration (g/l)				0.025		
Amount of raffinose (g/100 g flour sample)				0.051		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.528		
Sample A3				0.795		
ΔA				0.267		
D-galactose concentration (g/L)				0.527		
% Recovery (internal standard)				101.510		

Raffinose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.261	0.263		0.094	0.323	
Weight of sample (g/l)				0.609		
Amount of sample weighed (g)/100 ml solution				0.0609		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.025		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.261		
Blank A2				0.263		
Sample A1				0.094		
Sample A2				0.323		
ΔA				0.227		
Raffinose concentration (g/l)				0.618		
Amount of raffinose (g/100 g flour sample)				101.486		
Addition of internal standard						
Weight of D-galactose (g/L)				0.519		
Amount of D-galactose weighed (g)/100 ml				0.0519		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.323		
Sample A3				0.597		
ΔA				0.274		
D-galactose concentration (g/L)				0.541		
% Recovery (internal standard)				104.172		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.339	0.48	0.139
Weight of sample (g/l)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.339		
Sample A2				0.48		
ΔA				0.139		
Raffinose concentration (g/l)				0.018		
Amount of raffinose (g/100 g flour sample)				0.037		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.48		
Sample A3				0.745		
ΔA				0.265		
D-galactose concentration (g/L)				0.523		
% Recovery (internal standard)				99.980		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.401	0.534	0.131
Weight of sample (g/l)				49.053		
Amount of sample weighed (g)/100 ml solution				4.9053		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.401		
Sample A2				0.534		
ΔA				0.131		
Raffinose concentration (g/l)				0.017		
Amount of raffinose (g/100 g flour sample)				0.035		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.534		
Sample A3				0.803		
ΔA				0.269		
D-galactose concentration (g/L)				0.531		
% Recovery (internal standard)				101.489		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.428	0.571	0.141
Weight of sample (g/l)				49.067		
Amount of sample weighed (g)/100 ml solution				4.9067		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.428		
Sample A2				0.571		
ΔA				0.141		
Raffinose concentration (g/l)				0.096		
Amount of raffinose (g/100 g flour sample)				0.196		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.571		
Sample A3				0.835		
ΔA				0.264		
D-galactose concentration (g/L)				0.521		
% Recovery (internal standard)				99.602		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.531	0.675	0.142
Weight of sample (g/l)				49.071		
Amount of sample weighed (g)/100 ml solution				4.9071		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.531		
Sample A2				0.675		
ΔA				0.142		
Raffinose concentration (g/l)				0.097		
Amount of raffinose (g/100 g flour sample)				0.197		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.675		
Sample A3				0.942		
ΔA				0.267		
D-galactose concentration (g/L)				0.527		
% Recovery (internal standard)				100.734		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.427	0.705	0.276
Weight of sample (g/l)				49.013		
Amount of sample weighed (g)/100 ml solution				4.9013		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.427		
Sample A2				0.705		
ΔA				0.276		
Raffinose concentration (g/l)				0.626		
Amount of raffinose (g/100 g flour sample)				1.278		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.705		
Sample A3				0.975		
ΔA				0.27		
D-galactose concentration (g/L)				0.533		
% Recovery (internal standard)				101.866		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.432	0.729	0.295
Weight of sample (g/l)				49.068		
Amount of sample weighed (g)/100 ml solution				4.9068		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.1		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.432		
Sample A2				0.729		
ΔA				0.295		
Raffinose concentration (g/l)				0.201		
Amount of raffinose (g/100 g flour sample)				0.409		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.729		
Sample A3				0.992		
ΔA				0.263		
D-galactose concentration (g/L)				0.519		
% Recovery (internal standard)				99.225		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.338	0.6	0.26
Weight of sample (g/l)				49.072		
Amount of sample weighed (g)/100 ml solution				4.9072		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.525		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.338		
Sample A2				0.6		
ΔA				0.26		
Raffinose concentration (g/l)				0.034		
Amount of raffinose (g/100 g flour sample)				0.069		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.6		
Sample A3				0.862		
ΔA				0.262		
D-galactose concentration (g/L)				0.517		
% Recovery (internal standard)				98.848		

Raffinose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.263	0.265		0.095	0.323	
Weight of sample (g/l)				0.606		
Amount of sample weighed (g)/100 ml solution				0.0606		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.025		
Total Volume at the end of reaction, V (ml)				0.85		
Blank A1				0.263		
Blank A2				0.265		
Sample A1				0.095		
Sample A2				0.323		
ΔA				0.226		
Raffinose concentration (g/l)				0.615		
Amount of raffinose (g/100 g flour sample)				101.540		
Addition of internal standard						
Weight of D-galactose (g/L)				0.523		
Amount of D-galactose weighed (g)/100 ml				0.0523		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.8625		
Sample A2				0.323		
Sample A3				0.597		
ΔA				0.274		
D-galactose concentration (g/L)				0.541		
% Recovery (internal standard)				103.375		

5C6: Sucrose concentration in processed legume flours

Sucrose concentration (g/100g flour) in processed legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.456	0.938	0.37
Weight of sample (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.16		
Glucose sample A1				0.421		
Glucose sample A2				0.534		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.456		
Sucrose sample A2				0.938		
ΔA				0.37		
Sucrose concentration (g/L)				0.038		
Amount of sucrose (g/100 g) sample				0.077		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.523	0.897	0.165
Weight of sample (g/L)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.16		
Glucose sample A1				0.547		
Glucose sample A2				0.757		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.523		
Sucrose sample A2				0.897		
ΔA				0.165		
Sucrose concentration (g/L)				0.015		
Amount of sucrose (g/100 g) sample				0.031		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.374	1.067	0.14
Weight of sample (g/L)				49.057		
Amount of sample weighed (g)/100 ml solution				4.9057		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.16		
Glucose sample A1				0.272		
Glucose sample A2				0.826		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.374		
Sucrose sample A2				1.067		
ΔA				0.14		
Sucrose concentration (g/L)				0.191		
Amount of sucrose (g/100 g) sample				0.390		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.527	1.365	0.691
Weight of sample (g/L)				49.067		
Amount of sample weighed (g)/100 ml solution				4.9067		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.16		
Glucose sample A1				0.543		
Glucose sample A2				0.691		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.527		
Sucrose sample A2				1.365		
ΔA				0.691		
Sucrose concentration (g/L)				0.063		
Amount of sucrose (g/100 g) sample				0.128		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.468	0.676	0.206
Weight of sample (g/L)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				4.9059 g/100 ml// 25 ml/100 ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.160		
Glucose sample A1				0.432		
Glucose sample A2				0.435		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.468		
Sucrose sample A2				0.676		
ΔA				0.206		
Sucrose concentration (g/L)				0.282		
Amount of sucrose (g/100 g) sample				2.297		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.311	0.873	0.283
Weight of sample (g/L)				49.059		
Amount of sample weighed (g)/100 ml solution				4.9059		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.16		
Glucose sample A1				0.453		
Glucose sample A2				0.733		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.311		
Sucrose sample A2				0.873		
ΔA				0.283		
Sucrose concentration (g/L)				0.029		
Amount of sucrose (g/100 g) sample				0.059		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.385	0.998	0.38
Weight of sample (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.2		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.16		
Glucose sample A1				0.387		
Glucose sample A2				0.621		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.385		
Sucrose sample A2				0.998		
ΔA				0.38		
Sucrose concentration (g/L)				0.078		
Amount of sucrose (g/100 g) sample				0.159		

Sucrose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.304	0.305		0.369	1.165	0.626
Weight of sample (g/L)				2.113		
Amount of sample weighed (g)/100 ml solution				0.2113 g/100 ml		
Dilution of solution				0.2113g/100 ml//25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.158		
Glucose blank A2				0.160		
Glucose sample A1				0.365		
Glucose sample A2				0.536		
Sucrose blank A1				0.304		
Sucrose blank A2				0.305		
Sucrose sample A1				0.369		
Sucrose sample A2				1.165		
ΔA				0.626		
Sucrose concentration (g/L)				0.514		
Amount of sucrose (g/100 g) sample				97.225		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.432	0.891	0.344
Weight of sample (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.489		
Glucose sample A2				0.605		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.432		
Sucrose sample A2				0.891		
ΔA				0.344		
Sucrose concentration (g/L)				0.035		
Amount of sucrose (g/100 g) sample				0.072		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.512	0.839	0.222
Weight of sample (g/L)				49.053		
Amount of sample weighed (g)/100 ml solution				4.9053		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.57		
Glucose sample A2				0.676		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.512		
Sucrose sample A2				0.839		
ΔA				0.222		
Sucrose concentration (g/L)				0.020		
Amount of sucrose (g/100 g) sample				0.041		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.376	1.041	0.115
Weight of sample (g/L)				49.067		
Amount of sample weighed (g)/100 ml solution				4.9067		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.264		
Glucose sample A2				0.815		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.376		
Sucrose sample A2				1.041		
ΔA				0.115		
Sucrose concentration (g/L)				0.157		
Amount of sucrose (g/100 g) sample				0.320		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.515	1.268	0.648
Weight of sample (g/L)				49.013		
Amount of sample weighed (g)/100 ml solution				4.9013		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.548		
Glucose sample A2				0.654		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.515		
Sucrose sample A2				1.268		
ΔA				0.648		
Sucrose concentration (g/L)				0.059		
Amount of sucrose (g/100 g) sample				0.121		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.465	0.647	0.181
Weight of sample (g/L)				49.068		
Amount of sample weighed (g)/100 ml solution				4.9068		
Dilution of solution				4.9068g/100ml// 25ml/100ml		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.427		
Glucose sample A2				0.429		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.465		
Sucrose sample A2				0.647		
ΔA				0.181		
Sucrose concentration (g/L)				0.247		
Amount of sucrose (g/100 g) sample				2.018		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.275	0.841	0.38
Weight of sample (g/L)				49.072		
Amount of sample weighed (g)/100 ml solution				4.9072		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.46		
Glucose sample A2				0.647		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.275		
Sucrose sample A2				0.841		
ΔA				0.38		
Sucrose concentration (g/L)				0.039		
Amount of sucrose (g/100 g) sample				0.079		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.382	0.951	0.429
Weight of sample (g/L)				49.072		
Amount of sample weighed (g)/100 ml solution				4.9072		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.2		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.375		
Glucose sample A2				0.516		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.382		
Sucrose sample A2				0.951		
ΔA				0.429		
Sucrose concentration (g/L)				0.088		
Amount of sucrose (g/100 g) sample				0.179		

Sucrose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.308	0.309		0.361	1.194	0.674
Weight of sample (g/L)				2.156		
Amount of sample weighed (g)/100 ml solution				0.2156 g/100 ml		
Dilution of solution				0.2156g/100ml//25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Glucose blank A1				0.303		
Glucose blank A2				0.305		
Glucose sample A1				0.368		
Glucose sample A2				0.528		
Sucrose blank A1				0.308		
Sucrose blank A2				0.309		
Sucrose sample A1				0.361		
Sucrose sample A2				1.194		
ΔA				0.674		
Sucrose concentration (g/L)				0.553		
Amount of sucrose (g/100 g) sample				102.592		

5C7: D-glucose concentration in processed legume flours

D-glucose concentration (g/100g flour) in processed legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.421	0.534	0.111
Weight of sample (g/L)				49.045		
Amount of sample weighed (g)/100 ml solution				4.9045		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.421		
Sample A2				0.534		
ΔA				0.111		
Glucose concentration (g/L)				0.006		
Amount of glucose (g/100 g) sample				0.012		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.547	0.757	0.208
Weight of sample (g/L)				49.043		
Amount of sample weighed (g)/100 ml solution				4.9043		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.547		
Sample A2				0.757		
ΔA				0.208		
Glucose concentration (g/L)				0.010		
Amount of glucose (g/100 g) sample				0.020		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.272	0.826	0.552
Weight of sample (g/L)				49.057		
Amount of sample weighed (g)/100 ml solution				4.9057		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.272		
Sample A2				0.826		
ΔA				0.552		
Glucose concentration (g/L)				0.397		
Amount of glucose (g/100 g) sample				0.810		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.543	0.691	0.146
Weight of sample (g/L)				49.067		
Amount of sample weighed (g)/100 ml solution				4.9067		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.543		
Sample A2				0.691		
ΔA				0.146		
Glucose concentration (g/L)				0.007		
Amount of glucose (g/100 g) sample				0.014		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.475	0.804	0.327
Weight of sample (g/L)				49.056		
Amount of sample weighed (g)/100 ml solution				4.9056		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.475		
Sample A2				0.804		
ΔA				0.327		
Glucose concentration (g/L)				0.235		
Amount of glucose (g/100 g) sample				0.480		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.453	0.733	0.278
Weight of sample (g/L)				49.059		
Amount of sample weighed (g)/100 ml solution				4.9059		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.453		
Sample A2				0.733		
ΔA				0.278		
Glucose concentration (g/L)				0.015		
Amount of glucose (g/100 g) sample				0.031		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.387	0.621	0.232
Weight of sample (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.2		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.387		
Sample A2				0.621		
ΔA				0.232		
Glucose concentration (g/L)				0.025		
Amount of glucose (g/100 g) sample				0.051		

D-glucose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.158	0.16		0.365	0.536	0.169
Weight of sample (g/L)				0.287		
Amount of sample weighed (g)/100 ml solution				0.0287g /100ml		
Dilution of solution				0.0287g/100ml//25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.158		
Blank A2				0.16		
Sample A1				0.365		
Sample A2				0.536		
ΔA				0.169		
Glucose concentration (g/L)				0.073		
Amount of glucose (g/100 g) sample				101.709		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.489	0.605	0.114
Weight of sample (g/L)				49.034		
Amount of sample weighed (g)/100 ml solution				4.9034		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.489		
Sample A2				0.605		
ΔA				0.114		
Glucose concentration (g/L)				0.006		
Amount of glucose (g/100 g) sample				0.013		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.57	0.676	0.104
Weight of sample (g/L)				49.053		
Amount of sample weighed (g)/100 ml solution				4.9053		
Dilution of solution				no dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.57		
Sample A2				0.676		
ΔA				0.104		
Glucose concentration (g/L)				0.005		
Amount of glucose (g/100 g) sample				0.010		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.264	0.815	0.549
Weight of sample (g/L)				49.067		
Amount of sample weighed (g)/100 ml solution				4.9067		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.264		
Sample A2				0.815		
ΔA				0.549		
Glucose concentration (g/L)				0.395		
Amount of glucose (g/100 g) sample				0.805		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.548	0.654	0.104
Weight of sample (g/L)				49.071		
Amount of sample weighed (g)/100 ml solution				4.9071		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.548		
Sample A2				0.654		
ΔA				0.104		
Glucose concentration (g/L)				0.005		
Amount of glucose (g/100 g) sample				0.010		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.456	0.765	0.307
Weight of sample (g/L)				49.013		
Amount of sample weighed (g)/100 ml solution				4.9013		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.456		
Sample A2				0.765		
ΔA				0.307		
Glucose concentration (g/L)				0.221		
Amount of glucose (g/100 g) sample				0.451		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.46	0.647	0.185
Weight of sample (g/L)				49.068		
Amount of sample weighed (g)/100 ml solution				4.9068		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.46		
Sample A2				0.647		
ΔA				0.185		
Glucose concentration (g/L)				0.010		
Amount of glucose (g/100 g) sample				0.020		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.375	0.516	0.139
Weight of sample (g/L)				49.072		
Amount of sample weighed (g)/100 ml solution				4.9072		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.2		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.375		
Sample A2				0.516		
ΔA				0.139		
Glucose concentration (g/L)				0.015		
Amount of glucose (g/100 g) sample				0.031		

D-glucose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			Positive control		
	A1	A2	ΔA	A1	A2	ΔA
	0.303	0.305		0.368	0.528	0.158
Weight of sample (g/L)				0.275		
Amount of sample weighed (g)/100 ml solution				0.0275 g/100ml		
Dilution of solution				0.0275g/100ml//25ml/100ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.755		
Blank A1				0.303		
Blank A2				0.305		
Sample A1				0.368		
Sample A2				0.528		
ΔA				0.158		
Glucose concentration (g/L)				0.068		
Amount of glucose (g/100 g) sample				99.238		

5C8: D-fructose concentration in processed legume flours

D-fructose concentration (g/100g flour) in processed legume flours (first experiment)

	Blank			*Cajanus cajan*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.534	0.657	0.11
Weight of sample/litre (g/L)				49.045		
Amount of sample weighed (g)/50 ml solution				4.9045		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.534		
Sample A3				0.657		
ΔA				0.122		
Fructose concentration (g/L)				0.007		
Amount of fructose (g/100 g sample)				0.014		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.657		
Sample A4				0.938		
ΔA for internal standard				0.281		
D-glucose concentration (g/L)				0.497		
% Recovery (Internal standard)				99.321		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia ensiformis*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.757	0.959	0.201
Weight of sample/litre (g/L)				49.043		
Amount of sample weighed (g)/50 ml solution				4.9043		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.757		
Sample A3				0.959		
ΔA				0.201		
Fructose concentration (g/L)				0.010		
Amount of fructose (g/100 g sample)				0.020		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.959		
Sample A4				1.235		
ΔA for internal standard				0.276		
D-glucose concentration (g/L)				0.488		
% Recovery (Internal standard)				97.554		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Canavalia gladiata*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.826	0.937	0.11
Weight of sample/litre (g/L)				49.057		
Amount of sample weighed (g)/50 ml solution				4.9057		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.826		
Sample A3				0.937		
ΔA				0.11		
Fructose concentration (g/L)				0.080		
Amount of fructose (g/100 g sample)				0.162		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.937		
Sample A4				1.217		
ΔA for internal standard				0.28		
D-glucose concentration (g/L)				0.495		
% Recovery (Internal standard)				98.968		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Mucuna pruriens*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.691	0.796	0.104
Weight of sample/litre (g/L)				49.067		
Amount of sample weighed (g)/50 ml solution				4.9067		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.691		
Sample A3				0.796		
ΔA				0.104		
Fructose concentration (g/L)				0.005		
Amount of fructose (g/100 g sample)				0.010		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.796		
Sample A4				1.074		
ΔA for internal standard				0.278		
D-glucose concentration (g/L)				0.491		
% Recovery (Internal standard)				98.261		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Parkia biglobosa*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.804	0.947	0.142
Weight of sample/litre (g/L)				49.056		
Amount of sample weighed (g)/50 ml solution				4.9056		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.804		
Sample A3				0.947		
ΔA				0.142		
Fructose concentration (g/L)				0.103		
Amount of fructose (g/100 g sample)				0.210		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.947		
Sample A4				1.214		
ΔA for internal standard				0.267		
D-glucose concentration (g/L)				0.472		
% Recovery (Internal standard)				94.373		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Phaseolus lunatus*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.733	0.936	0.202
Weight of sample/litre (g/L)				49.059		
Amount of sample weighed (g)/50 ml solution				4.9059		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.733		
Sample A3				0.936		
ΔA				0.202		
Fructose concentration (g/L)				0.011		
Amount of fructose (g/100 g sample)				0.022		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.936		
Sample A4				1.208		
ΔA for internal standard				0.272		
D-glucose concentration (g/L)				0.481		
% Recovery (Internal standard)				96.140		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			*Vigna subterranea*		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.621	0.778	0.157
Weight of sample/litre (g/L)				49.034		
Amount of sample weighed (g)/50 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.2		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.621		
Sample A3				0.778		
ΔA				0.156		
Fructose concentration (g/L)				0.017		
Amount of fructose (g/100 g sample)				0.035		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.778		
Sample A4				1.046		
ΔA for internal standard				0.268		
D-glucose concentration (g/L)				0.474		
% Recovery (Internal standard)				94.726		

D-fructose concentration (g/100g flour) in processed legume flours (first experiment) continued

	Blank			Positive control		
	A2	A3	ΔA	A2	A3	ΔA
	0.16	0.161		0.534	0.915	0.38
Weight of sample/litre (g/L)				0.658		
Amount of sample weighed (g)/50 ml solution				0.0658 g/100ml		
Dilution of solution				0.0658 g/100 ml//25 ml/100 ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.16		
Blank A3				0.161		
Sample A2				0.534		
Sample A3				0.915		
ΔA				0.38		
Fructose concentration (g/L)				0.165		
Amount of fructose (g/100 g sample)				100.410		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.915		
Sample A4				1.212		
ΔA for internal standard				0.297		
D-glucose concentration (g/L)				0.525		
% Recovery (Internal standard)				104.977		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment)

	Blank			*Cajanus cajan*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.605	0.716	0.11
Weight of sample/litre (g/L)				49.034		
Amount of sample weighed (g)/50 ml solution				4.9034		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.605		
Sample A3				0.716		
ΔA				0.11		
Fructosee concentration (g/L)				0.006		
Amount of fructose (g/100 g sample)				0.012		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.716		
Sample A4				0.994		
ΔA for internal standard				0.278		
D-glucose concentration (g/L)				0.491		
% Recovery (Internal standard)				98.261		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia ensiformis*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.676	0.843	0.166
Weight of sample/litre (g/L)				49.053		
Amount of sample weighed (g)/50 ml solution				4.9053		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.676		
Sample A3				0.843		
ΔA				0.166		
Fructosee concentration (g/L)				0.008		
Amount of fructose (g/100 g sample)				0.016		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.843		
Sample A4				1.121		
ΔA for internal standard				0.278		
D-glucose concentration (g/L)				0.491		
% Recovery (Internal standard)				98.261		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Canavalia gladiata*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.815	0.925	0.109
Weight of sample/litre (g/L)				49.067		
Amount of sample weighed (g)/50 ml solution				4.9067		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.815		
Sample A3				0.925		
ΔA				0.109		
Fructosee concentration (g/L)				0.079		
Amount of fructose (g/100 g sample)				0.161		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.925		
Sample A4				1.211		
ΔA for internal standard				0.286		
D-glucose concentration (g/L)				0.505		
% Recovery (Internal standard)				101.089		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Mucuna pruriens*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.654	0.779	0.124
Weight of sample/litre (g/L)				49.071		
Amount of sample weighed (g)/50 ml solution				4.9071		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.45		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.654		
Sample A3				0.779		
ΔA				0.124		
Fructosee concentration (g/L)				0.006		
Amount of fructose (g/100 g sample)				0.012		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.779		
Sample A4				1.054		
ΔA for internal standard				0.275		
D-glucose concentration (g/L)				0.486		
% Recovery (Internal standard)				97.201		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Parkia biglobosa*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.765	0.901	0.135
Weight of sample/litre (g/L)				49.013		
Amount of sample weighed (g)/50 ml solution				4.9013		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.03		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.765		
Sample A3				0.901		
ΔA				0.135		
Fructosee concentration (g/L)				0.098		
Amount of fructose (g/100 g sample)				0.200		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.901		
Sample A4				1.181		
ΔA for internal standard				0.28		
D-glucose concentration (g/L)				0.495		
% Recovery (Internal standard)				98.968		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Phaseolus lunatus*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.647	0.832	0.184
Weight of sample/litre (g/L)				49.068		
Amount of sample weighed (g)/50 ml solution				4.9068		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.4		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.647		
Sample A3				0.832		
ΔA				0.184		
Fructosee concentration (g/L)				0.010		
Amount of fructose (g/100 g sample)				0.020		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.832		
Sample A4				1.118		
ΔA for internal standard				0.286		
D-glucose concentration (g/L)				0.505		
% Recovery (Internal standard)				101.089		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			*Vigna subterranea*		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.306		0.516	0.655	0.138
Weight of sample/litre (g/L)				49.072		
Amount of sample weighed (g)/50 ml solution				4.9072		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.2		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.516		
Sample A3				0.655		
ΔA				0.138		
Fructosee concentration (g/L)				0.015		
Amount of fructose (g/100 g sample)				0.031		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.655		
Sample A4				0.936		
ΔA for internal standard				0.281		
D-glucose concentration (g/L)				0.497		
% Recovery (Internal standard)				99.321		

D-fructose concentration (g/100g flour) in processed legume flours (second experiment) continued

	Blank			Positive control		
	A2	A3	ΔA	A2	A3	ΔA
	0.305	0.31		0.522	0.887	0.36
Weight of sample/litre (g/L)				0.615		
Amount of sample weighed (g)/50 ml solution				0.0615 g/100 ml		
Dilution of solution				0.0615 g/100 ml//25 ml/100 ml		
Volume of sample solution, v (ml)				0.05		
Total Volume at the end of reaction, V (ml)				0.76		
Blank A2				0.305		
Blank A3				0.306		
Sample A2				0.522		
Sample A3				0.887		
ΔA				0.364		
Fructosee concentration (g/L)				0.158		
Amount of fructose (g/100 g sample)				102.908		
Addition of internal standard						
Weight of D-glucose (g/L)				0.5		
Dilution of solution				No dilution		
Volume of sample solution, v (ml)				0.0125		
Total Volume at the end of reaction, V (ml)				0.7725		
Sample A3				0.887		
Sample A4				1.178		
ΔA for internal standard				0.291		
D-glucose concentration (g/L)				0.514		
% Recovery (Internal standard)				102.856		

5D: Ash and mineral nutrients concentrations in legume flours

5D1: Ash content of legume flours

Legume flour	Ash content of flour (mg/100g)		
	1	2	3
Cajanus cajan (raw)	3508.67	3776.84	4110.60
Cajanus cajan (processed)	2395.57	2452.65	2489.71
Canavalia ensiformis (raw)	2680.75	2707.14	2905.41
Canavalia ensiformis (processed)	2039.59	2086.23	2116.78
Canavalia gladiata (raw)	2530.16	2596.43	2754.47
Canavalia gladiata (processed)	2304.72	2361.35	2454.54
Dialium guineense (raw)	1475.87	1455.29	1679.22
Mucuna pruriens (raw)	3161.93	3245.51	3417.21
Mucuna pruriens (processed)	2520.52	2508.36	2599.01
Parkia biglobosa (raw)	5601.45	5534.16	5531.77
Parkia biglobosa (processed)	6198.48	7000.68	6076.78
Phaseolus lunatus (raw)	3336.45	3317.79	3813.60
Phaseolus lunatus (processed)	2367.25	2445.84	2654.83
Vigna subterranea (raw)	3015.93	3073.93	3341.54
Vigna subterranea (processed)	2173.87	2209.80	2392.91

5D2: Mineral nutrients concentrations of legume flours

Calcium

Legume flour	Calcium concentration (mg/100g flour) 1	2	3
Cajanus cajan (raw)	141.84	127.95	139.05
Cajanus cajan (processed)	176.88	165.76	160.72
Canavalia ensiformis (raw)	162.06	147.91	155.9
Canavalia ensiformis (processed)	164.3	156.85	156.65
Canavalia gladiata (raw)	83.02	78.67	76.79
Canavalia gladiata (processed)	101.04	98.73	96.13
Mucuna pruriens (raw)	134.88	124,49	128,63
Mucuna pruriens (processed)	121.53	115.49	109.56
Parkia biglobosa (raw)	570,57	551,65	554.84
Parkia biglobosa (processed)	483.91	492.15	492.15
Phaseolus lunatus (raw)	76.07	75.22	70.19
Phaseolus lunatus (processed)	72.82	67.45	66.36
Vigna subterranea (raw)	52.86	49.93	47.65
Vigna subterranea (processed)	49.55	45.2	44.61
Dailium guineense (raw)	52.66	50.69	49.08

Magnesium

Legume flour	Magnesium concentration (mg/100g flour) 1	2	3
Cajanus cajan (raw)	109.61	101.76	108.27
Cajanus cajan (processed)	93.19	87.32	87.51
Canavalia ensiformis (raw)	114.29	108.55	108.97
Canavalia ensiformis (processed)	93.35	93.12	91.18
Canavalia gladiata (raw)	94.00	92.31	91.36
Canavalia gladiata (processed)	91.35	91.93	90.10
Mucuna pruriens (raw)	114.29	111.34	111.62
Mucuna pruriens (processed)	95.39	93.08	91.35
Parkia biglobosa (raw)	272.91	269.61	258.76
Parkia biglobosa (processed)	269.92	268.19	267.96
Phaseolus lunatus (raw)	108.18	106.53	103.42
Phaseolus lunatus (processed)	81.10	73.52	72.92
Vigna subterranea (raw)	174.14	138.89	137.97
Vigna subterranea (processed)	100.33	98.78	98.53
Dailium guineense (raw)	26.68	26.70	28.23

Sodium

Legume flour	Sodium concentration (mg/100 g flour) 1	2	3
Cajanus cajan (raw)	0.63	0.50	0.70
Cajanus cajan (processed)	6,83	6,27	6,07
Canavalia ensiformis (raw)	2.21	1.47	1.69
Canavalia ensiformis (processed)	7.08	6.57	6.30
Canavalia gladiata (raw)	< LOQ	< LOQ	< LOQ
Canavalia gladiata (processed)	2.98	2.67	2.55
Mucuna pruriens (raw)	3.18	2.66	2.71
Mucuna pruriens (processed)	4.83	4.43	4.14
Parkia biglobosa (raw)	19.48	18.00	17.37
Parkia biglobosa (processed)	19.70	19.76	17.32
Phaseolus lunatus (raw)	0.52	< LOQ	< LOQ
Phaseolus lunatus (processed)	3.41	2.98	2.77
Vigna subterranea (raw)	4.14	1.33	0.71
Vigna subterranea (processed)	2.82	2.52	2.43
Dialium guineense (raw)	3.69	3.50	3.14

Potassium

Legume flour	Potassium concentration (mg/100 g flour) 1	2	3
Cajanus cajan (raw)	1604.18	1450.08	1522.81
Cajanus cajan (processed)	886.54	836.99	845.16
Canavalia ensiformis (raw)	1117.76	1075.67	1264.82
Canavalia ensiformis (processed)	715.78	688.33	693.84
Canavalia gladiata (raw)	1082.27	998.11	1005.50
Canavalia gladiata (processed)	909.34	873.36	890.24
Mucuna pruriens (raw)	1180.91	1149.05	1345.13
Mucuna pruriens (processed)	942.53	911.32	959.01
Parkia biglobosa (raw)	1067.14	947.56	1075.51
Parkia biglobosa (processed)	1044.14	1088.68	1064.36
Phaseolus lunatus (raw)	1342.13	1299.72	1309.34
Phaseolus lunatus (processed)	936.29	898.14	912.14
Vigna subterranea (raw)	1226.79	1191.48	1219.23
Vigna subterranea (processed)	803.82	786.52	838.97
Dialium guineense (raw)	580.50	577.41	639.45

Iron

Legume flour	Iron concentration (mg/100g flour) 1	2	3
Cajanus cajan (raw)	4.36	4.49	4.82
Cajanus cajan (processed)	6.11	5.57	5.47
Canavalia ensiformis (raw)	3.22	3.26	3.33
Canavalia ensiformis (processed)	4.05	4.44	4.32
Canavalia gladiata (raw)	2.68	3.19	2.62
Canavalia gladiata (processed)	6.11	6.29	6.45
Mucuna pruriens (raw)	7.08	7.38	7.25
Mucuna pruriens (processed)	6.36	6.58	6.83
Parkia biglobosa (raw)	271.44	346.92	328.48
Parkia biglobosa (processed)	346.21	637.73	491.96
Phaseolus lunatus (raw)	4.55	4.61	4.50
Phaseolus lunatus (processed)	4.96	6.46	5.48
Vigna subterranea (raw)	2.95	3.23	2.90
Vigna subterranea (processed)	3.21	3.21	3.17
Dialium guineense (raw)	3.20	3.16	2.96

Copper

Legume flour	Copper concentration (mg/100g flour) 1	2	3
Cajanus cajan (raw)	1.41	1.21	1.29
Cajanus cajan (processed)	1.28	0.94	1.19
Canavalia ensiformis (raw)	0.79	0.60	0.69
Canavalia ensiformis (processed)	0.74	0.66	0.70
Canavalia gladiata (raw)	0.62	0.51	0.59
Canavalia gladiata (processed)	0.69	0.59	0.63
Mucuna pruriens (raw)	2.05	1.71	1.93
Mucuna pruriens (processed)	2.05	1.72	1.93
Parkia biglobosa (raw)	1.32	1.17	1.08
Parkia biglobosa (processed)	1.34	1.17	1.16
Phaseolus lunatus (raw)	0.42	0.32	0.36
Phaseolus lunatus (processed)	0.42	0.36	0.38
Vigna subterranea (raw)	0.49	0.51	0.51
Vigna subterranea (processed)	0.52	0.48	0.51
Dialium guineense (raw)	1.07	0.83	0.86

Manganese

Legume flour	Manganese concentration (mg/100g flour) 1	2	3
Cajanus cajan (raw)	1.45	1.45	1.47
Cajanus cajan (processed)	1.56	1.63	1.52
Canavalia ensiformis (raw)	0.89	0.83	0.86
Canavalia ensiformis (processed)	0.86	0.90	0.84
Canavalia gladiata (raw)	1.16	1.19	1.03
Canavalia gladiata (processed)	1.08	1.05	1.02
Mucuna pruriens (raw)	2.12	2.05	2.09
Mucuna pruriens (processed)	2.38	2.41	2.33
Parkia biglobosa (raw)	13.97	14.38	14.25
Parkia biglobosa (processed)	15.77	15.40	14.95
Phaseolus lunatus (raw)	1.74	1.68	1.66
Phaseolus lunatus (processed)	1.47	1.45	1.47
Vigna subterranea (raw)	1.26	1.26	1.32
Vigna subterranea (processed)	1.18	1.14	1.20
Dialium guineense (raw)	5.18	4.85	5.17

Zinc

Legume flour	Zinc concentration (mg/100g flour) 1	2	3
Cajanus cajan (raw)	3.83	4.11	3.90
Cajanus cajan (processed)	3.68	4.14	3.80
Canavalia ensiformis (raw)	1.54	1.66	1.60
Canavalia ensiformis (processed)	1.65	2.03	1.74
Canavalia gladiata (raw)	1.97	1.72	1.60
Canavalia gladiata (processed)	1.96	2.73	2.94
Mucuna pruriens (raw)	2.69	3.14	3.15
Mucuna pruriens (processed)	3.75	3.50	3.23
Parkia biglobosa (raw)	2.66	3.53	3.56
Parkia biglobosa (processed)	2.84	4.13	3.54
Phaseolus lunatus (raw)	1.77	2.07	2.04
Phaseolus lunatus (processed)	1.77	2.14	2.04
Vigna subterranea (raw)	1.65	2.31	2.12
Vigna subterranea (processed)	3.88	3.99	4.04
Dialium guineense (raw)	0.49	0.74	0.65

5E: Amount of cyanide bound in legume flours

5E1: Amount of cyanide in raw legume flours (Titer = 0.9577)

Legume flour	V($AgNO_3$) in ml	Blank (BV) in ml	n(CN) in µmol	Weighed flour g	µmol CN/100 g Flour
Cajanus Cajan					
1	0.84	0.50	6.51	15.0720	43.19
2	0.73	0.54	3.64	15.1658	24.00
3	0.31	0.36	< BV	15.1492	0
Canavalia ensiformis					
1	0.48	0.36	2.30	15.1354	15.20
2	0.46	0.42	0.77	15.0970	5.10
3	0.84	0.58	4.98	15.1070	32.96
Dialium guineese					
1	0.76	0.36	7.66	15.0233	50.99
2	0.72	0.42	5.75	15.1015	38.08
3	0.70	0.58	2.30	15.2017	15.13
Canavalia gladiata					
1	1.08	0.36	13.79	15.0288	91.76
2	0.71	0.42	5.55	15.1153	36.72
3	1.11	0.58	10.15	15.1578	66.96
Mucuna pruriens					
1	0.50	0.50	< BV	15.1404	0
2	0.40	0.54	< BV	15.1050	0
3	0.40	0.36	0.77	15.0297	5.12
Vigna subterranea					
1	1.56	0.50	20.30	15.1005	134.43
2	1.66	0.54	21.45	15.0341	142.68
3	0.86	0.36	9.56	15.3842	62.14
Phaseolus lunatus					
1	0.50	0.50	< BV	15.0034	0
2	0.58	0.54	0.77	15.2628	5.04
3	0.56	0.36	3,83	15.0996	25.36
Parkia biglobosa					
1	0.84	0.42	8.04	15.0510	53.42
2	0.80	0.58	4.21	15.0396	27.99
3	0.38	0.38	< BV	15.0742	0

5E2: Amount of cyanide in processed legume flours

Legume flour	V($AgNO_3$) in ml	Blank value (BV) in ml	n(CN) in µmol	Weighed flour in g	µmol CN/ 100 g flour
Cajanus Cajan					
1	0.62	0.62	= BV	15.1614	0
2	0.42	0.22	< BV	15.2058	0
Canavalia ensiformis					
1	0.38	0.40	0.38	15.3763	2.47
2	0.60	0.54	1.19	15.3240	7.77
Canavalia gladiata					
1	1.08	0.36	13.79	15.0288	0
2	0.71	0.42	5.55	15.1153	10.20
Mucuna pruriens					
1	0.62	0.36	< BV	15.2456	0
2	0.54	0.21	< BV	15.3107	0
Vigna subterranea					
1	0.62	0.62	= BV	15.0074	0
2	0.54	0.42	2.39	15.0195	15.91
Phaseolus lunatus					
1	0.66	0.62	0.77	15.3166	5.03
2	0.40	0.42	< BV	15.6733	0
Parkia biglobosa					
1	0.36	0.38	< BV	15.4848	0
2	0.52	0.54	< BV	15.0626	0