CHEMICAL COMPOSITION AND FUNCTIONAL PROPERTIES OF AFRICAN LOCUST BEAN PULP FLOUR AND WHEAT FLOURS

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Abstract: Flour was prepared from African locust bean pulp. The pulp flour and wheat flour were evaluated for chemical composition and functional properties. The locust bean pulp flour (LBPF) and wheat flour (WF) contained 2.7 and 10.5% protein contents, respectively. The LBPF had higher levels of ash (2.9%), crude fiber (2.7%) and carbohydrates (80.8%) than wheat flour. The LBPF and wheat flour contained 10 % moisture each. The ash, crude fiber and carbohydrate contents of WF were 0.8, 0.2 and 76.5%, respectively. Similarly, the LBPF contained significantly ($p<0.05$) higher amounts of total sugars, reducing sugars, glucose and fructose than wheat flour. The levels of vitamin B_1, B2 and C in LBPF were 121, 16 and 34 mg/100 g, respectively. The wheat flour contained 0.65, 0.23 and 0.8 mg/100g vitamins B_1, B_2, and C, respectively. Citric and malic acids were more dominant in LBPF than in wheat flour. The LBPF contained 412, 764, 113, 170, 27 and 42 mg/100g P, K, Mg, Na, Ca and Fe, respectively. The P, K, Mg, Na, Ca and Fe contents of wheat flour were 180, 145, 65, 3.1,18 and 3.0 mg/100g, respectively. However, wheat flour (2.0 mg/100g) had significantly ($p<0.05$) higher Zn content than wheat flour (0.8 mg/100g). The water absorption capacities of LBPF and wheat flour were 380 and 106 %, respectively, The LBPF (257%) had significantly ($p<0.05$) higher oil absorption capacity than wheat flour (156%). The wheat flour had significantly higher ($p<0.05$) foaming capacity (35.1%), foam stability (75%), emulsion activity (25%),emulsion stability (20.5%) and bulk density (0.64 g/cm3) than LBPF. The foaming capacity, foam stability, emulsion activity, emulsion stability and bulk density of LBPF were 11.3, 61.9, 14.3, 13.0 5% and 0.28 g/cm^3, respectively.The foaming capacity and foam stability increased with increase in the concentration of LBPF.

Keywords: Functional properties, locust bean pulp, wheat flour, proximate composition.

Introduction

In Nigeria, African locust bean (*Parkia biglobosa*) tree grows widely throughout the savanna. The tree produces about 25-52 kg of pods (Akoma *et al*., 2001). A mature pod contains yellow, dry and powdery pulp in which dark brown seeds are embedded. The pulp is licked for its sweet taste but only to a small extent. The pulp is usually washed away when the seeds are processed into condiment called *dawadawa* or *iru*. *Dawadawa* is a source of protein intake among the low income groups and rural populations of West Africa. While the seed has been extensively studied (Addy *et al*., 1995), little has been done on the utilization of the pulp. In West Africa, the pulp is prepared as flour and used in soups and stews or eaten with cereals as porridge (Omauvbe *at al*., 2004). A traditional drink is prepared from the fruit by infusing the dried ground fruit pulp in hot water. This drink is widely consumed as health tonic and is valued for its many medicinal properties (Akoma *et al.*, 2001). Products processed from locust bean pulp on experimental basis include jam and syrup (Akubor, 2007).

Locust bean pulp is rich in dietary fiber, essential vitamins, minerals and phytochemicals such as flavonoids, phenols, carotenoids among others (Gernah, 2007). Phytochemicals provide health benefits due to risk reduction of chronic illness such as cancer and cardiovascular diseases. Thus, more food phytochemicals are required from conventional and new sources. There is the need to identify local sources of phytochemicals and enhance their levels through food processing and product development.

Due to its high contents of phytochemicals, vitamins and minerals (Akubor, 2007), locust bean pulp could be processed into flour and potentially used in similar ways to efforts reported on other flours. However, the use of locust bean pulp flour will depend on the knowledge of its chemical composition and functional properties. The objective of the study was to determine the chemical composition and selected functional properties of locust bean pulp flour in comparison with those of wheat flour.

Materials and Methods

Source of materials

Mature and ripe African locust bean (*Parkia biglobosa*) fruit pods were plucked from locust bean trees in a local farm in Ugwaka –Ollah Township, Kogi State, Nigeria. Commercial wheat flour was purchased from a local shop in Idah Township, sieved through 60 mesh sieve (0.05mm) and stored in high density polyethylene (HDPE) bag in deep freezer prior to use.

Preparation of locust bean pulp flour

The locust bean fruit pods were cleaned and split open manually. The yellow pulp along with the attached seeds were removed from the hulls, sun dried for 48hand pounded lightly in a mortar with pestle. The pulps were separated from the seeds, milled in a hammer mill and sieved through 60 mesh sieve (British standard). The flour was packed in high density polyethylene (HDPE) bags and stored in a refrigerator prior to use.

Evaluation of chemical composition

Moisture was determined by hot air oven drying at 105^{o}C to constant weight (AOAC, 2010). Ash, protein (micro-Kjeldahl, N x 6.25), crude fiber and crude fat (solvent extraction) were determined by the AOAC (2010) methods. Carbohydrate was calculated by difference as 100-(% Moisture +% Fat + % Fiber + % Ash +% Protein). Calorie was calculated using Atwater factors of 4 x % protein, 4 x% carbohydrate and 9 x % fat and then taking the sum. Sucrose, total sugars, reducing sugars, glucose, fructose, citric acid and malic acid were determined by the standard procedures of AOAC (2010). Vitamins C, B_1 and

B_2 were determined as described by the AOAC (2010) methods. Sodium and potassium were determined by flame photometry as described by the AOAC (2010) methods. Phosphorous was determined by the molybdovanadate method (AOAC, 2010). Magnesium, iron, copper and zinc were determined using atomic absorption spectrophotometer followed the methods as described by the AOAC (2010).

Evaluation of functional properties

Bulk density was determined as described by Onimawo and Akubor (2012). Water and oil absorption capacities were determined following the methods of Sathe et al.(1982).Emulsion activity and emulsion stability were determined by the methods of Onwuka (2005). Foaming Capacity (FC) and Foam Stability (FS) were measured by the method of Oshodi and Asu (1993). The volume of foam at 30 s of whipping was expressed as FC. The volume of foam was recorded one hour after whipping to determine F5 as percent of the initial foam volume. The least gelation concentration was determined as described by Sathe *et al.* (1982).

Statistical analysis

Data were subjected to analysis of variance in completely randomized design using Statistical Package for Social Sciences (SPSS) software (version 15, 2007). Means where significantly different were separated by the least significant difference (LSD) test (Steel and Torrie, 1980). Significance was accepted at $p< 0.05$.

Results and Discussion

Proximate composition

The proximate composition of locust bean pulp flour and wheat flour are shown in Table 1. The locust bean pulp flour (LBPF) contained lower protein and fat contents than wheat flour. The protein and fats contents of locust bean fruit were concentrated in the seed (Akubor, 2007). The low levels of protein and fat in LBPF are expected for fruits are generally not good sources of these nutrients (Enwere, 1998). However, LBPF had higher protein content (2.8%) than the 0.52 and 0.8% reported for other well known fruit pulps such as bush mango and *Vitex doniana* (Abuh, 2002), respectively. The protein content of LBPF could be improved by blending it with wheat flour as has been documented for other composite flours. The low fat contents of LBPF and wheat flour would enhance the keeping quality by reducing development of rancidity (Onimawo and Akubor, 2012). The ash content of LBPF (2.9%) was higher than the 0.8% in wheat flour and 1.4% reported for *Vitex doniana* fruit pulp (Abuh, 2002). Ash content influences flour quality. The high amount of ash in LBPF is indicative of its high mineral content. Ash influences color by imparting dark color to finished products. Some specialty products requiring particularly white flour call for low ash content while other products require high ash content (Lund and Smith, 1982). The crude fiber content of LBPF (2.7%) was higher than of the wheat flour (0.2%). The low level of fiber would enhance digestibility of the pulp, especially by children (Lund and Smith, 1982) and would complement its high contents of minerals (Table 2). Moderate level of crude fiber in foods is however, desirable for easy fecal movement (Lund and Smith, 1982). Based on the level of crude fiber, LBPF could be of potential usefulness for enriching cereal diets. This is because fruits are known to contain higher soluble fibers than cereals (Enwere, 1998). The therapeutic effects of soluble fibers in prevention of heart diseases, colon cancer and diabetes and their role in the treatment of digestive disorders (diversticulosis) and constipation are widely documented (Lund and Smith, 1982).

The moisture contents of the LBPF and WF were within the limit of not more than 10% suitable for stable storage of flours (Enwere, 1998). Mold growth and moisture dependent biochemical reactions are reduced in low moisture foods on storage. Moisture content of above 15% was reported to cause mould growth in foods (Enwere, 1998).The LBPF (234.6 Kcal/100g and wheat flour (366 Kcal/100g) contained adequate amounts of energy. These values were within the recommended daily dietary allowance of the USA for adults (WHO, 2003). The energy content of LBPF was lower than that of the wheat flour probably due to its lower fat and protein contents .Energy value of food is much more related to these nutrients (Onwuka, 2005).

Table 1: Proximate composition of locust bean pulp (LBP) and wheat flour (WF)

Constituents	LBP	WF	$Lsd_{0.05}$
Crude protein (%)	2.8^b	10.5^a	1.84
Crude fat (%)	0.8^b	2.0^a	1.00
Ash (%)	2.9^a	0.8^b	1.25
Crude fibre (%)	2.7^a	0.2^b	0.84
Moisture (%)	10.0^a	10.0^a	2.08
Carbohydrate (%)	80.8^a	76.5^b	2.01
Calorie (Kcal/100g)	341.6^b	366^a	3.48

Values are means ± SD of 3 replications; Means within a row with the same superscript were not significantly different ($P > 0.05$); Least significant difference (LSD)

Table 2: Sugar constituents of locust bean pulp flour (LBPF) and wheat flour (WF)

Constituents	LBPF	WF	$Lsd_{0.05}$
Reducing sugars (%)	10.5^a	0.9^b	0.89
Glucose (%)	5.1^a	0.6^b	1.00
Fructose (%)	4.9^a	0.5^b	1.02
Glucose/Fructose	1.04:1	1.2:1	

Values are means ± SD of 3 replications; Means within a row with the same superscript were not significantly different ($P > 0.05$); Least significant difference (LSD)

Sugar composition

The sugar constituents of locust bean pulp flour (LBPF) and WF are shown in Table 2. The LBPF contained higher amounts of total carbohydrate, total sugar, sucrose, glucose and fructose than WF. The total sugar content of 7.5% in LBPF explains why the pulp is sweet and cherished by people. This sugar concentration was comparable to those reported for other tropical fruit pulps such as banana (Nagy and Shaw, 1980), pineapple (Akubor, 2016), lemon (Nnam & Njoku, 2005), sour sop and *Vitex doniana* (Abu, 2002) which ranged from 4 to 15%.

Vitamin and organic acid composition

Table 3 shows the contents of some vitamins and organic acids in LBPF and wheat flour. The LBPF is a good source of vitamin C (34 mg/100g) and beta carotene (27 mg/100g) when compared to WF which contained 0.8 mg/100g vitamin C and 0.4 mg/100g beta carotene, respectively. The vitamin C content of LBPF was comparable to 18, 24, 25, 26, 17, and 18 mg/100g reported for banana, pineapple, mango, sour sop, black plum and velvet tamarind, respectively (Alobo, 2000). Vitamin C is necessary for the formation of bone and enamel (Fox and Cameron, 1980). Dentines of teeth lose their normal functional activity in the absence of vitamin C in the diet (Fox and Cameron, 1980). Lack of vitamin C in the diet causes scurvy, a condition characterized by haemorrhage under the skin and other tissues; and swollen and spongy gums from which the teeth are easily dislodged and may fall out (Fox and Cameron, 1980).

The LBPF has the potential of supplying enough vitamin C to meet the need of children and adult. The recommended daily allowance for vitamin C for human ranges from 15 to 60 mg per day depending on age, sex and physiological status (Fox and Cameron, 1980). The vitamin B_1 (121 mg/100g) and vitamin B_2 (16 mmg/100g) contents of LBPF were higher than 0.23 and 0.6 mg/100g, respectively for wheat flour. These vitamins are important in human nutrition (Fox and Cameron, 1980). On a thiamin deficient diet, animals accumulate pyruvic acid and its reduction product, lactic acid in the tissue resulting in weak muscle (WHO, 2003). And because acetyl coenzyme A is the important metabolite in the synthesis of fatty acids, lipogenesis or fat synthesis is reduced (Fox and Cameron, 1980).

In the absence of sufficient vitamin B_1, carbohydrate metabolism is upset and this produces a check in the growth of children together with loss of appetite and other symptoms such as irritability, fatigue and dizziness (WHO, 2003). The estimated requirement range of vitamin B_1 is from 0.12 to 0.5 mg per day (Foxand Cameron, 1980). Vitamin B_2 (riboflavin) in the living cell is converted into phosphate or flavin adenine dinucleotide (FAD) both of which combine with proteins to form the flavo proteins that act as important hydrogen carriers in biological oxidation system (Nagy and Shaw, 1980). A deficiency of riboflavin produces check in the growth of children and lesions on the tips of the mouth (WHO, 2003). The LBPF would supply adequate amount of riboflavin in diets. The recommended daily allowance for riboflavin is 1.7 mg for an adult man and 1.3 mg for adult woman (WHO, 2003)

Table 3: Vitamin composition of locust bean pulp flour (LBPF) and wheat flour (WF)

Constituents	LBPF	WF	$Lsd_{0.05}$
Vitamin B_1 (mg/g)	121^a	0.65^c	1.00
Vitamin B_2 (mg/g)	16^a	0.23^b	0.80
Vitamin C (mg/100g)	34^a	0.8^b	1.04
Beta-carotene (mg/100g)	27^a	0.4^b	1.34
Citric acid (mg/100g)	2.5^a	0.9^c	1.10
Malic acid (mg/100g)	2.1^a	0.1^b	0.5
Malic acid/Citric acid	1:5.95	1:9	

Values are means ± SD of 3 replicates; Means within a row with the same superscript were not significantly different (P > 0.05); Least significant difference (LSD)

Table 4: Mineral composition of locust bean pulp flour (LBPF) and wheat flour (WF)

Minerals (mg/100g)	LBPF	WF	$Lsd_{0.05}$
P	412 + 0.5^a	180 + 0.1^b	10.0
K	764 + 0.2^a	145 + 0.9^c	5.2
Mg	113 + 0.3^a	65 + 0.2^c	3.0
Na	170 + 0.1^b	3.1 + 0.6^c	5.8
Ca	27 + 0.9^a	18 + 0.7^c	2.0
Fe	42 + 0.6^a	3.0 + 0.2^c	1.0
Cu	0.9 + 0.7^a	0.6 + 0.9^a	1.0
Zn	0.8 + 0.2^a	2.0 + 0.1^a	1.5

Values are means ± SD of 3 replications. Means within a row with the same superscript were not significantly different (P > 0.05)

Mineral composition

The mineral composition of locust bean seed flour and WF are shown in Table 4. The mineral constituents of plants and their products vary in amounts depending on the stage of maturity, conditions of growth, fertilization and the nature of the soil (Enwere, 1998). The LBPF was high in P (412 mg/100g) and k (766 mg/100g), moderate in Mg (113 mg/100g), Fe (42 mg/100g) and Na (170 mg/100g) but relatively low in Cu (0.9 mg/100g) and Zn (0.8 mg/100g) when compared to those of black plum, *Spondias* and soybeans (Enwere, 1998). The levels of minerals in LBPF were higher than those reported for bananas, mangos, guava and oranges (Enwere, 1998). The LBPF was higher than WF in all the essential minerals except Zinc. Thus, LBPF could be incorporated into WF based foods to improve the levels of the minerals which would perform various body functions. Phosphorus (P) is an essential component of bone mineral where it occurs in the mass ratio of 1 phosphorus to 2 calcium. The level of p can affect Ca metabolism and requirement in the body (Fox and Cameron, 1980). Hence, the ratio of Ca:p in the diet becomes important. The Ca:P in LBPF was 1 :15.3. The ratio of Ca: P in diets varies with food consumption pattern (Fox and Cameron, 1980). The ratio of Ca: P LBPF was far from the recommended Ca:P ratio of 1:1.5. The dietary intake ratio of Ca: P was reported to have some effects on the level of Ca in the blood of many animals (Emwere, 1998).The high calorie content of LBPF would favorably complement its phosphorus level which promotes energy metabolism.

High intake of sodium is implicated in hypertension. Potassium, on the other hand, is frequently supplied in limited quantity and is readily lost in person taking diuretics (WHO, 2003). Thus, diet, with low level of sodium and high level of potassium is encouraged (FAO, 1988). The potassium (764 mg/100g) and sodium (170 mg/100g) contents of LBPF obtained in this study agreed well with report of (WHO, 2003) on the concentration of these minerals in fruits. The high potassium: sodium ratio (4.5:1) in LBPF is desirable because an average human diet is low in potassium but high in sodium (FAO, 1988).The moderate level of sodium in LBPF makes the pulp suitable for use in sodium restricted diets (WHO, 2003).

Micronutrient deficiency especially that of iron and Zinc is frequent in developing and developed countries (WHO, 2003). Therefore, consumption of LBPF which contained 47 mg/100g iron and its products in adequate amount would help to overcome some of the nutritional problems such as anemia and other micronutrient deficiencies which are prevalent in poor and urban rural areas (WHO, 2003). However, the Fe: Zn ratio (52.1:1) in LBPF may affect the absorption of Zn since Zn absorption is significantly reduced if non haeme FE/Zn ratio is 2:1 or more (Fox and Cameron, 1980). The high level of vitamin C (34 mg/100g) in LBPF is desirable because vitamin C is very vital in iron metabolism and subsequent fight against iron deficiency anemia (Fox and Cameron, 1980). Vitamin C favors iron absorption byreducing the inorganic iron 111 (Ferric) complexes in foods to iron 11 (Ferrous), a form in which it is more readily absorbed and then forming readily absorbed iron-ascorbate complex (Fox and Cameron, 1980). The consumption of milk and milk products, which would ensure regular supply of dietary calcium, is relatively uncommon among the Nigerian populace. Cereals and vegetables contribute the bulk of the dietary calcium (WHO, 2003).

Functional properties

The functional properties of locust bean pulp flour (LBPF) and wheat flour (WF) are presented in Table 5.The LBPF absorbed more water (318%) than oil (257%). The water and oil absorption capacities of WF were 106 and 156%, respectively .The LBPF probably contained more hydrophilic groups of proteins and carbohydrates than the lipophilic groups. Water absorption capacity is not merely dependent on the content of protein but also on the nature of the hydrophilic constituents (Kinsella, 1981). Polar amino groups of proteins are the primary sites of protein – water interactions (Kinsella, 1981). Cationic, anionic and non ionic sites bind different amounts of water (Alobo, 2003). Proteins absorbs water up to 200% its weight whereas carbohydrates absorbs only 15% of its weight (Toistoguzov, 1986). The high protein content of WF (10.5%) (Table 1) would have enhanced its water absorption capacity over LBPF with 2.8% protein content. This suggests the presence of higher amounts of hydrophilic and lipophilic groups in LBPF than WF. The high fiber content of LBPF (Table 1) probably contributed to its WAC. Fiber is characterized by high WAC as reported by Onimawo andAkubor (2012). With fat content of 2 % in WF as compared to 0.8% in LBPF, much of the binding sites of WF would have been taken up by the original fat. This is because the mechanism of fat absorption is attributed mainly to physical entrapment of oil by capillary attraction and binding of fat to the apolar chain of protein molecule (Kinsella, 1981).

However, hydrophobicity of proteins plays a major role in oil absorption (Igbdul *et al*., 2014). The water absorption capacity of LBPF was higher than 25, 198,80,142 and 179% reported for plantain flour (Fagbemi,1999), pawpaw kernel flour (Alobo, 2003), cassava flour (Akubor and Ukwuru, 2003) and African breadfruit kernel flour (Akubor and Badifu, 2004), respectively. Similarly, the oil absorption capacity of LBPF was higher than those reported for sweet potato flour (Akubor, 1997), plantain flour (Fagbemi, 1999), pawpaw kernel flour (Alobo, 2003), cassava flour (Akubor and Ukwuru, 2003) and African breadfruit kernel flou r (Akubor and Badifu, 2004) but less than 208% reported for soybean flour (Akubor and Ukwuru, 2003). The high water and oil absorption capacities placed LBPF over these reported flours in baked doughs where hydration to improve handling characteristics is required and in products such as doughnuts and pancakes where oil holding property is an important consideration (Sanni *et al.,* 2008). High OAC is important since oil acts as flavor retainer and increases the palatability of foods (Akubor, 2016). The high OAC of LBPF means that various kinds of mutagens and cholesterols can be adsorbed effectively, because most of these components are lipophilic (Kinsella, 1981). However, low fat absorption may also be desirable in some food applications such as cowpea cake (akara) and doughnut prepared by deep fat frying.

The foaming capacity of LBPF (11.3%) was low when compared to 35 % for wheat flour. The wheat flour also produced more stable foam (75%) than LBPF (61.9%). However, the foam stability of LBPF, defined as how quickly the foam collapsed once formed was high in relation to those of 2.5% reported for cassava flour (Akubor and Ukwuru, 2003) and 1.9% for plantain flour. Oshodi and Asu (1993) had earlier ascribed the superiority of soybean flour over cowpea flour in foaming capacity to the higher protein content of soybean. This probably explains the higher FC of WF with higher protein content over LBPF. The low foaming capacity of LBPF could also be attributed to the low solubility of the flour protein (Akubor, 2007). Similar observations were documented for many foods (Badifu and Akubor, 2001). On the other hand, the high carbohydrate content of LBPF (81.2%) may have had stabilizing effect on the foams prepared from the LBPF. Carbohydrate stabilizes foams because their hydrophilic nature serves to increase the viscosity of the colloidal flour solution, thereby preventing the collapse of gas bubbles (Apata and Akubor, 1999). Foam capacity and FS are indices of whippabilty (Apata and Akubor, 1999). Thus, based on the high values FC and FS, LBPF would be suitable for making baked and confectionery products that require high percentage of porosity. Whipping into foams helps to incorporate air into the dough mix and this assists in aeration of finished product (Akubor and Badifu 2004). The LBPF showed increased FC and FS with increase in the flour concentration (Table 6). Kinsella (1981) had made similar observation for soy and cowpea flours. A high soluble protein is required for optimum foaming properties of flour (Toistoguzov, 1986). Soluble proteins are surface active (Onimawo and Akubor, 2012). Increase in protein concentration facilitates adsorption of protein which results in enhanced stability of foams and emulsion (Yagoub and Abdakar, 2007).

Table 5: Functional properties of locust bean pulp flour (LBPF) and wheat flour (WF)

Property	LBPF	WF
Water absorption capacity (%)	3.80 ± 0.9^{a}	1.06 ± 1.0^{b}
Oil absorption capacity (%)	2.57 ± 1.2^{a}	1.56 ± 0.8^{b}
Foaming capacity (%)	11.3 ±1.0^{b}	35.1 ± 1.3^{a}
Foam stability (%)	61.9 ± 0.8^{b}	75.0 ± 0.4^{a}
Emulsion activity (%)	14.3 ± 0.7^{b}	25.4 ± 1.0^{a}
Emulsion stability (%)	13.0 ± 1.5^{b}	20.54 ± 1.0^{a}
Bulk density (g/cm^{3})	0.28 ± 0.3^{a}	0.64 ± 0.2^{a}
Least gelation concentration (%, w/v)	12.0 ± 0.2^{a}	12.0 ± 0.5^{a}

Values are means ± SD of 3 replications. Means within a row with the same superscript were not significantly different (P > 0.05).

Table 6: Effect of flour concentration on foaming capacity (FC) and foam stability (FS) of locust bean pulp flour

Flour Conc. (%, w/v)	FC (%)	FS (%)
2	9.0	51
4	10.0	52
6	13.0	55
8	15.0	58
10	18.0	60
12	20.0	63
14	25.0	65
16	27.0	68
18	30.0	71
20	31.0	75

Values are means of 3 replications

The emulsion activity of wheat flour (25.4%) was about 2-fold that of locust bean pulp flour (14.3%). Similarly, wheat flour also formed more stable emulsion (20.5%) than LBPF (13%). The low emulsion activity and emulsion stability of LBPF could be probably linked to presence of high levels of insoluble compounds inhibiting the formation and stabilization of emulsion (Akubor, 2016). Similar observation was documented for sweet potato flour (Akubor, 1997). Emulsion characteristics of proteins contribute to their functionality in foods (Onimawo and

Akubor, 2012). The efficiency of emulsification by flours varies with the type, concentration and solubility of the proteins (Onimawo and Akubor, 2012). Thus, the low protein concentration (Table 1) and solubility of the LBPF proteins (Akubor, 2007) may have affected its ability to form and stabilize emulsion. The high carbohydrate content of LBPF may have adversely affected its emulsion activity. Similar effect was reported for peanut flour (Kinsella, 1981). On the other hand, the low emulsion stability of LBPF could be due to presence of heat sensitive stabilizing agents such as phospholipids and glycolipids which have been reported in LBPF (Akubor, 2007). The low emulsion activity and emulsion stability suggested that LBPF would not be desirable for preparing comminuted meats like sausages, mayonnaise and salad dressing where high emulsifying property is required (Adegunwa *et al.*, 2012).

The bulk density of LBPF (0.28 g/cm^3) was lower than 0.64 g/cm3 for wheat flour, due to the presence of fibrous materials in LBPF, which are known to have low bulk density (Akubor, 2016). The low bulk density of LBPF is important for its packaging as the packaging cost and space would be very low (Toistoguzov, 1986). Uniformity in bulk density is important in determining packaging requirements, material handling and has application in wet processing of foods (Kinsella, 1981). The low bulk density of LBPF would also be of advantage in its use for formulation of complementary foods (Addy *et al*., 2003)

Both LBPF and WF had least gelation concentration of 12% (w/v), respectively. The LGC of LBPF was higher than 6,8 and 10%(w/v) reported for plantain flour, toasted African breadfruit kernel flour (Akubor *et al.*) and pawpaw kernel flour (Alobo, 2000) but lower than 14% (wlv) reported for Great Northern bean flour(Sathe *et al.*,1982) and 16 % for unfermented African oil bean (Akubor and Chukwu, 1999). The LGC which is defined as the lowest flour concentration at which gel remained in the inverted tube was used as an index of gelation capacity. The lower the LGC, the better the gelling ability of the flour. Sathe *et al*. (1982) linked variation in gelling properties of legume flours to the relative ratios of proteins, carbohydrates and lipids that make up the flours. They suggested that interactions between such components may also play significant role in other functional properties. The gelation capacity of LBPF and WF may have involved formation of a protein-polysaccharide complex. Toistoguzov (1986) had earlier reported that the occurrence of salt bridges between protein and polysaccharide results in formation of gels. Kinsella (1981) reported the formation of such complexes but suggested that the major forces responsible for the interaction were electrostatic in nature. According to Kinsella (1981), in the complex formation, the carboxylate groups of the polysaccharides interact with some or all of the positively charged protein residues such as alpha-amino, guanidine and imiddazole groups. The actual strength of the interaction was related to the number and distribution of these sites as well as the overall charge on the protein (Kinsella, 1981). Therefore, the availability of site for interaction as well as the relative ratios and composition may have contributed to the reported significant variations in the gelling capacities of flours. The low LGC of LBPF suggested that the flour would be good gel forming or firming agent and would be useful in food systems such as puddings, sausage emulsion, soups and snacks which require thickening and gelling (Akubor, 2016). Traditionally, LBPF is used in thickening soup. LBPF would also be important in baking of bread and other baked flour goods where it would contribute to desired crumb structure and texture (Akubor, 2016).

Conclusion

Locust bean pulp flour contained higher amounts of crude fiber, total and reducing sugars, vitamins (B_1, B_2 and C), minerals (P, K, Ca, Fe) than wheat flour .If the calcium in the LBPF was in the available form, LBPF would serve as a source of calcium to consumers. To ascertain this, the oxalates and phytates contents of LBPF should be determined. Locust bean pulp flour possessed higher water and oil absorption capacities but lower foaming and emulsion properties than wheat flour. Locust bean pulp flour would find applications in various food systems.

Conflict of interest

Researchers hereby declare that there is no conflict of interest whatsoever in this research.

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