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Quality evaluation of pulp powder and the developed functional jam from African locust bean fruit

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ABSTRACT

The pulp powder was prepared from fruits of African locust bean tree and used to produce jam. The pulp and jam were analyzed for the chemical composition, physicochemical, microbiological and sensory properties. The total soluble solids of the pulp and jam were 25.5 and 72.5 °Brix, respectively. The pulp had pH of 5.3, while the pH of the jam was 3.3. The jam had higher total titratable acidity than the pulp. The jam contained higher crude protein (3.16 %), crude fat (1.03%), ash (4.3%) and carbohydrate (76.044%) contents than the pulp. The crude protein, fat, ash and carbohydrate contents of the pulp were 2.86, 0.85, 2.93 and 68.81%, respectively. The energy content of the jam was also higher than that of the pulp. The flavonoids, carotenoids, tannins, oxalates, phytates, saponins and alkaloids contents of the jam were lower than those of the pulp. The total sugars, reducing sugars, glucose, fructose and sucrose contents of the pulp were 7.7, 10.7, 5. 5, 4.8 and 5.8%, respectively, while those of the jam were 75.5, 47.6, 20.3, 30.3 and 21.68%, respectively. The vitamins B1, B2 and C contents of the pulp were 122, 35 and 35 mg/100g, respectively and decreased to 113, 10.2 and 22mg/100g, respectively, in the jam. The citric acid increased from 12.9 in the pulp to 15.6mg/100gin the jam. The P, K, Mg, Cu, Zn and Ca contents of the jam were higher than those of the pulp, while the Na and Fe contents of the pulp were higher than those of the jam. The total plate counts of the pulp and the pulp jam were 4.0 x10^4 and 1.2 x 10^1, respectively. The yeast and mould counts of pulp were 2.4 x10^4, while that of the jam was 0.3 x 10^1. The commercial plum jam was rated higher than the pulp jam for all the sensory attributes assessed except spreadability and overall acceptability.

Introduction

In Nigeria, African locust bean (*Parkia, biglobosa*) tree grows abundantly in the wild and produces pods, which at maturity contain yellow and dry powdery pulp with dark brown seeds. The pulp is liked to a limited extent for its sweet taste. However, it is discarded as waste when the seeds are prepared into popular condiment called *dawadawa* or *iru*, which is used as a source of protein intake among low-income group in West Africa (Omauvbe et al., 2004). For this reason, the seed has been well studied for its quality properties and food uses (Addy et al., 1995; Aiyelaagbe et al., 1996). On the other hand, the pulp powder is used in soups and stews or eaten with cereals as porridge (Omauvbe et al., 2004). A traditional drink is prepared by infusing the powdery pulp in hot water (Akoma et al., 2001) and consumed as health tonic for the medicinal properties (Akoma et al., 2001; Musa et al., 2005). Among the locals, the pulp is also used as substitute for sugar because of its high sugar content (Akubor, 2016). The pulp potentially serves as raw material for the manufacture of syrup, jam, wine and nonalcoholic beverages (Akoma et al 2001; Musa et al., 2005; Akubor, 2017).

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In this regard, only the storage qualities of syrup and jam from the pulp powder were reported by Akubor (2017), leaving the detailed composition for further work. However, the chemical composition, amino acid profile, functional properties and storage stability potential of the pulp flour were elucidated, which highlighted the potential for fabricated foods (Akubor and Adedeji, 2016; Akubor, 2017). Previous works showed that the pulp flour is a good source of essential minerals, vitamins and phytochemicals with high antioxidant activity (Akubor, 2016; Akubor and Adedeji, 2016). However, there are no reported data on the utilization of the pulp as functional jam.

Jams are prepared from mixture of cooked fruit or vegetable, sugars, citric acid and pectin (Broomfield, 1996) in which fruit and sugar constitute 45 and 55% by weight, respectively. The fruit, sugar and the added pectin are boiled in acid medium (pH 3.0- 4.0) to 65% or above soluble solids (Broomfield, 1996). Flavours and colours may be added to make for the deficit in the fruit. Pectin, which is concentrated in the skin of fruits, binds with sugar and fruit acid to form gel (Nashi et al., 2020). Some fruits have enough natural pectin to gel firmly, while others require added pectin to produce good jam. Pectin has high water absorption capacity, gel forming and thickening properties (Nwosu et al., 2014). Pectin shortens cooking time of jams and jellies to produce fresh fruit flavour (Nashi et al., 2020). Sugar sweetens jam and works in synergy with pectin and fruit acid to form the gel structure of jam (Nwosu et al., 2014). Sugar also preserves the colour of fruits and inhibits mould growth. On the other hand, acid is needed for gel and flavour formation (Awolu et al., 2018). Thus, sugar must be present in the proper proportion with pectin and acid to make a good gel (Touati et al., 2014). The locust bean pulp powder, which is rich in pectin, sugar, acid and essential phytochemicals (Akubor, 2017), has the potential for making functional jam.

The use of functional foods is attracting attention worldwide due to increased awareness on health benefits of functional foods (Angew and Akpan, 2007). Functional foods contain antioxidants that provide protection to consumers against many chronic diseases as well as promote growth and development (Ndife and Abbo, 2009). The presence of flavonoids, carotenoids, vitamin C and dietary fibre in locust bean pulp powder would exert health promoting effects (Akubor, 2019). However, no research has described the suitability of locust bean pulp for production of functional jam to add value to the pulp powder, ensure consumption of the pulp powder throughout the year and promote recovery of essential bioactive constituents from the pulp. Therefore, the objective of this work was to evaluate the quality of jam produced from African locust bean pulp powder.

Materials and methods

Preparation of pulp powder from locust bean fruits

The fruit pods were opened manually and the pulps were removed. The seeds were removed from the pulps and the powdery pulps were sun dried to constant weight. The pulp powder samples were ground with pestle and mortar and then packaged in polyethylene bags before usage.

Production of jam from locust bean pulp powder

The jam was prepared following the method given by Akubor (2017). The locust bean pulp powder (100 g) was mixed manually with 700 ml distilled water (1:7, pulp: water) in a plastic bowl. White sugar (200 g), pectin (1.5%, w/v) and sodium benzoate (1%, w/v) were added to the slurry and the pH was adjusted to 3.2 with 20% food grade citric acid solution using a pH meter. The mixture was then boiled at 104 °C for 30 min in a stainless steel pot in a vacuum oven to 67 ^{o}Brix. The jam was filled hot into jam bottles to 1cm headspace, corked and stored at 10 ^{o}C in a refrigerator prior to use.

Assessment of sensory quality of jam

A panel of 20 trained judges were randomly selected, based on familiarity with jams, from Federal Polytechnic Idah Community and used to compare the locust bean pulp jam with a commercial jam (Plum). The jams were assessed for texture, flavour, taste, colour, spreadability and overall acceptability as described by Iwe (2003). Ten grams of the jam samples were given to the judges in three- digit coded white glass plates. Sachet water was given to the assessors to rinse their mouths before the next evaluation. The samples were assessed on 5point scale (5=liked extremely and 1 = disliked extremely) using score sheets in a sensory evaluation laboratory in the midmorning (10a.m). The evaluation was performed under good fluorescent lighting and adequate ventilation. For the assessment of spreadability, 2g of the jam samples was smeared lightly on thin sliced breads, which were observed for evenness of spread.

Measurement of physicochemical properties

*T*he pH and total titratable acidity were measured by the methods given by AOAC (2010). The jam (20 g) was added to 100 ml distilled water and the mixture was homogenized. The pH of 20 ml suspension was measured at ambient temperature (30 °C) with a pH meter. To measure the total titratable acidity, the suspension was filtered through Whatman No 4 filter paper. Three drops of phenolpthelin indicator were added to 10 ml of the filtrate and then, titrated with 0.1M NaOH solution. The total titratable acidity (TTA) was obtained as:

TTA (% citric acid) =100 x Conversion factor x Concentration of NaOH / Volume of sample (1)

The total soluble solids (TSS) and refractive index (RI) were determined using Abbe refractometer following the AOAC (2010) methods. A 10% suspension of the sample was prepared and a drop of it was smeared on the prism of a refractometer and the TSS and RI were read. The specific gravity was assessed with a pycnometer as:

Weight of the sample/ weight of equal volume of water (2)

Analysis of proximate composition and energy value

Crude fat content of the samples was evaluated by the Soxhlet extraction method using petroleum ether (AOAC, 2010). The moisture content of the samples was assessed by oven drying at 105 °C to constant weight as moisture loss divided by sample weight (AOAC, 2010). Ash content was determined by heating the samples in a Muffle furnace at 550 °C to grey white (AOAC, 2010). The nitrogen content was determined using the Kjeldahl method and crude protein content was calculated by multiplying the nitrogen content by a 6.25 conversion factor (AOAC, 2010). Crude fibre was determined as described by AOAC (2010) procedure. Carbohydrate content was obtained by difference (AOAC, 2010) as:

100- (% Ash + % Fat + % Protein + % Moisture + % Crude fibre) (3)

Calorie content was calculated using Atwater factors of 4 x % protein, 4 x % carbohydrate and 9 x % fat and then taking the sum (AOAC, 2010).

Determination of sugar, organic acid and vitamin contents

Sucrose, total sugar, reducing sugars, glucose, fructose, citric acid, malic acid, vitamins C, B1 and B2, niacin and beta-carotene contents were assessed following AOAC (2010) methods.

Determination of mineral contents

Sodium and potassium contents were evaluated by flame photometry following the AOAC (2010) procedures. The phosphorus content was evaluated by the molybdoanadate method (AOAC, 2010). Magnesium, iron, copper and zinc contents were determined by atomic absorption spectrophotometry (AOAC, 2010).

Evaluation of phytochemical contents

The tannins, saponins and flavonoids contents were determined as described by Edoga et al. (2008). The alkaloids and carotenoids contents were determined as described by Onimawo and Akubor (2012). The oxalates, phytates and hydrogen cyanide contents were determined as described by Oikeh et al. (2013).

Experimental design and data analysis

The experiment was conducted on completely randomized design. Data were analyzed by one-way analysis of variance using Statistical Package for Social Sciences version 17. Means, where significantly different, were separated by Duncan's multiple range test. Significance was accepted at $p<0.05$.

Results

Physical properties of pulp powder and pulp jam

The physical properties of the pulp powder and jam are given in Table 1. The soluble solids of the pulp powder and jam were 25.5 and 72.5 °Brix, respectively. The pH of the pulpr powder was 5.3, while that of the jam 3.3. The total titratable acidities of the pulp powder and jam were 0.57% and 0.95%, respectively. The refractive index (1.5400) and specific gravity (1.3225) of the jam were higher than the refractive index (1.4152) and specific gravity (0.4668) of the pulp powder.

Proximatel composition and energy value

Table 2 shows the proximate composition of the samples. The protein content of the jam was 3.16%, which was higher than 2.86% for the pulp powder. Similarly, the jam contained higher amount of fat (1.03%) than the pulp powder (0.85%). However, the moisture and crude fiber contents of the jam were lower than those of the pulp powder. The ash, carbohydrate and energy contents of the pulp powder were 2.93%, 68.81% and 295.5 Kcal/100 g, respectively. On the other hand, the jam contained 4.3%, 76.04% and 328.78 Kcal/100g ash, carbohydrate and energy contents, respectively.

Phytochemical composition

The phytochemical composition of the samples is presented in Table 3.The locust bean pulp jam had lower contents of oxalates, phytates and tannins than the fruit pulp powder. The flavonoids content of locust bean pulp powder was 3.98 mg/100 g and decreased to 2.88 mg/100 g in the jam. The carotenoids contents also decreased from 8.74% in the pulp powder to 7.39% in the jam. While the fruit pulp powder contained 0.5 mg/100 g hydrocyanic acid (HCN), HCN was not detected in the jam. The alkaloids content of the pulp powder and jam were 2.94 mg/100 g and 1.89 mg/100 g, respectively. The saponins contents of the pulp powder and jam were 8.94 and 7.35 mg/100 g, respectively.

Table 1. Physicochemical properties of locust bean pulp powder and locust bean pulp jam

Properties	Locust bean pulp powder	Locust bean pulp jam
Soluble solids(ºBrix)	25. 5^{b}±0.64	72.5^{a}±0.51
PH	5.3^{b}±0.13	3.3^{a}±0.07
Total titratable acidity(% citric acid)	0.57^{b}±0.09	0.95^{a}±0.12
Specific gravity	0.4668^{b}±0.82	1.3225^{a}±0.37
Refractive index	1.4152^{b}±0.43	1.5400^{a}±0.02

Data are means ± standard deviation of 3 replications (n=3).
Means within a row with the same superscript are not significantly (p>0.05) different.

Table 2. Proximate composition(%) and energy value(Kcal/100 g) of locust bean pulp powder and locust bean pulp jam

Composition	Locust bean pulp powder	Locust bean pulp jam
Crude protein	2.86^{b}±0.02	3.16^{a}±0.12
Crude fat	0.85^{b}±0.06	1.03^{a}±0.08
Moisture	22.2^{a}±0.95	15.32^{b}±0.42
Crude fiber	2.61^{a}±0.05	0.26^{b}±0.04
Ash	2.93^{b}±0.080.14	4.30^{a}±0.01
Carbohydrates	68.81^{b}±0.05	76.04^{a}±0.07
Energy	295.5^{b}±0.91	328.78^{a}±0.17

Data are means ± standard deviation of 3 replications (n=3).
Means within a row with the same superscript are not significantly (p>0.05) different.

Table 3. Phytochemical composition (mg/100g) of locust bean pulp powder and jam

Composition	Locust bean pulp powder	Locust bean pulp jam
Flavonoids	3.98^{a}±0.05	2.88^{b}±0.09
Carotenoids	8.74^{a}±0.06	7.39^{b}±0.06
Tannins	0.38^{a}±0.02	0.23^{a}±0.23
Oxalates	2.63^{a}±0.06	2.04^{b}±0.83
Phytates	0.26^{a}±0.42	0.14^{b}±0.02
Saponins	8.90^{a}±0.09	7.35^{b}±0.05
Alkaloids	2.94^{a}±0.21	1.89^{b}±0.03

Data are means ± standard deviation of 3 replications (n=3).
Means within a row with the same superscript are not significantly (p<0.05) different.

Sugar, vitamin and acid composition of pulp powder and jam

The sugar, vitamin and acid composition of the pulp powder and jam are shown in Table 4. The total sugars(75.5%),reducing sugars (47.6%) ,glucose (20.3%),fructose(30.3% and sucrose(21.68%) contents of the jam were significantly(p<0.05) higher than those of the pulp powder. The total sugars, reducing sugars, glucose, fructose and sucrose contents of the pulp powder were 7.7, 10.7, 5.5, 4.8 and 5.8%, respectively. On the other hand, the vitamins B1, B2 and C; and malic acid contents of the pulp powder were significantly (p<0.05) higher than those of the jam. The citric acid increased from 12.9 mg/100 g in the pulp powder to 15.6 mg/100 g in the jam.

Mineral composition

Table 5 shows the mineral composition of the pulp powder and jam. The phosphorus contents of the pulp powder and the jam were 414 and 419 mg/100 g, respectively. The potassium content increased from 760 mg/100 g in the pulp powder to 765 m/100 g in the jam. The magnesium content of the jam (117 mg/100 g) was higher than that of the pulp powder (114 mg/100 g). The sodium content decreased from 171 mg/100 g in the pulp to 167 mg/100 g in the jam. The iron content also decreased from 27.6mg/100g in the pulp powder to 21.9 mg/100 g in the jam. However, the copper, zinc and calcium contents of the jam were higher than those of the pulp powder.

Microbial quality

The microbial characteristics of the samples are presented in Table 6. The total plate count of the jam (12 cfu/g) was lower than that of the pulp powder (4.0 x 10^4 cfu/g). Similarly, the jam (3 cfu/g) had lower yeasts and molds counts than the pulp powder (2.4 x10^4). Coliforms and Escherichia coli were not detected in both the pulp powder and the jam.

Sensory quality of jams

The sensory attributes of locust bean pulp jam and the commercial jam (plum) are depicted in Table 7. There were no significant differences (p>0.05) in the flavour, taste, texture and overall acceptability between the jam samples. However, there were significant differences (p>0.05) in the colour and spreadability, where the pulp jam received higher score for spreadability (4.6), but lower rating for colour (3.3) than the commercial jam .The plum jam had 3.1 and 4.3 scores on a 5-point scale for spreadability and colour, respectively.

Table 4. Sugar, vitamin and organic acid composition of locust bean pulp powder and locust bean pulp jam

Sugar composition (%)	Locust bean pulp powder	Locust bean pulp jam
Total sugars (%)	7.7^b±0.06	75.5a±0.08
Reducing sugars (%)	10.7^b±0.02	47.6a±0.15
Glucose (%)	5.5^b±0.07	20.3^a±0.05
Fructose (%)	4.8^b±0.05	30.3^a±0.07
Sucrose (%)	5.8^b±0.08	21.68^a±0.01
Vitamin B1 (mg/100 g)	122^a±0.01	113^b±0.06
Vitamin B2 (mg/100 g)	17^a±0.25	10.2^b±0.86
Vitamin C (mg/100 g)	35^a±0.07	22^b±0.92
Beta carotene (mg/100 g)	27^a±0.09	18.5^b±0.34
Citric acid (mg/100 g)	12.9^b±0.16	15.6^a±0.04
Malic acid (mg/100 g)	2.3^a±0.02	1.4^b±0.06

Data are means ± standard deviation of 3 replications (n=3).Means within a row with the same superscript are not significantly (p>0.05) different.

Table 5. Mineral contents of locust bean pulp powder and locust bean pulp jam

Mineral composition (mg/100 g)	Locust bean pulp powder	Locust bean pulp jam
P	414^b±0.09	419^a±0.07
K	760^b±0.05	765^a±0.03
Mg	114^b±0.01	117^a±0.09
Na	171^a±0.05	167^a±0.52
Fe	27.6^a±0.07	21.9^b±0.05
Cu	0.98^b±014	1.3^a±0.02
Zn	0.73^b±0.01	0.91^a±0.07
Ca	27.9^b±0.08	29.9^a±0.01

Data are means ± standard deviation of 3 replications (n=3).
Means within a row with same superscript are not significantly (p>0.05) different.

Table 6. Microbiological qualities (cfu/g) of locust bean pulp powder and locust bean pulp jam

Parameter	Locust bean pulp powder	Locust bean pulp jam
Total plate count	4.0a x 104 ± 0.89	1.2b x 101 ± 0.49
Yeasts and molds	2.4a x 104 ± 0.54	0.3b x 101 ± 0.35
Coliform	ND	ND
Escherichia coli	ND	ND

Data are means± standard deviation of 3 replications (n=3). Means within a row with the same superscript are not significantly (p>0.05) different.ND= Not detected.

Table 7. Sensory attributes and spreadability of locust bean pulp jam and commercial jam (Plum)

Jam samples	Colour	Flavour	Taste	Texture	Overall acceptabiity	Spreadability
Locust bean pulp jam	3.3^{b}	3.6^{a}	3.9^{a}	3.9^{a}	4.7^{a}	4.6^{a}
Plum jam	4.3^{a}	3.9^{a}	4.3^{a}	4.4^{a}	4.3^{a}	3.1^{b}
Lsd 0.05	0.80	0.90	0.79	0.80	0.78	0.95

Data are means ± standard deviation of 3 replications (n=20).
Means within a column with the same superscript are not significantly ($p>0.05$) different.

Discussion

The soluble solids content of the jam (72.5 °Brix) was within the limit for jam and similar preserve (Riaz et al., 1999). This value was higher than 20-41 °Brix reported for jams from blends of banana, pineapple and watermelon (Awolu et al., 2018). The soluble solids content is an important quality property in food processing, because about 55% of soluble solids are sugars. The amount and the proportion of glucose and fructose influence sensory qualities of fruits. Thus, fruits with high total soluble solids are desirable as they give high yield of processed products. The refractive index of the jam agreed with the range recommended by Eke-Ejiofor and Owuno (2013) for jam. The jam had higher specific gravity due to increased solutes by evaporation. Specific gravity measures the concentration of soluble solids in fruits and fruit products. The pH of the jam was similar to a range of 3.36-3.96 reported for jams from blends of banana, pineapple and watermelon (Awolu et al., 2018) and that of black plum jam (Ajenifujah-Solebo and Aina, 2011). The added citric acid in the jam preparation caused the variation in pH. pH is related to microbial stability of fresh and processed food products, where pH of 4 or less is desirable in preventing growth of pathogens and spoilage microorganisms (Hussain and Shakar, 2010). Low pH is needed in jams to prevent bacterial contamination and growth. The pH of the jam will affect its viscosity for gel firmness is influenced by pH where pH range of 3-3.5 has been noted to support the formation of gel. Acidity is one of the most vital parameters influencing pectin gelation, texture and overall quality of fruit jams that should be controlled (Kanwal et al., 2017). Acidity increased due to the conversion of reducing sugars and pectin to pectic acid, similar to the finding of Kanwal et al. (2017). Acids in food improve palatability and influence nutritive value, flavour, brightness of colour, stability, consistency and keeping quality of food products (Onimawo and Akubor, 2012). Busa and Shivhare (2010) also noted that pH plays dual role of flavour promotion and preservative in fruit juices and fruit products. The low pH, high acidity and sugar content (Table 4) of the jam would enhance good storage stability by inhibition of fungal growth (Muhammad et al., 2012). Alkaline degradation and discoloration of the pulp jam during storage would be retarded because of its low pH (Touati et al., 2014).

The chemical composition of locust bean pulp powder and locust bean pulp jam in Table 2 shows that evaporation used in the processing increased due to moisture the protein, ash and carbohydrate contents but decreased the moisture content of the jam over those of the pulp powder. Moisture is vital to the quality, acceptability and shelf-life of food products (Touati et al., 2014). Fat acts as a lubricating agent to improve the texture, rheology and overall quality of food products (Basu and Shivhare, 2010). The low fibre content would complement the high level of minerals in the products (Delovic et al., 2017). The high level of ash in the jam relative to the pulp powder was due to the reduction in moisture content following heating of the jam. The ash content (4.3%) of the jam was high compared to those of the jams from tropical fruits such as blend of banana, pineapple and watermelon that ranged between 0.27 and 0.38%. Ash content gives indication of the mineral composition of food. Minerals are critical to many biochemical reactions in the physiological functioning of the major metabolic processes (Anjum et al., 2000). The higher protein, fat and carbohydrate contents of the jam accounted for the higher energy value over that of the pulp. The high calorie content of the jam would complement its high phosphorus level, which promotes energy metabolism (Ali et al., 2008).

The absence of HCN in the jam was due to heat destruction. Hydrogen cyanide does not occur freely but combined with sugars to form non-toxic compound, cyanogenic glycoside. High level of HCN inhibits the respiratory chain at the cytochrome oxidase level (Ogori et al., 2022). However, the levels of HCN in locust bean pulp powder and jam were below the toxic limit of 35 mg/100 g (Ogori et al., 2022). Oxalates and phytates, when present at high levels are antinutrients, which reduce nutrients intake, digestion, absorption and utilization. They adversely affect health through inhibition of protein digestion, growth, iron, zinc absorption and wound healing due to low availability of nutrients (Onimawo and Akubor, 2012). Phytates are antinutrients when available at >3 g/100 g (Onimawo and Akubor, 2012). The amount of oxalates was below the tolerable limits of 2.5 g/100 g

(Onimawo and Akubor, 2012). The alkaloids content of the pulp (2.92mg/100g) and jam (1.89 mg/100 g) were higher than those of the jams from tropical fruits such as pineapple jam (Orazulike and Lukman, 2004). Alkaloids are used as basic medicinal agent due to their analgesic, antispasmodic and antibacterial properties. The consumption of the pulp jam will offer the body with such therapeutic properties. The levels of alkaloids and flavonoids in locust bean pulp powder and jam were within the safe margin of 52.02 mg/100 g reported by Uzoma et al. (2021). Saponins are heat liable, which accounted for its reduction in the jam. Saponins have biological activities such as haemolytic, hypoglycemic, antioxidant, lowering of cancers risks, antimicrobial activity among others (Akubor et al., 2017). Saponins boost energy and serve as natural antibiotics (Onimawo and Akubor, 2012). The flavonoids content of locust bean pulp was 3.97 mg/100 g and decreased to 2.89 in the jam probably due to thermal destruction. These products would contribute in the diets high amount of flavonoids with antioxidant properties. Flavonoids protect consumers against the development of cardiovascular diseases, atherosclerosis, hypertension, ischemia/ reperfusion injury, diabetes mellitus, neurodegenerative diseases (Alzheimer's disease and Parkinson's disease), rheumatoid, arthritis and aging (Ogori et al., 2022). The high content of carotenoids in locust bean pulp powder and jam suggests that consumption of these products would provide health benefits (Uzoma et al., 2021). Carotenoids are powerful antioxidants which protect the cell by reacting with oxidizing factors and neutralizing their effects (Oikeh et al., 2013). Carotenoids are effective in preventing cancer and other degenerative diseases (Oikeh et al., 2013). Tannins have been reported to interfere with digestive processes leading to bloating, diarrhea and constipation (Adepoju and Karim, 2004). Tannins quicken healing of wounds and burns in human body (Edoga et al., 2008).

The total and reducing sugar contents of the jam were significantly higher than of those of the pulp due to the concentration of the pulp/water mixture to 72 ºBrix, the sucrose added to the jam and probably hydrolysis of sucrose in the acid medium (pH 3.3) of the jam. The concentration also increased the glucose and fructose contents of the jam. Based on these properties, the jam could be classified as a shelf stable product as microorganisms are inhibited in foods that contain above 65% sugar according to the report of Onimawo and Akubor (2012). The reducing sugars content of the jam (47.4%) was within the range of 15-55% given by Adepoju and Oyewole (2008) for jam, marmalades and jellies. Adepoju and Oyewole (2008) gave similar observation for pineapple jam. Compared to the pulp, the vitamins B1, B2 and C; and beta-carotente contents of the jam were low due to heat destruction and oxidation during the processing (Egbekun et al., 1996). The previous works showed that thermal processing of fruits into jams affected the vitamin C content (Addy et al., 1995; Chavan et al., 2015). Vitamin C content of food is affected by light, oxygen, heat, enzymes and metals (Chavan et al., 2015). Vitamin C is used for growth and repair of tissues in the body, necessary to form collagen, aid iron absorption and essential for healing of wound and repair and maintenance of cartilage (Chidinma et al., 2010). Vitamin C functions as an antioxidant and anti-allergic molecule and is relevant for the eye to deal with oxidative stress (Chidinma et al., 2010). It delays the progression of age- related macular degeneration and vision loss and is also involved in the stimulation of immune system. Beta-carotene is sensitive to heat (Uzoma et al., 2021), which explains the lower amount in the jam. The contents of vitamin C and beta carotene may make the jam functional food. The citric acid contents of the pulp powder and jam were 12.5 and 15 mg/100 g, respectively, where the food grade citric acid used in making the jam added to the citric acid content of the jam. However, the malic acid content decreased from 2.4 mg/100 g in the pulp powder to 1.0 mg/100 g in the jam due to dilution effect. Vitamins are organic components of food that are needed in small amount for growth and maintaining good health by their diverse biochemical functions. Niacin is needed for carbohydrate and protein metabolism and is active in preventing pellagra. The deficiency of thiamine is notably the cause of beriberi (Chidinma et al., 2010).

The levels of P, K, Na, Mg, Fe, Cu and Zn increased in the jam over those of the pulp powder probably due to concentration effect. The levels of the minerals in the jam were higher than those reported for black plum jam (Adepoju and Oyewole, 2008) and *Spondias* jams (Oyewole and Adepoju, 2005). The locust bean pulp jam may contribute to supplying significant amounts of essential minerals to those who consume it. These minerals are involved in diverse metabolic functions. For instance, iron is essential for hemoglobin formation (Adepoju and Karim, 2004), zinc stimulates the activity of enzymes needed in the biosynthesis of DNA and wound healing, supports normal growth and development during pregnancy as well as maintenance of health in childhood and adolescence (Soetan et al., 2010). Magnesium is used for muscle contraction and sodium for osmotic balance, while Ca is involved in bone and teeth formation. Copper plays a role in iron absorption and mobilization of stored iron as well as being a component of many enzymes (Oyewole and Adepoju, 2005). The content of sodium and potassium is very important for the functioning of the human body. They take part in the regulation of the osmotic pressure of cells, which ensures the maintenance of acid–base balance (Adepoju and Oyewole., 2008). However, their dietary content is often biased in favour of sodium. Thus, it is recommended to consume foods with high potassium to sodium ratio. An adequate amount of calcium in the diet is good for bone stability and in preventing osteoporosis (Soetan et al., 2010). The K contents of the pulp powder and pulp jam were high, which agreed with the report that K is an abundant mineral in Nigerian foodstuffs (Omojorho and Akubor, 2016). Potassium is useful in maintaining body fluid, electrolyte balance and cell integrity (Chidinma et al., 2010). Iron, Cu, Mg and Ca act as catalysts for enzymes involved in normal metabolic processes (Chidinma et al., 2010). Iron is essential for prevention of anemia and Ca is linked to bone health.

The microbial counts for the jam were in conformity with the microbiological profile of jams reported by Alobo (2000). The total plate count of the jam was far below the acceptable limit of <105 recommended by the International Commission on Microbiological Specifications for Food (Adepoju and Karimu, 2004; Muhammad et al., 2012). The heat applied to concentrate the jam as well as sugar and sodium benzoate incorporated into the jam caused the reduction of the microbial load (Muhammad et al., 2012). The reduction of pH of the jam from 5.2 in the pulp powder to 3.2 provided enabling environment for the sodium benzoate to inhibit the growth of bacteria, yeast and moulds (Ehsan et al., 2002). Sodium benzoate is used to reduce water activity of foods (Onimawo and Akubor, 2012). Acidity plays a critical role in the preservation of foods and contributes to inhibiting growth of food spoilage and pathogenic organisms with other factors such as moisture content and heat (Orazulike and Lukman, 2001). The sugar may have exerted osmotic pressure that kept osmophilic organisms low in the jam (Oyewole and Adepoju, 2005). The total plate count of 40 cfu/g and yeasts and moulds counts of 21 cfu/g were reported for mango jams (Muhammad et al., 2012). Coliforms and *E.coli* were not detected in the locust bean pulp powder and the jam. *E.coli* is the primary indicator for microbiological quality of water and food. Its presence in food indicates faecal contamination and such food is not safe for human consumption (APHA, 2001; Muhammad et al., 2012). The absence of *E.coli* and coliforms makes the jam safe for human consumption. The chemical reactions between the components and organic acids in the jam may have affected the colour of the pulp jam. Organic acids and sugars ratio creates sense of taste, which is felt by the taste buds in the tongue (Eke-Ejiofor and Owuno, 2013). The different proportions of the organic acids and sugars and the soluble solids contents of the jam probably caused the differences in the scores for mouth feel (Grigelmo-Maguel and Martin-Belloso, 1999). The consumer ratings for the locust bean pulp jam generally indicated good consumer acceptance. On a 5-point scale, the locust bean pulp jam and plum jam scored 4.7 and 4.3, respectively, for general acceptability. According to Hobbs et al. (2014), a newly developed food product must score at least 3 (like moderately on a 5-point scale) for it to be launched in the market. Therefore, African locust bean pulp fruit is suitable for jam manufacture.

Conclusions

Africa locust bean pulp is a good source of carbohydrate, thiamin, riboflavin, vitamin C, beta-carotene, K, Mg, Na, P and Fe, but has low contents of protein, fat, Cu and Zn. It also contains high amounts of total phenol, flavonoids, and carotenoids. The pulp powder is a good material for the production of jam. The jam produced from the pulp is generally accepted, safe and has high profile of essential minerals, vitamins and antioxidant phytochemicals, which will make it serve as a functional food.

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