Evaluation of Cassava enriched with defatted African Yam Bean Flour for Staple Food Production

Akinsola, A.O*., Taiwo-Oshin, M.A., Obisesan, D.O., and Segilola, V.O.

Department of Home Economics, Federal College of Education (Special), Oyo, Oyo State, Nigeria
*Corresponding author: akinsola4gold@gmail.com; +2348034800734

Abstract: The consumption of fortified cassava fermented *amala-lafun, foofoo, garri*, AFG, flour with legume could help in combating protein-energy-malnutrition in most of its consuming areas. This study was carried out to determine the nutritional composition of cassava enriched with defatted African yam beans (AYB) flour for staple food production. Cassava roots were divided into three portions for different processing to obtain AFG a local staple food. All the cassava products were sun-dried to ≤12% moisture content, mixed with defatted AYB (80:20) and milled separately into fine flour (250 micron). The entire samples were analyzed for proximate composition, functional properties and antinutritional factors using standard methods. Samples were made into gelatinized paste and evaluated for sensory attributes using Hedonic scale. Results showed that moisture, crude protein, crude fat, total ash, crude fibre and carbohydrate contents of the products obtained ranged from 6.10 to 7.90%, 4.80 to 6.80%, 0.30 to 0.60%, 0.70 to 2.10%, 0.71 to 2.40% and 80.8 to 82.9%, respectively. Functional properties of the samples ranged from 1.70 to 3.10, 0.76 to 1.30, 0.62 to 0.68, 1.40 to 2.80 and 14.5 to 23.8s for water absorption capacity, oil absorption capacity, bulk density, swelling power and wettability index, respectively. All meals prepared from the samples were accepted by the panelists. The findings showed that cassava flour substituted with 20% AYB could be used in the fortification of fermented cassava flour for the production of AFG paste for consumption.
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1. Introduction

Global food security however is becoming shaky with increasing dependence on a few major staple crops. This has resulted in an alarming reduction not only in crop diversity but also in the variability within crops. Root and tuber crops are the most importance food crops for direct human consumption in third world countries which require minimal processing method. Root and tuber crops are second only in importance to cereals as a global source of carbohydrates, and provide minerals and essential vitamins (Oyewole *et al*., 2004). Although a proportion of the minerals and vitamin in may be lost during processing (Udofia *et al*., 2010). There are two major issues in the utilization of cassava; first, cassava root is highly perishable and cannot be stored in fresh form for more than 3 days after harvesting. Physiological deterioration of the root occurs in 2 -3 days after harvesting follow by microbial deterioration in 3 – 5 days (Akingbala *et al.,* 2005). Second, the root contain two cyanogenic glucosides, *linamarin* and *lotausralin* which on hydrolysis by enzyme release toxic hydrogen cyanide which pose health risk to human being. These two reasons usually necessitate the immediate consumption and processing of cassava roots after harvesting (Arinola, 2016).

Among many food products derived from cassava, *gari* is by far the most popular (Oluwole *et al.,* 2004). Reports had shown that most traditional diets of root and tubers (RTs) meals usually go with vegetable soups, meat ground nuts, grain legumes and fish to compensate for RTs protein deficiencies. Roots and tubers are highly perishable difficult to store, handle, and transport, it has been estimated an average of 30% loss during storage (FAO, 2000), and in order to minimize its losses, there is needs to convert it's from perishable to non-perishable through food processing operation (Sanni *et al*., 2008).

Staple food comprises of root and tubers were reported to have low nutritional status providing substantial carbohydrate value. Staple foods are deficient in quality protein since it is majorly from root and tuber crops. Therefore, protein-energy malnutrition is prevalent in the areas where RTs serves as their major food. There is need to improve the protein contents of RTs to solve the problem of malnutrition in our society. With the ever increasing population pressure and fast depletion of natural resources, it has become necessary to explore the possibilities of exploiting new plant resources to meet the growing needs of the human society, which incidentally has depended only on a small fraction of plant resources comprising less than 30 crops; among which is the African yam bean, a leguminous crop (Ikhajiagbe, 2003). Although, African yam bean represents a less expensive source of dietary protein among Nigerians of low economic status, very little is known about its nutritional potential and with its incorporation as enrichment to staple food could pose a well-nourished product with protein-energy balance. At present, there is no adequate information available on the comparative quality characteristics of RTs enriched with African yam beans.

Consequently, converting these root and tuber crop into flour may be important process that would contribute to minimizing its losses and allow commercial food cottage industry to store them throughout the year. Studies (Agunbiade and Adanlawo, 2007; Udofia et al., 2010; Arinola, 2016) have shown that RTs when combined with legumes; products formed are characterized for having high content of biological quality protein. Hence, combining both at an optimum blending ratio could produce a composite flour rich in biological values. It is imperative, therefore to evaluate cassava products enriched with African yam beans flour for staple food production.

2. Materials and Methods

2.1. Materials

Cassava roots and Africa yam beans (*Sphenostylis stenocarp*) used for this study was obtained from a local (Ajegunle) market, Oyo town, Oyo State, Nigeria, while Africa Yam beans was obtained from research farm Federal Polytechnic, Offa, Kwara State, Nigeria.

2.2. Preparation of sample flours

2.2.1 Preparation of fermented "amala-lafun" flour

Dried cassava flour is known as "lafun" in Nigeria and "kokente" in Ghana. Freshly harvested cassava roots were peeled, washed, manually cut into pieces with stainless knife, and soaked in clean water to ferment for 5 days. The fermented cassava pulp drained using colander (large local sieve designed for such work). The semi-dried pulp was spread out on raised platform to sundry. The dried granular were milled into "lafun" flour using locally fabricated hammer mill machine. The sample was allowed to cool, packed, heat sealed in high density polyethene bag and store at room temperature (28 ± 2^{o}C).

2.2.2. Preparation of foofoo flour

The freshly harvested cassava roots were peeled, washed, manually cut into pieces with stainless knife, and soaked in clean water to ferment for 4 days. The fermented cassava pulp was grated into a mash using locally fabricated motorized grating machine. The mash obtained was put into a clean water of 1:1 ratio (wgt/vol), homogenized and put in a clean polyethene bag. The bag opening was knotted with rope, and de-watered using a locally fabricated hydraulic machine. The cake obtained was broken into granules and spread out on a raised platform to sundry. The dry cassava granular was milled into foofoo flour using locally fabricated hammer mill machine. The sample was allowed to cool, packed, heat sealed in high density polyethene bag and store at room temperature (28 ± 2^{o}C).

2.2.3. Preparation of "garri" coarse grits

Garri is creamy white granular flour with a slightly fermented flavour and as lightly sour taste made from fermented, gelatinized fresh cassava tubers. Freshly harvested cassava roots were peeled manually using stainless steel knife, washed in clean water and grated using a locally fabricated grating machine. The grated mash was put into a porous sack, tied with a string at the opening and dewatered using locally fabricated hydraulic machine. The mash was left to ferment for 5 days at room temperature. The resulting cake was crushed manually, sieved using locally made aluminum mesh in order to remove fibre. The cream-white granular grits were roasted (garified) in iron pot with constant stirring until a free flowing cream-brown colour is obtained. The sample was allowed to cool, packed, heat sealed in high density polyethene bag and store at room temperature (28 ± 2^{o}C).

2.3. Preparation of defatted Africa yam beans flour

The Africa yam beans, after removing particles and defective seeds were thoroughly washed in clean water. The seeds were boiled for 30 min, drained, cooled and dehulled by hands rubbing within two palms, after which the Africa yam beans cotyledon were dried in a Genlab drying cabinet (Model: DC 500; Serial number: 12B154) at 60±5 °C for 48 hr, winnowed and milled in a laboratory hammer mill (Fritsch, D-55743, Idar-oberstein-Germany). The sample was defatted using soxlet extractor as described by AOAC (2005). The defatted granular was then milled in a laboratory hammer mill (Fritsch, D-55743, Idar-oberstein-Germany), sieved using 250 µm screen, packed, heat sealed in high density polyethene bag and store at room temperature (28 ± 2^{o}C).

2.4. Formulation of each cassava product

The cassava fermented amala-lafun flour, cassava fermented foofoo flour, and cassava fermented garri coarse grits already obtained were mixed each with 20% of defatted Africa yam beans. Each mixed sample was homogenous in an Orbital shaker (SOI model, Stuart Scientific, USA) for 15 min. The samples were coded as sample A (foofoo), sample B (garri), and sample C (lafun). Each sample was stored in an airtight low-density polyethylene at room temperature (30 ± 2^{o}C) until required for analysis.

2.5. Production of each cassava product paste

Three litre of water was boiled in a pot on a gas cooker. 100g of amala-lafun, and garri sample was poured in the 200 ml boiling water, and stirred continuously until smooth consistency thick dough was attained. The same procedure was applied to foofoo sample, but a little quantity of hot water was added and re-heats to boiling point, to allow the paste cook properly. The paste was taken off the flame, stirred continuously until smooth consistency thick dough was attained. All the three dough obtained were used for sensory evaluation.

2.6. Methods

2.6.1. Proximate composition determination

The proximate analysis (moisture content, protein content, ash content, fat content and crude fiber) of the samples were analyzed according the official methods of analysis described by the Association of Official Analytical Chemist (2005), while carbohydrate was calculated by differences.

2.6.2. Functional properties determination

Bulk density was determined by the method of Wondimu and Malleshi (1996) method. Water absorption capacity was determined using the method described by Sosulski (1962), while oil absorption capacity was determined as described by AOAC (2005). The swelling index of each sample was determined using the method of Leach *et al.* (1959), while wettability index was done according to the procedure described by Okezia and Bello (1988). Gelation temperature was carried out according to method described by Pearson (1991).

2.6.3. Antinutritional factors determination

Determination of oxalate, and tannin were determined according to the method of Pearson (1991), while HCN the residual cyanide content was determined using the method of Essier *et al.* (1993). Phytic acid was determined as described by Makover (1970), and Wheeler and Ferrell (1971).

2.7. Sensory evaluation determination

Each of the staple food samples was prepared into paste and presented to twenty consumers of the cassava products. Each sample was reconstituted, coded, and evaluated for preference using the method of Iwe (2002). They were asked to score the pastes for colour, flavour, taste, texture and overall acceptability. Each panelist sat in an enclosed cubicle designed for sensory evaluation and water was provided to rinse mouths before and after tasting each of the samples. The panelists were presented with a score sheet using 9-point hedonic scale where 1 is disliked extremely and 9 liked extremely.

2.8. Statistical Analysis

All data were statistically analyzed using SPSS version 17.0 for analysis of variance, while Duncan multiple range test (DMRT) at $p<0.05$ was used to separate means where there is a significant difference. For each sample, triplicate determinations were carried out.

3. Results and discussion

3.1 Proximate composition of the formulated composite products

Proximate composition of the fortified composite flour is presented in Table 1. The moisture content, crude protein, fat, fibre, ash, and nitrogen free extract (NFE) contents ranged from 6.1 – 7.9%; 4.8 – 6.8%; 0.3 – 0.6%; 0.7 – 2.4%; 0.8 – 2.1% and 80.8 – 82.9%, respectively. Moisture content is a major determinant of the shelf stability of cassava products; high moisture content usually predisposes *garri* to problem of formation of lumps and mould growth within a very short period of storage. FAO (1992) had recommended a moisture safe level of 12% - 13% for storage of cassava flour, while Ukpabi and Ndimele (1990) had reported that *garri* samples with moisture content of 13% - 16% can be successfully stored for up to 7 months without mould infestation, while Standard Organization of Nigeria/International Institute of Tropical Agriculture (SON/IITA) recommended a moisture content safe level of 10% as reported by Sanni *et al.* (2005). This indicates that these three samples will have good storage potential and all things being equal will be fit for export. The range of protein content of the *garri* samples produced was comparable to 1.76% - 2.11% reported for cassava garri by Ogueke *et al*. (2013). The fat contents of all the samples were not significantly different and comparable to 1.62 – 2.23% reported for cassava garri by Arinola (2016).

Table 1: Proximate composition of the formulated composite products

Sample	%Moisture content	%Crude protein	%Crude fat	%Crude fibre	%Total ash	%NFE
A	9.6 ± 0.06^{a}	6.1 ± 0.19^{b}	0.3 ± 0.02^{a}	1.5 ± 0.14^{b}	0.95 ± 0.17^{a}	80.8 ± 1.68^{a}
B	11.4 ± 0.10^{a}	4.8 ± 0.03^{a}	0.4 ± 0.00^{a}	2.4 ± 0.15^{c}	2.1 ± 0.21^{b}	82.5 ± 2.16^{b}
C	10.3 ± 0.22^{a}	6.8 ± 0.17^{b}	0.6 ± 0.00^{a}	0.71 ± 0.10^{a}	0.79 ± 0.00^{a}	82.9 ± 0.93^{b}

Mean values with different superscripts within the same column are significantly different at $p<0.05$.
Sample A: amala-lafun flour; Sample B: Cassava foofoo flour; Sample C: garri coarse grit.

The ash and fibre contents The fibre contents of the samples reduced significantly as a result of fermentation of all the samples were not significantly different ($p<0.05$), but were lower than 2.75% maximum level permitted for *gari* by Codex Standard 151-1989 (2013). This result was comparable to other workers (Adebowale *et al*., 2008; Karim *et al*., 2009; Owuamanam *et al*., 2010; Oluwamukomi *et al*., 2012; Koubala *et al*., 2014) reports. This observation may be as a result of thermal degradation of fibrous materials in the samples which were exposed to heat for a longer period. The fibre contents of garri and lafun were below the regulatory standard of 2.0% Codex Standard 151-1989 (2013) as reported by Sanni *et al.* (2005). Generally, garri and other cassava products with low fibre content are considered to be of good quality (Almazan *et al.,* 1987) and it is preferred by most *gari* consumers. There was significant difference in the carbohydrate content of foofoo and garri compared to lafun, however, all the samples were high in carbohydrate which make them to be a cheap source of energy.

3.2. Functional properties of the formulated composite products

The functional properties of the formulated composite products are presented in Table 1. The bulk density, water absorption capacity, oil absorption capacity, swelling index, wettability, and gelation temperature ranged from 0.2 – 0.6g/ml; 1.7 – 3.1g/ml; 0.7 – 1.3 g/ml; 1.4 – 2.8 g/ml; 4.5 – 23.8sec; and 60.1 – 64.5°C. Water absorption capacity is the ability of the flour to absorb water and swell for improved consistency and acceptability in this type of products. It is desirable in food system to improve yield, consistency, and give body to food. WAC for sample A has the highest mean value (3.1), while sample C has the lowest (1.7). Bulk density of the food samples ranged from 0.20 in sample B to 0.62 in sample A. There is no significant difference ($p<0.05$) in the bulk density values. The WAC ranged from 1.71 g/ml in sample C to3.1 g/ml in sample A, while OAC ranged from 0.7 g/ml in sample A to 1.3 g/ml in sample A. The swelling index for the food flours ranged from 1.4 to 2.8 g/ml for sample A and B, respectively, while wettability of the sample flours ranged from 4.5 g/ml in sample C to 23.8 g/ml in sample B.

Gelation temperature ranged from 60.1°C in sample C to 65.5°C in sample A. This result agreed with that of Oluwamukomi and Jolayemi (2012), who worked on physico-thermal and pasting properties of soy-melon-enriched "garri" semolina from cassava, and Koubala *et al.* (2014), who worked effect of fermentation time on the physicochemical and sensory properties of garri from sweet potato, respectively. There were no significant differences ($p>0.05$) in bulk densities of the complementary food with values between 0.20 and 0.62. Low bulk density of food products had been reported to provide more nutrient dense meal, as more of the products can be eaten resulting in high nutrient intake per meal (Nnam, 2000). Wadud *et al.* (2004) reported that bulk density could also be affected by moisture content and reflects particle size distribution of the product flours. The food products were also significantly different ($p<0.05$) in their swelling index and wettability. Foofoo sample had the highest wettability among the other formulated samples, while amala-lafun sample had the highest gelation temperature. Wadud *et al.* (2004) and Solomon (2005) reported that processing methods, time and temperature amongst other factors affect the functional properties of a food product.

The food products were significantly different ($p<0.05$) in their water absorption capacity (WAC) values. Sample C had the highest WAC as they retained water more than other food samples. Water absorption capacity (WAC) observed in this study is probably related to the low viscosity patterns and weak internal organization resulting from starch granules as reported by Singh *et al.* (2003), who worked on cookie-making properties of corn and potato flours, respectively. This study showed that fermentation, and roasting methods significantly ($p<0.05$) decreased WAC of the complementary food samples. Flour from sample B had the least swelling index, while sample A had the highest. All the food samples were significantly different ($p>0.05$) in their swelling index. Generally, the low level of swelling index obtained for garri sample may have been caused by the presence of protein, lipid, and lactic acid bacteria activity which increased during fermentation of the cassava tubers. Hence, when cooked, the hydrolyzed starch swells less, retains less water, has lower viscosity, and increases nutrient/energy densities per unit volume.

Table 2: Functional properties of the formulated composite products

Sample	Bulk density	WAC g/ml	OAC g/ml	SWI gl/cm^3	Wettability	Gelation temp °C
A	$0.62{\pm}0.73^a$	$3.1{\pm}0.11^{bc}$	$1.3{\pm}0.10^b$	$2.8{\pm}0.04^c$	$18.6{\pm}0.07^b$	$65.5{\pm}0.98^b$
B	$0.20{\pm}0.02^a$	$2.70{\pm}0.14^b$	$0.7{\pm}0.00^a$	$1.4{\pm}0.06^a$	$23.8{\pm}0.13^c$	$64.5{\pm}1.58^b$
C	$0.30{\pm}0.08^a$	$1.7{\pm}0.25^a$	$0.8{\pm}0.06^a$	$2.1{\pm}0.00^b$	$4.5{\pm}0.42^a$	$60.1{\pm}0.10^a$

Mean values with different superscripts within the same column are significantly different at $p<0.05$.
BD: Bulk density, WAC: Water absorption capacity, OAC: Oil absorption capacity; SWI: Swelling index. Sample A: amala-lafun flour; Sample B: Cassava foofoo flour; Sample C: garri coarse grit.

3.3. Antinutritional content of the formulated composite products

The antinutritional content of the formulated composite products is as shown in Table 3. The oxalate, tannin, phytate, and HCN content ranged from 2.6 – 2.8 mg/100g; 0.9 – 3.6 mg/100g; 0.6 – 2.4 mg/100g; and 13 – 15.3 mg/100g, respectively. The decrease in phytate content which is most especially in sample B may be attributed to activity of the endogenous phytate enzymes from the raw ingredient and inherent microorganisms which are capable of hydrolyzing phytic acid in the food sample during processing into flours. The residual phytate content of the ferment flour falls with the FAO recommended safe level making the fermented flours safe human and animal consumption. Tannins a mixture of carbohydrate and phenol plays a major role in decreasing protein quality, absorption of iron, and a possible carcinogenic (Butler, 1989). This study result disagreed with that of Egbe and Akinyele (1990) who reported 0.59 mg/g tannic acid in raw lima, and Balogun and Fetuga (1988) who evaluated tannic acid contents in some wild under-utilized crop seeds in Nigeria and reported vlues ranged between 0.11% in *Coula edulis*; 1.15% in *Lophira alata*; *Hypaena thebaica* 1.11%; *Adasonia digitata* 0.98%; *Carapa procera* 0.87% and *Dioscoreophyllum comminsii* 0.076%.

Oxalate, C_2 dicarxylic acid anion, is produced and accumulated in many crop plants and pasture weeds (Alector and Omolara, 1994). The study result is in constract with the two authors who found 28.59 mg/100g DM, 25.36 mg/100g DM, and 73.40 mg/100g DM for *Cajanus cajan, Glycine max*, and *Vigna unquiculata*, respectively. The significant difference in the hydrogen cyanide contents of sample B compare to sample A and C indicates that fermentation and garification play a major role in the reduction of cyanide content of *gari*. Aworh (2008) reported that processing of cassava roots into *gari* is the most effective means of reducing cyanide content to a safe level and that most of the cyanide in cassava tubers is eliminated during the peeling, pressing and frying operation. The cyanide content of all the samples were below the recommended standard of 20mg/kg by SON/IITA as reported by Sanni *et al.*, (2005). This indicates that the products will be safe for consumption in communities where consumption of these products were very common.

Table 3: Antinutritional content of the formulated composite products

Sample mg/100g	Phytate	Tannin	Oxalate	HCN mg/kg
A	2.42 ± 0.41^c	0.89 ± 0.02^a	2.64 ± 0.24^a	13.32 ± 0.00^a
B	0.58 ± 0.10^a	3.61 ± 0.00^b	2.41 ± 0.05^a	15.33 ± 0.17^b
C	1.62 ± 0.16^b	2.86 ± 0.73^b	2.82 ± 0.31^a	13.64 ± 0.19^a

Mean values with different superscripts within the same column are significantly different at $p<0.05$.
Sample A: amala-lafun flour; Sample B: Cassava foofoo flour; Sample C: garri coarse grit.

3.4. Sensory attributes of the formulated composite products

Table 4 shows the sensory attributes of the formulated composite products. The mean score for colour, taste, flavour, texture, appearance, and overall acceptability ranged from 7.9 – 8.8; 7.1 – 8.4; 7.3 – 7.9; 7.7 – 8.5; 7.1 – 8.8, respectively. Sample A is preferred than others in term of colour and taste. This result shows that 20% of defatted Africa yam beans flour can even be added to the cassava product. Sample A and C have the highest mean score which shows that they are more preferable than sample B in term of flavour by the panelist. Sample A has the highest mean score in term of overall acceptability. The result shows that the fortification of 20% AYB flour with 80% cassava tuber would be generally more acceptable for the production of amala-lafun, a cassava fermented paste staple food product. Sample A has the highest mean score, while sample B had the least mean score. This result shows that defatted African yam beans flour could be used as an improver and fortification of such composite food products. Sample C has the highest mean score in term of appearance, while sample B has the least mean score. Sample C is more preferable in term of appearance.

Table 4: Sensory attributes of the formulated composite products

Sample	Colour	Taste	Flavour	Texture	Appearance	Overall acceptability
A	8.8 ± 0.14^b	8.4 ± 0.23^b	7.9 ± 0.10^b	8.5 ± 0.13^a	7.1 ± 0.00^a	8.8 ± 0.07^{ab}
B	7.8 ± 0.21^a	7.1 ± 0.16^a	7.3 ± 0.18^a	7.7 ± 0.12^a	6.8 ± 0.32^a	7.6 ± 0.22^a
C	7.9 ± 0.27^a	7.8 ± 0.11^a	7.9 ± 0.21^b	8.3 ± 0.08^a	7.6 ± 0.19^b	8.3 ± 0.15^a

Mean values with different superscripts within the same column are significantly different at $p<0.05$.
Sample A: amala-lafun flour; Sample B: Cassava foofoo flour; Sample C: garri coarse grit.

Conclusion

The result of this study shows that the formulation of composite flours of cassava tuber products of 20% defatted African yam bean could be an alternative and cheap source of protein in the diet of its consumers as shown by the proximate composition results. The study shows that amala-lafun, foofoo, and garri could be produced and accepted by fortifying cassava tubers with 20% defatted African yam bean.

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Corresponding Author Address:
Akinsola, Akinjide Olubunmi PhD.
Department of Home Economics,
Federal College of Education (Special),
Oyo, Oyo State, Nigeria
Telephone: +2348052209288
Email: akinsola4gold@gmail.com

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