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Physico-Chemical Quality of Processed Nutrient-Dense Garri (NDG) from Pro-Vitamin a Cassava and Soybean

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ABSTRACT: *Garri is a popular and commonly consumed staple food in Nigeria especially among the Eastern and Southern Nigerians. It is nutritionally inadequate with main nutrient as carbohydrate. We examined the potential of yellow cassava fortification with soybean in the production of Nutrient dense garri (NDG) to improve nutrient quality of garri. Garri from three geographical locations in Nigeria serve as control. The Hydrogen cyanide (HCN), pH, and carotene content of the pro-vitamin A cassava decreased with processing. General linear model analysis of the functional properties returned* $F_{(11,\ :0.05)}$ *= 24175.5, 5.12, 7.51, 9.43, 7.45 and 346.30 that are all significant for pH, TTA, loose bulk density, packed bulk density, swelling capacity and gelatinous capacity respectively. Fermented NDG has the least mean HCN, the highest carotene and protein while unfermented NDG contained highest fat, fibre, ash and minerals. The study concluded and recommended fortification of yellow flesh cassava with soybean in garri processing to reduce malnutrition*

KEY WORDS: Pro-vitamin A Garri, nutrient dense garri, fermented garri, unfermented garri, nutrients content

INTRODUCTION

Worldwide, cassava (Manihot esculenta Crantz) is grown mostly in tropical and subtropical locations in a variety of soil types and environmental circumstances. Cassava is a vital dietary energy crop for many in sub-humid tropics of Africa. It is one of best raw materials for industrial and domestic starch. Nigeria produced 60 million tonnes of cassava in 2020, making it the world's largest grower. The crop is grown throughout the nation's agro-ecological zones. (FAO, 2020).

However, Benue, Kogi, Enugu, Imo, Cross-River, Ondo, Ogun, Delta, Anambra, Edo, and Taraba are important cassava-producing states in Nigeria.

Cassava tubers easily deteriorates after harvesting and also contains some anti-nutrients, processing of the crop to prevent post-harvest deterioration and reduce anti-nutrients content is thus inevitable. Despite the fact that cassava is a cheap food source for over 250 million people in Africa, it is highly lacking in important nutrients including protein and essential micronutrients such as vitamin A (Adenle, et al., 2012). In an attempt to improve nutrition and reduce Vitamin A deficiency, genetically improved cassava varieties through bio-fortification with vitamin A were developed (Talsma et al., 2013). Some bio-fortified varieties of cassava with significant carotenoid content have been developed to enhance vitamin A intake in Africa through conventional breeding methods. However, even with the improvement in vitamin A content of product from the Pro-vitamin A cassava, such product is still deficient of some vital nutrients such as protein.

Soybean (*Glycine max*) is a protein rich leguminous crop, which is grown for its edible seed. The top producer of soybeans for food in West Africa is Nigeria (FAO, 2020). Legumes have reportedly been identified as accessible sources of plant protein to the low-income earners, serving as alternative to the expensive animal protein (Olatunde *et al.,* 2021). The versatility, high nutritional content, functionalities and health advantages of soy have been documented. It is rich in high quality protein, vitamins, minerals and phytochemicals. Previous studies have confirmed that soybean helps in improving brain and nerve functions (Acuna *et al.,* 2012; Okoye *et al.,* 2022).

In most African countries cultivating cassava, different traditional methods are employed to process cassava into foods. Some of the foods from cassava tuber is flour, starch, *fufu*, tapioca, *makopa, chingwage, baton de manioc, rali*, and *garri* (Abass et al., 2018).

Garri is the most available and accessible staple food consumed by masses crosswise West Africa because it is cheap particularly in Nigeria, Republic of Benin, Ghana and Togo (Felber *et al.,* 2017; Wossen *et al*, 2019). Gari is produced from cassava tuber by peeling, grinding, pressing, sieving the wet cake into small pieces (grits) and then roasting in a pan over hot heat to form the final dry-crispy product. It comes out in white or cream, but yellow when yellow cassava tuber is used or when fried with palm oil.

It may be consumed soaked in water complimented with or without sugar/salt and/or any protein (fried or roasted fish/meat, bean cake (akara) and groundnuts) and snacks (coconuts, palm kernel) or by stirring in boiled water to form a gelatinized budding, ‘eba’. Eba is served with stews or soups or vegetables. Also, it may be consumed by sprinkling on cooked beans (Arisa *et al.,* 2011; Adinsi *et al.,* 2019). Garri is high in carbohydrate and low in protein, fat and micronutrients. Regular intake of low protein diet can result in protein energy malnutrition (Alozie and Ekerette, 2017). Low nutrient intake is a major cause of malnutrition in public health problem in West Africa. The use of pro-Vitamin A cassava fortified with soybean in the production of garri; the

cheapest and most accessible food staple will significantly contribute to nutrient (particularly vitamin A and protein) intake and alleviate problems related to nutrient deficiency especially among the masses within the *garri*-consuming regions.

Protein and Vitamin A deficiency (VAD) related ill health are major public health problem. Nigeria is reported to be one of the countries worldwide with the highest prevalence in Africa (Afolami *et al.*, 2021). The most severe effects of this deficiency are seen in young children and pregnant women. Deficiency symptoms include stunted growth, diarrhoea, measles and high mortality rate in children and in severe cases of vitamin A deficiency, night blindness (IITA, 2014; Bolarinwa et al., 2017; WHO, 2022). Vitamin A biofortified cassava was developed to combat vitamin A deficiency. These biofortified cassava varieties are yellow in colour and due to their high β-carotene content; they are known as pro-vitamin A cassava (PVAC). Presently, six varieties of pro-vitamin A cassava have been produced in Nigeria with distinct qualities such as: high yields, resistant to pests and diseases (Ayetigbo *et al.*, 2018; Adeola *et al.*, 2017).

The study investigated the importance of the use of provitamin A cassava and soybean in garri processing to enhance the nutrient quality of the end product - Nutrient Dense Garri (NDA), an innovative product and economical household food staple. Also by extension, improve the nutritional status of garri consumers across West Africa.

THEORETICAL UNDERPINNING

Processing of agricultural food crops is the backbone of the food industry for an enhanced market because it adds value and enhances market value. Developing and releasing new product innovations for both start-ups and established companies remain the main objective for higher product economic values. Novel new product development creates opportunities for agribusiness along agricultural value chains and contributes to employment generation, and improved food and nutrition security (FNS). Nutrient dense garri (NDG) developed in this study is a novel technology which aimed at nutritional improvement of consumers and enhancement of agribusiness along agricultural value chain

METHODOLOGY

Source of materials and Processing: Pro-vitamin A cassava tuber (07/0593) were obtained from Ilora outstation of Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria. Soybean grains (TGX/1448/2E) was obtained from the seed store of IAR&T main station Ibadan, Nigeria. Pro-vitamin A cassava tubers were peeled, washed and grated into mash. The grated mash was portioned into four, two of which were fermented for three days and the two other parts were unfermented. Soy residue was added to one portion each of the fermented and unfermented cassava

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mash at a predetermined ratio of 25:75 (1:3). Whereby, 25% of soybean paste to 75% of cassava mash. All samples were dewatered, the solid cake was pulverized and the granules fried into garri (Fig 1). The resultant garri samples were sieved, packaged and labelled appropriately. Samples were taken for chemical analysis and functional properties. Samples were also taken from non-fortified garri collected through survey from local garri processors in Ogun, Oyo and Edo states for chemical analysis and functional properties. These were compared with nutrient-dense-garri for potential value addition.

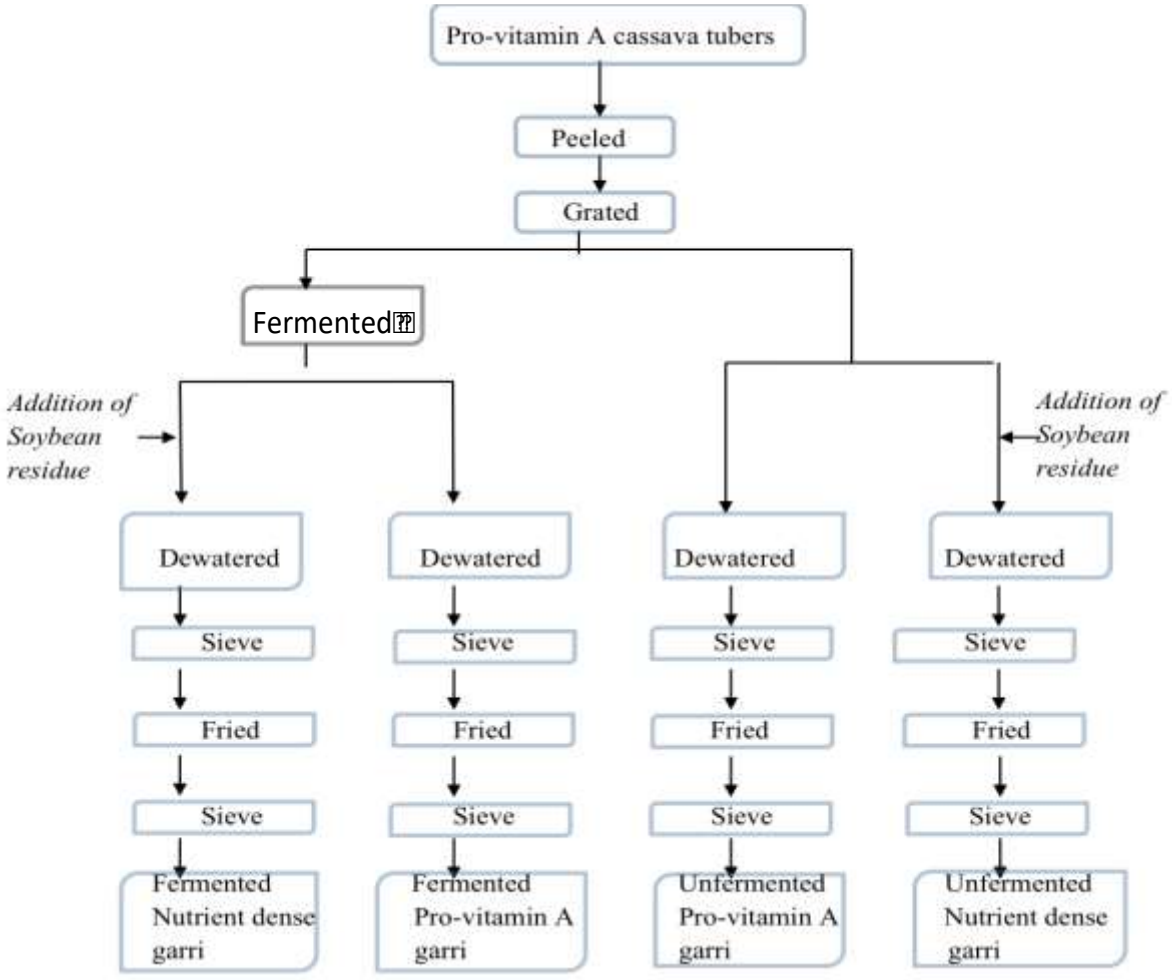

Fig 1: Algorithm for Processing of Pro-vitamin A and Nutrient Dense Garri

TTA, pH and Functional properties Analysis

The titratable acidity (TTA), pH and functional properties (Bulk Density, Swelling Capacity, Water Absorption Capacity and Gelation Capacity) of the garri samples were determined using the method described by Akoma *et al* (2006), Ikenebomeh. (1989) and Ngoma et al. (2019) respectively.

Proximate, mineral, carotene and cyanide analysis

Method (AOAC, 2005) was used for determination of proximate composition and mineral content of the samples. Carotene and cyanide contents were determined using Rodriguez-Amaya and Kimura (2004) method and Odoemelam et al. (2020) respectively. Results were compared with garri samples obtained from different locations in three States (Ogun, Oyo and Edo) of Southwest Nigeria.

Carotene content determination

Spectrophotometry method of Rodriguez-Amaya and Kimura (2004) was used to determine the carotene content of the garri samples. A portion of about 10g of homogenous sample was weighed into a mortar and about 3g of hyflosupercel (celite) were added. The mixture was ground with 50 ml of cold acetone. After proper grinding, the mixture was suction filtered through filter paper in a Buchner funnel. The residue as well as the utensils (mortar, pestle and funnel) were washed with small amounts of acetone, receiving the washings in the suction flask through the funnel. Extraction was repeated 3-4 times until the final residue was colourless. About 20ml of petroleum ether (PE) was transferred into a 500 ml separator funnel with Teflon stop-cock and the acetone extract was added. 300mls of distilled water was slowly added, allowing flowing along the walls of the funnel without shaking to avoid formation of an emulsion. The two phases were allowed to separate and the lower phase was discarded. The residual acetone in the upper phase (petroleum ether phase) was removed by washing the petroleum ether (PE) phase for about 4 times with 200 ml distilled water. Residual water in the PE phase was removed by passing it through a funnel containing anhydrous sodium sulfate (about 15 g) and collecting the extract in a 25ml volumetric flask. Volume was made up to mark using PE. Final extract from the partitioning step was made up to mark in the volumetric flask and the absorbance of the extract was read at 328nm on a spectrophotometer. Total carotenoid in the solution was obtained following Beer–Lambert law, which says absorbance is directly proportional to the concentration of the solution. The carotene content was thus calculated as follows

$$\text{Carotenoid content (ug/g)} = \frac{A \times \text{Volume (ml)} \times 10^4}{A \times 1\%/1\ \text{cm} \times \text{sample weight (g)}}$$

where A=absorbance; volume = total volume of extract (50 or 25 mL);

A x 1%/1cm = 2592 (absorption coefficient of β−carotene in petroleum Ether).

Cyanide determination

Simple picrate paper method described by Odoemelam et al. (2020) was used to determine the cyanide content of the garri samples. Sample (100 mg) of the sample was placed in a fat-bottomed plastic bottle containing the enzyme (linamarinase), bufer and picrate paper. The contents were left to incubate in the dark for 24 h at room temperature. The picrate papers that became darkened as a result of cyanide production were then placed in a test tube with 5 ml of distilled water. This was allowed to stand at room temperature for 30 mins after which the ultraviolet (UV) absorbance was measured at a wavelength of 510 nm and the total cyanide content calculated as:

Total cyanide content (ppm) = 396 × Absorbance

Statistical Analysis

Data obtained were analysed using descriptive (mean and variance) and inferential statistics. Variance-covariance matrix as well as correlation matrix of some of the functional properties was computed. General linear model of the variables was computed and the Duncan multiple range test was used to separate substantially different means. Results were accepted at $P < 0.05$ significant level using both SAS version 9 and IBM SPSS (version 17).

RESULTS/FINDINGS

The means and variance analysis of data generated for the pH, HCN and carotene of pro-vitamin A cassava at different stages of processing is presented in Table 1. The pH, HCN and carotene content of the pro-vitamin A cassava decreased with stages of processing.

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Table 1. Descriptive Statistics of the pH, hydrogen cyanide (HCN) and carotene content of Pro-vitamin A Cassava at different processing stages

	pH (a)		HCN ((mg/kg)		B carotene (µg/g)	
Samples	**Mean**	**Variance**	**Mean±SE**	**Variance**	**Mean±SE**	**Variance**
FD1	3.805	0.00005	7.525±0.015	0.0004	0.395±0.015	0.00045
FD2	3.605	0.00005	7.205±0.025	0.00125	0.38±0.01	0.0002
FD3	3.585	0.00005	6.87±0.02	0.0008	0.34±0.01	0.0002
E	6.13	0.0008	28.775±0.015	0.00045	1.680±0.01	0.0002
F	5.835	0.00005	23.660±0.01	0.0002	1.520±0.01	0.0002
G	5.33	5.33	10.21±0.02	0.0008	0.550±0.01	0.0002
H	4.98	4.98	11.3±0.02	0.0008	0.38±0.01	0.0002
I	5.575	0.00005	4.85±0.02	0.0008	1.4±0.02	0.0008
J	3.915	0.00005	8.88±0.01	0.0002	0.44±0.01	0.0002
L	5.585	0.00005	4.15±0.01	0.0002	1.71±0.03	0.0018
N	4.35	4.35	8.77±0.01	0.0002	0.495±0.015	0.00045
R	3.58	3.58	8.7±0.02	0.0008	0.45±0.01	0.0002
S	3.605	0.00005	4.31± 0.02	0.0008	1.61±0.02	0.0008
U	4.1	4.1	3.905±0.015	0.00045	2.08±0.01	0.0002

E = Unpeeled Pro-vitamin A cassava tuber, F= Peeled Pro-vitamin A cassava tuber, G = Grated Pro-vitamin A cassava, H = Dewatered Pro-vitamin A cassava mash, N = Dewatered Pro-vitamin A cassava mash + soy residue, FD3 = Fermented Pro-vitamin A cassava mash (3 days), FD2 = Fermented Pro-vitamin A cassava mash (2 days), FD1 = Fermented Pro-vitamin A cassava mash (1 day), R = Fermented, dewatered Pro-vitamin A cassava mash, J = Fermented, dewatered Pro-vitamin A cassava mash + soy residue, I = Unfermented Pro-vitamin A garri, L = Unfermented nutrient dense garri (NDG), S = Fermented Pro-vitamin A garri, U = Fermented nutrient dense garri (NDG)

The Mean separation of variables for pH, hydrogen cyanide (HCN) and carotene content of Pro-vitamin A Cassava at different processing stages is shown in Table 2. The pH of the samples ranged between 3.58 in both FD3 (Pro-vitamin A cassava mash fermented for 3 days) and R (Fermented, dewatered Pro-vitamin A cassava mash (R) to 6.13 in E (Unpeeled Pro-vitamin A cassava tuber) while HCN ranged between 3.90 (mg/kg) in sample U (Fermented nutrient dense garri) to 28.77 (mg/kg) in E (Unpeeled Pro-vitamin A cassava tuber).

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Table 2. General Linear model analysis and Mean Separation of pH, hydrogen cyanide (HCN) and carotene content of Pro-vitamin A Cassava at different processing stages

	Variables	pH	HCN (mg/kg)	B carotene (µg/g)
	F statistics	21387.9	183664	1961.85
	Df	13	13	13
	FD1	3.805i	7.525h	0.395i
	FD2	3.605j	7.205i	0.38ij
	FD3	3.585jk	6.87j	0.34j
	E	6.13a	28.775a	1.68b
Mean Separation	F	5.835b	23.66b	1.52d
Using DMRT	G	5.33d	10.21d	0.55f
	H	4.98e	11.3c	0.38ij
	I	5.575c	4.85k	1.4e
	J	3.915h	8.88e	0.44h
	L	5.585c	4.15m	1.71b
	N	4.35f	8.77f	0.495g
	R	3.58k	8.7g	0.45h
	S	3.605j	4.31l	1.61c
	U	4.100g	3.905n	2.08a

E = Unpeeled Pro-vitamin A cassava tuber, F= Peeled Pro-vitamin A cassava tuber, G = Grated Pro-vitamin A cassava, H = Dewatered Pro-vitamin A cassava mash, N = Dewatered Pro-vitamin A cassava mash + soy residue, FD3 = Fermented Pro-vitamin A cassava mash (3 days), FD2 = Fermented Pro-vitamin A cassava mash (2 days), FD1 = Fermented Pro-vitamin A cassava mash (1 day), R = Fermented, dewatered Pro-vitamin A cassava mash, J = Fermented, dewatered Pro-vitamin A cassava mash + soy residue, I = Unfermented Pro-vitamin A garri, L = Unfermented nutrient dense garri (NDG), S = Fermented Pro-vitamin A garri, U = Fermented nutrient dense garri (NDG)

The General Linear Model and Mean Separation of garri from different locations and NDG samples are presented inTable 3. The general linear model analysis of the functional properties of $F_{(11,\ :0.05)}$ = 24175.5, 5.12, 7.51, 9.43, 7.45 and 346.30 for pH, TTA, loose bulk density, packed bulk density, swelling capacity, and gelatinous capacity respectively were all significant. Mean TTA obtained for sample K (Unfermented yellow garri, Ogun State) (1.573) was significantly the highest.

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Table 3. GLM of and Mean Separation Using Duncan Multiple Range Test

	Variables	pH	TTA	LBD	PBD	SC	WAC	GC
	F statistics	24175.5**	5.12**	7.51**	9.43**	7.45**	1.5	346.30**
	Df	11	11	11	11	11	11	11
	A	4.11^{d}	0.447^{c}	0.48^{cd}	0.5^{de}	17.73^{c}	7.7^{ab}	11.495^{c}
	B	4.305^{c}	0.621^{bc}	0.565^{ab}	0.621^{ab}	27.015^{a}	7.6^{ab}	12.14^{a}
	C	3.895^{f}	0.182^{c}	0.55^{abc}	0.63^{ab}	17.32^{c}	6.85^{ab}	10.705^{g}
	D	3.665^{i}	0.671^{bc}	0.515^{bc}	0.575^{cb}	16.435^{c}	6.275^{ab}	12.01^{b}
Mean Separation by DMRT	**I**	5.575^{a}	0.456^{bc}	0.435^{d}	0.475^{e}	23.395^{b}	8.1^{a}	10.71^{g}
	K	3.985^{e}	1.573^{a}	0.595^{a}	0.685^{a}	16.495^{c}	5.8^{b}	10.58^{h}
	L	5.585^{a}	0.248^{c}	0.49^{cd}	0.5^{de}	17.485^{c}	7.6^{ab}	10.68^{g}
	M	3.875^{g}	0.502^{bc}	0.595^{a}	0.67^{a}	18.115^{c}	7.6^{ab}	10.57^{h}
	P	4.52^{b}	0.274^{c}	0.595^{a}	0.68^{a}	17.775^{c}	7.6^{ab}	11.14^{f}
	S	3.605^{j}	0.57^{bc}	0.435^{d}	0.49^{de}	16.685^{c}	7.1^{ab}	11.235^{de}
	T	3.765^{h}	1.0355^{b}	0.058^{a}	0.6^{abc}	18.32^{c}	8.1^{a}	11.175^{ef}
	U	4.1^{d}	0.743^{bc}	0.475^{cd}	0.53^{cde}	17.845^{c}	7.4^{ab}	11.3^{d}

K= Unfermented yellow garri (Odeda, Ogun State), M = Fermented yellow garri (Egbere, Edo State), P = Unfermented yellow garri (Edo State), D = Fermented white gari (Iweta, Ogun State), C = Fermented white garri (Ajaawa, Oyo State), B = Fermented white garri (Abeokuta, Ogun State T = Fermented white garri (Ilora, Oyo State), A = Fermented white gari (Eruwa, Oyo State), I = Unfermented Pro-vitamin A garri, L = Unfermented nutrient dense garri, S = Fermented Pro-vitamin A garri, U = Fermented nutrient dense gari

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Tables 4 and 5 showed the Variance-covariance and Correlation matrices of proximate composition and mineral elements, while Table 6 presents descriptive analysis of the mineral content of the garri samples. The variance results indicated that majority (68%) of the variance covariance V_{ij} were positive while some others were negative. The correlation values fall between -0.959 for crude protein and carbohydrate and 0.87 for Gross energy and crude fat (Tables 4&5).The results of the summary statistics analysis indicated that mean Potassium falls between 0.466 (±0.001) for sample U (fermented nutrient dense garri) and 0.516 (±0.003) for sample L (Unfermented nutrient dense garri). The variability ranged between 0.000002 for both sample S (fermented pro-vitamin A garri) and sample U and 0.000013 for sample L. Similar results were obtained for Calcium where the mean Calcium ranged from 0.022 (±0.001) for sample U to 0.048 (±0.001) for sample L. Phosphorous followed the same pattern, where the means fall between 0.060(±0.01) for sample U and 0.265 for sample L (Table 6).

Table 4. Variance –covariance and correlation matrices of the proximate composition of the garri samples

		%CP	%CFAT	%CFIBRE	%ASH	%M	%CHO	G.E(kcal)
Variance-covariance	%CP	1.416	0.493	0.046	0.034	-0.201	-1.871	2.871
	%CFAT		0.648	0.029	0.13	-0.648	-0.693	4.431
	%CFIBRE			0.006	0.008	-0.026	-0.064	0.221
	%ASH				0.052	-0.212	-0.012	1.18
	%M					1.01	0.084	-5.925
	%CHO						2.574	-3
	G.E(kcal)							40.052
Correlation	%CP	1						
	%CFAT	0.515**	1					
	%CFIBRE	0.513**	0.471*	1				
	%ASH	0.125	.708**	.449*	1			
	%M	-0.168	-0.802**	-0.342	-0.921**	1		
	%CHO	-0.959**	-0.526*	-0.537*	-0.032	0.051	1	
	G.E(kcal)	0.381	0.87**	0.464*	.816**	-0.932**	-0.291	1

CP= crude protein, CFibre = crude fibre, CFat = crude Fat, M =moisture, CHO = carbohydrate and GE = Gross energy

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Table 5. Variance –covariance and correlation matrices of the mineral elements of the samples.

		%K	%Ca	%P	Fe(mg/kg)	Cu(mg/kg)	Mn(mg/kg)
Variance-covariance	%K	0.0004	0.0002	0.0017	0.142	0.03	0.038
	%Ca		0.00012	0.0009	0.076	0.016	0.021
	%P			0.0074	0.611	0.127	0.164
	Fe(mg/kg)				56.654	12.025	14.462
	Cu(mg/kg)					2.561	3.042
	Mn(mg/kg)						3.781
Correlation	%K	1					
	%Ca	0.987**	1				
	%P	0.989**	0.977**	1			
	Fe(mg/kg)	0.945**	0.914**	0.944**	1		
	Cu(mg/kg)	0.926**	0.891**	0.925**	0.988**	1	
	Mn(mg/kg)	0.978**	0.963**	0.979**	0.988**	0.978**	1

K = Potassium, Ca = Calcium, P= Phosphorous, Fe = Iron, Cu = Copper, Mn = manganese

Samples	%K		%Ca		%P		Fe(mg/kg)		Cu(mg/kg)		Mn(mg/kg)	
	Mean±SE	Variance	Mean SE	Variance	Mean SE	Variance	Mean SE	Variance	Mean SE	Variance	Mean SE	Variance
I	0.491±0.002	0.000005	0.037±0.001	0.000002	0.16± 0.01	0.0002	29.690±0.02	0.0008	4.14± 0.01	0.0002	8.655±0.015	0.00045
L	0.516±0.003	0.000013	0.048±0.001	0.000002	0.265±0.015	0.00045	43.8± 0.02	0.0008	7.305±0.025	0.0013	11.7± 0.02	0.0008
S	0.476±0.001	0.000002	0.026±0.002	0.0000045	0.085±0.005	0.00005	27.165±0.015	0.00045	3.78 ± 0.010	0.0002	7.365±0.015	0.00045
U	0.466±0.001	0.000002	0.022±0.001	0.000002	0.060± 0.01	0.0002	26.475±0.015	0.00045	3.69± 0.02	0.0008	7.135±0.015	0.00045

Table 6. Descriptive Statistics of the Samples mineral elements.

I = Unfermented Pro-vitamin A garri, L = Unfermented nutrient dense garri, S = Fermented Pro-vitamin garri, U = Fermented nutrient dense gari, K = Potassium, Ca = Calcium, P= Phosphorous, Fe = Iron, Cu = Copper, Mn = manganese

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Table 7 presents the result of Descriptive Statistics of the HCN and Carotene of the garri samples from different locations and pro-vitamin A garri samples while the Proximate composition of the Garri Samples from different sites and Pro-vitamin A garri samples is presented in Table 8. The mean hydrogen cyanide (HCN) obtained for sample A (Fermented white garri Eruwa, Oyo State (7.250 ± 0.07) was the highest while sample U has the least mean HCN of 3.905 ±0.015. Sample U has the highest carotene content of 2.08 µ/g (Table 7). The mean crude protein ranged from 1.535(± 0.015) for sample T (Fermented white garri, Ilora, Oyo State to 6.02 (± 0.045) for sample U and the variances fall between 0.0002 for sample I (unfermented pro-vitamin A garri) and 0.045 for sample U (Table 8).

Table 7. Descriptive Statistics of the HCN and Carotene of the garri samples from different locations and pro-vitamin A garri samples

	HCN		Carotene	
Samples	**Mean±SE**	**Variance**	**Mean±SE**	**Variance**
A	7.250±0.010	0.0002	0	0
B	7.025±0.015	0.0005	0	0
C	6.805±0.015	0.0005	0	0
D	5.405±0.015	0.0005	0	0
I	4.850±0.02	0.0008	1.4±0.02	0.0008
K	4.410±0.020	0.0008	0.74±0.010	0.0002
L	4.15±0.010	0.0002	1.710±0.03	0.0018
M	4.495±0.015	0.0004	0.675±0.015	0.00045
P	4.605±0.025	0.00125	0.600±0.00.02	0.0008
S	4.31±0.02	0.0008	1.61±0.00.02	0.0008
T	5.14±0.0.02	0.0008	0	0
U	3.905±0.015	0.00045	2.08±0.01	0.0002

K= Unfermented yellow garri (Odeda, Ogun State), M = Fermented yellow garri (Egbere, Edo State), D = Fermented white gari (Iweta, Ogun State), C = Fermented white garri (Ajaawa, Oyo State), B = Fermented white garri (Abeokuta, Ogun State), P = Unfermented yellow garri (Edo State), T = Fermented white garri (Ilora, Oyo State), A = Fermented white gari (Eruwa, Oyo State), I = Unfermented Pro-vitamin A garri, L = Unfermented nutrient dense garri, S = Fermented Pro-vitamin A cassava gari, U = Fermented nutrient dense gari

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Table 8. Proximate composition of the Garri Samples from different sites and Pro-vitamin A garri samples

	CP		CFAT		Cfibre		Ash		M		CHO		GE	
Samples	Mean±SE	Variance	Mean±SE	Variance	Mean±SE	Variance	Mean±SE	Variance	Mean±SE	Variance	Mean±SE	Variance	Mean±SE	Variance
A	1.79±0.02	0.0008	1.315±0.025	0.0013	1.245±0.00.005	0.00005	1.575±0.015	0.00045	11.89±0.02	0.0008	82.185±0.005	0.00005	353.55±0.15	0.045
B	1.705±0.025	0.025	1.39±0.02	0.0008	1.265±0.015	0.0005	1.55±0.01	0.0002	11.91±0.03	0.0018	82.18±0.01	0.0002	352.7±0.1	0.02
C	1.65±0.02	0.0008	1.465±0.015	0.00045	1.275±0.015	0.00045	1.585±0.005	0.00005	11.86±0.03	0.0018	82.165±0.015	0.00045	353.2±0.1	0.02
D	2.115±0.045	0.00405	1.875±0.015	0.00045	1.320±0.01	0.0002	1.625±0.015	0.00045	11.805±0.015	0.00045	81.26±0.02	0.0008	353.05±0.15	0.045
I	2.18±0.01	0.0002	2.435±0.015	0.00045	1.165±0.015	0.00045	1.640±0.01	0.0002	11.05±0.03	0.0018	81.47±0	1	360.5±0.3	0.18
K	1.915±0.025	0.00125	2.705±0.025	0.00125	1.2±0.01	0.0002	1.765±0.015	0.00045	11.285±0.025	0.00125	81.13±0	1	360.5±0.3	0.18
L	3.005±0.035	0.00245	3.97±0.01	0.0002	1.36±0.01	0.0002	2.295±0.015	0.00045	8.245±0.025	0.00125	81.125±0.075	0.01125	375.45±0.25	0.125
M	2.01±0.0.04	0.0032	1.95±0.01	0.0002	1.145±0.015	0.00045	1.6±0.01	0.0002	11.235±0.025	0.00125	82.06±0	0	354.95±0.15	0.045
P	2.19±0.0.02	0.0008	2.280±0.01	0.0002	1.22±0.01	0.0002	1.45±0.01	0.0002	11.35±0.02	0.0008	81.51±0.01	0.0002	355.4±0.1	0.02
S	2.575±0.0.095	0.018	2.880±0.01	0.0002	1.3±0.01	0.0002	1.48±0.01	0.0002	11.595±0.015	0.00045	80.06±0.04	0.003	359.95±0.55	0.605
T	1.535±0.015	0.00045	1.165±0.015	0.00045	1.13±0.01	0.0002	1.375±0.015	0.0004	12.115±0.025	0.00125	82.68±0.02	0.0008	352.4±0.1	0.02
U	6.02±0.045	0.045	2.765±0.015	0.00045	1.335±0.005	0.00005	1.545±0.005	0.00005	11.705±0.015	0.00045	76.61±0.05	0.005	354.35±0.15	0.045

K= Unfermented yellow garri (Odeda, Ogun State), M = Fermented yellow garri (Egbere, Edo State), D = Fermented white gari (Iweta, Ogun State), C = Fermented white garri (Ajaawa, Oyo State), B = Fermented white garri (Abeokuta, Ogun State), P = Unfermented yellow garri (Edo State), T = Fermented white garri (Ilora, Oyo State), A = Fermented white gari (Eruwa, Oyo State), I = Unfermented Pro-vitamin A garri, L = Unfermented nutrient dense garri, S = Fermented Pro-vitamin garri, U = Fermented nutrient dense gari

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DISCUSSION

The pH, hydrogen cyanide (HCN) and carotene content of the pro-vitamin A cassava decreased with stages of processing. Previous studies have reported that grating, fermentation and roasting significantly reduced total cyanide in cassava roots (Bolarinwa *et al.,* 2016; Ndubuisi and Chidiebere, 2018). Similarly, the decrease in β-carotene at subsequent processing is in line with recent findings (Eyinla *et al.,* 2019; Taleon *et al.,* 2019). Chiemela *et al.* (2012) also reported decrease in cyanide and carotene content during processing of yellow cassava tubers into flour. According to Maziya-Dixon (2015); Odoemelam *et al*, (2020), interaction of factors such as heat, light, oxygen, food enzymes, or a combination of all of the above can result in high reduction of carotenoids in the processing of provitamin A cassava. Mean pH of the samples ranged from 3.585 for sample FD3 (Pro-vitamin A cassava mash fermented for 3 days) and 6.13 for sample E (unpeeled Pro-vitamin A cassava tubers). Most of the samples have equal variance (0.00005), which is the least, while the highest variability (5.33) was obtained for sample G (grated Pro-vitamin A cassava). This implies that all of the value fall within acidic pH and slight alkaline pH. Sample E also has the highest HCN of 28.775 (+0.015) while sample U (fermented nutrient dense garri) has the least HCN of (3.905+0.015). The variability of the HCN also followed the trend as that of pH. Some of the samples returned equal variance of 0.0002, which is the least while; the highest variance of 0.00125 was obtained for sample FD2 (Pro-vitamin A cassava mash fermented for 2 days). Beta Carotene falls between 2.08 (±0.01) for sample U and 0.34 (±0.01) for sample FD3, the variability was equally suitable with those of pH and HCN. Many of the samples have equal variances. The pH and HCN of all the samples were significantly different. Mean Beta-carotene was partitioned into eleven significantly different classes. Mean carotene obtained for U (2.08 µg/g) was significantly the highest followed by mean carotene obtained for E (1.68 µg/g)) and L (unfermented nutrient dense garri) (1.71(µg/g).The mean pH was statistically partitioned into 10 significantly different classes. These are, $\bar{x}_{sampleL}$ (5.585) & $\bar{x}_{sampleI}$ (5.575)> $\bar{x}_{sampleP}$ (4.52)> $\bar{x}_{sampleB}$ (4.305). > $\bar{x}_{sampleS}$ (3.605 – Table 3). It is interesting to note that, pH values for samples L (5.585) and I (5.575) was higher than other samples because they were unfermented. pH is a measure of hydrogen ion concentration in food samples. According to Awoyale et al., (2020), fermentation results in changes in the pH and organic acids production. The pH values obtained from other samples in this study were within the recommended range of 3.5 to 4.5 for fermented products (Sanni et al., 2005). This is an indication for good keeping quality. Mean TTA were partitioned into 3 significantly different classes with some intermediate classes. Mean TTA obtained for sample K (unfermented yellow garri, Ogun State) (1.573) was significantly the highest while mean TTA obtained for samples A (fermented white garri, Eruwa, Oyo State) (0.447), L (unfermented nutrient dense garri (0.248), P (unfermented yellow garri, Edo State) (0.274) and C (fermented white garri, Ajaawa, Oyo State) (0.182) were significantly low. The middle class was the mean TTA obtained for sample T (fermented white garri, Ilora, Oyo State) (1.0355) while other samples formed intermediate group between the three classes. The values of TTA recorded in all the provitamin A garri samples with or without soybean fall below the recommended upper limit of 1.0% for garr*i* samples. They were in line with the Nigerian

Industrial Standard NIS 181:2004 standard for garri (Sanni et al., 2005) and the Codex standard TTA for garri (0.6 and 1.0% which is measured as lactic acid) (FAO, 2019). This further emphasized the benefit of enrichment of provitamin A garri.

Findings in this study revealed that the variance of HCN for all the samples were very low and ranged between 0.0002 for both sample A (Fermented white garri, Eruwa, Oyo State) and sample L (unfermented nutrient dense garri) and 0.00125 for sample P (unfermented yellow garri Edo State). The hydrogen cyanide content of the garri sample in this study is within the maximum recommended acceptable level of 10 mg in cassava products by FAO 1988 as reported by FAO/WHO (2005). Hence, it can be considered safe for consumption in terms of the hydrogen cyanide content. According to Eyinla et al., (2019), short fermentation can result in improved retention of β-carotene content. It is noteworthy that carotene values for variance of some of the samples are homoscedastic while none of the samples returned zero variances. Carotenoids are class of colourful plant pigments that the body can convert to vitamin A, they are also powerful antioxidants that have been found active in reducing the risk of some cancer and heart diseases as well as boosting immune systems responses to infections (Eleazu and Eleazu, 2012). In developing countries, most people obtain their vitamin A through consumption of diets rich in beta carotene. It has been reported to provide about 66% of vitamin A in their diets (Sanusi and Adebiyi, 2009).

Mean Loose bulk density (LBD) obtained for garri samples from local processor (K, M and P) were the same and significantly the highest (0.595) while the mean LBD obtained for NDG sample S and I (0.435) were also the same and significantly the least. These values are similar to those recorded for garri produced in Edo and Delta by Nwancho *et al*. (2014). Other samples LBD are within the highest and the least of these two groups. Similar trends were observed for Packed Bulk Density (PBD) in which samples K (unfermented yellow garri, Ogun State), M (fermented yellow garri, Egbere, Edo State) and P (unfermented yellow garri, Edo State) had highest PBD while samples S (fermented pro-vitamin A garri) and sample I (unfermented pro-vitamin A garri) had the least PBD. Hasmadii et al (2020) affirmed that bulk density of a food sample signifies its heaviness and this is usually influenced by the particle size and density of the food sample. Bulk density is a vital factor in the selection of food handling and packaging material (Kaushal, Kumar, and Sharma 2012). Samples functionality differences could be attributed to the method of processing, particle size distribution, nutrients contents and food additives content. The $F_{(11,\ :0.05)} = 1.5$ obtained for water absorption capacity was however not significant ($P < 0.05$). The mean water absorption capacity of the NDG samples ranged from 7.1 to 8.1 ml/g. This was lower than the water absorption capacity range of 29.00 to 149.07ml/g reported by Okoye (2022) for soy garri samples. The water absorption capacity is the ratio of the weight of water absorbed by a food material in saturated state to the weight of the dry material.

The variance covariance analysis of the proximate composition of the garri samples indicated that majority (68%) of the variance covariance V_{ij} were positive while some others were

negative. This implied that as the variance of some of the variables increases, the variance of the corresponding pairing variables also increase. It is noteworthy that none of them returned zero values thus it can be concluded that the variable are not independent of the others. The V_{ij} for Moisture and Gross Energy (GE) is -5.925. Similarly, majority of the correlation values, ρ_{ij} were significant ($P < 0.01$) while the remaining were not significant. Most of the pairing variables (52%) were positively correlated while the remaining average (48%) was inversely correlated. The results of the variance covariance analysis of the samples' elements indicated that all the V_{ij} were positive and ranged from 0.0002 for V_{ij} of potassium and calcium to 56.654 for V_i of Iron. Although some of the variance covariance values were very low but none of them returned zero values. Also, the correlation analysis indicated that all the ρ_{ij} were directly correlated and it ranged between 0.891 for ρ_{ij} of copper (cu) with calcium and 0.989 for ρ_{ij} of phosphorous with potassium. All the ρ_{ij} values were significant ($P<0.01$) and none returned inverse relationships. The 2 variables (Calcium and Phosphorous) returned almost equal variance for all the samples. Similar results were obtainable for Fe, Cu and Mn where sample L returned the highest of 43.8mg/kg, 7.305mg/kg and 11.7mg/kg respectively for Fe, Cu and Mn. This can be attributed to the addition of soybeans which is known to be rich minerals. It is equally noteworthy to state that sample U returned the least of 26.475mg/kg, 3.69mg/kg and 7.135mg/kg for Fe, Cu and Mn respectively. This can be attributed to the fermentation process. Fermentation can lead to mineral loss due to acidic nature of the substrate and microbial activities involving the utilization of the nutrients for growth (Ayetigbo et al., 2018). Addition of soybean coupled with fermentation were found to improve the protein content of fortified garri samples as observed the in fermented nutrient dense garri (U). The values of crude protein content of garri samples obtained from different processing locations were lower than the values for both unfermented and fermented nutrient dense garri in this study, an indication of positive effect of fortification on the nutrient content of the garri. The protein content of the unfermented nutrient dense garri and fermented nutrient dense garri (3.00 and 6.02% respectively) were higher than the minimum value in the protein content range of between 2.64 – 15.10% in soy garri samples reported by Okoye et al., (2022). In terms of the moisture content, sample T (fermented white garri, Oyo State) has the highest moisture content of 12.11 (±0.025) while the least moisture content of 8.245 (±0.025) was obtained in sample L (Unfermented nutrient dense garri). The observed moisture contents in this study agreed with that reported by Oluba (2020) and also within the range of 6.34% to 14.58% observed by Apea-Bal *el al.*, (2011). Hasmadi et al. (2020) reported that moisture content is a significant factor in cassava product storage and recommended not higher than 12% moisture content to prevent microbial growth and permit a positive state for comparatively extended shelf life for the product. Airadion et al., 2019 on the other hand observed a moisture content of 14% would be appropriate for dried foods. All the developed products (NDG) whether fermented or unfermented had good moisture contents below 12% an implication for better shelf life potential (Oluba et al., 2017). In addition low moisture content in cassava products is desirable for decreased HCN and at the same time improve product's palatability. Sample L (Unfermented NDG) has the highest crude fat content of 3.97 (± 0.01) while the least crude fat of 1.165 was obtained for sample T (Fermented white *garri* from Oyo State). Fat content in dry

flour influenced paste texture that favours stable viscosity. Hasmadi et al. (2020) however observed that high fat content in cassava flour have an adverse effect of possibility for high rancidity and increase cloudiness in product as well as causing low swelling capacity and solubility. Low rancidity, high swelling capacity and solubility are some of desirable attribute for especially consumers who soak in room temperature water before consumption. Most of the samples are homoscedastic. Similarly, highest crude fibre of 1.36 (± 0.01) was obtained for sample L while the least of 1.13 was obtained for sample T. It was observed that the crude fibre in all samples is lower than the range of 1.66% to 4.27% crude fibre content observed by Fakir *et al.* (2012) for cassava flour. The same trend was obtained for ash content and gross energy (GE). The values for ash content in nutrient dense garri (NDG) samples (1.48-2.29%) obtained in this study was higher than the ash content (1.83-3.47%) reported by Oluwamukomi and Adeyemi, (2013) for "garri" semolina fortified with different types of soy melon supplements and were similar to the ash content (1.25-2.64%) for garri enriched with soybean flour reported by Okoye et al., (2022). The high ash content in NDG samples suggests high mineral content, which could be attributed to the inclusion of soybean residue as a raw material along the production line.

IMPLICATION OF THE RESEARCH AND PRACTICE

Conventional garri is nutritionally inadequate with main nutrient as carbohydrate because the only raw material is cassava. Nutrient dense garri is an innovative product produced from food materials (pro-vitamin A cassava and soybean) that are rich in nutrients such as protein, vitamin A and minerals. It has the potential for reducing malnutrition and improve well-being of consumers in garri-consuming populations worldwide. The raw materials are available and easily accessible in the study areas, hence the processors could be trained on the production of nutritious garri (nutrient dense garri) from pro-vitamin A cassava and soybean.

CONCLUSIONS

The raw materials used (yellow flesh cassava and soybean) in the garri processing have high industrial potential for food products processing as well as improving the nutrition and livelihood of malnourished within the society. The physical, chemical and functional characteristics of garri from yellow cassava and soybean give optimistic results towards enhancing nutritional status and well-being. This study found the use of pro-vitamin A cassava and soybean as having great impact on the nutrients content of the garri, where significant differences were observed for crude protein and crude fat contents when compare to garri samples from local processors who uses only white cassava and sometimes colour with palm oil during processing. Moreover, fermentation during processing significantly affected the pH, TTA, bulk density, water absorption and swelling capacity of all samples. The reduction in hydrocyanic acid content as orchestrated by the processing period makes the product safer for consumption. This study also optimizes the use of cassava (Provitamin A) and soybean as raw materials in SME. It is recommended that future research should focus on harmonization procedure to harness the best nutrients from the process of fermentation and non-fermentation.

FUTURE RESEARCH

Future research could look at the uptake promotion of Nutrient-Dense-Garri (NDG) among the local garri processors in South-western Nigeria for adoption and commercialisation.

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