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Comparative Analysis of Functional Properties, Nutrient Composition and Sensory Quality of Bio-fortified and Traditionally Prepared Cassava Granules

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Abstract
The success of bio-fortification of cassava for production of vitamin A rich cassava granules commonly known as garri depends on the consumers' acceptance. The study aimed at determining the quality of bio-fortified and traditional cassava granules. Four sample types were used for the study. This includes the bio-fortified sample and three traditionally prepared samples. The cassava granules samples were analyzed for functional properties, nutrient and anti-nutrient composition and sensory quality. Data obtained were subjected to analysis of variance (ANOVA) and means were separated using Duncan multiple range test. Results obtained indicated that there was significant ($p<0.05$) difference in the bulk density, swelling capacity and water holding capacity. Ijebu white cassava granules recorded the highest swelling capacity (3.80 %) while Ohafia cassava granules had the lowest swelling capacity (2.42 %). Ohafia cassava granules had the highest bulk density (0.65 g/cm^3) and water absorption capacity (413.5 %) while the Ijebu white cassava granules had the least. The study revealed that Ohafia cassava granules had the highest crude fiber (7.10 %), ash (0.60 %) and moisture content (10.25 %). While the highest protein (2.59 %) and vitamin A (21.11 μg/g) were found in bio-fortified cassava granules There was significant difference in the moisture content, crude fiber, protein, ash and vitamin A. The

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hydrogen cyanide content of Ohiafia yellow cassava granules had the lowest value of 2.8 mg/kg while the Ijebu white cassava granules recorded the highest value (4.5 mg/kg). There was no significant (p<0.05) difference in the colour and the taste of the cassava granules samples. The Oyo white cassava granules followed by the fortified cassava granules were the most preferred for texture, aroma and overall acceptability. Bio-fortified cassava granules had comparative quality properties with the traditional cassava granules and could be beneficial in formulating diet rich in vitamin A and protein.

Keywords: Cassava granules, starch, bio-fortified, Vitamin A, Hydrogen cyanide

INTRODUCTION

Starch is important in human nutrition and calorie intake, as it provides more than one fifth of the calories consumed worldwide by humans. Starch is a complex carbohydrate that is found in cereal grains, cassava, potatoes, legumes, fruits, and vegetables. It is composed of two components, amylose and amylopectin, and provides an important source of energy for the body (Anderson *et al*., 2004). Starch is an important source of dietary fiber, minerals, and vitamins. It can also help to regulate blood sugar levels, promote digestion, and reduce the risk of certain chronic diseases. (Youness *et al*., 2022). Cassava (*Manihot esculenta Cranz*) is a woody shrub native to South America of the spurge family, *Euphorbiaceae*. Cassava is extensively cultivated as an annual crop in tropical and subtropical regions for human consumption. Cassava is a major food staple and source of carbohydrates. It is a major source of dietary energy in many developing countries, providing a basic diet for over half a billion people. It is one of the most drought-tolerant crops, capable of growing on marginal soils. Cassava is classified as either sweet or bitter. Bitter varieties of cassava contain high amounts of toxic compounds known as cassava cyanogenic glycosides. The bitter varieties of cassava must be processed to remove the toxins before consumption. Cassava is a major staple food in the developing world, providing a basic diet for over half a billion people (Uthpala *et al*., 2021). Cassava is also used as an ingredient in many processed food products, such as fufu, tapioca, and cassava granules (Agugo *et al*., 2019).

In Nigeria, as in most African countries, cassava is one of the most important carbohydrate sources. About 95 percent of cassava is consumed as food and less than 5 percent of it is used for industrial purposes (Ojo and Akande, 2017). It is usually consumed in processed forms. In recent times, several processing options have emerged from cassava such as, fufu, starch, flour, tapioca and chips (Airaodion *et al*., 2019). Irrespective of these options, cassava granules and edible starch (which is a by-product from drying the grated tubers) have maintained an important position in the food timetable of many households in Nigeria and other countries of the world (Agugo *et al*., 2019).

Cassava granules *(Garri)* is a lactic acid fermented product of cassava root that can be processed with palm oil rich in carotenoid (yellow garri) or without palm oil (Airaodion *et al*., 2019). In Nigeria, cassava granules is widely acceptable and consumed by both the poor, the middle men or average Nigerian, and also the rich because it serves as a major source of carbohydrate (Okechukwu and Okoye 2010). Cassava granules can be taken in various forms; some people use it to make cassava jam or soak inside water along with groundnut, mashed beans, or bean cake (akara). The major problem of consuming cassava granules is the toxicity which may arise from poor processing of cassava which is rich in cyanogenic glucosides (Tshala-Katumbay *et al*., 2016). Consumption of cyanide and its accumulation in human body normally lead to neurological disorders and goiter (Ojo and Akande, 2013). However, cyanide has been found to be greatly reduced during the processing of cassava to cassava granules (Ojo and Akande, 2013).

All over the world, there has been growing concern about the challenges posed by nutritional deficiency and biotechnological (bio-fortification) alternative has been adjudged to be efficient and cost effective compared to every other known approaches. The white cassava according to Ukenye *et al*. (2013) is low in yield, low in dry matter yield and low in nutrient composition with high cyanide concentration. These attributes are at variances with the potentials of vitamin A cassava as reported by Harvest Plus (2010) and IITA (2014). However, the success of bio-fortification of cassava for production of vitamin A rich garri depends on the consumers' acceptance. Vitamin A remains a very important component of human nutrition as it is involved in vision, immune system function, reproduction, cell growth and communication, and protection of the skin and organs from disease and damage (Ionita-Mîndrican *et al*., 2022). The study was carried out with a view to determining the quality and acceptability of bio-fortified and traditionally made cassava granules.

MATERIALS AND METHODS

Source of Raw Material

Bio-fortified (sample A) and white cassava granules (sample C) were obtained from a cassava granule processing plant in Ibadan, Oyo State, while another freshly produced sample of white garri called Ijebu white cassava granule (sample D) was obtained from Ilishan-Remo, Ogun State, Nigeria. Ohafia yellow cassava granule (sample B) was gotten from Ohafia, Abia State, Nigeria. The samples were packaged and kept at ambient condition till they were required for analysis.

Determination of Functional Properties of the Cassava Granules Samples

Bulk density, swelling index and water absorption capacity of the samples were determined by the method described by Adeoye *et al*. (2018).

Proximate Analysis

The samples were analyzed for moisture, ash, crude fibre, protein (N*6.25), crude fat and the carbohydrate was determined by difference according to the method described by AOAC (2005).

Determination of β-carotene

The β-carotene of the cassava granules samples was determined following the method reported by Sadaf *et al* (2013). β-carotene was converted to Vitamin A as described by FAO/WHO (1988).

Determination of Residual Cyanide of the Cassava Granules Samples

The cyanide content of the cassava granules samples was done as described by Abass *et al*. (2018).

Sensory Evaluation

The cassava granules samples were reconstituted with water at room temperature to prepare soaked cassava granules. The sensory evaluation was conducted with fifteen (15) untrained taste panel (University students), using a nine-point hedonic rating scale. The students were properly guided to present true individual perception about the cassava granules samples. The soaked cassava granules were served to the panelist using plates that were randomly coded. The ratings of samples were done using a 9- point hedonic scale. (Adeoye *et al*., 2018).

Statistical Analysis

The data obtained from the procedures was collated and analyzed using Statistical Package of Social Science (SPSS) version 21.0. The means obtained was separated using Duncan's Multiple Range Tests at 5% level of probability.

RESULTS AND DISCUSSION

Functional Properties of Cassava Granules

The results of the physical properties of the cassava granule samples are shown in Table 1. The study showed that there was significant difference in the bulk density, swelling capacity and water holding capacity of the cassava granules samples. The results of the bulk density, swelling capacity and water absorption capacity of the samples varied between 0.57 - 0.65 g/cm^3, 2.42 – 3.80% and 277.50 - 413.50%. The bulk density of Ohafia cassava granules which is sample B (0.65 g/cm^3) was significantly higher ($p<0.05$) than that of other samples while sample D (Ijebu white cassava granules) had the lowest (0.57 g/cm^3). The high bulk density of Ohafia yellow cassava granules could be attributed to the short fermentation period of the cassava granules which results in high content of starch (Apea-Bah *et al*., 2009) and particle size is also a very important factor that may be responsible for the variation observed (Adebowale *et al*., 2008a; Ajanaku *et al*., 2012). Generally, the bulk density of the samples (0.57 – 0.65 g/cm^3) was lower than 0.82 -0.84 g/cm^3 reported by Olakunle *et al.* (2012) for cassava granules samples from different processing factories.

Swelling power measures the hydration capacity and it was observed that significant differences existed among the samples. Sample D (Ijebu white cassava granules) was significantly higher than other sample with swelling capacity of 3.8%. This was followed by bio-fortified cassava granules with swelling capacity of 3.6%. Oyo white cassava granules with value of 2.42% had the lowest result for swelling capacity. These finding are comparable to the report of Onyeneke (2019) for products of white and yellow cassava. However, the significantly high water absorption capacity of Ohafia cassava granules (413.50%) is an indication of its higher starch content as reported by Abiodun *et al.* (2020) that starch content decreases with increase in the length of fermentation. Ohafia cassava granules have short fermentation period and thus are not characteristically sour which is an attribute of garri that is well fermented. The water absorption capacity of sample A (354.50%) was higher than that of the remaining samples. However, the water absorption of all the samples was higher than what was reported by Olakunle *et al.* (2012) for cassava granules samples from different processing factories.

Table 1: Functional properties of the *Cassava Granules* Samples

Functional Property	A	B	C	D
Bulk density (g/cm^3)	$0.59^{bc}\pm0.00$	$0.65^{a}\pm0.03$	$0.63^{ab}\pm0.00$	$0.57^{c}\pm0.03$
Swelling capacity (%)	$3.6^{b}\pm0.70$	$3.09^{c}\pm0.00$	$2.42^{d}\pm1.41$	$3.8^{a}\pm0.71$
Water Absorption Capacity (%)	$354.50^{b}\pm2.12$	$413.50^{a}\pm0.71$	$289.50^{c}\pm7.78$	$277.50^{c}\pm28.9$

Means in the same row with the same superscript are not significantly different at $p<0.05$.

Proximate Composition of Cassava granules

The proximate compositions of the cassava granules samples are shown in Table 2. Moisture content is an indicator of shelf life stability (Abioye *et al*., 2018). Increase in moisture content enhances microbial contamination and chemical reactions that could lead to reduction in the food quality and stability (Abioye *et al*., 2018). The result of the moisture content varied between 7.25-10.25%. Sample B (Ohafia yellow) was significantly ($p < 0.05$) different in moisture content (10.25%) and Oyo white garri had the least moisture content of 7.25% which was comparable to 7.50% reported by Oyeyinka, *et al*. (2020). The low moisture content of the garri samples was due to the processing of garri which involves dewatering (Olorunfemi, and Afobhokhan, 2017). The moisture content of all the cassava granules samples was within acceptable limit as foods with moisture content less than 14% can resist microbial growth and thus have better storability.

The result of the ash content varied between 0.39 - 0.60%. Ohafia yellow garri had significantly high ($p < 0.05$) ash content (0.60 %) and Ijebu cassava granules had the least amount (0.39%). The protein content of the samples ranged between 0.42 - 2.59% and protein content (2.59%) of bio-fortified cassava granules was significantly higher compared with other cassava granules samples. The bio-fortified cassava granules (sample A) with higher content of protein could be due to the added nutrient-rich ingredient used in the production process This is in line with the findings of Ojo and Akande (2017) who observed higher protein content in bio-fortified cassava granules produced from cassava and sweet potato tuber mixes..

The fibre content of the samples was between 3.50 – 7.10% with Ohafia cassava granules having the highest value and biofortified the lowest fibre. This is contrary to the report of Oluba *et al*. (2017) who reported higher content of crude fibre in bio-fortified cassava granules compared to the traditional cassava granules. Oyo white cassava granules significantly had high level of fat (1.05%) and carbohydrate (86.16%). The carbohydrate content of the cassava granules samples (80.72 – 86.16%) was comparable to 88 % reported by Oyeyinka, *et. al*. (2020). The differences in nutrient content may be due to the differences in the types of cassava granules, the processing methods used, and the environmental factors that affect the growth and cultivation of the grains.

Table 2: Proximate Composition of Cassava Granules Samples

Nutrient	A	B	C	D
Moisture (%)	$8.00^{b}\pm0.00$	$10.25^{a}\pm1.06$	$7.25^{b}\pm0.35$	$7.50^{b}\pm0.00$
Ash (%)	$0.58^{ab}\pm0.00$	$0.60^{a}\pm0.00$	$0.48^{ab}\pm0.14$	$0.39^{b}\pm0.00$
Protein (%)	$2.59^{a}\pm0.12$	$0.46^{b}\pm0.01$	$0.42^{b}\pm0.01$	$0.45^{b}\pm0.01$
Crude Fat (%)	$0.10^{b}\pm0.00$	$0.90^{a}\pm2.28$	$0.35^{b}\pm0.07$	$1.05^{a}\pm0.07$
Crude Fiber (%)	$3.50^{c}\pm0.00$	$7.10^{a}\pm0.14$	$6.95^{a}\pm0.07$	$4.45^{b}\pm0.07$
Carbohydrate(%)	$85.24^{ab}\pm0.12$	$80.72^{c}\pm0.66$	$84.53^{b}\pm0.33$	$86.16^{a}\pm0.13$

Means in the same row with the same superscript are not significantly different at $p<0.05$.

Sample A: Bio-fortified cassava granules
Sample B: Ohafia yellow cassava granules
Sample C: Oyo white cassava granules
Sample D: Ijebu white cassava granules

Vitamin A Content of the Cassava Granules Samples

Vitamin A content of the cassava granules garri samples was determined as beta-carotene. Once ingested, beta-carotene is converted to vitamin A in the body (Oyenika *et al*., 2019). The vitamin A (21.11 μg/g) was significantly high in sample A which is the fortified garri (Omodamiro *et al*., 2012).This corroborates the earlier report of Harvest plus (2010) and IITA

(2011) of the high content of vitamin A in bio- fortified cassava. Also, Afolami *et al*. (2021) found that daily consumption of meal from bio-fortified cassava could improve serum retinol and haemoglobin concentrations.

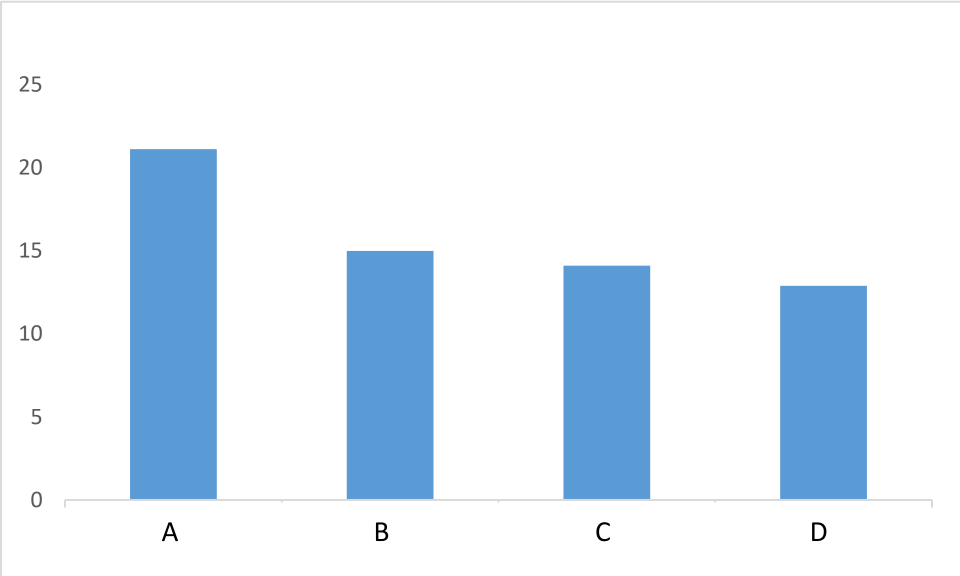

Figure 1: Vitamin A content of cassava garnules samples

Sample A: Bio-fortified garri
Sample B: Ohafia yellow garri
Sample C: Oyo white garri
Sample D: Ijebu white garri

Cyanide Contents of the Cassava Granules **Samples**

Manihot esculenta and its products have been widely studied and reported to have beneficial effect and sometimes toxic effects which are due to the presence of some non-nutrient factors (Bechoff, 2015). Hydrogen cyanide is the major non-nutrient compound and it is poisonous as it binds with cytochrome oxidase and stops its action in the electron transport chain which is a key energy conversion process in the body. Consequent effects include acute intoxication with symptoms of dizziness, headache, stomach pains, vomiting and diarrhea (Olayinka *et al*., 2016). The cyanide content of the garri samples was determined and it was found that there was significant difference among the samples. Ijebu white garri had the highest hydrogen cyanide content (4.5 mg/kg) while Ohafia yellow garri had the lowest (2.8 mg/kg). This finding is in agreement with the report of Airaodion *et al*. (2019) and Ibegbulem and Chikezie (2018) who reported low concentration of hydrogen cyanide for garri containing palm oil. The range of the cyanide content of the samples is lower than 4.48 - 6.41 mg/kg reported by Oyeyinka *et al.* (2019b) for garri prepared from frozen cassava roots. However, all the values for the garri samples are lower than 10 mg/kg of which is considered safe limit (Sanni *et al.,* 2008)

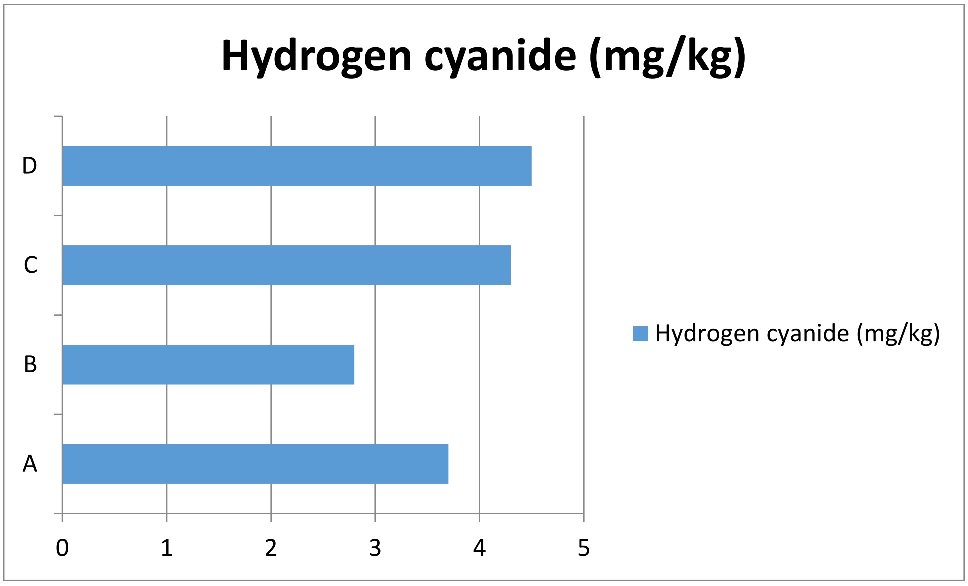

Figure 2: Hydrogen Cyanide of the garri samples

Sensory Evaluation of the Cassava Granules Samples

Table 4 shows the results of the sensory evaluation of the garri samples. The colour of the garri samples ranged from 5.73 - 7.07, Texture ranged from 5.20 - 6.67, Taste ranged from 5.33 - 6.87, Odour ranged from 5.47 - 7.20 and the overall acceptability varies between 5.60 - 7.20. There was a significant difference in the sensory qualities and this corroborates the earlier report of Olakunle *et al.* (2012) on variability in the quality of garri from different sources. It was found that the colour of the garri samples was not significantly different in preference. But Oyo white garri was significantly different from the other samples in texture (6.67), odour (7.20) and overall acceptability (7.20) while the bio-fortified garri (sample A) competed favourably with sample C (Oyo white garri) in taste (5.60). The bio-fortified garri was next to the Oyo white garri in overall acceptability (7.07).

Table 3: Sensory Evaluation of the Cassava Granules (Garri) Samples

Sensory Quality	A	B	C	D
Colour	$6.73^{a}\pm1.22$	$7.07^{a}\pm1.94$	$6.53^{a}\pm1.81$	$5.73^{a}\pm2.37$
Texture	$5.8^{ab}\pm1.42$	$5.40^{ab}\pm1.68$	$6.67^{a}\pm1.40$	$5.20^{b}\pm2.34$
Taste	$6.80^{a}\pm2.08$	$5.33^{a}\pm1.88$	$6.87^{a}\pm1.25$	$5.40^{a}\pm2.35$
Odour	$6.80^{ab}\pm1.90$	$5.47^{b}\pm1.96$	$7.20^{a}\pm1.21$	$6.27^{ab}\pm1.94$
Overall acceptability	$7.07^{ab}\pm1.98$	$5.73^{b}\pm1.75$	$7.20^{a}\pm1.32$	$5.60^{c}\pm2.32$

Means in the same row with the same superscript are not significantly different at $p<0.05$.

CONCLUSION

The results obtained from the study revealed that Ijebu cassava granules (garri) sample had the highest swelling capacity while the Ohafia garri had the highest bulk density and water holding capacity. The bio-fortifed sample was shown to have highest vitamin A and protein content. The highest crude fiber, ash and moisture content was found in Ohafia garri sample while the bio-fortified garri contained the highest protein and vitamin A. Ohafia garri had the least hydrogen cyanide content which was followed by the fortified garri. The study also showed that white Oyo garri sample had the highest overall acceptability among the garri samples followed by the bio-fortified garri sample.

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