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Functional and sensory properties of iron fortified West African cassava fermented meals; “gari” and “fufu”

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The functional and sensory properties of iron fortified “gari” and “fufu”, West African cassava fermented meals were investigated. Cassava tubers (*manihot esculanta*) were prepared using traditional methods for “gari and fufu” production. A 2 x 4 factorial was used, two products (gari and fufu), and four conditions with 0.2 g/kg ferrous sulphate (FeS), Iron III sulphate (F₃S), ferric alum (FA), and control (FC). The samples were fortified and fermented in a solid state for 24 h. “Gari and fufu” samples were analyzed for Water Absorption Capacity (WAC), Swelling Index (SI), Packed Bulk Density (PBD), Loose Bulk Density (LBD), Iron content, and sensory properties of texture, color, aroma, consistency and overall acceptability as quality indicators. Results showed differences in WAC and PBD of gari samples (P<0.05). “Fufu” samples showed differences in the functional properties, with sample F₃S having the highest values (P<0.05). Samples FA for “gari” and F₃S for fufu had the highest iron content (P<0.05), with values of 12.40 ± 0.10 mg/100 g and 14.76 ± 0.15 mg/100 g, respectively, which compared favorably with the WHO adult standards for Iron. The panelists rated samples F₃S and FA for “gari and fufu”, respectively higher for consistency, aroma, and overall acceptability (P<0.05) but there was no difference in taste. Fortification with iron III sulphate could be a viable proposition to combat iron deficiency anemia, which represents a major public health concern in West Africa.

Key words: Cassava meals, fermentation, iron fortification, anemia, functional property, sensory property.

INTRODUCTION

Cassava is the staple food of 250 million of Africans (Vlavanou, 1988). Different kinds of foods result from cassava processing, eg “gari and fufu”, which are fermented cassava derived foods consumed at least once a day by West African people. Though cassava is an excellent energy source, but it contains only \cong 4 mg/100 g Iron (Maziya-Dixon et al., 2010). Cassavas consumers are at high risk of inadequate iron intakes. Supplementation intervention programs or fortification of staple foods such as cassava-derived foods can represent available option to contrast iron deficiency. Anemia is a condition in which the total amount of Red Blood Cells is reduced. Iron deficiency occurs when iron dietary intake or absorption are inadequate resulting in a reduced hemoglobin synthesis (Brady, 2007). Iron deficiency anemia represents the most common form of anemia affecting about 20% of women, 50% of

pregnant women, and 3% of men (Mabry-Hernandez, 2009) in Africa. World wide, 23% of pre-school aged children suffer from iron deficiency anaemia (Blak et al., 2000). Iron deficiency compromises also immune system function and is associated with impaired cognitive development in children. Moreover, Iron deficiency anemia can cause reduced resistance to infection, preterm birth of under-weight babies and maternal death. A large percentage of population living in developing countries are unable to achieve their full mental and physical potentials owing to micronutrient deficiency. So, contrasting iron deficiency represent an essential tool not only to improve public health, but also to sustain economic and national growth. Any effective nutrition intervention should include short term strategies which are cost-effective and sustainable, such as nutrient supplementation and food fortification (Vinodini, 2003). Particularly, food fortification can play a major role to improve diet quality, with respect to the micronutrient needs of the population. It does not require any modification in dietary patterns of the population and can

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provide a significant proportion of the recommended dietary allowance for nutrients. Food fortification does not require compliance, as it can be introduced into the existing food system. Technical considerations in food fortification include selection of appropriate food vehicles, consumed by a notable proportion of the population. "Gari and fufu" staples consumed on a daily basis could be used for this purpose.

Currently, few information are available about iron fortification of West African food staples, like "gari and fufu". The aim of our work therefore, was to produce an acceptable quality iron fortified "gari and fufu", in order to significantly reduce the public health concern of anemia.

MATERIALS AND METHODS

Matured cassava tubers were purchased from a local market in Calabar, Nigeria and stored at 4°C until processed. The tubers were sorted to remove damaged and unwanted tubers, then peeled, washed with potable tap water and finally divided into two equal parts for the production of gari and fufu, respectively.

Experimental design

The design used was 2 x 4 factorial; two products and four conditions for treatment.

Gari production

Peeled cassava tubers were ground with hammer mill (Model – D Comminuting, Machine, W. J. Fitzpatrick Company, Chicago, USA) into a fine mash size. The mash, in duplicate, was divided into four samples; 3 samples were fortified with ferrous sulphate (FeS), Iron III sulphate (F3S) and ferric alum (FA) respectively, in the amount of 0.2 g per kg of cassava mash. Unfortified cassava mash represented the control sample (GC). Each sample was then packed into separate jute bags, pressed with a weight and left to ferment in a solid state for 24 h. The wet mash was sieved, so that flour would pass through a 450 µm stainless steel sieve (W. S. Tyler Co., Member, Ohio, USA), and stir-fried in a saucepan at open fire until dry, to obtain granules.

Fufu production

Peeled cassava tubers (10 kg) were immersed in 30 lt of potable tap water, into a 50 lt plastic container at open-air temperature (30°C). After 3 days, the tubers were dewatered and the rough tendrils and ropes removed. The mash in duplicates were divided into 4 batches: FeS, F₃S and FA, which were fortified as for gari, and sample FC representing the control, and then sieved, bagged in a cheese cloth and drained overnight.

Measurements

Objective measurements

Water absorption capacity

Water Absorption Capacity was determined by the centrifuge method of Sosulki (1973). Each sample (0.3 g) was weighed into 50 ml centrifuge tube and 10 ml of was added distilled water, and

stirred for 5 min with a glass rod. The obtained suspension was maintained at rest for 10 min during which the sample particles adhering to the sides of the tube were scrubbed down with a glass rod. The suspension was mixed seven additional times for 20 s, respecting 10 min rest among the mixing. The sample was centrifuged at 5100 rpm for 25 min and the water decanted. Percentage of absorbed water was calculated from the equation:

$$\text{Percentage of water} = \frac{\text{Weight retained}}{\text{Weight of Sample}} \times 100$$

Swelling index

The method of AOAC (1984) was used to determine the Swelling Index. The sample (3 g) was weighed (w_1) into a graduated cylinder. The mixture was then dispersed in 12 ml of distilled water and stirred with a magnetic stirrer for 5 min. The slurry was heated at desired temperatures ranging from 40 to 90°C for 30 min with thermostate water bath (Tethmel Texas, USA). The mixture was centrifuged at 2200 rpm for 15 min, and the residue obtained after centrifugation was transferred into the test tube and reweighed (w_2). Swelling Index expressed in percentage was calculated using the following equation:

$$\% \text{ swelling of starch} = \frac{W_2 - W_1}{W_1} \times \frac{100}{1}$$

W_2 - Weight retained, W_1 - weight of the sample.

Packed bulk and loose bulk density

The method of Murphy et. al. (2003) was used to determine Bulk Density (BD). Each sample (5 g) was weighed into a graduated 10 ml cylinder that was tapped via agitation to eliminate air space between samples and allowed to stand for 1 h. For Loose Bulk Density (LBD) space was not eliminated by tapping. PBD and LBD were expressed as kgm^{-3} .

Iron content

Iron content was determined using the Atomic Absorption Spectrophotometric method of Njoku and Ohia (2007). Upon ashing, 3 drops of 1m HNO_3 acid were added to the sample in each of the crucibles, to digest them. 50 ml of distilled water was used to rinse the digest into 10 ml flasks respectively, and the flasks were filled up to the marks with distilled water. The digests were filtered into sample bottles each using the Whatman filter paper (125 mm) prior to analyses. The iron content of the samples was determined using Atomic Absorption Spectrometer (AAS) at 248.3 nm by air – acetylene flame. The concentrations of the element in the samples were calculated using the formula.

$$\text{Concentration (mg/100 g)} = \frac{\text{Concentration}}{\text{Sample weight}} \times 10$$

Subjective measurements

Ethical approval for sensory work carried by out by this panel was granted by the university of Calabar Human Ethics committee.

Table 1. Water absorption capacity of gari and fufu samples (%).

Sample	*Fufu	*Gari
FeS	33.37 ^b ± 0.28	46.70 ^c ± 0.52
F ₃ S	34.97 ^a ± 0.01	48.70 ^a ± 0.52
FA	32.74 ^c ± 0.12	47.60 ^b ± 0.15
FC	28.96 ^d ± 0.15	36.60 ^d ± 0.57

^{a,b,c,d} *Means with the same superscript within the column are not significant (P<0.05). *Means of three determinations. Sample FeS: Ferrous sulphate fortified; sample F₃S: Iron III Sulphate fortified; sample FA: ferric alum fortified, Sample FC: Control.

Table 2. Packed Bulk Density of Gari and fufu samples (Kgm⁻³).

Sample	*Gari	*Fufu
FeS	5.60 ^d ± 0.19	8.46 ^b ± 0.17
F ₃ S	6.70 ^c ± 0.03	7.20 ^c ± 0.20
FA	7.40 ^b ± 0.60	6.50 ^d ± 0.20
FC	8.20 ^a ± 0.17	9.30 ^a ± 0.10

^{a,b,c,d} *Means with the same superscript within the column are not significant (P<0.05). Means of three determinations. Sample FeS: Ferrous sulphate fortified; sample F₃S: Iron III Sulphate fortified; sample FA: ferric alum fortified; Sample FC: Control.

“Gari” Samples (500 g) were each separately stirred into 50 ml boiling water (100°C) contained in a bowl, to obtain a thick gari meal (GM). Also the raw fufu samples (500 g) were mixed with potable tap water in a ratio of 1:2 in a pot over a heating metal and stirred continuously for 10 min to obtain a thick fufu meal (FM).

The method of Larmond (1977) was used for sensory evaluation, which was performed by 9 untrained panelists, who consume gari and fufu in daily basis. Each panelist was served a 50 g sample in clear plastic plates. The serving was at room temperature and the room had both fluorescent illumination and natural light in individual booths. Panelists were asked to rank the products on a hedonic scale of 1 to 7, with 1 being excellent, and 7 being very poor for each of the following characteristics: color, mouth feel, taste, consistency, aroma and overall acceptability. The panelists assessed the samples in duplicates.

Data analysis

Statistical analyses were performed by analysis of variance (ANOVA), using SPSS software. The Duncan comparison test was carried out on the means. Differences were considered statistically significant at P<0.05. All values reported are the mean of 3 measurements.

RESULTS AND DISCUSSION

Objective measurements

Water absorption capacity (WAC)

The WAC of gari (Table 1) ranged from 36.60 ± 0.57 to 48.70 ± 0.52%, while the WAC of fufu ranged from 28.96 ± 0.15 to 34.97 ± 0.01%. The fortified samples had

significantly higher values than the control (P<0.05), having F₃S for gari and fufu the highest WAC of 48.70 ± 0.52 and 34.97 ± 0.01%, respectively. As porosity can cause an increase in water retention capacity of starchy fibers (Blum, 1997), we can suppose that Iron III sulphate can confer some degree of textured porosity to the gari sample (Brown, 2001), and we can hypothesize that the different iron complexes can exert different effects on the starchy components resulting in different porosity of the fortified samples. In addition, Iron salts can promote a larger exposition of hydroxyl groups of the starchy molecules, making hydrogen available to bond with water, causing increased water content (Nelson and Cox, 2006). The WAC of the fortified “gari” samples was higher than “fufu”, and this can depend on the higher content of damaged starchy granules, compared to “fufu”. Water absorption capacity is important for certain product characteristics such as moistness of the product, starch retrogradation and subsequent product staling (Siddiq et al., 2010).

Packed bulk density (PBD)

The PBD values (Table 2) which ranged from 5.60 ± 0.19 to 8.20 ± 0.17 kgm⁻³ for gari samples and from 6.50 ± 0.20 to 9.30 ± 0.10 kgm⁻³ for fufu samples, were significantly different (P<0.05). The PBD value for the control samples for gari and fufu were significantly higher than the fortified samples (P<0.05), with values of 8.20 ± 0.17 kgm⁻³ and 9.30 ± 0.10 kg m⁻³, respectively.

Table 3. Loose Bulk Density of Gari and fufu samples (Kgm^{-3}).

Sample	*Gari	*Fufu
FeS	4.50 ^b ± 0.20	4.60 ^b ± 0.16
F ₃ S	4.30 ^b ± 0.10	4.40 ^b ± 0.23
FA	4.33 ^b ± 0.30	4.70 ^b ± 0.13
FC	5.03 ^a ± 0.06	5.33 ^a ± 0.15

^{a,b,c,d} *Means with the same superscript within the column are not significant ($P < 0.05$). *Means of three determinations. Sample FeS: Ferrous sulphate fortified; sample F₃S: Iron III Sulphate fortified; sample FA: ferric alum fortified; Sample FC: Control.

Table 4. Swelling Index of Gari and fufu samples (%).

Sample	*Fufu	*Gari
FeS	78.60 ^b ± 0.26	66.50 ^c ± 0.10
F ₃ S	79.20 ^a ± 0.13	66.60 ^c ± 0.10
FA	76.80 ^c ± 0.14	80.10 ^b ± 0.20
FC	80.60 ^a ± 0.23	83.20 ^a ± 0.10

^{a,b,c,d} *Means with the same superscript within the column are not significant ($P < 0.05$). *Means of three determinations. Sample FeS : Ferrous sulphate fortified; sample F3S: Iron III Sulphate fortified; sample FA:ferric alum fortified; Sample FC: Control.

PBD is an index reflecting the load the sample can support if allowed to rest directly on one another. The lower the PBD value, the higher the amount of load. Fufu samples had higher PBD values compared to “gari”. Samples FeS for “gari” and FA for “fufu” had the lowest PBD values of $5.60 \pm 0.19 \text{ kgm}^{-3}$ and $6.50 \pm 0.20 \text{ kgm}^{-3}$, respectively. However, the fortified samples had lower PBD values than the control samples of gari and fufu, providing more derivable energy (Ramahngsutaim, 1995).

We can suppose that iron fortification can generally reduce the ease with which the starchy granules could stay together (Sheard, 1994).

Loose bulk density (LBD)

The LBD values for “gari and fufu” presented in Table 3 ranged from 4.30 ± 0.10 to $5.03 \pm 0.06 \text{ kgm}^{-3}$ and from 4.40 ± 0.23 to $5.33 \pm 0.15 \text{ kgm}^{-3}$, respectively. No significant difference in the LBD values of the fortified samples for both gari and fufu was detected while we found a significant difference between the fortified samples and control samples ($P < 0.05$). LBD represents the lowest attainable density without compression (Sheard, 1994). The control samples for both “gari and fufu” had the highest LBD values (5.03 ± 0.06 and $5.33 \pm 0.15 \text{ kgm}^{-3}$, respectively), while samples F₃S had the lowest values (gari: $4.30 \pm 0.10 \text{ kgm}^{-3}$; fufu: $4.40 \pm 0.23 \text{ kgm}^{-3}$).

The higher LBD value of the control samples, in comparison with the fortified samples, again suggests

that the Iron compounds can affect starch integrity. This can allow the fortified gari to store longer under appropriate conditions without clumping together. However, LBD values of “gari and fufu” were comparable.

Swelling index (SI)

The SI values ranged from 66.50 ± 0.10 to $83.20 \pm 0.10\%$ for gari and from 76.80 ± 0.14 to $80.60 \pm 0.23\%$ for fufu (Table 4). Percent SI of gari and fufu samples were significantly higher than for fortified samples ($P < 0.05$). The samples with the highest SI for gari and fufu were samples FA ($80.10 \pm 0.20\%$) and F3S ($79.20 \pm 0.26\%$), respectively.

Again, we can hypothesize that the Iron salts used for the fortification of the samples can damage starch, which could absorb a larger amount of water. The higher SI values of fufu samples in respect to gari could be attributable to the processing. However, the SI of the samples were within acceptable range and therefore would not impact negatively the acceptability of the products.

Iron content

Table 5 shows that the Iron content of the “gari and fufu” samples were significantly different ($P < 0.05$), ranging from 1.01 ± 0.10 to $12.40 \pm 0.10 \text{ mg}/100 \text{ g}$ and from 1.29 ± 0.18 to $14.76 \pm 0.15 \text{ mg}/100 \text{ g}$, respectively. Iron fortification of gari and fufu samples significantly

Table 5. Iron Content of Gari and fufu samples (mg/100 g).

Sample	*Gari	*Fufu
FeS	10.70 ^b ± 0.30	13.40 ^b ± 0.26
F ₃ S	8.80 ^c ± 0.10	14.76 ^a ± 0.15
FA	12.40 ^a ± 0.10	13.85 ^b ± 0.15
FC	1.01 ^d ± 0.10	1.29 ^c ± 0.18

^{a,b,c,d} *Means with the same superscript within the column are not significant (P<0.05). *Means of three determinations. Sample FeS: Ferrous sulphate fortified; sample F₃S: Iron III Sulphate fortified; sample FA: ferric alum fortified; Sample FC: Control.

Table 6. Panelists mean score of gari and fufu samples.

Parameters	*Gari				*Fufu			
	FeS	F ₃ S	FA	FC	FeS	F ₃ S	FA	FC
Colour	3.1 ^a ±0.01	3.2 ^a ±0.01	3.3 ^a ±0.01	3.3 ^a ±0.01	5.6 ^a ±2.3	5.1 ^a ±2.1	5.2 ^a ±2.0	5.1 ^a ±2.6
Mouth feel	4.3 ^a ±0.04	3.8 ^b ±0.01	3.9 ^b ±2.0	3.4 ^c ±1.0	4.6 ^a ±1.7	4.5 ^a ±1.8	4.9 ^a ±1.7	4.9 ^a ±1.8
Taste	4.0 ^a ±0.03	3.7 ^a ±0.05	3.8 ^a ±0.06	3.8 ^a ±1.04	4.2 ^a ±1.2	4.1 ^a ±1.0	3.9 ^a ±1.4	3.9 ^a ±1.3
Consistency	3.8 ^b ±1.23	4.1 ^a ±2.0	3.7 ^b ±1.0	3.5 ^c ±1.03	5.1 ^a ±2.4	4.0 ^c ±2.1	4.9 ^b ±2.3	4.0 ^c ±2.2
Aroma	4.1 ^a ±1.10	3.4 ^b ±1.01	3.2 ^c ±1.10	3.2 ^c ±1.0	6.2 ^a ±1.6	4.8 ^c ±2.0	5.7 ^b ±1.3	4.8 ^c ±1.4
Overall acceptability	4.3 ^a ±0.10	4.0 ^b ±0.12	3.6 ^c ±0.02	3.7 ^c ±0.01	6.2 ^a ±2.6	5.5 ^b ±2.7	5.7 ^b ±2.6	5.6 ^b ±2.5

^{a,b,c,d} means with different superscript in the same column are significant (P<0.05). *Means with lower values indicates greater preference. Sample FeS, F₃S, FA: Fortified with Ferrous sulphate; Iron III Sulphate, ferric alum respectively, FC Control.

increased the Iron content (P<0.05). The highest iron content in “gari and fufu” was found in samples FA (12.40 ± 0.10 mg/100 g) and F₃S (14.76 ± 0.15 mg/100 g), respectively, while the iron content of the control samples was the lowest.

The Iron content of gari samples FeS and FA and of all the fufu samples, can easily allow to meet the WHO recommended daily allowance (RDA) of 10 mg/100 g for men and 15 mg/100 g for women; on the contrary, the control samples presented a very low Iron content (1.01 ± 0.10 mg/100 g and 1.29 ± 0.18 mg/100 g, respectively, for “gari and fufu”).

Subjective measurement

The results of the sensory evaluation are presented in Table 6. The colour ratings of all “gari and fufu” samples were not significantly different, ranging from 3.1 to 3.3 and from 5.1 to 5.6, respectively. Colour is an important quality indicator of a food system, as an unpleasant colour may affect consumer acceptance. Iron fortification did not confer any unpleasant colour to the samples. Panelists' ratings for mouth feel were significantly different for gari samples (P<0.05) as the values ranged from 3.4 to 4.3, while the ratings for fufu samples were not significantly different.

Taste ratings for all samples were not significantly different, while consistency, aroma and overall

acceptability ratings were significantly different (P<0.05). Samples FA (3.7 ± 1.0) for “gari” and sample F₃S (4.0 ± 2.1) for “fufu” had the best consistency ratings, as lower values indicated greater preference. However, also the higher values were within acceptable ranges.

Swelling index and water absorption capacity are important parameters that determine consistency. Gari and “fufu” with poor consistency rating would be unacceptable to consumers. However, the Iron salts did not negatively affect the samples consistency as the ratings were within acceptable ranges.

Aroma ratings for sample FA of “gari”, and samples F₃S of “fufu”, and their equivalent control samples, were not significantly different. Overall acceptability ratings of sample FA for “gari”, and samples FA, as well as F₃S for “fufu”, were not significantly different from their controls.

Conclusion

Our results showed that iron fortification of “gari and fufu” samples improved the iron content significantly (P < 0.05) with sample FA for “gari”, and sample F₃S for “fufu” having the highest Iron value of 12.40 ± 0.10 mg/100 g and 14.76±0.15 mg/100 g, respectively. These values are almost comparable to the WHO iron RDA for both sexes. The iron fortified samples also yielded the desired functional property of gari and fufu, although sample FA (gari) and sample F₃S (fufu) had the best functional

properties showing the best ratings for consistency, aroma and overall acceptability.

On the contrary overall acceptability rating of samples FA (gari) and Sample F₃S and FA (fufu) were not significantly different from control. Panelists' ratings of the samples for taste were not significantly different. Therefore, fortification of gari and fufu with either ferric alum or iron III sulphate could represent valuable intervention in order to contrast iron deficiency anemia in West Africa.

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