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Chemical Composition, Pasting and Sensory Properties of Iron-Fortified Cassava *Gari*

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ABSTRACT

The need to eradicate nutritional anaemia with a local diet is important for successful intervention at the community level in Nigeria. Enhancing the micronutrient content of commonly consumed staple foods like cassava *gari* can reduce iron deficiency in Nigeria. This study investigates the extent to which inclusion of iron fortificants (sodium iron EDTA, Fe fumarate and Fe sulphate) could affect proximate and mineral composition, pasting and sensory properties of fortified cassava *gari* samples. Investment cost of iron fortified cassava *gari* was also investigated. *Gari* was fortified with these three fortificants at three concentrations (25, 35 and 45 mg/kg). There were significant differences ($P < 0.05$) in the proximate and pasting properties of iron-fortified *gari* samples compared to unfortified samples. Iron content of unfortified *gari* was 12 mg/kg and this value appreciably increased from 17 to 20 mg/kg, 18 to 25 mg/kg and 21 to 28 mg/kg for NaFeEDTA-, Fe sulphate- and Fe fumarate-fortified *gari* samples, respectively. There were no significant differences ($P > 0.05$) in taste, texture and odour of unfortified and fortified samples. In terms of overall acceptability, panellists rated unfortified *gari* samples higher followed by samples with 45 mg/kg NaFeEDTA. The rate of return on investment for iron fortified *gari* is 1.36.

Keywords: cassava, fortification, *gari*, micronutrient, Nigeria

INTRODUCTION

Iron deficiency is a serious health problem affecting a large proportion of the world's population (Ratana *et al*. 2006; Sanni *et al*. 2008). It is considered by World Nutrition Experts to be the most common worldwide nutritional deficiency and affects approximately 20% of the world population (Sanni *et al*. 2008). Its most severe form, iron deficiency anaemia, is reported to have a higher overall cost to society than any other disease except tuberculosis (Pizarro and Olivares 2006). Women and young children are especially at risk. Adverse effects include lower growth rate and impaired cognitive scores in children and poor pregnancy outcome and lower working capacity in adults (Walker 1998). The global nature of the problem and its public health significance has been reviewed by Hambraeus (1999). Food fortification programs are cost-effective means for reducing the prevalence of iron deficiency (Cook and Reusser 1983). The effectiveness of a food fortification program depends on the consistent and uniform addition of iron compounds to appropriate food vehicles, such as flour and milk-based powders, which are widely consumed by the target population (Mejia 1994). To be effective, a combination of an iron fortificant compound and food vehicle must be selected which is safe, acceptable to and consumed by the target population, does not adversely affect the organoleptic qualities and shelf-life of the food vehicle, and provides iron in a stable, highly bioavailable form (INACG 2002; Pizarro and Olivares 2006; Ratana *et al*. 2006; Sanni *et al*. 2008).

Basically, foods of all major groups can be fortified. The efficacy of food fortification as a nutrition intervention strategy has been extensively investigated in large field studies involving thousands of participants (FAO/ILSI 1999). The fortification of certain foods such as flour, sugar, salt, etc. is now been practiced in Nigeria with the introduction of legislation by the Federal Government mandatory fortification of such food items (Omosanya 2002). However, there are little efforts on fortification procedures for traditional foods, especially from cassava.

Gari, a fermented cassava product, is widely known in Nigeria and other West African countries (Igbeka 1987). In Boukina Faso, it is called *atoukpou* (Nweke 1994). Certain processing steps in *gari* making such as grating and water expressing are mechanised (Sanni *et al*. 1998). Urban consumers prefer *gari* because it is a pre-cooked convenience food. It is commonly consumed either by soaking in cold water with sugar, coconut, roasted peanut, fish, or boiled cowpea as complements or as a paste made with hot water and eaten with vegetable sauce (Sanni and Ayinde 2002). Cassava and its products such as *gari* is very deficient in protein and micronutrients such as calcium, phosphorus, irons, and vitamins such as vitamin C, A, thiamine, riboflavin and niacin. Some of these minerals and vitamins however are lost during processing (Sanni *et al*. 1998).

Cassava fortification in Nigeria has been dominated with the enrichment of local Nigerian staple foods like *gari*, *lafun* and *fufu* with soybean protein (Oyewole and Aibor 1992; Oyewole and Asagbra 2003). This was aimed at solving protein malnutrition in children, pregnant women, lactating mothers, the aged and the sick (Enwere 1998). However, there is no information on the micronutrient fortification of some of these traditional cassava products. This paper reports our findings on the effects of iron fortificants (sodium iron EDTA, Fe fumarate and Fe sulphate) on the proximate, minerals, pasting and sensory properties of iron-fortified *gari* samples. Cost and return benefits of iron fortified cassava *gari* production are also reported.

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MATERIALS AND METHODS

Cassava roots

Cassava roots (TMS 30572, low cyanogens variety) used for this study were obtained from the research farm of the University of Agriculture, Abeokuta, Nigeria. The plants were 12 months old at the time of harvest. Cassava roots were processed within 60 min after harvesting.

Food grade iron fortificants

Iron (II) sulfate heptahydrate (EINECS 231-753-5, Lancaster), iron (II) fumarate (EINECS 205-447-7, Lancaster) and ethylenediaminetetraacetic acid iron (III) sodium salt (NaFeEDTA, E6760-500G, Sigma) used in this study were obtained from the UK.

Gari production

The method described by Akingbala *et al.* (1991) was employed for *gari* production at the Pilot Plant of the Cassava EU/SME Project, University of Agriculture, Abeokuta, Nigeria. Freshly harvested cassava roots were peeled manually with a stainless steel knife, washed thoroughly with potable water to remove all dirt and adhering sand particles. The washed peeled cassava roots were then grated into mash using a petrol engine driven stainless steel grater, packed into Hessian sacks and left for 3 days at room temperature to ferment. After 3 days, the fermented mash was dewatered using a hydraulic press. The fermented pressed mash was then sieved manually with a stainless steel sieve to pulverize the pressed cake and separate fibrous materials. The pulverized cake was roasted in a large, shallow stainless steel pan with constant stirring with a stainless steel plate for 7-10 min depending on the quantity and heat intensity. The resulting *gari* was spread on a stainless steel tray to cool and then sieved to obtain granules of small particle size (1.4 mm) before been packaged into polyethylene bags and stored at 4°C before fortification.

Fortification of *gari* samples

A Kenwood mixer (Model FP 505, Kenwood, UK) was used for dry mixing of the three different types of fortificants (iron sulfate, iron fumarate and sodium iron EDTA) with the cassava *gari* samples at 25, 35 and 45 mg of fortificants to 1 kg of cassava *gari* samples for 5 min for effective mixing (Philar 2001). Unfortified cassava *gari* samples served as the control.

Chemical analysis

Proximate (moisture, protein, carbohydrate, fat, ash, fibre) composition analysis of the cake samples were determined by the AOAC (2001) methods. Mineral contents were determined at Waite Analytical Services, School of Agriculture and Wine, University of Adelaide, Australia using ICP-ES using the methods of Zarcinas *et al*. (1987). A sample of 0.6 g of the ground material was cold digested in 50 ml tubes overnight using 11 ml of nitric/perchloric acid mixture (10:1) and made to a final volume of 25 ml. Aliquots of the digested samples were analysed for iron and other minerals using inductively coupled plasma Atomic Emission Spectrometry (ARL Model 3580B, Switzerland). Pasting characteristics were determined with a Rapid Visco Analyser (RVA), (model RVA 3D+, Network Scientific, Australia) as described by Sanni *et al*. (2003). All analyses were replicated thrice.

Sensory evaluation

The sensory evaluation of iron-fortified and unfortified cassava *gari* samples was conducted using 15-member trained panellists. Panellists were selected from the staff and students of the University of Agriculture, Abeokuta, Nigeria on the basis of interest, availability and familiarity with cassava products. *Gari* was poured into boiled water on fire, with constant stirring using a wooden ladle till a consistent paste was formed. Cooked samples were coded with 3-figure random numbers and presented in random order to each panellist at ambient room conditions (25-30°C). The judges were asked to score for odour, colour, texture, taste and overall acceptability using a 9-point hedonic scale, where 1 and 9 represent dislike extremely and like extremely, respectively (Sanni *et al*. 2003).

Economic analysis

Economic analysis was carried out to determine the cost implications of iron fortified *gari* samples produced in this study, in order to ascertain the profitability of adding iron fortificants to cassava products. Analysis carried out here was standardized on per tonne basis. Profit was determined using the formula described by Makeham and Malcolm (1986):

$$\Pi = TR - TC$$

where Π = profit; TR = total revenue (quantity of item produced multiplied by the price per unit in N) and TC = total cost, which includes total variable cost and total fixed cost.

Fixed inputs used in the production of these *gari* samples were depreciated using the straight line method of depreciation (Makeham and Malcolm 1986). The relative weight of inputs (fixed and variable, including the relative weight of the fortificants) used in production were depicted as percentage of total fixed cost (TFC), total variable cost (TVC) and TC. Profit was calculated using return to investment which indicates what the potential entrepreneur gains per unit of money (Naira) invested in the business is given by total revenue divided by total cost of production (Penson *et al.* 1996).

Statistical analysis

All data obtained were subjected to analysis of variance [ANOVA] and means were separated with Duncan's multiple range test (DMRT) (Larmond 1977) with a statistical significant of $P < 0.05$ using SPSS Version 10.2, 2002.

RESULTS AND DISCUSSION

Table 1 presents the proximate composition of unfortified and iron-fortified *gari* samples. There were significant differences ($P < 0.05$) in the proximate composition of fortified samples compared to unfortified samples. Unfortified *gari* sample had the following composition: moisture, 11.35%, protein, 1.13%, sugar, 0.42%, starch, 72.55%, amylose, 14.60%, fat, 0.0% and ash, 1.19% while iron-fortified *gari* samples had moisture content ranging from 11.05 to 11.56% with the least value recorded for *gari* fortified with 45 mg NaFeEDTA and the highest value recorded for those fortified with 35 mg Fe sulphate. Protein content ranged from 0.46 to 1.14% with the least value recorded for those fortified with 25 mg Fe sulphate and the highest value recorded for those fortified with 25 mg NaFeEDTA. Sugar content range from 0.53 to 0.86% with *gari* samples fortified with 25 mg Fe fumarate and highest value recorded for those fortified with 35 mg Fe sulphate. Starch content ranged from 53.61 to 75.64% with least value recorded for *gari* samples fortified with 35 mg Fe fumarate and highest value for fortified *gari* sample with 35 mg NaFeEDTA. Fat content varied from 0.00 to 0.46% with *gari* fortified with 45 mg NaFeEDTA having the lowest and the highest value were recorded by *gari* fortified with 35 mg Fe sulphate. Ash content ranged from 1.23 to 1.55% with those fortified with 25 mg Fe fumarate recording the least value and those fortified with 45 mg Fe sulphate recording the highest value. The percentage starch content was within the range (6.80-93.2%) reported by various authors (Oyewole and Odunfa 1989; Ayankunbi *et al*. 1991; Sanni *et al*. 1998). Low protein, ash and fibre contents obtained in this study have been reported by Sanni and Akingbala (2000). Amylose content of the *gari* samples falls within values reported by Akingbala *et al.* (2005). The greater the percentage of amylose fraction of starch-based foods, the quicker the formation of the gel (Sanni *et al.* 2003). Amylose content affects gelatinization properties, degree of

Table 1 Proximate composition (%) of unfortified and Iron-fortified *gari*.

Samples	Moisture*	Protein	Sugar	Starch	Amylose	Fat*	Ash
Unfortified *gari*	11.35	1.13 c	0.42 a	72.55 e	14.60 a	0.00	1.19 a
Gari + 25 mg/kg EDTA	11.41	1.14 c	0.54 ab	68.61 c	14.23 a	0.02	1.36 b
Gari + 35 mg/kg EDTA	11.54	1.13 c	0.60 ab	75.64 f	15.00 ab	0.01	1.33 ab
Gari + 45 mg/kg EDTA	11.05	0.92 b	0.70 bc	69.78 cd	16.04 c	0.00	1.30 ab
Gari + 25 mg/kg Fe sulphate	11.12	0.46 a	0.67 ab	79.03 g	15.67 bc	0.05	1.53 c
Gari + 35 mg/kg Fe sulphate	11.56	0.58 a	0.86 c	60.79 b	19.47 e	0.46	1.53 c
Gari + 45 mg Fe sulphate	11.29	0.46 a	0.67 bc	61.60 b	16.40 c	0.12	1.55 c
Gari + 25 mg/kg Fe fumarate	11.38	0.93 b	0.53 ab	70.74 d	23.14 f	0.37	1.23 ab
Gari + 35 mg Fe fumarate	11.34	1.14 c	0.66 bc	53.61 a	18.30 d	0.14	1.25 ab
Gari + 45 mg/kg Fe fumarate	11.12	0.92 b	0.63 bc	68.80 c	22.46 f	0.50	1.30 ab

Values are means of three replicates
Means values having different letters within column are significantly different ($P < 0.05$)
* = not significantly different ($P > 0.05$).

Table 2 Mineral contents (mg/kg) of unfortified and iron-fortified cassava *gari*.

Sample	Mn	B*	Cu*	Mo	Co	Ni*	Ca	Mg	Na	K	P	S	Al	Ti
Unfortified *gari*	5.90 abc	1.90	1.20	< 0.4	< 0.4	0.49	1620.00 g	300.00 b	8.70 e	4400.00 b	430.00 b	102.00 c	9.00 ef	0.75 ab
Gari + 25 mg/kg EDTA	6.00 cd	2.00	1.20	< 0.4	< 0.4	0.56	1570.00 e	300.00 b	11.00 g	4400.00 b	440.00 c	103.00 d	9.00 ef	0.68 ab
Gari + 35 mg/kg EDTA	6.00 cd	2.00	1.30	< 0.4	< 0.4	0.48	1540.00 c	310.00 c	12.00 h	4600.00 d	450.00 d	103.00 d	8.80 d	1.10 c
Gari + 45 mg/kg EDTA	5.90 abc	2.00	1.20	< 0.4	< 0.4	0.47	1560.00 d	300.00 b	10.00 f	4400.00 b	430.00 b	101.00 b	8.50 c	0.98 bc
Gari + 25 mg/kg Fe sulphate	6.10 f	2.00	1.20	< 0.4	< 0.4	0.52	1560.00 d	300.00 b	8.00 d	4500.00 c	440.00 c	101.00 b	11.00 f	0.66 a
Gari + 35 mg/kg Fe sulphate	6.10 f	2.00	1.20	< 0.4	< 0.4	0.59	1560.00 d	300.00 b	7.60 c	4400.00 b	440.00 c	103.00 d	9.10 f	0.75 ab
Gari + 45 mg/kg Fe sulphate	5.90 abc	2.00	1.20	< 0.4	< 0.4	0.49	1580.00 f	290.00 a	7.60 c	4400.00 b	430.00 b	107.00 f	8.60 c	0.72 ab
Gari + 25 mg/kg Fe fumarate	6.00 cd	2.10	1.20	< 0.4	< 0.4	0.49	1500.00 b	300.00 b	7.50 c	4400.00 b	440.00 c	105.00 e	9.00 ef	0.66 a
Gari + 35 mg/kg Fe fumarate	5.80 a	2.00	1.20	< 0.4	< 0.4	0.49	1550.00 d	300.00 b	7.10 b	4400.00 b	440.00 c	103.00 d	8.50 c	0.67 ab
Gari + 45 mg/kg Fe fumarate	5.90 abc	2.00	1.10	< 0.4	< 0.4	0.63	1470.00 a	290.00 a	6.80 a	4300.00 a	420.00 a	97.00 a	8.30 a	0.66 a

Values are means of three replicates
Means values having different letters within column are significantly different ($P < 0.05$)
* = not significantly different ($P > 0.05$)

swelling and enzymatic susceptibility of starch and starch-based food products (Gerard *et al.* 2001). In this study iron fortification of *gari* was found to increase the amylose profile of these products compared with values obtained in unfortified samples. An increase in amylose content has also been reported to increase the gelatinization temperature (Narpinder *et al.* 2005). The ash content of a food material represents the inorganic or mineral constituents of the foods. The ash content obtained in the present study is considerably lower than the maximum that is recommended by the Standard organization of Nigeria (Sanni *et al.* 2005).

The mineral contents of unfortified and iron-fortified *gari* samples are presented in **Table 2**. Manganese (Mn) contents ranged from 5.90 mg/kg for the unfortified sample to 5.80-6.10 mg/kg for iron-fortified *gari* samples. Boron (B) ranged from 1.90 mg/kg for the control to1.90-2.10 mg/kg for iron-fortified *gari* samples, while copper (Cu) ranged from 1.20 mg/kg for the unfortified sample to 1.10-1.30 mg/kg for iron fortified *gari* samples. Nickel (Ni) ranged from 0.49 mg/kg for unfortified to 0.47-0.59 mg/kg for iron-fortified *gari* samples. Calcium (Ca) ranged from 1620 mg/kg for control to 1470-1620 mg/kg for iron-fortified *gari* samples. Magnesium (Mg) ranged from 300 mg/kg in the control to 290-310 mg/kg for iron-fortified *gari* samples. Sodium (Na) ranged from 8.70 mg/kg in the control to 6.80-12.00 mg/kg for iron-fortified *gari* samples. Potassium (K) ranged from 4400 mg/kg in the control to 4300-4600 mg/kg for iron-fortified *gari* samples, while Phosphorus (P) contents ranged from 430 mg/kg to 420-450 mg/kg for the control and iron-fortified *gari* samples, respectively. Sulphur (S) ranged from 102 mg/kg to 97-107 mg/kg for the control and iron-fortified *gari* samples, respectively. Aluminium (Al) ranged from 9.00 mg/kg to 8.30-11.00 mg/kg for the control and iron-fortified *gari* samples, respectively. Tin (Ti) ranged from 0.75 mg/kg in the unfortified sample to 0.66-1.1 mg/kg for iron-fortified *gari* samples while molybdenum (Mo) and Cobalt (Co) contents were less than 0.40 mg/kg respectively. Variations in mineral contents of iron-fortified *gari* samples were consistent with the results of previous studies (Oyewole and Odunfa 1989; Ayankunbi *et al.* 1991; Osagie and Eka 1998). High amounts of minerals such as calcium, magnesium obtained in this study are expected to be useful after consuming iron fortified cassava products. The lower values of iron, copper, zinc, iodine and selenium obtained in this study are within the previous values reported by various authors for fortified food commodities (Dennison and Kirk 1982; Tannenbaum *et al.* 1985; Greenwood and Earnshaw 1998). These micronutrients are nutritionally important as they are needed at lower level compared with macronutrients.

Table 3 Heavy metal contents (mg/kg) of unfortified and iron-fortified cassava *gari*.

Samples	Cr	Cd	Pb	Se
Unfortified *gari*	0.28	< 0.09	< 1.00	< 4.00
Gari + 25 mgkg NaFeEDTA	0.40	< 0.10	< 1.00	< 4.00
Gari + 35 mg/kg NaFeEDTA	< 0.2	< 0.10	< 1.00	< 4.00
Gari + 45 mg/kg NaFeEDTA	0.26	< 0.09	< 1.00	< 4.00
Gari + 25 mg/kg Fe sulphate	0.31	< 0.09	< 1.00	< 4.00
Gari + 35 mg/kg Fe sulphate	0.59	< 0.09	< 1.00	< 4.00
Gari + 45 mg/kg Fe sulphate	0.29	< 0.09	< 1.00	< 4.00
Gari + 25 mg/kg Fe fumarate	0.30	< 0.10	< 1.00	< 4.00
Gari + 35 mg/kg Fe fumarate	0.24	< 0.09	< 1.00	< 4.00
Gari + 45 mg/kg Fe fumarate	0.48	< 0.09	< 1.00	< 4.00

Table 3 presents the results of heavy metal contents of iron-fortified cassava *gari* samples. For iron-fortified cassava *gari*, chromium (Cr) ranged from < 0.20-0.59 mg/kg, cadmium (Cd) was < 0.09 mg/kg, lead (Pb) was < 1 mg/kg, selenium (Se) was less than 4 mg/kg. The low values of heavy metal contents of unfortified and iron-fortified cassava products samples provided enough support for their safety (Ahmed and Al-Swaidan 1993; Garrow and James 1993) and expected nutritional benefits (Greeword and Earnshaw 1998) of the iron-fortified cassava products to humans. Philpott and Pickering (2004) reported permissible limits of 1.0 ppm, 1.0 ppm and 200 mg/kg for arsenic, lead and tin respectively for bread, flour and similar products. The implication of this study is that iron fortification, if properly carried out with the use of clean processing equipment and less polluted environment, will produce safe and wholesome cassava products (Sanni *et al.* 1998). The Codex Alimentarius Commission (CODEX) standard for

Table 4 Pasting properties of iron-fortified and unfortified cassava *gari*.

Samples	Peak (RVU)	Trough (RVU)	Break down (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (min)*	Pasting temperature (°C)
Unfortified *gari*	107.75 b	65.29 c	42.46 b	191.54 b	126.25 b	7.00	80.03 e
Gari + 25 mg/kg NaFeEDTA	105.88 b	58.38 bc	47.50 bc	203.75 b	145.38 bc	7.00	76.55 c
Gari + 35 mg/kg NaFeEDTA	129.88 c	81.96 d	47.92 bc	234.67 c	152.71 cd	7.00	78.84 d
Gari + 45 mg/kg NaFeEDTA	115.09 b	64.67 c	50.42 bc	209.88 b	145.21 bc	7.00	80.03 e
Gari + 25 mg/kg Fe sulphate	152.46 d	101.59 e	50.88 bc	265.96 d	164.38 cd	7.00	78.53 d
Gari + 35 mg/kg Fe sulphate	145.09 d	86.00 d	59.09 c	257.05 d	171.05 d	7.00	77.63 c
Gari + 45 mg/kg Fe sulphate	146.67 d	88.59 d	58.08 c	259.92 d	171.33 d	7.00	78.28 d
Gari + 25 mg/kg Fe fumarate	65.59 a	40.42 a	25.17 a	128.63 a	88.21 a	7.00	58.93 a
Gari + 35 mg/kg Fe fumarate	75.50 a	46.67 ab	28.84 a	142.92 a	96.25 a	7.00	73.48 b
Gari + 45 mg/kg Fe fumarate	71.83 a	44.58 a	27.25 a	135.50 a	90.92 a	7.00	72.05 b

Values are means of three replicates
Means values having different letters within column are significantly different ($P < 0.05$)
* = not significantly different ($P > 0.05$)

Table 5 Sensory qualities of Iron fortified and unfortified cassava *gari*.

Samples	Appearance*	Taste*	Texture*	Odor*	Overall acceptability
Unfortified *gari*	6.80	7.00	7.20	6.40	7.50 a
Gari + 25 mg/kg EDTA	6.20	6.00	6.00	6.40	5.30 c
Gari + 35 mg/kg EDTA	6.20	6.00	6.10	6.10	5.70 b
Gari + 45 mg/kg EDTA	6.40	6.80	6.80	6.00	6.80 a
Gari + 25 mg/kg Fe sulphate	6.30	6.30	5.30	6.30	5.50 b
Gari + 35 mg/kg Fe sulphate	6.10	6.20	5.60	6.00	5.50 b
Gari + 45 mg/kg Fe sulphate	6.00	6.50	6.60	6.00	6.20 b
Gari + 25 mg/kg Fe fumarate	6.30	6.00	5.40	6.20	5.50 c
Gari + 35 mg/kg Fe fumarate	6.40	6.00	5.70	6.00	5.80 c
Gari + 45 mg/kg Fe fumarate	6.40	6.60	6.80	6.00	6.30 b

Va Values are means of scores of 30 panelists.
Means values having different letters within column are significantly different ($P < 0.05$).

gari and edible cassava flour specifies that the products should be free from heavy metals in amounts which may represent a hazard to human health (CODEX STAN 151-1989 and 176-19890). The values of heavy metals in the fortified and unfortified *gari* were very low to constitute a health hazard to the consumer.

Pasting properties of unfortified and iron-fortified *gari* samples are presented in **Table 4**. There were significant differences ($P < 0.05$) in the pasting properties of fortified *gari* samples except for peak time. The peak viscosity for unfortified *gari* was 107.75 RVU for control and 105.80-129.88, 145.09-152.46, and 65.59-71.83 RVU for the different concentrations of NaFeEDTA, Fe sulphate- and Fe fumarate-fortified *gari*, respectively. The pasting temperature viscosity for unfortified *gari* was 80.03°C and 76.55-80.03, 77.63-78.53, 58.93-73.48°C for NaFeEDTA-, Fe sulphate- and Fe fumarate-fortified *gari*, respectively. The hot paste (trough) for unfortified *gari* was 65.29 RVU and 58.38-81.96, 86.00-101.59 and 40.42-46.67 RVU for NaFeEDTA-, Fe sulphate- and Fe fumarate-fortified *gari*, respectively. The final viscosity for unfortified *gari* was 191.54 RVU and 203.75-234.67, 257.05-265.96, 128.63-142.92 RVU for NaFeEDTA-, Fe sulphate- and Fe Fumarate-fortified *gari*, respectively. The breakdown viscosity for unfortified *gari* was 42.46 RVU and 47.50-50.42, 50.88-59.09, 25.17-28.84 RVU for NaFeEDTA-, Fe sulphate- and Fe Fumarate-fortified *gari*, respectively. The setback viscosity for unfortified *gari* was 126.25 RVU and 145.21-152.71, 164.38-171.33, 88.21-96.25 RVU for NaFeEDTA-, Fe sulphate- and Fe fumarate-fortified *gari*, respectively. The variations in the peak viscosities for unfortified and iron-fortified *gari* samples showed some level of starch granule modification (Sanni and Akingbala 2000). The cooking time was fairly close to pasting time, which depends more on the rate of granule swelling (Zobel 1984; Shittu *et al*. 2001). Also, the more accessible the internal matrix is, the faster the rate of swelling. Therefore, the higher inclusion of iron in cassava products could have caused its faster rate of cooking especially for NaFeEDTA- and Fe sulphate-fortified products. The higher temperature recorded for NaFeEDTA- and Fe sulphate-fortified cassava products required more heating before the flour paste. Paste consistency is a notable quality of starch dough like *gari*. When the dough is warm or cold, paste consistency affects hand-feel and the ease of swallowing. Higher set back values may result in reduced dough digestibility (Karlsson and Svanberg 1982). Unfortified *gari* and Fe sulphated-fortified *gari* samples are least prone to this effect as they had the lowest setback viscosities.

As presented in **Table 5**, there were significant ($P < 0.05$) differences in overall acceptability of iron-fortified *gari* samples at 45, 35 and 25 mg/kg inclusion of iron fortificants, respectively. There were however, no significant differences ($P < 0.05$) in the sensory attributes (taste, texture, and odour) of fortified *gari* samples compared with the control. NaFeEDTA-fortified *gari* sample at 45 mg/kg was rated highest by the sensory panellist (6.80) for overall acceptability. The variability in overall acceptability of cassava products fortified with NaFeEDTA and Fe sulphate may be due to the nature and quantity of the fortificant level used. Ratana *et al*. (2006) reported that NaFeEDTA is more bioavailable and acceptable than Fe sulphate. The higher sensory scores given to the NaFeEDTA followed by Fe fumarate-fortified *gari* samples by panellists indicates that there was little interference of iron complex in colour change of the product. Addition of iron fortificants to cassava products, when done properly, does not alter in any way the taste, colour, and appearance of *gari*. Fortification, when done properly, is usually invisible to the consumer (INACG 2002; Ratana *et al*. 2006). In this study, iron fortification did not appear to significantly ($P > 0.05$) alter the taste, odour and texture of fortified *gari*.

As in **Tables 6-8**, the return per kg *gari* produced after fortification is N32 and the return to investment is 1.36 for all the fortificants. Relative to the production of *gari*, the use of these fortificants has also been shown to be profitable. At the same price per unit of output, *gari* production using ferrous sulphate was however most profitable. This is reflected in the profit per tonne of N31, 998.99 and the return to investment of 1.36. This was followed by *gari* fortified with Fe fumarate with profit per tonne of N31, 998.86 and *gari* fortified with sodium iron EDTA with profit per

Table 6 Analysis of cost and return for modified *gari* using ferrous fumarate as fortificant.

Items	Input cost (₦)	% of TFC	% of TC
(a) Fixed inputs			
Hydraulic press	1333.33	9.80	1.52
Grating machine	4666.67	34.29	5.30
Sealing machine	845.50	6.21	0.96
Sacks	1095.00	8.05	1.24
Frying bowls	3500.00	25.72	3.98
Knives	800.00	5.88	0.91
raffia sieves	250.00	1.84	0.28
Rent on building	1000.00	7.35	1.14
Sieve	120.00	0.88	0.14
(b) Total fixed cost	13610.50		15.47
(c) Variable cost (₦)		% of TVC	0.00
Cassava	40000.00	53.77	45.45
Staff salary	24000.00	32.26	27.27
Fuel wood for frying	1890.00	2.54	2.15
Maintenance and repair	4500.00	6.05	5.11
Polyethylene bags	4000.00	5.38	4.55
Ferrous fumarate	0.64	0.00	0.00
(d) Total variable cost	74390.64		84.53
(e) Total cost (b+d)	88001.14		
Revenue			
1,000 kg of *gari* at ₦120 per kg	120000.00		
Profit	31998.86		
Profit per kg *gari* produced	32.00		
Return to investment	1.36		

1$ = N121 as at January 2008

Table 7 Analysis of cost and return for modified *gari* using NaFeEDTA as fortificant.

Items	Input cost (₦)	% of TFC	% of TC
(a) Fixed inputs			
Hydraulic press	1333.33	9.80	1.52
Grating machine	4666.67	34.29	5.30
Sealing machine	845.50	6.21	0.96
Sacks	1095.00	8.05	1.24
Frying bowls	3500.00	25.72	3.98
Knives	800.00	5.88	0.91
Raffia sieves	250.00	1.84	0.28
Rent on building	1000.00	7.35	1.14
Sieve	120.00	0.88	0.14
(b) Total fixed cost	13610.50		15.47
(c) Variable cost (₦)		% of TVC	0.00
Cassava	40000.00	53.77	45.45
Staff salary	24000.00	32.26	27.27
Fuel wood for frying	1890.00	2.54	2.15
Maintenance and repair	4500.00	6.05	5.11
Polyethylene bags	4000.00	5.38	4.55
Na+ EDTA	1.28	0.00	0.00
(d) Total variable cost	74391.28		84.53
(e) Total cost (b+d)	88001.78		
Revenue			
1,000 kg of *gari* at ₦120 per kg	120000.00		
Profit	31998.22		
Profit per kg *gari* produced	32.00		
Return to investment	1.36		

1$ = N121 as at January 2008

tonne of N31, 998.22. Any economic barrier in fortified food consumption must favour the low income group in which nutritional aneamia is more prevalent (Cook and Reusser 1983). The uniform rate of return on an investment of 1.36 obtained for iron-fortified *gari* implies that use of the fortificant does not impose additional noticeable cost on the producer but given value addition to the product, the producer can decide to increase the unit price per kg of *gari* from N100.00 (the ruling market price) to N150; which makes it more profitable than selling at the ruling market price. Sanni and Ayinde (2002) reported that large-scale

Table 8 Analysis of cost and return for modified *gari* using ferrous sulphate as fortificant.

Items	Input cost (₦)	% of TFC	% of TC
(a) Fixed inputs			
Hydraulic press	1333.33	9.80	1.52
Grating machine	4666.67	34.29	5.30
Sealing machine	845.50	6.21	0.96
Sacks	1095.00	8.05	1.24
Frying bowls	3500.00	25.72	3.98
Knives	800.00	5.88	0.91
Raffia sieves	250.00	1.84	0.28
Rent on building	1000.00	7.35	1.14
Sieve	120.00	0.88	0.14
(b) Total fixed cost	13610.50		15.47
(c) Variable cost (₦)		% of TVC	0.00
Cassava	40000.00	53.77	45.45
Staff salary	24000.00	32.26	27.27
Fuel wood for frying	1890.00	2.54	2.15
Maintenance and repair	4500.00	6.05	5.11
Polyethylene bags	4000.00	5.38	4.55
Ferrous sulphate	0.51	0.00	0.00
(d) Total variable cost	74390.51		84.53
(e) Total cost (b+d)	88001.01		
Revenue			
1,000 kg of *gari* at ₦120 per kg	120000.00		
Profit	31998.99		
Profit per kg *gari* produced	32.00		
Return to investment	1.36		

1$ = N121 as at January 2008

dried cassava (*fufu*) production is a profitable venture with a positive present value and a cost benefit ratio of 0.81 as well as internal rate of return of 43%. It can therefore be concluded that using any of these fortificants at this rate will be potentially profitable to a *gari* producer.

CONCLUDING REMARKS

Specifically, based on the results of this study, it can be concluded that:

- This project has demonstrated the feasibility of iron-fortified cassava *gari* with NaFeEDTA, Fe fumarate and Fe sulphate as fortificants, especially NAFeEDTA, at 45 mg/kg, an acceptable level of fortification.
- The rate of return on investment for iron fortified *gari* is 1.36. This implies on a general note that using fortificants for value addition of cassava products is profitable.

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REFERENCES

Ahmed KO, Al-Swaidan HM (1993) Lead and cadmiun in Urban dust of Riyadh, Saudi Arabia. *Science of the Total Environment* **136**, 205-210

Akingbala JO, Oguntimehin GB, Abass AB (1991) Effect of processing methods on the quality and acceptability of *fufu* from low cyanide cassava. *Journal of Science of Food and Agriculture* **57 (1)**, 151-154

Akingbala JO, Oyewole OB, Uzo-Peters PI, Karim OR, Baccus-Taylor GSH (2005) Evaluating stored cassava quality in *gari* production. *Journal of Food, Agriculture and Environment* **3 (1)**, 75-80

AOAC (2001) Official Methods of Analysis of the Association of Official Analytical Chemists, Washington D.C., pp 152-252

Ayankunbi MA, Keshinro OO, Egele P (1991) Effect of methods of preparation on the nutrientcomposition of some cassava products - *gari* (eba) *lafun*, and *fufu*. *Food Chemistry* **41**, 349-354

CODEX STAN 151 (1989) CODEX Standard for *gari*. CODEX STAN 151

Cook JD, Reusser ME (1983) Iron fortification: an update. *American Journal of Clinical Nutrition* **38**, 648-659

Dennison DB, Kirk JR (1982) Effect of trace mineral fortification on the storage stability of ascorbic acid in a dehydrated model food system. *Journal of*

Food Science **47**, 1198-1217

Enwere NJ (1998) *Foods and Plant Origin*, Afro-Orbis Publishing Ltd., Nsukka, Nigeria, 34 pp

FAO/ILSI (1999) Preventing micronutrient malnutrition: A guide to food-based approaches. Food and Agriculture Organization of the United Nations and International Life Science Institute, Washington D. C., USA, 9 pp

Garrow JS, James WPT (Eds) (1993) Toxicity. In: *Human Nutrition and Dietetics* (9th Edn), Livingstone Churchill, New York, 174 pp

Gerard C, Barron P, Colonna P, Planchot V (2001) Amylose determination in genetically modified starches. *Carbohydrate Polymers* **44**, 19-27

Greenwood NN, Earnshaw A (1998) *Chemistry of the Elements* (2nd Edn), Butterworth/Heinemann, New York, 117 pp

Hambraeus L (1999) Animal and plant food based diets and iron status: benefits and costs. *Proceedings of the Nutrition Society* **58 (2)**, 235-242

Igbeka JC (1987) Simulation of moisture profile in stored *gari*. *Journal of Food and Agriculture* **1**, 5-9

INACG (2002) *Technical Brief on Iron Compounds for Fortification of Staple Foods*, The International Nutritional Anaemia Consultative Group, Washington, DC USA, 6 pp

Karlsson A, Svanberg U (1982) Dietary bulk intake as a limiting factor for nutrient intake in preschool children, IV. Effect of digestive enzymes on the viscosity of starch-based weaning foods. *Journal of Tropical Paediatrics* **28**, 1-5

Larmond E (1977) *Methods for Sensory Evaluation of Food*, Food Research Central ExperimentalFarm, Canada Department of Agriculture, Ottawa, 88 pp

Makeham JP, Malcolm LR (1986) *The Economics of Tropical Farm Management*, Cambridge University Press, Cambridge, 192 pp

Mejia LA (1994) Fortification of foods: historical development and current practices. Food and *Nutrition Bulletin* **15 (4)**, 278-281

Narpinder S, Kawaljit SS, Maninder K (2005) Physicochemical properties including granular morphology, amylose content, swelling and solubility, thermal and pasting properties of starches from normal, waxy, high amylose and sugary corn. *Progress in Food Biopolymer* **1**, 43-54

Nweke FI (1994) Processing potentials for cassava production growth. COSCA Working paper No. 3.Collaborative Study of Cassava in Africa, IITA, Ibadan, Nigeria

Omosanya S (2002) Nigeria make Vitamin A fortification Mandatory. *Nutriview* **2**, 6-8

Osagie AU, Eka OU (Eds) (1998) *Nutritional Quality of Plant Foods*, University of Benin, Research Centre, 35 pp

Oyewole OB, Odunfa SA (1989) Effects of fermentation on the carbohydrate, mineral and protein contents of cassava during *fufu* production. *Journal of Food Composition and Analysis* **2**, 170-178

Oyewole OB, Aibor AM (1992) Fermentation of cassava with cowpea and soyabean for an enriched *fufu*. *Tropical Science* **33**, 9-15

Oyewole OB, Asagbra Y (2003) Improving traditional cassava processing for nutritional enhancement. In: *Food Approaches for a healthy nutrition*, Ouagadougou, 2nd International Workshop, pp 369-382

Penson JB, Capps O, Rosson CP (1996) *Introduction to Agricultural Economics*, Prentice Hall, New Jersey, 75 pp

Philar R (2001) Small-Scale Fortification of Staple Foods in Ghana and Burkina Faso, Trip Report (Oct 25 o Nov. 3, 2001) Centre/ MI File: 5615-000-07-5 (Contract # 105897)

Philpott T, Pickering D (2004) *Practical Food Law Referencer*, Sweet and Maxwell Ltd., London, United Kingdom, 476 pp

Pizarro WTF, Olivares M (2006) Iron bioavailability in corn-masa tortillas is improved by the addition of disodium EDTA. *American Nutritional Society* **X**, 3158-3161

Ratana W, Visith C, Ratchanee K (2006) Fortification of soy sauce using various iron sources: Sensory acceptability and shelf stability. *Food and Nutrition Bulletin* **27**, 19-24

Sanni LO, Akingbala JO (2000) Effect of drying methods on physicochemical and sensory qualities of *fufu*. *Drying Technology* **18 (1&2)**, 421-431

Sanni LO, Ayinde IA (2002) Consumer acceptance and economic feasibility of dried *fufu* production in Nigeria. *ASSET-An International Journal A* **3 (1)**, 107-115

Sanni LO, Kosoko SB, Adebowale AA, Adeoye RJ (2003) The Influence of palm oil and chemicalmodification on the pasting and sensory properties of *fufu* flour. *International Journal of Food Properties* **7 (2)**, 229-237

Sanni LO, Akingbala JO, Oguntunde AO, Bainbridge ZA, Graffham AJ, Westby A (1998) Processing of *fufu* from cassava in Nigeria: Problems and prospects for development. *Science, Technology and Development* **16 (1)**, 58-71

Sanni LO, Maziya-Dixon B, Akanya CI, Alaya Y, Egwuonwu CV, Okechukwu RU, Ezedinma C, Akoroda M, Lemchi J, Ogbe F, Okoro E, Tarawali G, Mkumbira J, Patino M, Ssemakula G, Dixon A (2005) Standards for cassava products and guidelines for export IITA, Ibadan, Nigeria, pp 11-39

Sanni SA, Adebowale AA, Olayiwola IO, Maziya-Dixon B (2008) Chemical composition and pasting properties of iron fortified maize flour. *Journal of Food, Agriculture and Environment* **6**, 172-175

Shittu TA, Lasekan OO, Sanni LO, Oladosu MO (2001) The effect of drying methods on the functional and sensory characteristics of *pupuru*-a fermented cassava product. *ASSET - An International Journal A* **1 (2)**, 9-16

Tannenbaum SR, Young VR, Archer M (1985) Vitamins and minerals. In: Fennema O (Ed) *Food Chemistry* (2nd Edn), Marcel Dekker Inc., New York, pp 477-543

Walker AR (1998) The remedying of iron deficiency: what priority should it have? *Bromatological Journal of Nutrition* **79 (3)**, 227-235

Zarcinas BA, Cartwright B, Spouncer LR (1987) Nitric-acid digestion and multi-element analysis of plant-material by inductively coupled plasma spectrometry. *Communications in Soil Science and Plant Analysis* **18 (1)**, 131-146

Zobel HF (1984) Gelatinization of starch and mechanical properties of starch paste. In: Whistler RL, BeMiller JN, Paschall EF (Eds) *Starch Chemistry and Technology* (2nd Edn), Academic Press Inc., Orlando, 57 pp