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NUTRITIONAL COMPOSITION AND SENSORY PROPERTIES OF IRON FORTIFIED *FUFU* FLOUR

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ABSTRACT

Cassava *fufu* flour was fortified with iron Sulphate, iron fumarate and sodium iron EDTA at three concentrations (25, 35 and 45 mg/kg) in this study. The samples were analyzed for proximate and minerals composition as well as sensory and pasting properties. There were significant differences ($p < 0.05$) in the proximate and pasting properties of iron-fortified *fufu* samples compared to unfortified samples. Iron contents of unfortified samples ranged from 8.50 to 11.36 mg/kg compared to iron contents of fortified *fufu*. There were no significant differences ($p > 0.05$) in sensory taste, texture and odour of unfortified and fortified samples. In terms of overall acceptability, panelists rated unfortified cassava products higher followed by samples with 25 mg/kg NaFeEDTA and iron sulphate respectively. The rate of return on investment for iron fortified *fufu* flour was 1.41. The study has shown that the use of iron fortified cassava products has potentials for practical application and economic viability.

Keywords: Iron fortification, Cassava, Nutritional, Sensory, Cost.

INTRODUCTION

Diet plays a key role in the prevention of chronic diseases. Chronic diet related diseases are public health problem throughout the world (Adelekan, 2007). Despite concerted efforts to reduce poverty, improve nutrition, education and secure access to healthy foods, more than 2 billion people are sick or disabled and millions die prematurely each year as a result of micronutrient deficiency (Rakhshanda *et al*., 2002). The commonest of micronutrient deficiencies of public health significance are vitamin A deficiency, zinc, iodine and iron deficiency. Iron deficiency which may cause anaemia is well recognised as the most common dietary deficiency in the world including developed countries (Gilliespie, 1998). Maziya-Dixon *et al*. (2004) revealed that Iron deficiency is a confirmed public health problem in Nigeria and calls for adequate and appropriate interventions.

Cassava is of great significance in the tropics as it accounts for more than a third of all staple foods produced in sub-Saharan Africa (Sanni et al., 1998). Nigeria, with an estimated annual cassava production of 34.5mt, cropped in about 3.1m ha, is presently the world largest producer of cassava. Cassava plays a very important role in Nigeria's food security since majority of Nigerians eat cassava products at least once a day.

Basically, most foods in 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. 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 food item (Omosanya, 2002). However, there are little efforts on the fortification procedures for traditional foods especially from cassava.

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 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 presents 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 *fufu* flour samples. Cost and return benefits of iron fortified cassava *fufu* production were also reported.

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. The plants were 12 months old at the time of harvest. Cassava root with stalks were kept intact in a cool place and processed within 60 minutes of 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 United Kingdom through Steven Nicholas Chemicals.

Production of Fufu Flour

The traditional method described by Sanni *et al*. (2003) was employed for the production of *fufu* flour 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 and the woody tips were removed. The peeled roots were washed thoroughly with potable water to remove all dirts and adhering sand particles, cut into chunks of about 15cm length using a stainless steel hand knife and steeped in water in a plastic bowl for 5 days at room temperature (28-32^{o}C). After 5 days, the roots were sufficiently soft. The roots were taken out, broken by hand and the fibres were removed by sieving. The sieving was done manually by washing the mash through a mesh cloth sieve. Sieved mash samples were allowed to sediment for 24 hours in a large plastic bowl. After sedimentation, the water was decanted and the sediment further washed with water. The sediment (*fufu*) was dewatered by putting it into Hessian sacks, and pressing with a hydraulic press to remove excess water. The pressed mash was then dried in a cabinet dryer at 65°C for 8 hr and milled using a stainless steel hammer mill.

Fortification of fufu flour

A Kenwood mixer (Model FP 505, Kenwood, Britain, UK) was used for the mixing of the three different types of fortificants (Iron Sulfate, Iron Fumarate and Sodium Iron EDTA) with the cassava *fufu* samples at 25, 35 and 45mg of fortificants to 1kg of cassava *fufu* samples for 5 minutes for effective mixing (Philar, 2001). Unfortified cassava *fufu* flour samples served as the control.

Determination of Proximate Composition

Proximate (moisture, protein, carbohydrate, fat, ash, fibre) composition analysis of the cake samples were determined by the AOAC (2001) methods. All analyses were replicated thrice.

Determination of Pasting Properties

Pasting characteristics were determined with a Rapid Visco Analyser (RVA; Model RVA 3D+, Network Scientific, Australia); 2.5 g of fortified samples were weighed into a dried empty canister; 25 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA, as recommended. The slurry was heated from 50 to 95 °C with a holding time of 2 mins followed by cooling to 50 °C with 2 min holding time. The rates of heating and cooling were at a constant rate of 11.25 °C/min. Peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature were read from the pasting profile with the aid of Thermocline for Windows Software connected to a computer (Newport Scientific, 1998). All analyses were replicated thrice.

Determination of Mineral Contents

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 0.6g of the ground material was cold digested in 50ml tubes overnight using 11 ml of nitric/perchloric acid mixture (10:1) and made to a final volume of 25ml. Aliquots of the digested samples were analysed for iron and other minerals using inductively coupled plasma Atomic Emission Spectrometry (ARL Model 3580B, Switzerland). All analyses were replicated thrice.

Sensory Evaluation

The sensory evaluation of iron-fortified and unfortified cassava gari and *fufu* samples was conducted using 15 -member trained panelists. Panelists 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. *Fufu* samples were prepared by first reconstituting the powder in water at a ratio of 2: 3 (flour: water) and cooked 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 panelist at ambient room conditions (25-30^{o}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 *fufu* and 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):

$\prod = TR - TC$

where, $\prod$ = Profit;

TR = Total revenue (quantity of item produced multiplied by the price per unit in N)

TC = Total cost, which include total variable cost and total fixed cost.

Fixed inputs of production (gari and *fufu* flour) 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 total cost (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 Multiple Range Test (DMRT) according to Larmond (1977) with a statistical significance of $p<0.05$ using SPSS [Version 10.2, 2002] statistical package.

RESULTS

The proximate composition of unfortified and iron-fortified cassava gari and fufu flour samples

The proximate composition of unfortified and iron-fortified cassava *fufu* flour samples is presented in Table 1. There were significant differences ($p < 0.05$) in the proximate composition except for moisture of fortified samples compared to unfortified samples. Unfortified *fufu* flour had moisture value of 9.12%, protein 0.45%, fat 0.59%, ash 0.25%, starch 74.33%, sugar 1.39% and amylose 22.09%. The range of the chemical composition of iron-fortified *fufu* flour samples were as follows: moisture, 8.58 to 9.37%; protein, 0.45 to 0.46%; fat, 0.03 to 0.40%; ash, 0.27-0.73%; starch, 62.59 to 74.32%; sugar, 0.18 to 1.83%; and amylose, 18.7 to 27.7%. *Fufu* flour fortified with 35mg Fe Sulphate had the least moisture content while *fufu* flour fortified with 45mg Fe sulphate had the least protein of 0.45% and sugar content of 0.18%. *Fufu* flour fortified with 25mg EDTA had the least fat content of 0.03% but the highest ash content of 0.73% while *fufu* flour fortified with 35mg Fe sulphate had the least amylose content of 18.7%.

The total iron and zinc contents of unfortified and iron-fortified fufu flour samples

The total iron contents of unfortified and iron-fortified cassava *fufu* flour samples are presented in Table 2. Iron contents of unfortified *fufu* flour were 8.50 mg/kg with increase in iron content after addition of iron fortificants, respectively. Increase in concentration of NaFeEDTA at 25-45 mg increased the iron content of *fufu* flour from 12 mg/kg to 16 mg/kg. The same trend was exhibited by fufu flour fortified with Fe fumarate with total iron content ranging from 20 to 32 mg/kg. Iron content of *Fufu* flour samples fortified with Fe sulphate ranged from 11 to 18 mg/kg. Zinc content of unfortified *fufu* flour sample was 4.0 mg/kg. While zinc content of fortified *fufu* flour ranged from 4.10 to 4.7 mg/kg for Fe Fumarate fortified *fufu* flour, from 4.30 to 5.00 mg/kg for NaFeEDTA fortified *fufu* flour and from 4.00 to 4.80 mg/kg for Fe sulphate fortified *fufu* flour, respectively.

Mineral contents of unfortified and iron-fortified cassava fufu flour samples

The mineral contents of unfortified and iron -fortified *fufu* flour are presented in Table 3. Manganese (Mn) content ranged from 4.5 mg/kg for the unfortified *fufu* flour to 3.9-4.8 mg/kg for iron fortified *fufu* flour samples. Boron (B) content ranged from 0.48

Table 1: Proximate composition (%) of unfortified and iron-fortified cassava *fufu* flour

Samples	Moisture*	Protein	Sugar	Starch	Amy-lose	Fat	Ash
Unfortified fufu	9.12	0.45a	1.39f	74.66h	22.09c	0.59e	0.25a
Fufu + 25mg/kg EDTA	8.88	0.46b	1.28ef	74.32h	26.32e	0.03a	0.34e
Fufu + 35mg/kg EDTA	8.82	0.46b	1.09cd	73.26g	26.50e	0.27bc	0.39bcd
Fufu + 45mg/kg EDTA	9.09	0.46b	1.83g	65.78c	27.70f	0.30c	0.41cd
Fufu + 25mg Fe/kg sulphate	8.88	0.46b	1.00c	66.42d	20.97b	0.30c	0.30d
Fufu + 35mg/kg Fe sulphate	8.58	0.46b	0.35ab	62.59b	18.70a	0.25bc	0.32ab
Fufu + 45mg/kg Fe sulphate	8.91	0.45a	0.18a	66.65d	21.61bc	0.40d	0.39bcd
Fufu + 25mg Fe fu-marate	9.37	0.46b	0.40ab	68.37e	22.09c	0.19b	0.33d
Fufu + 35mg/kg Fe fumarate	9.30	0.45a	0.50b	71.61f	23.78d	0.27bc	0.38d
Fufu + 45mg/kg Fe fumarate	8.94	0.46b	0.47b	61.08a	24.08d	0.40d	0.38d

Values are means of three replicates.

*Mean values having different superscripts within a column are significantly different ($p<0.05$). * = not significantly different ($p>0.05$).*

Table 2: Iron and zinc content of unfortified and iron-fortified cassava *fufu*

Samples	Iron content (mg/kg)	Zinc Content (mg/kg)*
Unfortified fufu	8.50^{f}	4.00
Fufu + 25mg/kg EDTA	12.00^{e}	4.30
Fufu + 35 mg/kg EDTA	13.00^{e}	5.0
Fufu + 45 mg/kg EDTA	16.00^{d}	4.30
Fufu + 25 mg/kg Fe sulphate	15.00^{d}	4.00
Fufu + 35 mg/kg Fe sulphate	11.00^{d}	4.80
Fufu + 45 mg/kg Fe sulphate	18.00^{c}	4.20
Fufu + 25 mg/kg Fe fumarate	28.00^{b}	4.10
Fufu + 35 mg/kg Fe fumarate	20.00^{c}	4.20
Fufu + 45 mg/kg Fe fumarate	32.00^{a}	4.70

Values are means of three replicates

Means values having different superscripts within a column are significantly different ($p<0.05$).

** = not significantly different ($p>0.05$).*

Table 3: Mineral contents (mg/kg) of unfortified and iron-fortified cassava *fufu* flour

Samples	Mn	B*	Cu	Mo*	Co*	Ni	Ca	Mg*	Na	K	P	S	Al	Ti*
Unfortified fufu flour	4.70^{bc}	0.62	6.60^{c}	< 0.4	< 0.4	1.30^{bc}	1420.00^{b}	171.00	23.00^{b}	2200.00	430.00^{c}	102.00^{c}	11.00^{c}	0.51
Fufu + 25mg/kg EDTA	4.50^{b}	0.48	4.00^{a}	< 0.4	< 0.4	0.87^{a}	1420.00^{b}	166.00	23.00^{b}	2200.00	420.00^{b}	100.00^{b}	9.70b	0.56
Fufu + 35 mg/kg EDTA	3.90^{a}	0.50	5.70^{b}	< 0.4	< 0.4	1.20^{bc}	1230.00^{a}	144.00	20.00a	1870.00	360.00^{a}	86.00^{a}	8.60a	0.48
Fufu + 45 mg/kg EDTA	4.50^{b}	0.51	6.70^{c}	< 0.4	< 0.4	1.40^{c}	1410.00^{ab}	167.00	23.00^{b}	2200.00	420.00^{b}	101.00^{c}	11.00^{c}	0.68
Fufu + 25 mg/kg Fe sulphate	4.50^{b}	0.47	4.50^{ab}	< 0.4	< 0.4	0.87^{a}	1420.00^{b}	166.00	26.00^{d}	2200.00	420.00^{b}	102.00^{c}	11.00^{c}	0.56
Fufu + 35 mg/kg Fe sulphate	4.50^{b}	0.52	4.10^{a}	< 0.4	< 0.4	1.00^{bc}	1420.00^{b}	167.00	23.00^{b}	2200.00	420.00^{b}	105.00^{f}	9.70^{b}	0.61
Fufu + 45 mg/kg Fe sulphate	4.70^{bc}	0.50	6.40^{c}	< 0.4	< 0.4	1.50^{c}	1430.00^{c}	170.00	24.00^{c}	2200.00	430.00^{c}	104.00^{e}	11.00^{c}	1.10
Fufu + 25 mg/kg Fe fumarate	4.80^{c}	0.49	4.50^{a}	< 0.4	< 0.4	0.97^{ab}	1430.00^{c}	165.00	23.00^{b}	2200.00	420.00^{b}	153.00^{g}	10.00^{b}	0.52
Fufu + 35 mg/kg Fe fumarate	4.80^{c}	0.53	4.00^{a}	< 0.4	< 0.4	0.80^{a}	1450.00^{d}	169.00	24.00^{c}	2200.00	430.00^{c}	103.00^{d}	12.00^{d}	0.71
Fufu + 45 mg/kg Fe fumarate	4.60b c	0.47	4.40^{ab}	< 0.4	< 0.4	0.92^{ab}	1420.00^{b}	166.00	23.00^{b}	2200.00	420.00^{b}	102.00^{c}	9.80^{b}	0.57

Values are means of three replicates.

Means values having different superscripts within a column are significantly different ($p<0.05$).

** = not significantly different ($p >0.05$).*

mg/kg for the unfortified sample to 0.47-0.62 mg/kg for iron fortified *fufu* flour samples. Copper (Cu) ranged from 4.0 for unfortified flour to 4.0-6.6 mg/kg for iron fortified *fufu* flour samples, while Molybdenum (Mo) and Cobalt (Co) values were less than 0.40 mg/kg, respectively. Nickel (Ni) ranged from 0.87 mg/kg to 0.8-1.5 mg/kg for iron fortified *fufu* flour samples. Calcium (Ca) ranged from 1420 mg/kg for the unfortified sample to 1410-1430 mg/kg for iron fortified *fufu* flour samples; Magnesium (Mg) ranged from 166 mg/kg in the control to 144-171 mg/kg for iron fortified *fufu* flour samples. Sodium (Na) ranged from 23 mg/kg in the control to 20-26 mg/kg for iron fortified *fufu* flour samples. Potassium (K) ranged from 2200 mg/kg for the unfortified sample to 1870-2200 mg/kg for iron fortified *fufu* flour samples, while Phosphorus (P) ranged from 420 mg/kg in the control to 360-420 mg/kg for iron fortified *fufu* flour samples. Sulphur (S) content, however, ranged from 100 mg/kg in the control to 86-153 mg/kg for iron fortified *fufu* flour samples. Aluminium (Al) ranged from 9.7 mg/kg in the control to 8.6-12.0 mg/kg for iron fortified *fufu* flour samples, while tin (Ti) ranged from 0.56 mg/kg in the unfortified sample to 0.48-1.1 mg/kg for iron fortified *fufu* flour samples.

Heavy metals content of unfortified and iron-fortified cassava fufu flour samples

Table 4 presents the results of heavy metal contents of iron-fortified cassava *fufu* flour samples, respectively. For iron-fortified cassava *fufu* flour samples, Chromium (Cr) was less than 0.2 mg/kg, Cadmium (Cd) was less than 0.09 mg/kg, Lead (Pb) was less than 1 mg/kg, Selenium (Se) was less than 4 mg/kg.

Pasting properties of Iron-fortified and unfortified cassava fufu flour samples

Pasting properties of unfortified and iron-fortified *fufu* flour samples are presented in Table 5. There were significant differences ($p < 0.05$) for the pasting properties of fortified *fufu* flour samples except for peak viscosity and hot paste viscosity (trough). The peak viscosity for unfortified *fufu* flour was 312.04 RVU and 287.25-308.38, 309.25-318.71, and 301.96-334.96 RVU for the different concentration of NaFeEDTA, Fe sulphate and Fe Fumarate fortified *fufu* flour respectively. The peak time for unfortified *fufu* flour was 6.7 minutes and 6.84-7.0, 6.67-6.9, 6.87-7.0 minutes for NaFeEDTA, Fe sulphate and Fe Fumarate fortified *fufu* flour, respectively. The pasting temperature for unfortified *fufu* flour was 72.53 ^{o}C and 72.43-72.85, 73.63-78.03, 70.48-72.0 ^{o}C for NaFeEDTA, Fe sulphate and Fe Fumarate fortified *fufu* flour, respectively. The final viscosity for unfortified *fufu* flour was 312.42 RVU and 314.42-321.75, 304.08-319.75, 309.05-366.96 RVU for NaFeEDTA, Fe sulphate and Fe Fumarate fortified *fufu* flour, respectively**.** The breakdown viscosity for unfortified *fufu* flour was 89.08 RVU and 107.71-161.38, 89.34-98.00, 123.70-152.09 RVU for NaFeEDTA, Fe sulphate and Fe Fumarate fortified *fufu* flour, respectively. The setback viscosity for unfortified *fufu* flour was 89.46 RVU and 113.75-195.88, 84.17-103.05, 118.67-183.09 RVU for NaFeEDTA, Fe sulphate and Fe Fumarate fortified *fufu* flour, respectively.

Sensory qualities of Iron-fortified and unfortified cassava fufu flour

The results of sensory evaluation of iron fortified cassava *fufu* flour are presented in Table 6. There were no significant differences ($p>0.05$) for the fortified *fufu* samples except for appearance and overall acceptability. *Fufu* flour containing 25 mg/kg NaFeEDTA had

Table 4: Heavy metal contents (mg/kg) of unfortified and iron-fortified cassava *fufu* flour

Samples	Cr	Cd	Pb	Se
Unfortified fufu	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 25mg/kg NaFeEDTA	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 35mg/kg NaFeEDTA	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 45mg/kg NaFeEDTA	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 25mg/kg Fe sulphate	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 35mg/kg Fe sulphate	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 45mg/kg Fe sulphate	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 25mg/kg Fe fumarate	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 35mg/kg Fe fumarate	< 0.20	< 0.09	< 1.00	< 4.00
Fufu + 45mg/kg Fe fumarate	< 0.20	< 0.09	< 1.00	< 4.00

Table 5: Pasting properties of Iron-fortified and unfortified cassava *fufu* flour

Samples	Peak (RVU)*	Trough (RVU)*	Break down (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (min)	Pasting temperature (°C)
Unfortified fufu	312.04	222.96	89.08^{a}	312.42^{a}	89.46^{ab}	6.70^{ab}	72.53^{cd}
Fufu + 25mg/kg NaFeEDTA	308.38	200.67	107.71^{ab}	314.42^{a}	113.75^{ab}	6.84^{ab}	72.85^{d}
Fufu + 35mg/kg NaFeEDTA	287.25	125.88	161.38^{b}	321.75^{a}	195.88^{c}	7.00^{b}	72.80^{bc}
Fufu + 45mg/kg NaFeEDTA	286.55	152.50	134.04^{ab}	319.38^{a}	166.88^{abc}	6.90^{ab}	72.43^{cd}
Fufu + 25mg/kg Fe sulphate	309.88	211.88	98.00^{ab}	314.92^{a}	103.05^{abc}	6.87^{ab}	78.03^{f}
Fufu + 35mg/kg Fe sulphate	309.25	219.92	89.34^{a}	304.08^{a}	84.17^{a}	6.67^{ab}	77.58^{f}
Fufu + 45mg/kg Fe sulphate	318.71	220.96	97.75^{ba}	319.75^{a}	98.80^{abc}	6.70^{ab}	73.63^{e}
Fufu + 25mg/kg Fe fumarate	301.96	149.88	152.09^{ab}	321.17^{a}	$171.29a^{ab}$	6.97^{ab}	72.00^{bc}
Fufu + 35mg/kg Fe fumarate	334.96	183.88	151.09^{ab}	366.96^{b}	183.09^{bc}	7.00^{b}	71.53^{b}
Fufu + 45mg/kg Fe fumarate	314.17	190.38	123.79^{ab}	309.05^{a}	118.67^{abc}	6.87^{ab}	70.48^{a}

Values are means of three replicates.
Mean values having different superscripts within a column are significantly different ($p<0.05$)
** = not significantly different ($p >0.05$).*

Table 6: Sensory qualities of Iron fortified and unfortified cassava *fufu* flour

Samples	Appearance	Taste*	Texture*	Odor*	Overall acceptability
Unfortified fufu	7.80[a]	6.40	6.70	6.50	8.00[a]
Fufu + 25mg/kg EDTA	6.50[b]	6.40	6.50	6.50	6.80[b]
Fufu + 35 mg/kg EDTA	6.00[b]	6.00	6.00	6.00	5.40[c]
Fufu + 45 mg/kg EDTA	6.10[c]	6.30	5.80	6.00	5.50[bc]
Fufu + 25 mg/kg Fe sulphate	6.30[b]	6.40	6.40	6.40	6.20[a]
Fufu + 35 mg/kg Fe sulphate	5.80[bc]	6.30	5.80	5.80	5.50[bc]
Fufu + 45 mg/kg Fe sulphate	5.70[c]	6.00	5.70	5.80	5.10[c]
Fufu + 25 mg/kg Fe fumarate	6.30[b]	6.40	6.40	6.40	6.50[b]
Fufu + 35 mg/kg Fe fumarate	5.60[bc]	6.00	5.70	5.60	5.30[c]
Fufu + 45 mg/kg Fe fumarate	5.00[c]	6.10	5.80	5.70	5.00[c]

Values are means of scores of 30 panelists.
Mean values having different superscripts within a column are significantly different ($p < 0.05$)
** = not significantly different ($p > 0.05$).*

values (6.5 and 6.8) closer to the control (unfortified *fufu* flour).

Cost and return of using fortificants in fufu production

The cost and return using fortificants in *fufu* production are presented in Tables 7 to 9. The percentage of total variable cost relative to total cost remained the same given the small variation in the cost of the fortificants. At present, cost of NaFeEDTA is N1.28/kg, ferrous fumarate is N0.64/kg and ferrous sulphate is N0.51/kg. The return per kg *fufu* produced after fortification is 43.92 and the return to investment is 1.41 for all the fortificants. Furthermore, the return on investment for all the three fortificants was also constant at 1.41 indicating that the economic efficiency attained is the same. The same amount was also obtained for return per kg of *fufu* produced. Profit per tonne of *fufu* fortified with ferrous sulphate, ferrous fumarate and NaFeEDTA were N43, 917.32, N43, 917.19, and N43, 916.55 respectively. The return per kg *fufu* produced after fortification is N43.92 and the return to investment is 1.41 for all the fortificants. Furthermore, the return on investment for all the three fortificants was also constant at 1.41 indicating that the economic efficiency attained is the same. The same was obtained for return per kg of *fufu* produced.

DISCUSSION

Cassava *fufu* flour is a starch based product with less protein, fat, minerals and vitamins and this fact is in agreement with previous reports (Oyewole and Aibor, 1992). Introduction of iron fortificants to cassava products provided significant differences ($p < 0.05$) in the chemical properties of fortified samples compared to unfortified samples except moisture content and fat contents of fortified *fufu*. The percentage starch content is in agreement with previous authors (Oyewole and Odunfa, 1989; Sanni *et al.*, 1998). The low sugar contents observed in this work are in agreement with the reports of Hahn *et al.* (1992).

Table 7: Analysis of cost and return for modified *fufu* using ferrous fumarate as fortificant

Items	Input Cost (N)	% of TFC	% of TC
(a) Fixed inputs			
Rotary Drier	26666.67	74.64	0.07
Hydraulic press	1333.33	3.73	0.00
Grating machine	4666.67	13.06	0.01
Sealing machine	845.50	2.37	0.00
Plastic bowl	1095.00	3.06	0.00
Rent on building	1000.00	2.80	0.00
Sieve	120.00	0.34	0.00
(b) Total fixed cost	35727.17		
(c) Variable cost (N)		% of TVC	
Cassava	40000.00	56.85	0.05
Staff salary	16000.00	22.74	0.02
Coal	1890.00	2.69	0.00
Maintenance and repair	5265.00	7.48	0.01
Electricity and water bills	3200.00	4.55	0.00
Polyethylene bags	4000.00	5.69	0.01
Ferrous fumarate	0.64	0.00	0.00
(d) Total variable cost	70355.64		66.32
(e) Total cost (b + d)	106082.81		
Revenue			
1,000kg of fufu at N150 per kg	150000.00		
Profit	43917.19		
Return per kg fufu produced	43.92		
Return to investment	1.41		

$1 = N150 as at March 2010

Table 8: Analysis of cost and return for modified *fufu* using NaFeEDTA as fortificant

Items	Input Cost (N)	% of TFC	% of TC
(a) Fixed inputs			
Rotary Drier	26666.67	74.64	0.07
Hydraulic press	1333.33	3.73	0.00
Grating machine	4666.67	13.06	0.01
Sealing machine	845.50	2.37	0.00
Plastic bowl	1095.00	3.06	0.00
Rent on building	1000.00	2.80	0.00
Sieve	120.00	0.34	0.00
(b) Total fixed cost	35727.17		
(c) Variable cost (N)		% of TVC	
Cassava	40000.00	56.85	0.05
Staff salary	16000.00	22.74	0.02
Coal	1890.00	2.69	0.00
Maintenance and repair	5265.00	7.48	0.01
Electricity and water bills	3200.00	4.55	0.00
Polyethylene bags	4000.00	5.69	0.01
Sodium ion EDTA	1.28	0.00	0.00
(d) Total variable cost	70356.28		66.32
(e) Total cost (b + d)	106083.45		
Revenue			
1,000kg of fufu at N150 per kg	150000.00		
Profit	43916.55		
Return per kg fufu produced	43.92		
Return to investment	1.41		

$1 = N150 as at March 2010

Table 9: Analysis of cost and return for modified *fufu* using ferrous sulphate as fortificant

Items	Input Cost (N)	% of TFC	% of TC
(a) Fixed inputs			
Rotary Drier	26666.67	74.64	0.07
Hydraulic press	1333.33	3.73	0.00
Grating machine	4666.67	13.06	0.01
Sealing machine	845.50	2.37	0.00
Plastic bowl	1095.00	3.06	0.00
Rent on building	1000.00	2.80	0.00
Sieve	120.00	0.34	0.00
(b) Total fixed cost	35727.17		
(c) Variable cost (N)		% of TVC	
Cassava	40000.00	56.85	0.05
Staff salary	16000.00	22.74	0.02
Coal	1890.00	2.69	0.00
Maintenance and repair	5265.00	7.48	0.01
Electricity and water bills	3200.00	4.55	0.00
Polyethylene bags	4000.00	5.69	0.01
Ferrous sulphate	0.51	0.00	0.00
(d) Total variable cost	70355.51		66.32
(e) Total cost (b + d)	106082.68		
Revenue			
1,000kg of fufu at N150 per kg	150000.00		
Profit	43917.32		
Return per kg fufu produced	43.92		
Return to investment	1.41		

$1 = N150 as at March 2010

Similarly, low protein, ash and fibre contents obtained in this study have been reported by various authors (Sanni and Akingbala, 2000). Amylose content of the *fufu* samples falls within values reported by several authors (Akingbala *et al.,* 2005, Sanni *et al.,* 2006). It should be noted that the greater the percentage of the amylose fraction of starch-based foods, the quicker the formation of the gel (Sanni *et al.,* 2006). Amylose content affects gelatinization properties, degree of swelling and enzymatic susceptibility of starch and starch-based food products (Gerard *et al*., 2001). In this study iron fortification of *fufu* 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).

Variations in mineral contents of iron-fortified *fufu* samples were consistent with the results of previous studies that fermentation, cooking and other culinary practices may affect mineral contents of cassava products through microbial metabolism and/or processing losses (Oyewole and Odunfa, 1989; Osagie and Eka, 1998). Different minerals perform important body functions including oxygen transport, nerve-muscle function, enzyme activity, energy metabolism, and formation of some hormones, water balance, acid-base balance and growth tissues (Hegarty, 1995). Inadequate mineral intake can be a problem, especially for the vulnerable groups like the infants and young children, teenage girls, premenopausal women and the elderly (Hegarty, 1995). Deficiencies of some minerals may have physical, psychological and/or economic implications in the life of an individual (Hegarty, 1995).

Compared to unfortified samples, fortification considerably increased the values of iron contents of iron fortified cassava products. The iron content of the fortified *gari* and *fufu* with different iron fortificants were significantly different ($p<0.05$). Iron is an important component of the red blood cells, which enhances the oxygen-carrying capacity of the red blood cells (Cook and Reuser, 1983). Cook and Reusser (1983) reported that in selecting vehicle for fortification, consideration must be given to both the pattern of its consumption and the technical feasibility of its fortification. The vehicle must also reach a high proportion of the vulnerable population and be consumed evenly throughout the region or country. Since *gari* and *fufu* are consumed in all parts of Nigeria and most part of sub-sahara Africa, fortification of these two staples (which has been proved to be technically feasible in this study) has the potential of mitigating iron deficiency that is prevalent in this part of the world.

The low values of zinc recorded for iron fortified cassava products have been corroborated as to contribute to the healthy nature of man (Matseshe *et al.*, 1980). With increasing amounts of zinc in a meal, fractional zinc absorption will decrease, and may form complex with high amount of iron and so, the need for low value of zinc in human diets (Matseshe *et al.*, 1980).

Calcium, magnesium, potassium, sodium, phosphorus, sulphur and chloride are the macro minerals needed in highest amounts by the body. High amounts of these macro minerals obtained in this study are expected to be useful after consuming iron fortified cassava products. The 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. These micronutrients are nutritionally important as they are needed at lower level compared with macronutrients. Long-term intakes higher than requirements could interact with the metabolism of other trace elements, e.g., high dose of zinc could impair immune responses, and lower copper and ceruloplasmin levels. Symptoms are nausea, vomiting, diarrhoea, fever and lethargy (Hegarty, 1995). Analysis of phosporus in starch-based food products is also very important because it has been reported that starch and glycogen are degragded by phosporolysis in the presence of inorganic phosporus (Elliasson, 1996). The high phosporus values observed in fortified *fufu* flours compared to the control might be responsible for the high set back viscosity exhibited by fortified *fufu* flour in this study.

Many metals naturally present in the earth's crust are essential components of biological systems, but the toxic heavy metals and metalloids of dietary significance (including arsenic, tin, cadmium, mercury and lead) are not needed for biological processes and tend to be toxic to living organisms even at low concentrations (Dingle, 1992). The presence of heavy metals in food is undesirable because it can cause adverse effects both to the environment and to a variety of living species including humans. Metals can be distinguished from other toxic pollutants, as they are not biodegradable and can be accumulated in living tissues, causing various diseases and disorders. 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) and expected nutritional benefits of the iron fortified cassava products to humans. Philpott and Pickering (2004) reported permissible limits of 1.0ppm, 1.0ppm and 200mg/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 study by Anderson *et al*. (1997) indicated that 15 mg/kg bw/day chromium (as chromium chloride) was not associated with adverse effects in rats. Based on this study, and allowing uncertainty factors of 10 for inter-species variation and 10 for inter-individual variation, a total daily intake of about 0.15 mg/kg bw/day (or 10 mg/person) would be expected to be without adverse health effects. The Codex Alimentarius Commission (CODEX) standard for 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 *fufu* were very low to constitute a health hazard to the consumer.

Pasting is the phenomenon following gelatinization in the dissolution of starch. Pasting involves granular swelling, exudation of molecular components from starch granules, and eventually total distruption of the granules. Addition of iron fortificants to gari and *fufu* significantly ($p<0.05$) affected their pasting parameters except peak viscosity of fortified gari and time to attain peak viscosity in fortified *fufu*. The variations in the peak viscosities for unfortified *fufu* flour and iron fortified *fufu* flour samples showed some level of starch granule modification. The values obtained are in agreement with previous reports (Sanni and Akingbala, 2000). Two factors interact to determine the peak viscosity of a cooked starch paste: the extent of granule swelling and solubility. Higher swelling index is expected to give higher viscosity peak whereas; high solubility that results from starch degradation or dextrinization is expected to reduce peak viscosity (Shittu *et al*., 2001). High peak viscosities indicate the stability of the paste of the flour during heating. It is often correlated with the final product quality. The cooking time was fairly closer to time to reach to form a paste, which depends more on the rate of granule swelling (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. 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 *fufu*; when the dough is warm or cold, paste consistency affects its hand-feel and the ease of swallowing it. The setback visicosity indicates the tendency of the dough to undergo retrogradation- a phenomenon that causes the dough to become firmer and increasingly resistant to enzyme attack. It has serious implication on the digestibility of the dough when consumed. Higher set back values may result in reduced dough digestibility (Karlsson and Svanberg, 1982). Unfortified *fufu* and Fe sulphated fortified *fufu* samples are least prone to this effect as they had the lowest setback viscosities.

In general, the dough consistency (when cold or hot) reflected in the overall acceptance of cooked *fufu* which maintained its characteristics firmness (Sanni and Akingbala, 2000; Sanni and Ayinde, 2002). Panelists rated *fufu* samples fortified with 25 mg iron fortificants and gari samples fortified with 45 mg iron fortificants higher for overall acceptability. The variability in overall acceptability of cassava products fortified with NaFeEDTA and iron 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 iron sulphate. The higher sensory scores given to the NaFeEDTA followed by iron fumarate fortified *fufu* samples by panelists indicates that there was little interference of iron complex in color change of the product. Addition of iron fortificants to flour, when done properly does not alter in any way the taste, color, appearance properties. Fortification, when done properly is usually invisible to the consumer (Ratana *et al*., 2006). In this study, iron fortication did not appear to significantly ($p>0.05$) alter the taste, odour and texture of fortified *fufu*.

Any economic barrier in fortified food consumption must favour low income group in which nutritional aneamia is more prevalent (Cook and Reusser, 1983). The uniform rate of return on investment of 1.41 obtained for iron fortified *fufu* flour 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 kilogramme of *fufu* 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) had reported that large scale dried *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 profitable to a potential *fufu* producer.

CONCLUSION

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

- Cassava products especially *fufu* flour are promising food vehicles for iron fortification to reduce incidence of iron deficiency anaemia in at-risk communities or groups.
- Iron fortification of cassava products is feasible and beneficial especially at 25 and 35 mg/kg level with NaFeEDTA and Fe sulphate.
- *Fufu* flour are cheap, common, regularly consumed, fast to prepare, effective, sustaining and adequate for fortification without significant change in structural appearance, smell, taste etc.
- Iron-fortified cassava *fufu* with NaFeEDTA fortificant were the most acceptable by panelists.

- The rate of return on investment for iron fortified *fufu* flour is 1.41. This implies on a general note that using fortificants for value addition of cassava products is profitable.
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