



## Chemical composition and pasting properties of iron-fortified maize flour

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### Abstract

The aim was to study the chemical composition and pasting properties of iron-fortified maize flour. The maize flour was mixed with different quantities (25, 35 and 45 mg/kg) of iron fortificants (iron EDTA, iron sulphate and iron fumarate). The flour samples were analyzed for proximate, mineral and heavy metal composition as well as pasting profile. There were significant differences ( $P < 0.05$ ) in the proximate composition of the fortified maize flour, except in moisture and fat contents. Fortification of maize flour significantly affected the mineral contents of the flours. Compared to unfortified samples, fortification increased the values of iron contents of the fortified flours from 16.1 to 29.7 mg/kg. The values of heavy metals in the fortified maize flour were very low to constitute a health hazard to the consumer. Addition of iron fortificants to maize flour significantly ( $P < 0.05$ ) affected its pasting parameters, except time to attain peak viscosity.

**Key words:** Iron fortificants, proximate, mineral and heavy metal composition, pasting profile.

### Introduction

Iron deficiency is a serious health problem affecting a large proportion of the world's population <sup>1</sup>. It is considered to be the commonest worldwide nutritional deficiency. Iron deficiency anemia, is reported to have a higher overall cost to society than any other disease except tuberculosis <sup>2</sup>. Women and young children are especially at risk. The global nature of the problem and its public health significance has been reviewed by several authors <sup>1-3, 5, 30</sup>. Food fortification programs are cost effective means for reducing the prevalence of iron deficiency <sup>4, 5</sup>. The effectiveness of a food fortification program depends on the consistent and uniform addition of iron compounds to appropriate food vehicles, such as flour, which are widely consumed by the target population <sup>6</sup>. 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.

Maize is one of the major staple foods in almost all West African countries. In Nigeria, maize is widely consumed by all ethnic groups without cultural barriers or taboos. Its domestic food utilization follows two main paths: one is when the dry maize grains are steeped for two to three days, milled, moistened and allowed to ferment for three or more days. The fermented maize dough is used in many forms such as porridge and stiff pastes. The alternative use is dry milling of the flour which may pass through a pre-dehulling process to produce the dehulled and degermed maize flour. Maize flour is used in the preparation of thick pastes known as *ugali* in East Africa, *tuwo* and porridge in Nigeria, *owo* in the Republic of Benin <sup>7</sup> and *akple* in Ghana. As

reported by Ayernor and Houssou <sup>8</sup>, dehulled-degermed maize flour can lend itself to prolonged storage and diversified modes of food utilization.

Maize has desirable properties as a vehicle for iron <sup>4</sup>. Corn meal and corn grits have been fortified with iron in the USA for many years and present no major technical problems <sup>9</sup>. Flour is considered the ideal vehicle for Fe fortification in countries with cereal-based diets because it is usually milled in a few places in the country and is widely consumed, irrespective of age, sex and socioeconomic status. Moreover, there is no risk of over consumption <sup>4</sup>. Certain technical difficulties are encountered by adding iron (Fe) to flour, mainly related to the chemical properties of the Fe compounds used. Ferrous Fe salts may be oxidized to form colored ferric oxides. The water content of flour is usually between 10 and 15% and various chemical reactions may thus take place. Fe may also catalyze lipid oxidation reactions during storage of flour, causing negative effects, such as rancidity, which may make the flour organoleptically unacceptable. The objective of this study, therefore, is to determine the effect of iron fortification on the chemical composition and pasting properties of maize flour.

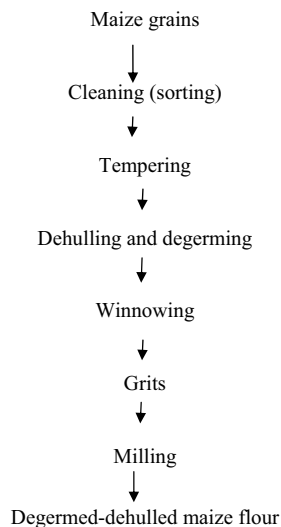
### Materials and Methods

**Preparation and fortification of maize flour:** The clean maize grains were dehulled, degermed and milled at a commercial maize mill in Osiele market, Abeokuta, Ogun state, Nigeria. The flow profile for the production of the flour is shown in Fig. 1. A Kenwood mixer (Model FP 505, Kenwood, Britain, UK) was used for mixing of the three different types of fortificants (iron sulfate, iron fumarate and sodium iron EDTA) with the maize flour at 25, 35 and 45 mg of

fortificants to kg of maize flour for 5 minutes for effective mixing.

**Determination of chemical properties:** Moisture, ash, protein and fat contents were determined using AOAC method <sup>10</sup>. Amylose content was determined using the method of Williams *et al.* <sup>11</sup> while starch and sugar was determined using the method of Dubois, *et al.* <sup>12</sup>. 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.* <sup>13</sup>. 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).

**Determination of pasting properties:** Pasting properties were determined using a Rapid Visco Analyser (RVA) (model RVA 3D+; Network Scientific, Australia). The sample was turned into slurry by mixing 3 g with 25 ml of water inside the RVA can and inserted into the tower, which is then lowered into the system. The slurry was heated from 50 to 95°C and cooled back to 50°C within 12 min, rotating the can at a speed of 160 rpm with continuous stirring of the content with a plastic paddle. Parameters estimated were peak viscosity, setback viscosity, final viscosity, pasting temperature and time to reach peak viscosity.



**Figure 1.** The flow profile for the production of the flour.

**Table 1.** Chemical composition (%) of Fe-fortified maize flour.

Sample	Moisture <sup>ns</sup>	Protein	Sugar	Starch	Amylose	Fat <sup>ns</sup>	Ash
Maize flour (Control)	10.53	10.12 <sup>ab</sup>	1.21 <sup>cd</sup>	75.78 <sup>c</sup>	26.16 <sup>d</sup>	1.37	1.19 <sup>a</sup>
Maize + 25 mg/kg Fe EDTA	10.76	10.23 <sup>b</sup>	0.68 <sup>ab</sup>	66.97 <sup>b</sup>	27.57 <sup>f</sup>	1.45	2.03 <sup>c</sup>
Maize + 35 mg/kg Fe EDTA	10.89	9.95 <sup>a</sup>	1.22 <sup>cd</sup>	66.05 <sup>ab</sup>	26.96 <sup>c</sup>	1.71	3.05 <sup>c</sup>
Maize + 45 mg/kg Fe EDTA	10.60	10.26 <sup>bc</sup>	1.24 <sup>cd</sup>	72.92 <sup>d</sup>	28.12 <sup>g</sup>	1.26	2.64 <sup>d</sup>
Maize + 25 mg/kg Fe sulphate	10.91	11.55 <sup>c</sup>	1.21 <sup>cd</sup>	65.12 <sup>a</sup>	26.81 <sup>c</sup>	1.82	1.33 <sup>a</sup>
Maize + 35 mg/kg Fe sulphate	10.82	10.96 <sup>d</sup>	0.84 <sup>b</sup>	69.78 <sup>c</sup>	23.32 <sup>a</sup>	1.29	1.24 <sup>a</sup>
Maize + 45 mg/kg Fe sulphate	11.03	10.18 <sup>ab</sup>	1.09 <sup>c</sup>	67.54 <sup>b</sup>	25.43 <sup>c</sup>	1.28	1.37 <sup>av</sup>
Maize + 25 mg/kg Fe fumarate	10.60	10.22 <sup>b</sup>	0.86 <sup>b</sup>	71.72 <sup>d</sup>	27.73 <sup>fg</sup>	1.30	2.28 <sup>c</sup>
Maize + 35 mg/kg Fe fumarate	10.94	10.50 <sup>c</sup>	0.56 <sup>a</sup>	69.77 <sup>c</sup>	26.87 <sup>c</sup>	1.27	1.65 <sup>b</sup>
Maize + 45 mg/kg Fe fumarate	10.91	10.97 <sup>d</sup>	1.44 <sup>d</sup>	67.33 <sup>b</sup>	24.42 <sup>b</sup>	2.16	1.65 <sup>b</sup>

Values are mean of three replicates, Mean values having different superscript within column are significantly different (P<0.05) ns not significantly different (P>0.05).

## Results and Discussion

**Proximate composition:** The chemical composition of the iron fortified maize flour is shown in Table 1. There were significant differences (P<0.05) in the chemical composition of the fortified maize flour, except in moisture and fat contents. The moisture content of a food is a reflection of the amount of solid matter in that food. The lower the initial moisture content of a product to be stored the better the storage stability of the product <sup>14</sup>. Low residual moisture content is advantageous in that microbial proliferation is reduced and storage life is enhanced and prolonged. High moisture content in foods has been shown to encourage microbial growth <sup>15</sup>. The moisture content of the flour samples were lower than the limit set by Ukpabi and Ndimale <sup>16</sup> (<16% but >13%), hence, the fortified flours are expected to be conveniently stored for more than 6 months under ambient condition. The proximate composition of the fortified flours almost agrees with the result of Housou and Ayernor <sup>8</sup>. However, the protein content and fat was within the range recommended by Codex Alimentarius <sup>17</sup>: protein content should not be less than 7.0% and fat content not more than 2.25%. The ash content of a food material represents the inorganic or mineral constituents of the foods. Ash is the inorganic residue remaining after the water, and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food. Ash content obtained in this study was slightly higher than the limit of not more than 1.0% set by Codex Alimentarius <sup>17</sup>. The addition of iron fortificant significantly affected the proximate composition (except fat) of maize flours irrespective of the type of iron fortificant.

**Mineral composition:** Table 2 shows the mineral composition of iron-fortified maize flour. Addition of Fe fortificant to maize flour significantly affected the mineral content of the flours. Compared to unfortified samples, fortification increased the values of iron contents of the fortified flours. Iron is an important component of the red blood cells, which enhances the oxygen-carrying capacity of the red blood cells <sup>18</sup>. Despite the presence of abundant quantities of iron in the physical environment and the relatively low requirements of the body for iron, iron deficiency remains one of the commonest nutritional problems among vulnerable groups especially in developing countries. Consequently, high values of iron recorded for fortified maize flour will be useful for the expected vulnerable groups. Cook and Reusser <sup>4</sup> 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 maize flour are consumed in all parts of

Nigeria and most parts of sub-Saharan Africa, fortification of these staples have the potential of mitigating iron deficiency that is prevalent in this part of the world.

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<sup>19</sup>. 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<sup>19</sup>. It is evident that maize flour is really an energy food. Fortifying with one mineral source like iron will make the products to be beneficial for the consuming population.

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 maize flour and its 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<sup>20</sup>.<sup>21</sup>. 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 low copper and ceruloplasmin levels. Analysis of phosphorus in starch-based food products is also very important because it has been reported that starch and glycogen are degraded by phosphorylation in the presence of inorganic phosphorus<sup>22</sup>. The high phosphorus values observed in fortified flours compared to the control might be responsible for the high set back viscosity recorded by fortified maize flour in this study.

**Heavy metal composition:** The heavy metal composition of iron-fortified maize flour is shown in Table 3. 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 (such as tin, chromium, cadmium, selenium and lead) are not needed for biological processes and tend to be toxic to living organisms even at low concentrations<sup>23</sup>. 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. The low values of heavy metal contents of the fortified maize flour provided enough support for their safety<sup>24</sup>.<sup>25</sup> and expected nutritional benefits<sup>21</sup>. Philpott and Pickering<sup>26</sup> 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 study by Anderson *et al.*<sup>27</sup> indicated that 15 mg/kg bw/day chromium (as chromium chloride) was not associated

**Table 3.** Heavy metal contents (mg/kg) of Fe fortified maize flour.

Sample	Ti	Cr	Cd	Pb	Se
Maize flour (Control)	< 0.05	< 0.2	< 0.09	< 1	< 4
Maize + Fe EDTA 25 mg	0.30	0.50	< 0.09	< 1	< 4
Maize + Fe EDTA 35 mg	0.25	< 0.2	< 0.09	< 1	< 4
Maize + Fe EDTA 45 mg	< 0.05	0.44	< 0.09	< 1	< 4
Maize + Fe sulphate 25 mg	< 0.06	0.36	< 0.1	< 1	< 4
Maize + Fe sulphate 35 mg	0.53	0.23	< 0.09	< 1	< 4
Maize + Fe sulphate 45 mg	< 0.05	0.24	< 0.09	< 1	< 4
Maize + Fe fumarate 25 mg	< 0.05	0.45	< 0.09	< 1	< 4
Maize + Fe fumarate 35 mg	< 0.05	0.50	< 0.09	< 1	< 4
Maize + Fe fumarate 45 mg	0.07	0.61	< 0.1	< 1	< 4

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 values of heavy metals in the fortified maize flour were very low to constitute a health hazard to the consumer.

**Pasting properties:** 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 disruption of the granules. Table 4 showed the pasting profile of iron-fortified maize flour. Addition of iron fortificants to maize flour significantly ( $P < 0.05$ ) affected its pasting parameters except time to attain peak viscosity. The commonest parameters used to estimate the functional properties of starch-based products are the pasting properties<sup>28</sup>. Maize flour are usually consumed after cooking into paste, hence, its pasting properties are important in predicting the behaviour of its cooked paste. Addition of iron fortificants reduced the peak viscosities of the maize flour. Final viscosity is the most commonly used parameter to define a particular sample's quality, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well the resistance of the paste to shear force during stirring. The higher the amount of iron fortificant added to maize, the higher was its set back viscosity. The setback viscosity indicates the tendency of the dough to undergo retrogradation — a phenomenon that causes the dough to become firmer and increasingly resistant to enzyme attack<sup>29</sup>. It has serious implication on the digestibility of the dough when consumed. Setback has been correlated with texture of various products. High setback is also associated with syneresis or weeping during freeze/thaw cycles. Since fortification increased the set back viscosities of the maize flour, fortified maize flour may be prone to this effect as they had higher setback viscosities.

**Table 2.** Mineral composition (mg/kg) of Fe-fortified maize flour.

Sample	Fe	Zn	Mn	B <sup>ns</sup>	Cu <sup>ns</sup>	Ca	Mg	K	P	S	Al
Maize flour (Control)	16.1 <sup>b</sup>	10.8 <sup>b</sup>	3.6 <sup>ab</sup>	0.7	1.4	19.9 <sup>b</sup>	460 <sup>b</sup>	1370 <sup>d</sup>	1240 <sup>c</sup>	1380 <sup>c</sup>	1.4 <sup>ab</sup>
Maize + 25 mg/kg Fe EDTA	16.3 <sup>b</sup>	10.7 <sup>b</sup>	3.6 <sup>ab</sup>	0.7	1.4	21.9 <sup>ef</sup>	460 <sup>b</sup>	1360 <sup>c</sup>	1240 <sup>c</sup>	1340 <sup>b</sup>	2.0 <sup>bcd</sup>
Maize + 35 mg/kg Fe EDTA	17.9 <sup>c</sup>	9.8 <sup>a</sup>	3.5 <sup>a</sup>	0.6	1.4	20.9 <sup>cd</sup>	420 <sup>a</sup>	1300 <sup>b</sup>	1150 <sup>b</sup>	1410 <sup>a</sup>	1.3 <sup>a</sup>
Maize + 45 mg/kg Fe EDTA	29.7 <sup>f</sup>	13.5 <sup>c</sup>	4.3 <sup>b</sup>	0.7	1.6	23.5 <sup>h</sup>	590 <sup>g</sup>	1610 <sup>j</sup>	1550 <sup>h</sup>	1320 <sup>a</sup>	2.3 <sup>d</sup>
Maize + 25 mg/kg Fe sulphate	16.2 <sup>b</sup>	11.7 <sup>c</sup>	4.2 <sup>ab</sup>	0.7	1.5	21.4 <sup>de</sup>	500 <sup>d</sup>	1450 <sup>g</sup>	1340 <sup>c</sup>	1460 <sup>i</sup>	1.6 <sup>abc</sup>
Maize + 35 mg/kg Fe sulphate	21.0 <sup>c</sup>	10.8 <sup>b</sup>	4.1 <sup>ab</sup>	0.8	1.5	20.4 <sup>bc</sup>	470 <sup>c</sup>	1380 <sup>c</sup>	1260 <sup>d</sup>	1490 <sup>i</sup>	1.6 <sup>abc</sup>
Maize + 45 mg/kg Fe sulphate	18.0 <sup>c</sup>	9.8 <sup>a</sup>	3.7 <sup>ab</sup>	0.7	1.4	19.1 <sup>a</sup>	420 <sup>a</sup>	1290 <sup>a</sup>	1140 <sup>a</sup>	1490 <sup>i</sup>	1.5 <sup>ab</sup>
Maize + 25 mg/kg Fe fumarate	14.7 <sup>a</sup>	11.0 <sup>b</sup>	5.1 <sup>c</sup>	0.7	1.4	21.0 <sup>d</sup>	470 <sup>c</sup>	1390 <sup>f</sup>	1260 <sup>d</sup>	1390 <sup>g</sup>	1.8 <sup>abcd</sup>
Maize + 35 mg/kg Fe fumarate	17.7 <sup>c</sup>	12.2 <sup>cd</sup>	6.4 <sup>d</sup>	0.8	1.5	22.2 <sup>fg</sup>	520 <sup>c</sup>	1470 <sup>h</sup>	1390 <sup>f</sup>	1370 <sup>d</sup>	2.3 <sup>d</sup>
Maize + 45 mg/kg Fe fumarate	19.6 <sup>d</sup>	12.5 <sup>d</sup>	7.4 <sup>e</sup>	0.6	1.6	22.5 <sup>g</sup>	530 <sup>f</sup>	1500 <sup>i</sup>	1410 <sup>g</sup>	1360 <sup>c</sup>	2.2 <sup>cd</sup>

Values are mean of three replicates. Mean values having different superscript within column are significantly different ( $P < 0.05$ ) ns not significantly different ( $P > 0.05$ ).

**Table 4.** Pasting properties of Fe-fortified maize flour.

Sample	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (min) <sup>ns</sup>	Pasting temperature (°C)
Maize flour (Control)	38.13 <sup>bcd</sup>	29.92 <sup>bcd</sup>	8.21 <sup>ab</sup>	76.13 <sup>abc</sup>	46.21 <sup>ab</sup>	7.00	72.93 <sup>a</sup>
Maize + Fe EDTA 25 mg	37.00 <sup>abcd</sup>	29.75 <sup>bcd</sup>	7.25 <sup>a</sup>	72.05 <sup>abc</sup>	42.29 <sup>ab</sup>	7.00	76.43 <sup>c</sup>
Maize + Fe EDTA 35 mg	35.88 <sup>abc</sup>	28.17 <sup>bcd</sup>	7.71 <sup>ab</sup>	70.13 <sup>abc</sup>	41.96 <sup>ab</sup>	7.00	75.73 <sup>b</sup>
Maize + Fe EDTA 45 mg	38.17 <sup>bcd</sup>	30.96 <sup>cd</sup>	7.21 <sup>a</sup>	79.80 <sup>bcd</sup>	48.84 <sup>b</sup>	6.94	76.48 <sup>c</sup>
Maize + Fe sulphate 25 mg	34.63 <sup>ab</sup>	25.34 <sup>ab</sup>	9.29 <sup>bc</sup>	64.00 <sup>a</sup>	38.67 <sup>a</sup>	7.00	76.60 <sup>c</sup>
Maize + Fe sulphate 35 mg	40.88 <sup>d</sup>	30.25 <sup>bcd</sup>	10.63 <sup>c</sup>	91.04 <sup>d</sup>	60.80 <sup>c</sup>	7.00	72.57 <sup>a</sup>
Maize + Fe sulphate 45 mg	32.88 <sup>a</sup>	22.92 <sup>a</sup>	9.96 <sup>c</sup>	66.96 <sup>ab</sup>	44.05 <sup>ab</sup>	7.00	72.38 <sup>a</sup>
Maize + Fe fumarate 25 mg	34.46 <sup>ab</sup>	27.13 <sup>abc</sup>	7.34 <sup>a</sup>	67.67 <sup>ab</sup>	40.55 <sup>ab</sup>	7.00	76.35 <sup>c</sup>
Maize + Fe fumarate 35 mg	36.96 <sup>abcd</sup>	29.59 <sup>bcd</sup>	7.38 <sup>a</sup>	73.34 <sup>abc</sup>	43.75 <sup>ab</sup>	7.00	77.53 <sup>d</sup>
Maize + Fe fumarate 45 mg	40.59 <sup>cd</sup>	32.71 <sup>d</sup>	7.88 <sup>ab</sup>	81.96 <sup>cd</sup>	49.25 <sup>b</sup>	7.00	77.33 <sup>d</sup>

Values are mean of three replicates Mean values having different superscript within column are significantly different ( $P < 0.05$ ) ns not significantly different ( $P > 0.05$ ).

### Conclusions

The chemical composition and pasting properties of iron-fortified maize flour were presented. There were significant differences ( $P < 0.05$ ) in the chemical composition of the fortified maize flour, except in moisture and fat contents. Fortification of maize flour significantly affected the mineral content of the flours. Compared to unfortified samples, fortification increased the values of iron contents of the fortified flours. The amount of heavy metals in the fortified maize flour were very low to constitute a health hazard to the consumer. Addition of iron fortificants to maize flour significantly ( $P < 0.05$ ) affected its pasting parameters except time to attain peak viscosity.

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