A Research Article in AJRTC (2010) Vol. 8 No. 2: Pages 60–68

Changes in iron and moisture contents, pH and peak viscosity of iron-fortified fufu flour during storage in different packaging materials

S.A. Sanni[1], B. Maziya-Dixon[2] and C.R.B. Oguntona[1]

[1]Department of Nutrition and Dietetics, University of Agriculture, Abeokuta, PMB 2240, Nigeria

[2]International Institute of Tropical Agriculture, Ibadan, Nigeria

Corresponding Author: S.A. Sanni
E-mail: silajok@yahoo.com

Manuscript received: 15/11/2010; accepted: 09/12/2010

Abstract

The need to eradicate nutritional iron deficiency anemia with local diet is important for a successful intervention at the community level in Nigeria. Fufu — a fermented dried wet-sieved mash from cassava major staple food in Nigeria — was fortified with iron sulphate, iron fumarate and sodium iron EDTA at three concentrations (25, 35 and 45 mg/kg). The fortified fufu flour samples were packaged inside high density zip-lock polyethylene bags and plastic jars, and stored at ambient temperatures (28 ± 4 °C) simulating the marketing conditions for fufu in Nigeria. Changes in moisture, iron, pH and peak viscosity of the fortified fufu samples were monitored under storage for 5 months. Samples were analyzed monthly during storage using standard analytical procedures. High density zip-lock polyethylene bags provide a better protective barrier than plastic jars. Moisture content and peak viscosity decreased as storage time increased; pH increased during storage. The iron in fufu stored inside high density zip-lock polyethylene bags was less susceptible to oxidation, and hence, low losses in iron were low after 5 months of storage. NaFeEDTA-fortified fufu samples packed inside zip-lock high density polyethylene bags were more stable during storage than iron sulphate and iron fumarate.

Key words: fufu, iron fortification, storage, changes, chemical composition.

Introduction

Cassava plays a very important role in Nigeria's food security since many Nigerians eat cassava products at least once a day (Ayankunbi et al., 1991). In Nigeria, cassava is traditionally processed before consumption into various products such as gari (roasted fermented granules), fufu (dried fermented starch flour), lafun (dried fermented flour), tapioca (unfermented roasted granules from starch), and pupuru (smoked dried fermented balls) (Nweke, 1994).

Despite its high potentials, cassava and its products are mainly carbohydrate foods (Sanni et al., 1998). Cassava products are major sources of dietary fibers, and so, have some laxative effects, thereby protecting the lower sections of the gastro-intestinal tract against cancers of the colon and rectum (Sanni, 2008). Cassava is very deficient in protein and micronutrients such as irons, calcium, phosphorus, and in vitamins C, A, thiamine, riboflavin and niacin.

Cassava fortification in Nigeria has been dominated by the enrichment of local staple foods (such as 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 (Sanni et al., 2010). Micronutrient fortification of cassava products has been reported (Sanni, 2008; Sanni et al., 2010). Specifically, cassava products fortified with iron (Sodium Iron EDTA, Fe fumarate and Fe sulphate) have been reported to be nutritionally, and economically viable (Sanni et al., 2010). Minerals are more resistant to losses from manufacturing processes and storage than vitamins. However, they do undergo changes when exposed to heat, air, or light, especially during storage. Also, during the storage and processing of food products, added ferrous sources are susceptible to oxidation. This is influenced by the food matrix (pH is an important factor) and storage condition. This paper investigates the effects of storage conditions on the moisture and Fe contents, pH and peak viscosity of iron-fortified and unfortified fufu flour.

Materials and methods

Cassava roots: Cassava roots (TMS 30572, low cyanogen 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. The cassava roots were processed within 60 minutes after harvest.

Food grade Iron fortificants: Iron (II) Sulfate heptahydrate (EINECS 231-753-5, Lancaster), Iron (II) fumarate (EINECS 205-447-7, Lancaster, UK) and Ethylenediaminetetraacetic acid iron (III) sodium salt (NaFeEDTA, E6760-500G, Sigma, UK) used in this study were obtained from the United Kingdom.

Production of *fufu* flour. Fufu flour was produced by the traditional method described by Sanni et al. (2003) at the Pilot Plant of the Cassava EU/SME Project, University of Agriculture, Abeokuta. 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 dirt and adhering sand particles, cut into chunks of about 15 cm long using a stainless steel knife and steeped in water in a plastic bowl for 5 days at room temperature (30±2°C). After 5 days, the roots were sufficiently soft and were taken out and broken by hand. The fibers were removed by manual sieving: the mash was washed through a muslin 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 was again washed with water. The sediment (fufu paste) was dewatered by being put it into hessian sacks, and pressed with a hydraulic press. The pressed mash was dried in a cabinet dryer at 65°C for 8 hr and then milled into flour using a stainless steel hammer mill.

Fortification of *fufu* flour. A Kenwood mixer (Model FP 505, Kenwood, Britain, UK) was used to mix the three different types of fortificants (Iron sulfate, Iron fumarate and Sodium Iron EDTA) with the fufu flour at 25, 35 and 45 mg of fortificants to 1 kg of fufu flour for 5 minutes (Philar, 2001).

Storage Studies. Iron fortified and unfortified cassava fufu were divided into 1 kg lots and packed into zip-lock high density polyethylene bags (poly bags) and plastic jars. Packaged samples were then stored at ambient temperature (28 ± 2°C) representing the marketing situation in south west Nigeria (Sanni et al., 1998). Stored samples were assessed for iron, moisture, pH and pasting properties (at Crop Utilization Laboratory, IITA, Ibadan, Nigeria) every month throughout the 5 months of storage (Parrish et al., 1980). Moisture content and pH of the samples was determined using AOAC (2001) method. Iron contents were determined using Inductively-Coupled-Plasma-Emission-Spectroscopy-(ICP-ES) as described by Zarcinas et al. (1987). The method described by Sanni et al. (2003) was used to determine peak viscosity using a Rapid Visco Analyser (RVA), (model RVA 3D+, Network Scientific, Australia). All analyses were done in triplicate.

Statistical Analysis. Data obtained were subjected to analysis of variance [ANOVA] and means were separated with Duncan Multiple Range Test (DMRT) (Larmond, 1977) with a statistical significant of $P < 0.05$ using SPSS [Version 10.2, 2002] statistical package.

Results and Discussion

There were changes in moisture content of Iron-fortified fufu flour during storage in different packaging materials for 5 months under ambient conditions (30±2°C) (Fig. 1). Unfortified fufu flour samples in plastic jars had an initial moisture content of 9.12%. This increased to 12.88% after month 5. Iron content increased over the storage period in fortified fufu flour stored in poly bags, as follows: with Fe fumerate from 8.94–9.37% to 12.30–13.42% with Fe sulphate from 8.58–9.11% to 12.31–12.90% and with NaFeEDTA from 8.82–8.91% to 12.65–13.06%. Unfortified fufu flour stored in poly bags, increased moisture content from 9.12% in month 1 to 12.37% in month 5. Iron content increased over the storage period in fortified fufu flour stored in poly bags as follows: with Fe fumerate from 8.94–9.37% to 11.91–12.49% with Fe sulphate from 8.58–8.91% to 11.88 to 12.45% and with NaFeEDTA from 8.82–9.09% to 11.86–12.92%

Cassava products including (fufu) are assumed to be hygroscopic in nature (Igbeka, 1987) and would be expected to gain or lose moisture depending on the relative humidity of the environment and barrier properties of the packaging materials. This would make flour susceptible to deteriorative biological and chemical changes during storage, handling and marketing (Sanni *et al*., 1998). The stability of *fufu* during storage depends greatly on the initial moisture content of the products, storage condition (humidity)

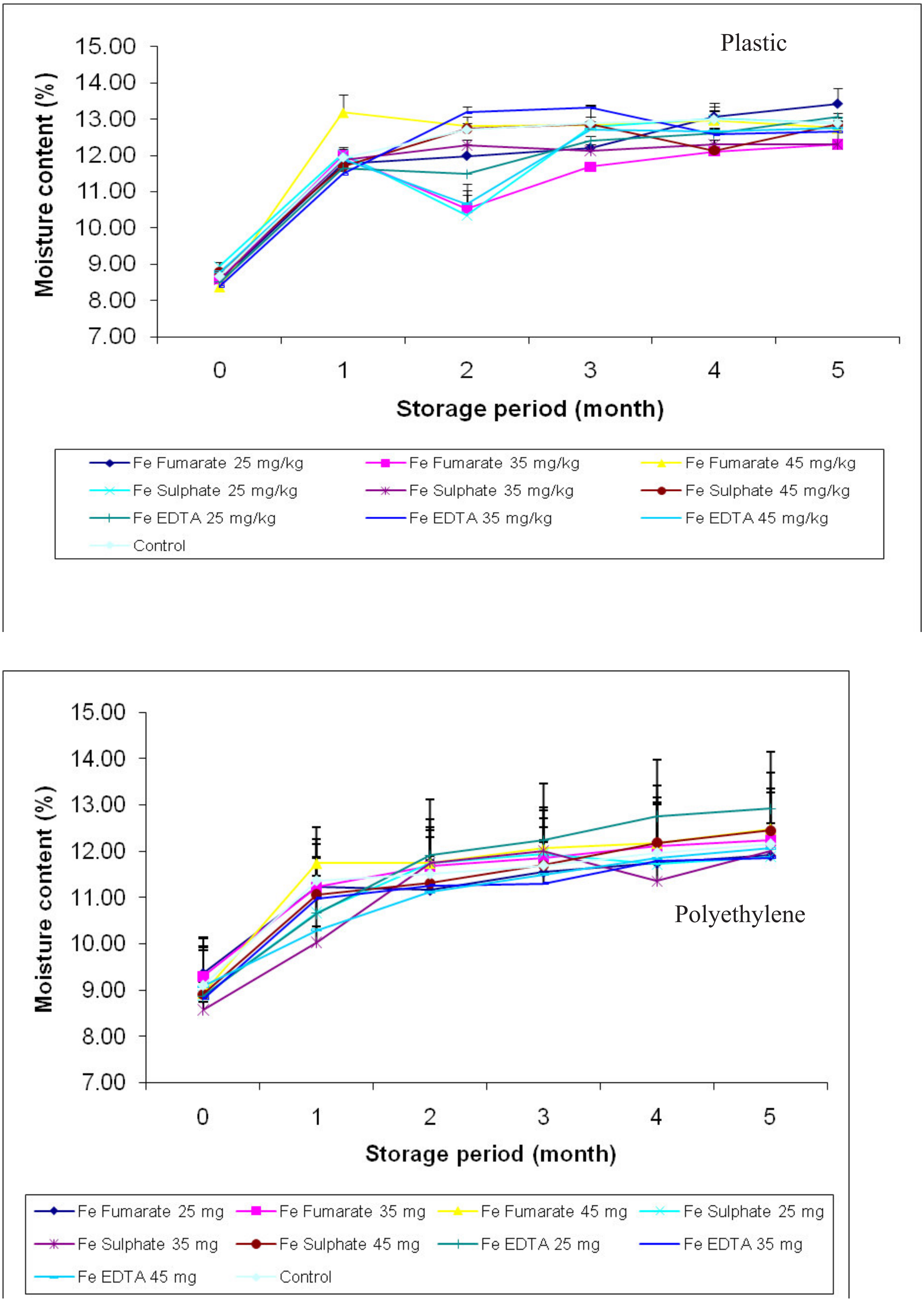
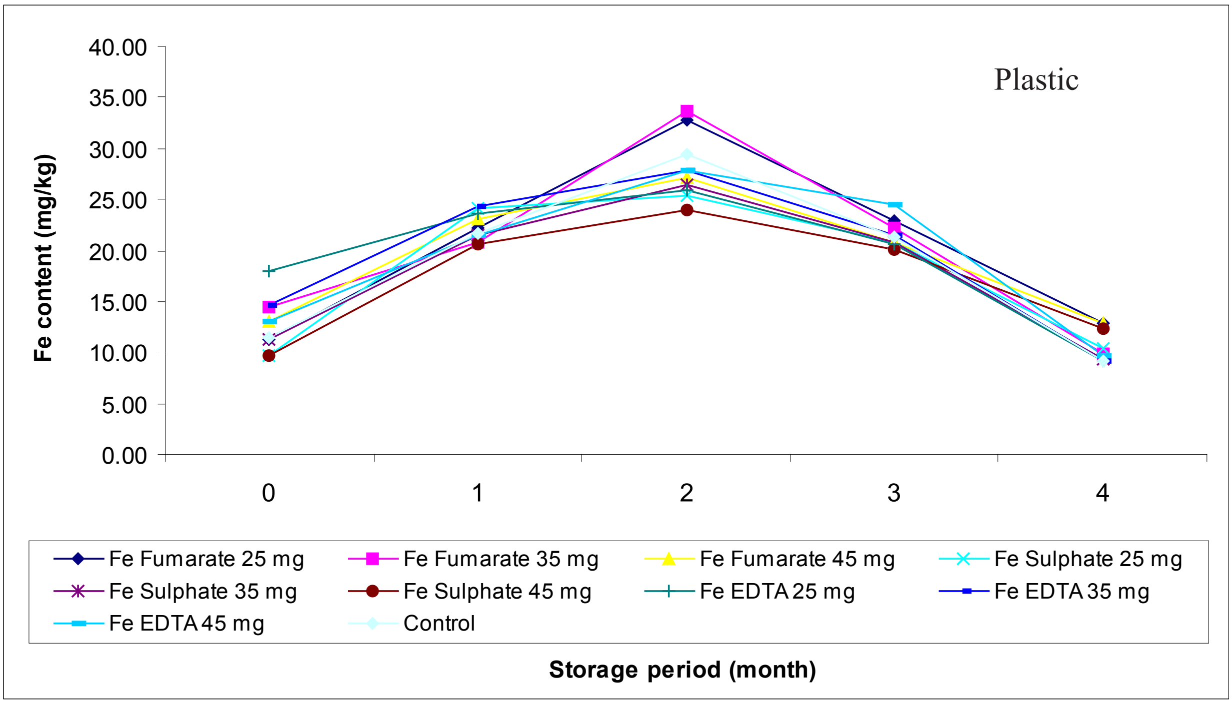


Figure 1: Changes in moisture content of Iron-fortified fufu flour during storage in different packaging materials

and packaging material (Igbeka, 1987; Sanni *et al*., 1998). The lower the initial moisture content of a product to be stored the better the storage stability of the product. With moisture contents above 15% stored foods easily spoil (Shittu *et al*., 2001). The role of the weather condition on the stored product shows that the lower the humidity of the storage area the lower the tendency of stored product to absorb moisture and vice versa (Igbeka, 1987; Shittu *et al*., 2001). High moisture content will expose the flour to insect attack, mold, and bacteria.

Figure 2 presents changes in Fe content of Iron-fortified *fufu* flour during 5 months storage in different packaging materials under ambient conditions (30±2°C). Unfortified *fufu* flour sample stored in polyethylene bag had an initial iron content of 11.39 mg/kg before storage that increased up to the second month of storage and decreased to 9.23 mg/kg after month 5. The iron content in fortified *fufu* flour stored in plastic jars was as follows: for Fe fumerate 11.52–15.06% mg/kg for Fe sulphate 11.62–15.72% mg/kg and for NaFeEDTA 12.89–16.04 mg/kg and increased by month 2 then decereased by month 5 as follows: for Fe fumerate 9.85–12.91 mg/kg, for Fe sulphate 9.26–12.27 mg/kg and to NaFe 9.24–9.73 mg/kg. Unfortified *fufu* flour stored in poly bag, had an initial value of 11.39 mg/kg that increased in the two months of storage and thereafter reduced to 9.13 mg/kg by month 5. The initial iron content of fortified *fufu* flour



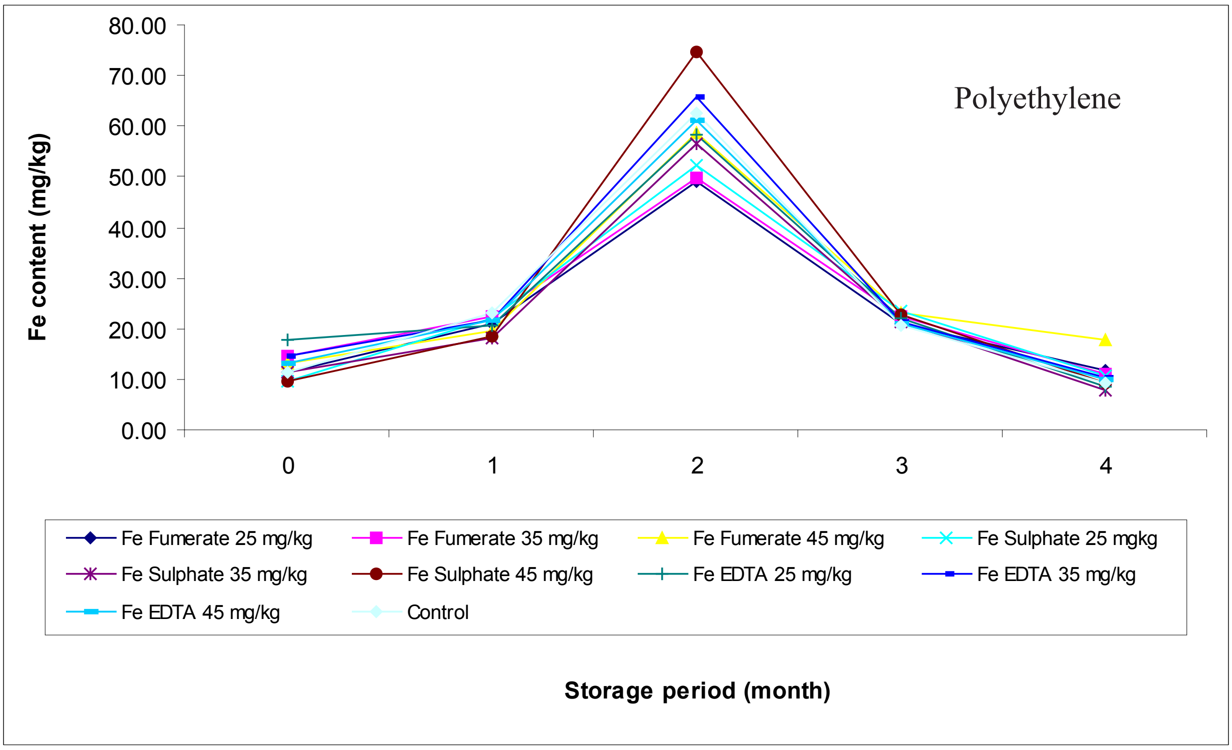


Figure 2: Changes in iron content of Iron-fortified fufu flour during storage in different packaging materials

stored in poly bags was 11.39 mg/kg and decreased to 11.13–17.87 mg/kg (Fe fumerate) 7.91–10.69 mg/kg (Fe sulphate) and 8.59–10.44 mg/kg (NaFeEDTA).

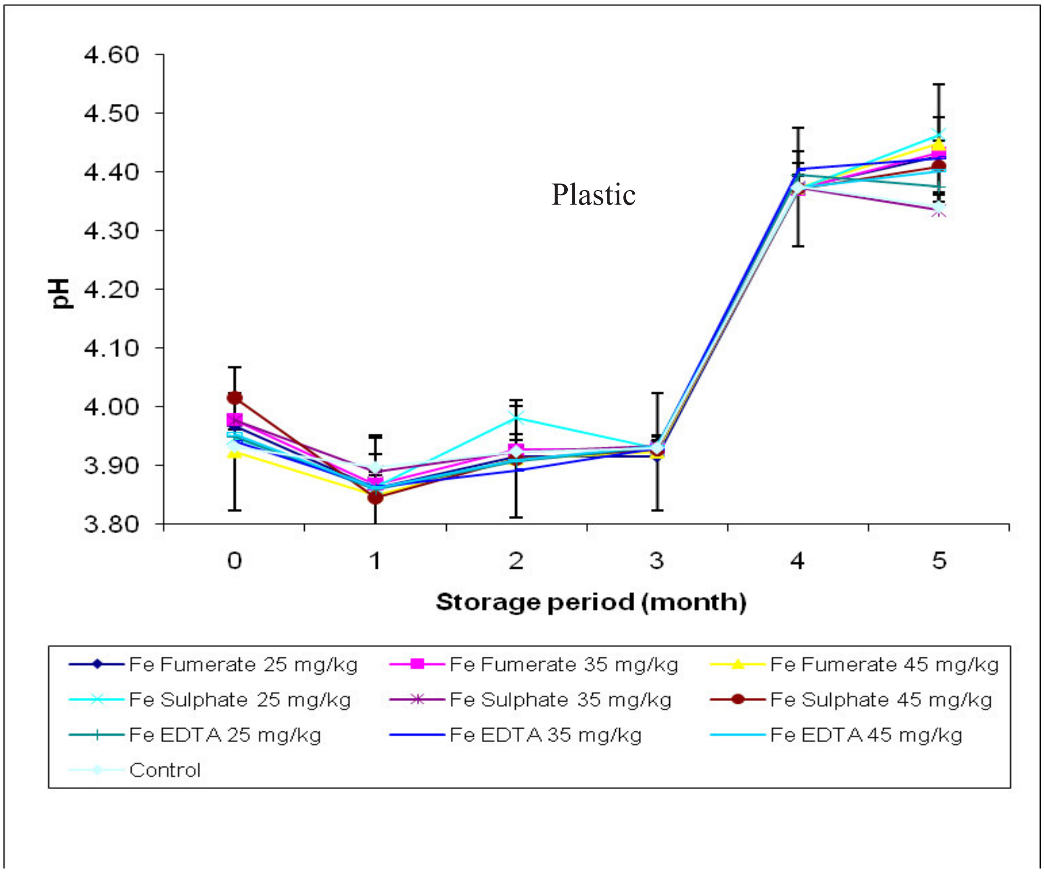
The higher iron content recorded in *fufu* samples packaged in poly bags at the end of storage period showed higher barrier properties than those packaged in plastic jars. Martınez-Navarrete *et al.* (2002) reported that ferrous oxidation increases at a higher moisture level and during oxidation the ferrous form (Fe^{2+}) is converted into the ferric form (Fe^{3+}). Packaging material with an adequate moisture barrier may retain more iron content in fortified samples over a storage period (Nestel, 1993). Lacera *et al.* (1983) had reported satisfactory storage stability using double polyethylene bags with an outer paper layer for instant cereals, and stored in a cool, dry place. Thus moisture proof packaging materials cool and dry storage environment are needed for iron fortified *fufu* flour. Changes in the iron content of fortified *fufu* flour after storage might be due to the oxidation of iron as a result of moisture absorption from the surrounding environment(Martinez-Navarrete *et al.* (2002)

The observed low changes in iron contents during storage for NaFeEDTA fortified cassava products is in agreement with a previous report that the Iron-EDTA complex is relatively stable under most storage conditions (INACG, 2002). Sodium EDTA has been reported to be an accepted food additive that is stable during storage and food preparation (Lynch *et al*., 1993; INACG, 2002). In a study of iron fortification of infant cereals, Hurrell *et al*. (1989) proposed the use of ferrous fumarate and ferrous succinate as they produce no objectionable flavours, odours or colours on storage. According to Bauernfeind (1991a,b), an acceptable iron fortificant for a powdery product is one which does not discolour the salt nor impart a flavour or odour and remains stable and bio-available on storage.

Alleen and Gillespies (2001) have shown that when iron fortificants are added to refined cereals, iron salts such as ferrous sulphate and fumarate are reasonably well absorbed and are suitable. However, the most suitable forms of iron cause oxidation the rancidity of fats and colour changes in food over time. To increase the shelf-life of food products, reduced iron is preferred, but this will not be well absorbed unless the size of the particles is very small (Alleen and Gillespies, 2001). Hence, NaFeEDTA has the potential to be a widely used iron fortificant in *fufu* flour. Ratana *et al*. (2006) showed that ferrous fumarate and ferrous bisglycinate immediately caused precipitation in all types of pasteurized soy sauce stored in a corrugated kraft paper case at room temperature (day time, 25-32°C, night time, 25°C). Over 15 days, the naturally fermented soy sauce fortified with NaFeEDTA was more stable than soy sauce fortified with ferrous fumarate and ferrous bisglycinate.

Figure 3 presents the changes in pH of Iron-fortified *fufu* flour during storage in different packaging materials for 4 months under ambient conditions (30±2°C). Unfortified *fufu* flour sample stored in plastic jar had initial pH of 3.93 before storage that decreased and later increased up to 4.34 after the fifth month of storage. The pH in iron-fortified *fufu* flour stored in plastic jars increased as follows: by month 4 for Fe fumerate from 3.92–3.98 to 4.43–4.45 for Fe sulphate from 3.95–4.02 to 4.33–4.46 and for NaFeEDTA from 3.94–3.95 to 4.37–4.42. As for unfortified *fufu* flour stored in polyethene bag, the initial pH value of 3.92, decreased after first month of storage and then increased up to 4.40 by the fifth month of storage. The pH of iron fortified *fufu* flour stored in poly bags decreased after month 1 but later increased as follows: with Fe fumerate from 3.93–3.96 to 4.54 with Fe sulphate from 3.92–4.06 to 4.30–4.54 with NaFeEDTA from 3.91–3.97 to 4.39. pH is an important factor in the oxidation of iron during storage. The pH of iron fortified *fufu* increased during storage both in samples stored inside poly bags and in plastic jar. This might be due to oxidation of iron as a result of increased moisture content (Martınez-Navarrete *et. al.* 2002).

Figure 4 shows the changes in peak viscosity of Iron-fortified *fufu* flour during storage in different packaging materials for 5 months under ambient conditions (30±2°C). Unfortified samples stored in plastic jars had an initial peak viscosity of 305 RVU before storage, thus decreased up to month 3 and later increased up to 285 RVU after month 5 of storage. In iron fortified *fufu* flour stored in plastic jar,initial peak viscosities decreased and later increased up to month 5 as follows: with Fe fumerate from 298–305 to 275–289 RVU with Fe sulphate from 291–293 to 281–284 RVU with NaFeEDTA from 290–309 to 275–284 RVU. As for unfortified *fufu* flour stored in polyethylene bag, the initial peak viscosity of 305 RVU, decreased after first month of storage and then increased up to 290 RVU by the fourth month of storage. In iron fortified *fufu* flour stored in poly bags, initial peak viscosities decreased after month 1 and 3 then increased up to month 5 as follows: with Fe fumerate from 298–305 to 281–286 RVU with Fe sulphate from 291–293 to 275–299 RVU with



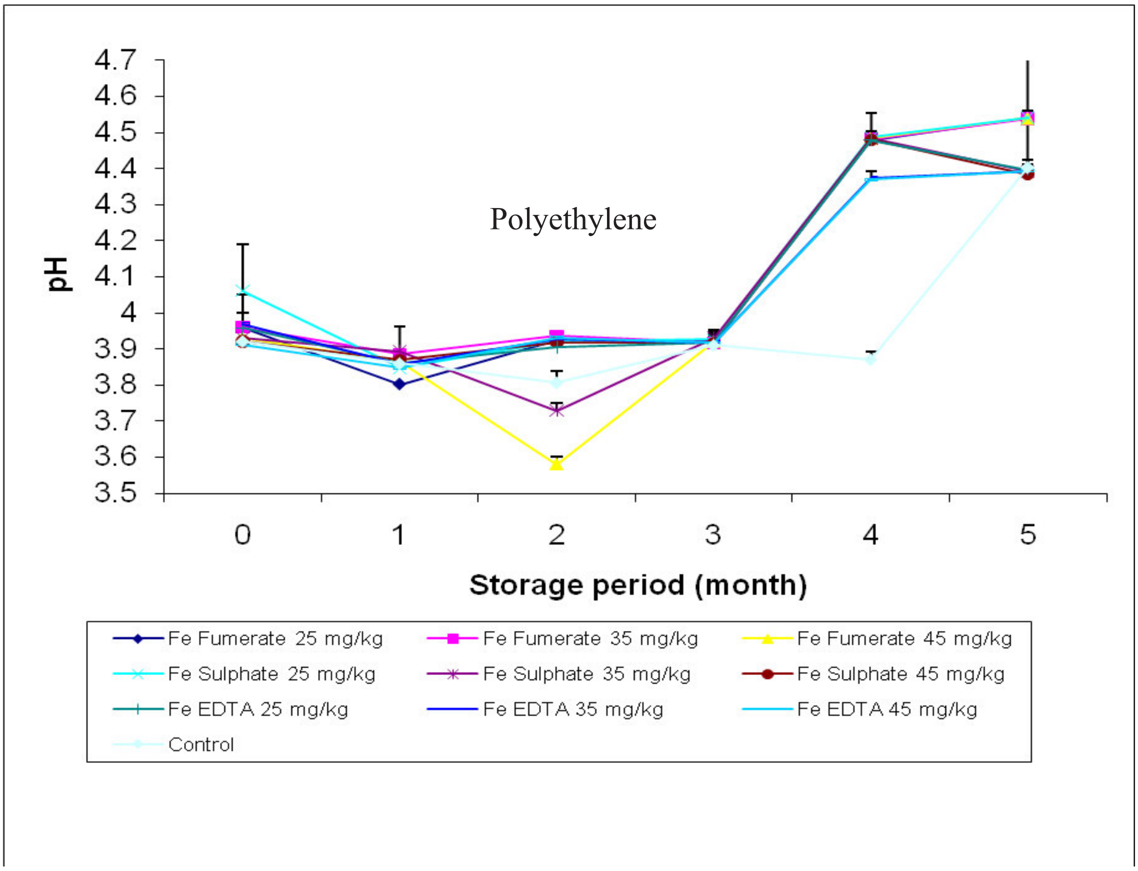
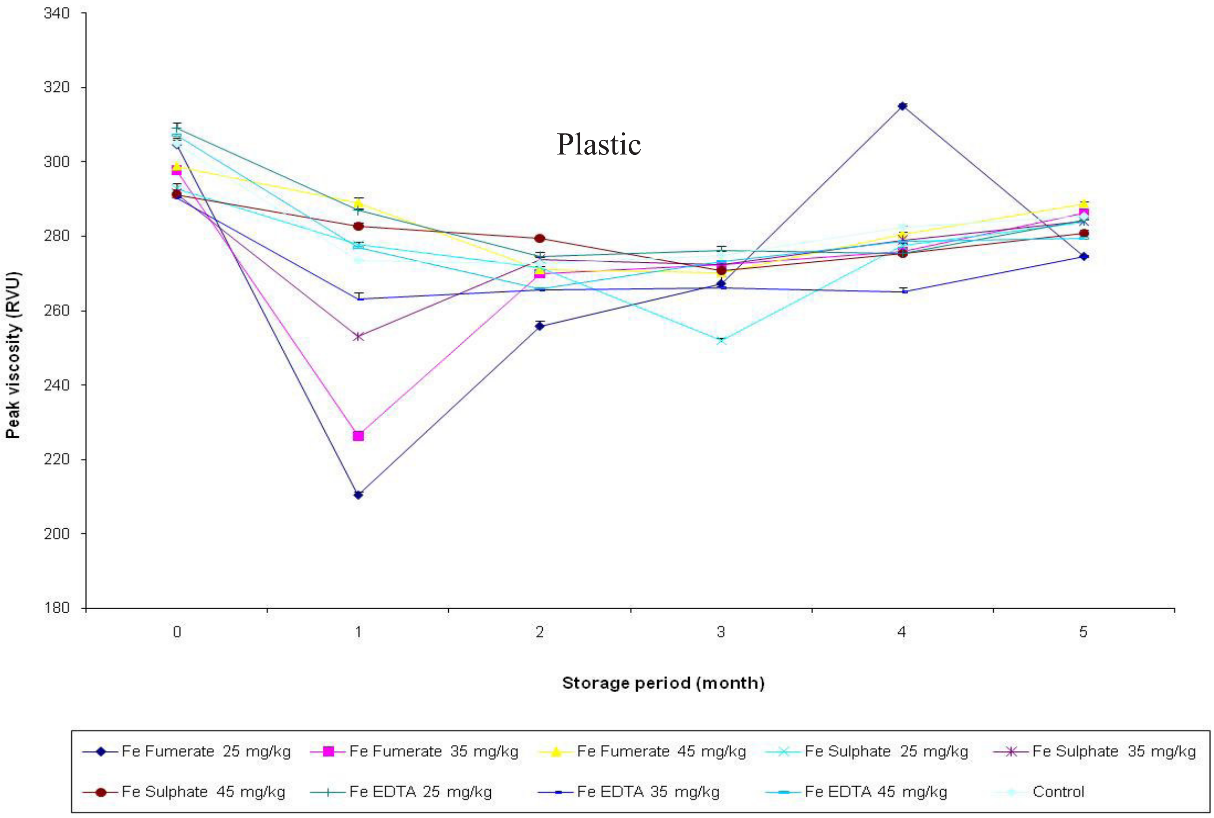


Figure 3. Changes in pH of Iron-fortified fufu flour during storage in different packaging materials



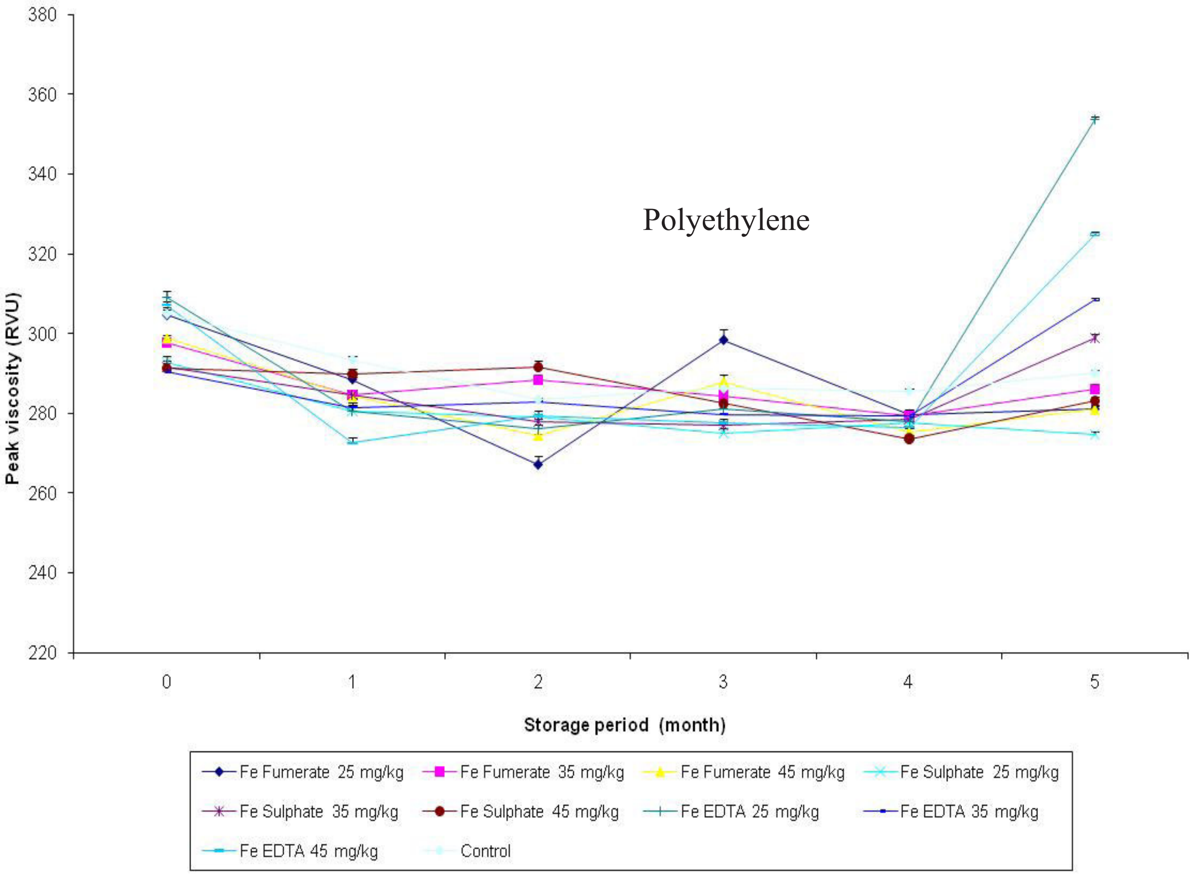


Figure 4: Changes in peak viscosity of Iron-fortified fufu flour during storage in different packaging materials

NaFeEDTA from 290–309 to 308–354 RVU.

The most common form of *fufu* consumption is in the form of cookedstiff paste; hence, its pasting properties are important in predicting the behaviour of iron fortified *fufu* after cooking. The addition of iron fortificants has been reported to reduce the peak viscosities of maize flour (Sanni *et al*. 2008b). Peak viscosity indicates the water-binding capacity of the starch-based products. It is often correlated with the final product quality, and also provides an indication of the viscous load likely to be encountered during mixing and cooking. In this study, peak viscosity decreased as storage time increased. However, changes in the peak viscosity of iron fortified *fufu* are relatively insignificant in both forms of packaging used.

Conclusion

The changes in moisture, pH iron and peak viscosity of iron fortified *fufu* stored in different packaging materials under ambient condition (30±2°C) were presented. Poly bags showed a better protective barrier than plastic jars. NaFeEDTA fortified *fufu* samples packed inside poly bags were the most stable during storage.

References

Alleen, L. H. and Gillespies, S. R. 2001. What works? A Review of the Efficacy and Effectiveness of Nutrition Interventions. Published by the Asian Development Bank, Manila, The Philippines. pp 50–51.

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

Ayankunbi, M. A, Keshinro, O.O and Egele, P. 1991. Effect of methods of preparation on the nutrient composition of some cassava products- Gari (Eba) Lafun, and *Fufu*. Food Chemistry, 41,349-354.

Bauernfeind, J. C. 1991a. Foods considered for nutrient addition: fats and oils. In: Nutrient Additions to Food. Eds. J. C. Bauernfeind and P. A. Lachance. Food and Nutrition Press, Connecticut, USA.

Bauernfeind, J. C. 1991b. Foods considered for nutrient addition: condiments.In: Nutrient Additions to Food. Eds. J. C. Bauernfeind and P. A. Lachance. Food and Nutrition Press, Connecticut, USA.

Hurrell, R. F., Furniss, D. E., Burn, J., Whittaker, P., Lynch, S. R. and Cook, J. D. 1989. Iron fortification of infant cereals. American Journal of Clinical Nutrition, 49 (6): 1274-1282.

Igbeka, J. C. 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 20005 USA. 6 pp.

Lacera, A., Mejia, L. A., Molina, M. R. and Bressani, R. 1983. Fortificacion de azúcar con aceite de higado de tiburon para alimentacion Humana.*In* Proc. Int. Con. Marine Resources of the Pacific'. P. M. Arena, (ed) Ina Del Mar, Chile.

Larmond, E. 1977. Methods for Sensory evaluation of food. Food Research Central Experimental Farm, Canada Department of Agriculture, Ottawa, Canada.

Lynch, S.R., Hurrell, R. F., Bothwell, T.H., and MacPhail, P. 1993. Iron EDTA for food fortification. International Nutritional Anaemia Consultative Group/ILSI Press. Washington, DC, USA.

Martınez-Navarrete, N., Camachoa, M.M. Martı´nez-Lahuerta,J., Martınez-Monzo´,J. and Fito, P. 2002. Iron deficiency and iron fortified foods – a review. Food Research International, 35: 225–231.

Nestel, P. 1993. Food fortification in developing countries. U.S. Agency for InternationalDevelopment. New York, USA.

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

Oyewole, O. B. and Aibor, A. M. 1992. Fermentation of cassava with cowpea and soyabean for an enriched *fufu*. Tropical Science, 33: 9-15.

Oyewole, O. B. and Asagbra, Y. 2003. Improving traditional cassava processing for nutritional enhancement. In: Food Approaches for a Healthy Nutritional, Ouagadougou, 2nd International Workshop, 369-382.

Parrish, D. B., Eustace, W. D., Ponte, J. G. and Herod, L. 1980. Distribution of vitamin A in fortified flours and effect of processing, simulated shipping and storage. *Cereal Chemistry* 57 (4): 284-287.

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

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

Sanni, L. O., Kosoko, S. B., Adebowale, A. A. and Adeoye, R. J. 2003. The Influence of palm oil and chemical modification on the pasting and sensory properties of *fufu* flour. International Journal of Food Properties 7(2): 229-237.

Sanni, L. O., Akingbala, J. O., Oguntunde, A. O., Bainbridge, Z. A., Graffham, A. J. and Westby, A. 1998. Processing of *fufu* from cassava in Nigeria: Problems and prospects for development. Science, Technology and Development 16 (1): 58-71.

Sanni, S.A. 2008a. Nutritional and sensory qualities of iron fortified cassava *gari* and *fufu* flour. PhD Thesis, University of Agriculture, Abeokuta, Nigeria.

Sanni, S. A., Adebowale, A. A., Olayiwola, I. O.1 and Maziya-Dixon, B. 2008b. Chemical composition and pasting properties of iron-fortified maize flour. Journal of Food, Agriculture & Environment Vol. 6 (3&4): 172-175.

Sanni, S. A., Oguntona, C. R. B., Oguntona, E. B. and Maziya-Dixon, B. 2010. Chemical composition and Sensory Properties of Iron Fortified Cassava *Gari.* Foods (Japan) 4: 55-60.

Shittu, T. A., Lasekan, O. O., Sanni, L. O. and Oladosu, M. O. 2001. The effect of drying methods on the functional and sensory characteristics of *pukuru*-a fermented cassava product. ASSET-An International Journal*, A* (1) (2): 9-16.

Zarcinas, B. A., Cartwright, B. and Spouncer, L. R. 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.