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Impact of Okra (*Abelmoschus esculentus)* Seed Flour on Nutrients, Functional Properties and Zinc Bioavailability of Plantain Flour

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ABSTRACT

Introduction: In Nigeria, nursing mothers are advised to give their infants plantain flour paste 'amala ogede' with 'ewedu' *Corchorus olitorius* soup during the process of weaning. Over-matured okra is typically discarded resulting in substantial post-harvest waste; the seed could be processed into okra seed flour for the fortification of plantain flour. The aim of this study is to evaluate the effect of the addition of okra seed flour on the nutrients, functional properties, minerals and zinc bioavailability of plantain flour. **Methods:** Okra seed flour was used to fortify plantain flour in the ratio 90:10, 80:20 and 70:30. **Results:** The addition of okra seed flour to the plantain flour resulted in a significant increase in the protein, fat, fibre and ash content of the fortified plantain flour, while that of moisture and carbohydrate decreased. The mineral levels of Zn, K and Fe increased significantly while the calcium content decreased. The calculated phytate - zinc molar ratio and [Ca][Phytate]/[Zn] molar ratio of the fortified plantain flour were below the critical levels. **Conclusion**: The study showed that fortifying plantain flour with okra seed flour resulted in an increase in several nutrients, rendering the zinc more bioavailable. This fortified food has potential as a complimentary food in Nigeria.

Keywords: Complimentary food, okra seed flour, plantain flour, phytate, zinc bioavailability

INTRODUCTION

The effects of zinc deficiency in humans can be devastating because it is an important mineral for normal foetal growth and development and for milk production during lactation; it is also needed during the first years of life when the body is growing rapidly. Zinc deficiency triggers an array of health problems in children, including weight loss, stunted growth, weakened resistance to infections, and early death. There is evidence that zinc deficiency impairs the immune responses of young children and that zinc supplementation can reduce or prevent the severity of common diseases such as diarrhoea and lower respiratory tract infections. Marginal zinc deficiency is associated with diets based on plant foods, especially those diets rich in phytate, a potent inhibitor of zinc absorption (Salgueiro *et al.*, 2002).

Plantains and bananas are a good source of vitamin A (carotene), vitamin B complex (thiamin, niacin riboflavin and B6) and vitamin C (ascorbic acid). Plantains

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provide a better source of vitamin A than most other staples. Although plantains are not a particularly good source of calcium, iron and iodine, they are notably high in potassium and low in sodium (Zakpaa Mak-Mensah & Adubofour, 2010). In Nigeria, a popular method of preparing and preserving the unripe plantain (*Musa paradisiacal* Linn) is the production of flour: the fruit is sliced, sundried and then ground into a fine powder 'elubo ogede'. The flour is used in gruel and eaten with vegetables or okra soup (Ohiokpehai, 1985). Flour from plantain is considered to have commercial potential alone or as a supplement when mixed with other ingredients such as baby weaning foods, puddings, soups and gravies.

Okra (*Abelmoschus esculentus* L.) is widely consumed as a fresh vegetable. The mature seed is known to have superior nutritional quality. In an earlier study, Karakoltsides & Constantinides (1975) found that the Protein Efficiency Ratio (PER) of okra seed flour heated at 130°C for 3 h was not different from the non-heated flour, indicating the absence of anti-nutritional factors. According to these authors, the amino acid composition of okra seed protein is similar to that of soybean and the PER is higher than that of soybean. Okra seed is known to be rich in high quality protein especially with regard to its essential amino acids relative to other plant protein sources (Oyelade, Ade-Omowaye & Adeomi, 2003). Okra seed flour has been reported to be rich in minerals and vitamins. Its addition to predominantly high carbohydrate foods might be expected to enrich such foods and improve their nutritional status (Otunola, Sunny-Roberts & Solademi, 2007). Okra seed flour has been used to supplement 'ogi' (Aminigo & Akingbala, 2004; Otunola *et al.*, 2007). In Nigeria, nursing mothers are advised to give their babies plantain flour paste 'amala ogede' with 'ewedu' (*Corchorus olitorius* soup) during the process of weaning. Over-mature okra that cannot be easily cut with a kitchen knife are typically discarded in Nigeria. This results in substantial but unnecessary post-harvest losses as the seed in the over mature fruit could be processed into okra seed flour for the fortification of plantain flour.

The aim of this work is to evaluate the effect of the addition of okra seed flour on the nutrients, functional properties, minerals and Zn bioavailability of plantain flour.

METHODS

The plantains were bought from Emure market in Emure Uli in Ondo State. The okra used were freshly harvested from a farm in Rufus Giwa Polytechnic, Owo; they were mature, fibrous okra that could not be easily cut with a kitchen knife.

Sample preparation

The plantain flour was produced according to the method of Mepba, Eboh & Nwaojigwa (2007). The fingers were washed, peeled, cut into thin slices of approximately 2 cm thick and blanched in 1.25% $NaHSO_3$ solution at 80°C for 5 min. Blanched plantain slices were drained and dehydrated in an air-recirculating oven at 60°C for 24 h. Dried plantain slices were milled into flour using a Hammer mill. Flour thus obtained was sifted through a 250μm aperture sieve and packed in a two-ply medium density polythene bag.

The okra seed were removed from the pods, sundried, dry milled and sieved to obtain a particle size of less than 250μm. Thereafter, the plantain flour was fortified with the okra seed flour at ratios of 90:10, 80:20 and 70:30% on a dry weight basis. Each sample was thoroughly mixed. The nutrients, functional properties, phytate, minerals and Zn bioavailability of the fortified plantain flour were determined.

Nutrient analysis

Nutrient composition (fat, crude fibre, and ash) was determined by the standard method of the Association of Official Analytical Chemist AOAC (1990). The protein content was determined using the micro-Kjedahl method (N × 6.25) and carbohydrate determination was by difference. Food energy was calculated by the method of Jideani & Bello (2009) using the factor of [(4 × Protein) + (4 × Carbohydrate) + (9 × Fat)].

Functional property analysis

The bulk density of the flour samples were determined according to the method described by Fagbemi (1999) and were calculated as mass of flour per unit volume (g/cm^3). The method of Mweta *et al.* (2008) was used to determine the swelling capacity. The water and oil absorption capacity (WAC) and (OAC) of the flour were determined using the method described by Fagbemi (1999). The weight of water or oil absorbed by the flour was calculated as WAC or OAC. All determinations were done in triplicates and the mean value recorded in each case.

Phytate and mineral analysis

The phytate content was determined by the method of Maga (1982) which depends on the ability of standard ferric chloride to precipitate phytate in dilute HCl extract of the flour. The mineral contents were determined using an atomic absorption spectrophotometer AAS (model 372). The method of Ferguson *et al.* (1988) was used for the calculation of phytate - zinc, calcium - phytate and [Ca] [phytate]/ [Zn] molar ratios and used for the Zn bioavailability prediction [Phytate = 660, Zn = 65.40, Ca = 40].

Statistical analysis

Analysis of variance (ANOVA) was performed in order to determine the significance of the fortification (SAS, 2002). Mean separations were performed to indicate significant differences using the Duncan's multiple range test procedure as described in the SAS software. Significance was accepted at $P \leq 0.05$.

RESULTS

Nutritional composition

The nutrient composition of plantain flour fortified with okra seed flour is presented in Table 1. When the plantain flour was fortified with okra seed flour, the carbohydrate content was reduced significantly ($P \leq 0.05$) from 59.64% to 49.79% as the percentage of okra seed flour increased. As the percentage of okra seed flour increased there was a significant ($P \leq 0.05$) increase in the value of protein (3.88 – 10.50%), fat (6.01-14.06%), fibre (3.03 – 9.98%) and ash (2.72 – 6.42%).

Functional properties

The functional properties of plantain flour fortified with okra seed flour is presented in Table 2. The bulk density of the fortified flour decreased significantly ($P \leq 0.05$) as the percentage of okra seed flour increased (0.769 – 0.745g/cm^3). The swelling capacity of the fortified plantain flour decreased significantly ($P \leq 0.05$) (5.32 – 4.20) as the

Table 1. Nutrient composition of plantain flour fortified with okra seed flour (%)

%PF: OSF	*Moisture content*	*CHO*	*Protein*	*Fat*	*Fibre*	*Ash*	*Energy (Kcal)*
100:0	11.23c	73.13d	3.88a	6.01a	3.03a	2.72a	362a
90:10	10.48b	59.64c	8.31b	12.71b	5.71b	3.15b	386b
80:20	10.19b	54.17b	10.06c	14.05c	7.06c	4.47c	383b
70:30	9.25a	49.79a	10.50c	14.06c	9.98d	6.42d	368a

Values represent mean of triplicate. Values with the same letter along the column are not significantly different ($P \leq 0.05$). PF: Plantain flour, OSF: Okra seed flour, CHO: Carbohydrate

Table 2. Functional properties of plantain flour fortified with okra seed flour

%PF: OSF	*Bulk Density (g/cm^3)*	*Swelling capacity(g)*	*Water absorption capacity (WAC)*	*Oil absorption capacity (OAC)*
100:0	0.769b	5.32c	160.13a	95.92a
90:10	0.769b	5.19c	220.04b	98.56b
80:20	0.764b	4.90b	240.01c	101.20c
70:30	0.745a	4.20a	260.11d	123.20d

Values represent mean of triplicate. Values with the same letter along the column are not significantly different ($P \leq 0.05$). PF: Plantain flour, OSF: Okra seed flour

Table 3. Phytate and mineral content of plantain flour fortified with okra seed flour in mg/100g.

%PF: OSF	*Phytate*	*Calcium*	*Zinc*	*Potassium*	*Iron*
100:0	1.93c	5.11c	0.10a	11.13a	3.30b
90:10	1.26b	6.03d	0.97b	13.84c	2.15a
80:20	0.93a	4.01b	1.00c	12.57b	3.65c
70:30	0.91a	3.12a	1.27c	13.00b	5.12d

Values represent mean of triplicate. Values with the same letter along the column are not significantly different ($P \leq 0.05$). PF: Plantain flour, OSF: Okra seed flour

percentage of okra seed flour increased. The water absorption capacity and oil absorption capacity (WAC and OAC) of the fortified plantain flour increased significantly ($P \leq 0.05$) as the percentage of okra seed flour increased (WAC: 160 – 260, OAC: 95.92 – 123.20).

Phytate and mineral content

The phytate and the mineral content of plantain flour fortified with okra seed flour is presented in Table 3. The phytate content of the flour decreased significantly ($P \leq 0.05$) from 1.93g/100g to 0.91g/100g as the percentage of okra seed flour increased. The results in Table 3 show that the plantain flour contains 5.11mg/100g Ca, 0.10mg/100g Zn, 11.13mg/100g K and 3.30mg/100g Fe. The addition of okra seed flour to the plantain flour resulted in a significant ($P \leq 0.05$) increase in the minerals: Zn, 0.10 – 1.27mg/100g, K, 11.13 – 13.00mg/100g and Fe, 3.30 – 5.12mg/100g of the fortified plantain flour, while calcium content of the plantain flour decreased significantly ($P \leq 0.05$) Ca, 5.11 – 3.12mg/100g.

Zinc bioavailability

The calculated phytate - zinc, calcium - phytate and [Ca][Phytate]/[Zn] molar ratios are presented in Table 4. The phytate – zinc molar ratio of the fortified flour ranged between 12.7 – 7.41 as the percentage of okra seed flour increased.

DISCUSSION

Nutritional composition

The carbohydrate content of the plantain flour 73.13% is within the value reported by Fagbemi (1999) and Pacheco-Delahaye (2008) for unripe plantain flour. The protein, fat, fibre and ash content of plantain flour compared favourably with the value observed by Pacheco-Delahaye (2008). The

Table 4. Calculated phytate - zinc, calcium - phytate and [Ca][Phytate]/[Zn] molar ratios of plantain flour fortified with okra seed flour.

%PF: OSF	*phytate : Zn*	*Ca : phytate*	*[Ca][Phytate]/[Zn]^X*
100:0	193.3	0.45	0.25
90:10	12.70	0.79	0.019
80:20	9.30	0.71	0.0093
70:30	7.41	0.57	0.0059

^{X} mol/kg PF: Plantain flour, OSF: Okra seed flour

increase in these nutrients (protein, fat, fibre and ash) as okra seed flour is added is similar to the report of workers who had worked on fortification of foods (Ogi, yam flour) with okra seed flour or soy bean flour (Amingo & Akingbala 2004; Otunola *et al.*, 2007). The increase in the fibre content of the fortified plantain flour supports the call for the need to increase fibre intake as the dietary guidelines of USDA 2000 in Marlett, Yang & Slavin (2002) who recommend a minimum dietary intake of dietary fibre of 25g equivalent to 12.5g/1000 calories consumed. This is more than the fibre content of plantain flour.

The increase in the nutrients may be attributed to the okra seed flour which is higher in protein, fat, fibre and ash content (Karakoltsides & Constantinides 1975, Oyelade *et al.*, 2003; Adelakun *et al.*, 2009) than plantain flour. The results indicate that the fortification of plantain flour with okra seed flour increased the nutrient and mineral content (ash), while reducing the moisture content resulting in a more stable shelf-life of the product.

Functional properties

The reduction in the bulk density of the fortified flour agreed with the observation of (Adetuyi *et al.*, 2009) who evaluated maize-soybean flour blends. The reduction in the bulk density of the plantain flour fortified with okra seed flour will be an added advantage in the preparation of supplementary foods and where packaging is a serious problem (Ikujenlola 2008). The reduction in the swelling capacity agreed with the observation of Ikujenlola & Fashakin (2005) but not with the findings of Adetuyi *et al.* (2009) who examined maize – soybean flour blends. The decrease in the swelling capacity could be attributed to the decrease in carbohydrate content of the fortified flour because the ability to swell is a function of the carbohydrate content. The water absorption capacity (WAC) and oil absorption capacity (OAC) of the plantain flour were lower than the value reported for unripe plantain flour by Fagbemi (1999). The increase in the WAC and OAC of the fortified plantain flour could be attributed to the increase in the protein content of the fortified flour. This is responsible for high hydrogen bonding and high electrostatic repulsion which according to Altschul & Wilcke (1985) are conditions that facilitate binding and entrapment of water. The increase in protein also enhances the hydrophobicity and exposes more of the polar amino acid to the fat (Chau & Cheung, 1998). According to Kinsella (1976), OAC is the ability of the flour protein to bind fat by capillary attraction and it is of great importance because fat acts as a flavour retainer that increases the mouth feel of foods.

Phytate and mineral content

The phytate content of the plantain flour was within the range reported by Adeniji *et al.* (2007) for different plantain cultivars. The potassium reported in this study was lower than the value reported for flour produced from ripe 'apem' plantain in Ghana, French horn and false horn (Zakpaa *et al.*, 2010; Amankwah *et al.*, 2011). The calcium content 0.10mg / 100g was lower than the value (0.419mg / 100g) reported for flour produced from ripe 'apem' plantain in Ghana (Zakpaa *et al.*, 2010). The iron content of 3.30mg / 100g was in the same range as the value reported by Zakpaa *et al*. (2010) but higher when compared to the iron content of the French horn (0.71mg / 100g) and the false horn (0.87mg / 100g) (Amankwah *et al*., 2011). The values of potassium, calcium and iron were lower than the value reported for black Sitrotoga resistant *musa* hybrid flour K - 1160mg / 100g, Ca - 75mg / 100g and Fe – 9.46mg / 100g while the value of zinc was similar (Adeniji & Tenkouano, 2008). The differences in the value of minerals of the plantain flour in this study and other works on plantain flour could be attributed to differences in morphological traits and physicochemical characteristics, differences in soil conditions (soil type and mineral content) as well as different conditions of experimental analysis (Amankwah *et al.*, 2011; Zakpaa *et al.*, 2010). The addition of okra seed flour to the plantain flour resulted in a significant ($P \leq 0.05$) increase in the mineral content of Zn, K and Fe in the fortified plantain flour while Ca content of the plantain flour decreased significantly ($P \leq 0.05$). These results agree with the observation of Abioye *et al.* (2011) in the fortification of plantain flour with soy bean flour.

Zinc bioavailability

The phytate–zinc molar ratio of the plantain flour (193.3) is higher than the value (15.0) considered desirable (Fergusson *et al.*, 1988; WHO 1996). This indicates that the phytate content of the plantain flour will reduce the bioavailability of zinc. The phytate–zinc molar ratio values of the fortified plantain flours were lower than the critical value of 15 indicating that the fortified plantain flours have relatively high zinc bioavailability. Diets with a phytate–zinc molar ratio greater than 15 are considered to have relatively poor Zn bioavailability while those with phytate–zinc molar ratios of less than 15 have relatively good zinc bioavailability (WHO, 1996). The calculated calcium–phytate molar ratios of the plantain flour (0.45) and the fortified plantain flours (0.79 – 0.57) were lower than the critical value of 6.0 (Fergusson *et al*., 1988). The solubility of phytate and the proportion of zinc bound to the complex depend on dietary calcium levels. Therefore, phytate precipitation is not complete until the dietary calcium–phytate molar ratios attain a value of approximately 6.0. At lower ratios, phytate precipitation is incomplete causing some dietary zinc to remain in solution (Akindahunsi & Oboh, 1999). The calculated [Ca][Phytate] / [Zn] molar ratio is considered a better index for predicting zinc bioavailability when compared with the phytate– zinc ratio because of the calcium to phytate interaction (Akindahunsi & Oboh, 1999). The calculated [Ca][Phytate] / [Zn] molar ratio for the plantain flour (0.25) and the okra seed-fortified plantain flours (0.19– 0.0059mol / kg) were below the critical level (0.5mol / kg), an indication of the bioavailability of dietary zinc (Akindahunsi & Oboh, 1999). The zinc is more bio-available in the fortified plantain flours as reflected in their lower values. The calculated [Ca][Phytate] / [Zn] molar ratios for the okra seed-fortified plantain flours (0.019 – 0.0059mol / kg) were lower than the values observed for some okra varieties in Nigeria and some selected tropical vegetables (Adetuyi *et al.*, 2011, Akindahunsi & Oboh, 1999). The higher the percentage of okra seed flour added to the plantain flour, the greater the bioavailability of zinc.

CONCLUSION

The results from this study suggest that fortifying plantain flour with okra seed flour increases the concentrations and availability of protein, fat, fibre and ash while reducing the moisture content, facilitating a stable shelf-life. The functional properties of plantain flour could be enhanced / improved by fortification with okra seed flour. The WAC and OAC increased as the degree of fortification increased which suggests its utility as a thickener in liquid and semi-liquid foods. The minerals Zn, K and Fe increased significantly ($P \leq 0.05$) as the percentage of added okra seed flour increased. The addition of okra seed flour to the plantain flour increased Zn bioavailabilty in the fortified flours since the calculated phytate– zinc molar ratio and [Ca][Phytate] / [Zn] molar ratios were far below the critical levels.

REFERENCES

Abioye VF, Ade-Omowaye BIO, Babarinde GO & Adesigbin MK (2011). Chemical, physico-chemical and sensory properties of soy-plantain flour. *Afr J Food Sci* 5(4): 176 – 180.

Adelakun OE, Oyelade OE, Ade-Omowaye BIO, Adeyemi IA & Van De Venter M (2009). Influence of pretreatment on yield, chemical and antioxidant properties of a Nigerian okra seed (*Abelmoschus esculentus* Moench) flour. *Food Chem Toxicol* 47 (3) 657 – 661

Adeniji TA, Sanni LO,Barimalaa IS & Hart AD (2007). Anti-nutrients and heavy metals in some new plantain and banana cultivars. *Nig Food J* 25 (2) : 165 – 170.

Adeniji TA & Tenkouano A (2008). Effect of processing on the proximate, mineral and pasting properties of whole flour made from some new plantain and banana hybrids pulp and peel mixture. *J Trop Agric Food Envir Ext* 7 (2): 99 – 105.

Adetuyi FO, Badejo OF, Ikujenlola AV & Omosuli SV (2009).Storage influence on the functional properties of malted and unmalted maize (*Zea mays* L ssp mays) and soybean (*Glycine max* L Merrill) flour blends. *Afr J Food Sci* 3(2): 056–060.

Adetuyi FO, Osagie AU & Adekunle AT (2011). Nutrient, antinutrient, mineral and zinc bioavailability of okra *Abelmoschus esculentus* (L) Moench Variety. *Amer J Food Nutr* 1(2): 49-54. doi:10.5251 / ajfn.2011.1.2.49.54.

Akindahunsi AA & Oboh G (1999). Effect of some post-harvest treatments on the bioavailability of zinc from some selected tropical vegetables. *La Rivista Italiana Delle Grasse* 76: 285-287.

Altschul AM & Wilcke AL (1985). New Protein Food. Food Science and Technology, Academic Press, Orlando, FL.

Amankwah EA, Ayim I,Dzisi KA & Barimah J (2011). Nutritional content and functional properties of French horn, false horn and FHIA-21. *Amer J Food Techn* 6 (4): 322 – 328.

Aminigo ER & Akingbala JO (2004). Nutritive composition and sensory properties of ogi fortified with okra seed meal. *J Appl Sci Envir Managt* 8 (2): 23 – 28

AOAC (1990). Methods of Analysis of the Association of Official Analytical Chemists. 15th ed. Washington DC, USA.

Chau CF & Cheung PCK (1998). Functional properties of flours prepared from three Chinese indigenous legume seeds. *Food Chem* 61: 429–433.

Fagbemi TN (1999). Effect of blanching and ripening on functional properties of plantain (*Musa aab*) flour. *Plt Fd Hum Nut* 54: 261 – 269.

Ferguson E.L. Gibson RS, Lilian TU, Berry N & Ounpuu S (1988). Phytate, zinc and calcium content of 30 East Africa foods and their calculated phytate : Zn, Ca : phytate and [Ca] [phytate] / [Zn] molar ratios. *J Food Comp Analy* 1: 316–325.

Ikujenlola AV (2008). Chemical and functional properties of complementary food from malted and unmalted acha (*Digitariaexilis*), soybean (*Glycine max*) and defatted sesame seeds (*Sesamun indicuml*). *J Eng App Sci* 39: (6) 471 – 475.

Ikujenlola AV & Fashakin JB (2005). The physico-chemical properties of a complementary diet prepared from vegetable proteins. *J Food Agric Environ Finland* 3(3&4): 20–22.

Jideani VA & Bello BM (2009). Functional properties of okra protein products containing different levels of mucilage. *J Food Agric & Environ* 7 (2): 252 – 255.

Karakoltsides PA & Constantinides SM, (1975). Okra seeds, a new protein source. *J Agric Food Chem* 23: 1024.

Kinsella JE (1976). Functional properties of proteins in foods. *Crit Rev Food Sci Nutr* 1(3): 219-280.

Maga JA (1982). Phytate: its chemistry, occurrence, food interaction, nutritional significance and methods of analysis. *J Agric Food Chem* 30: 1–9.

Marlett JM, Yang EJ & Slavin JL (2002). Position of the American Dietetic Association: Health implications of dietary fibre. *J Amer Dietc Assoc* 102: 375 – 380.

Mepba HD, Eboh L & Nwaojigwa SU, (2007). Chemical composition, functional and baking properties of wheat-plantain composite flours. *Afr J Food Agric Nutr Dev* 7 (1)1 – 22.

Mweta DE, Labuschagne MT, Koen E, Benesi IRM& Saka JDK, (2008). Some properties of starches from cocoyam (*Colocasia esculenta*) and cassava (*Manihot esculenta* Crantz.) grown in Malawi. *Afr J Food Sci* 2: 102–111.

Ohiokpehai O (1985). Plantain as food in Nigeria. Home Economics Program, Faculty of Agriculture, University of Ife, Ile Ife, Nigeria, pp.164 – 165

Otunola ET, Sunny-Roberts EO & Solademi AO (2007). Influence of the addition of okra seed flour on the properties of 'Ogi', a Nigerian fermented maize food. Conference on International Agricultural Research for Development, University of Kassel Witzenhausen and University of Gottingen, 9–11 October 2007

Oyelade OJ, Ade-Omowaye BIO & Adeomi VF (2003). Influence of variety on protein, fat contents and some physical characteristics of okra seeds. *J Food Eng* 57(2): 111–114.

Pacheco-Delahaye E, Maldonado R,Pérez E & Schroeder M (2008). Production and characterisation of unripe plantain (*Musa paradisiacal* L) flours. *Intersciencia* 33 (4): 290 – 296

Salgueiro MJ, Zubillaga MB, Lysionek AE, Caro RA, Weill R & Boccio JR (2002). The role of zinc in the growth and development of children. *Nutrition* 18:510 – 519

SAS (2002). Statistical Analysis System Proprietary software. Release 8.3. SAS Institute Inc., Carry, NC

WHO (1996). Trace Elements in Human Nutrition and Health. WHO, Geneva.

Zakpaa HD, Mak-Mensah EE & Adubofour J (2010). Production and characterisation of flour produced from ripe 'apem' plantain (*Musa sapientum* L. var. paradisiacal; French horn) grown in Ghana. *J Agric Biotechn Sustainable Dev* 2(6): 92–99.