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REGULAR ARTICLE

EFFECT OF THE ADDITION OF DEFATTED OKRA SEED (*Abelmoschus esculentus*) FLOUR ON THE CHEMICAL COMPOSITION, FUNCTIONAL PROPERTIES AND Zn BIOAVAILABILITY OF PLANTAIN (*Musa paradisiacal* Linn) FLOUR

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ABSTRACT

In Nigeria it is advised that nursing mothers should give their baby plantain flour paste "amala ogede" with 'ewedu' *Corchorus olitorius* soup during the process of weaning their baby. The over matured okra that cannot be cut with kitchen knife are thrown away in Nigeria, this lead to postharvest loss of okra. The seed in this okra could be utilised by processing into okra seed flour for the fortification of plantain flour. Since the okra seed flour is rich in oil and the oil contains cyclopropenoid fatty acids which cause some toxicity concerns therefore this work is to evaluate the chemical composition, the functional properties and Zn bioavailability of plantain flour mixed with defatted okra seed flour.

The nutrient content increased significantly ($P \leq 0.05$), protein; 3.88 – 11.38 %, fibre; 3.03 – 16.30 % and ash; 2.72 – 5.77 % while the fat and carbohydrate content reduced significantly ($P \leq 0.05$) as the percentage of defatted okra seed flour increased. The bulk density of the plantain flour decreased significantly ($P \leq 0.05$) from 0.795 g/cm3 to 0.769 g/cm3 as the percentage of okra seed flour increased while the least gelation concentration increased significantly ($P \leq 0.05$) (10 to 20). The calculated [Ca][Phytate]/[Zn] molar ratio for the plantain flour mixed with defatted okra seed flour (0.02 – 0.04 mol/kg) were below the critical level. The increase in the least gelation concentration coupled with increase in the protein content of the resultant flour from the blend means more of the protein will be available in the food made from the plantain flour mixed with defatted okra seed flour.

Keywords: plantain flour, defatted okra seed flour, nutrients, functional property, Zn bioavailability

INTRODUCTION

Okra (*Abelmoschus esculentus L.*) is widely consumed as a fresh vegetable in both temperate and tropical countries. **Rubatzky and Yamaguchi (1997)** reported that the seed is a rich source of protein and oil; contains cyclopropenoid fatty acids which cause some toxicity concerns and is used as a substitute for coffee in some countries. In an earlier study, **Karakoltsides and Constantinides (1975)** found that the Protein Efficiency Ratio (PER) of okra seed flour heated at 130°C for 3hr 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 regards to its content of essential amino acids relative to other plant protein sources **(Oyelade et al, 2003).** It is also reputed to be rich in minerals and vitamins. Its addition to predominantly carbohydrate foods therefore may potentially enrich such foods and considerably improve its nutritional status **(Otunola et al, 2007).** Plantains (*Musa paradisiacal* Linn) are major starch staple crops of considerable importance in the developing world. They are consumed as an energy yielding food and as a dessert. It has been estimated that plantain and other bananas provide nearly 60 million people in Africa with more than 200 calories (food energy) a day. Nearly 90 % of the total banana and plantain produced worldwide are consumed locally in producing countries leaving only 10 % for export **(CGIAR, 1992; 1993; Stover and Simmonds 1987).** In Nigeria plantain have been popular for many years and are an ingredient in many traditional recipes. The most popular method of preparing and preserving the unripe plantain 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).**

In Nigeria it is advised that nursing mother should give their baby plantain flour paste "amala ogede" with 'ewedu' *Corchorus olitorius* or okra soup during the process of weaning their baby. The over matured okra that cannot be cut with kitchen knife are thrown away in Nigeria, this lead to postharvest loss of okra. The seed in this okra could be utilised by processing into okra seed flour for the fortification of plantain flour. Since the okra seed flour is rich in oil and the oil contains cyclopropenoid fatty acids which cause some toxicity concerns.

Therefore the aim of this work is to evaluate the chemical composition, the functional properties and Zn bioavailability of plantain flour blend with defatted okra seed flour.

MATERIAL AND METHODS

Sample collection

The plantains were bought from 'Emure' market in 'EmureUli' in Ondo State. The okra used was freshly harvested, matured and fibrous okra that cannot be cut with kitchen knife. The okra was harvested from a farm in Rufus Giwa Polytechnic, Owo.

Sample preparation

The plantain flour was produced according to the method of **Mepba et al (2007).** The fingers were washed, peeled, cut into thin slices of 2 cm thick and blanched in 1.25% $NaHS0_3$ solution at 80°C for 5 min. Blanched plantain slices were drained and dehydrated in an air-recirculating oven at 60°C for 24 hours. Dried plantain slices were milled into flour using Hammer mill. Flour obtained were sifted through a 250 μm aperture sieve and packed in a two-ply medium density polythene bag. The okra seed were removed from the pod, sundried, dry milled and sieved to obtain a particle size of less than 250μm, the okra seed flour was defatted using petroleum ether in a soxhlet extractor. Samples were extracted for 16hr at a condensation rate of 2-3 drops/s, and the fat was dried at 100^oC for 30 min **(Aminigo and Akingbala, 2004).**

Thereafter, the plantain flour was mixed with the okra seed flour at a ratio of 80:20 and 70:30%. Each sample was thoroughly mixed. The chemical composition, the functional properties and the Zn bioavailability of the plantain flour and defatted okra seed flour blend were determined.

Nutrient analysis

Nutrient composition (fat, crude fibre, and ash) were determined by the standard method of Association of Official Analytical Chemist, the protein content was determined using the micro-kjeldahl method (N x 6.25) and the carbohydrate determination was by difference **(AOAC, 1990).**

Antinutrient analysis

The phytate content was determined by the method of **Maga (1982),** which depend on the ability of standard ferric chloride to precipitate phytate in dilute HCl extract of the flour. The tannin content was determined by treating the flour sample with a mixture of acetone and acetic acid for five hours; the absorbance was measured using spectronic 21D spectrophotometer at a wavelength of 500nm and compared with the absorbance of standard solutions of tannic acid **(Griffiths and Jones, 1977).**

Mineral analysis and Zn bioavailability calculation

One gram of the sample, in triplicate, was dry-ashed in a muffle furnace at 550^{o}C for 8 hours until a white residue of constant weight was obtained. The minerals were extracted from the ash by adding 20.0 ml of 2.5% HCl, heated in a steam bath to reduce the volume to about 7.0 ml, and this was transferred quantitatively to a 50 ml volumetric flask. It was diluted to volume (50 ml) with deionised water, mineral contents were determined using an atomic absorption spectrophotometer (model 372) **(Perkin-Elmer, 1982).** The method of Ferguson et al 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] **(Ferguson et al, 1988).**

Functional property analysis

The bulk density of the flour samples were determined according to the method described by **Okazie and Bello (1988)** and were calculated as mass of flour per unit volume (g/cm^3). The water and oil absorption capacity (WAC) and (OAC) of the flour were determined using the method described by **Beuchat (1977).** The weight of water or oil absorbed by the flour was calculated as WAC or OAC. The method of **Fagbemi (1999)** was used for the determination of least gelation concentration (LGC). Increasing flour concentrations were suspended in 10ml of water in test tubes and heated in a boiling water bath for 1 hour. The tubes were rapidly cooled to 4°C. The least gelation concentration (%) was taken as the minimum concentration when the sample in an inverted tube did not slip or fall down. All determinations were done in triplicates and the mean value recorded in each case.

Statistical analysis

Analysis of variance (ANOVA) was performed on the results for each quality variable to determine the significance of the blend. Mean separation was done where there is a significant difference using Duncan multiple range test procedure as described in the SAS software. Significance was accepted at $P \leq 0.05$ **(SAS, 2002).**

RESULTS AND DISCUSSION

Nutrient

The nutrient composition of plantain flour fortified with okra seed flour is presented in Table 1. When the plantain flour was mixed with defatted okra seed flour, the carbohydrate content reduced significantly ($P \leq 0.05$) from 73.13% to 52.64% as the amount of okra seed flour increased. The protein, fat, fibre and ash content of plantain flour compared favourably with the amount observed by **Pacheco-Delahaye (2008).** There was a significant ($P \leq 0.05$) increase in the value of the nutrients: protein from 3.88% to 11.38% and fibre from 3.03% to 16.30% as the percentage of defatted okra seed flour increased. The increase in these nutrients (protein, 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 soybean flour **(Aminigo and Akingbala, 2004; Jimoh and Olatidoye, 2009).**

The fat content of the plantain flour reduced significantly ($P \leq 0.05$) from 6.01% to 3.96% as the defatted okra seed flour increased, this agreed with the report of Aminigo and Akingbala (2004). The increase in the fibre content of the fortified plantain flour supported the call for the need to increase fibre intake as the dietary guidelines **(USDA, Marlett et al, 2002)** recommended a minimum dietary intake of dietary fibre of 25 g equivalent to 12.5 g/1000 calories consumed which was more than the fibre content of plantain flour. More over the fibre rich flour appears as a promising ingredient for functional foods. The increase in the nutrients may be attributed to the fact that defatted okra seed flour is high in protein, fibre and ash content than plantain flour **(Karakoltsides and Constantinides, 1975; Oyelade et al, 2003; Adelakun et al, 2009).** The decrease in the fat content of the flour may be attributed to the reduction of the fat content of the okra seed flour due to defatting; therefore there was movement of fat from the plantain flour into the defatted okra seed flour. This result shows that the aim of fortification, which was to increase the nutrient content and mineral content (ash) of food was obtained and at the same time the lower moisture content recorded indicates a more shelf stable product.

Table 1 Nutrient content of plantain flour mixed with defatted okra seed flour in %

%PF:DOSF	Moisture content	Carbohydrate	Protein	Fat	Fibre	Ash
100:0	11.23c	73.13d	3.88a	6.01c	3.03a	2.72a
0:100	7.13a	13.73a	47.00c	3.00a	17.74d	11.40d
80:20	10.21b	59.47c	11.38b	4.24b	11.10b	3.60b
70:30	9.95b	52.64b	11.38b	3.96b	16.30c	5.77c

Legend: Value represent mean of triplicate. Values with the same letter along the same row are not significantly different (P≤0.05). PF: Plantain flour, DOSF: Defatted okra seed flour

Antinutrient

The phytate and tannin content of the plantain flour mixed with defatted okra seed flour is presented in Figure 1. The phytate content of this work was within the range reported by **Adeniji et al (2007)** for different plantain cultivars. This value was lower to the value reported for yam, cassava and maize flour **(Adeyeye et al, 2000).** The phytate content of the flour decreased significantly (P≤0.05) from 1.93 g/100g to 1.23 g/100g as percentage defatted okra seed flour increased. The tannin content of the flour was similar to the value reported by **Adeniji et al (2007)** and **Eleazu et al (2010).** The tannin content of the flour decreased significantly (P≤0.05) from 1.56 mg/g to 0.50 mg/g as percentage addition of defatted okra seed flour increased. Reduction of antinutrients in food may be necessary especially when their levels are higher than those generally regarded as safe for human consumption **(Adeniji et al, 2007).**

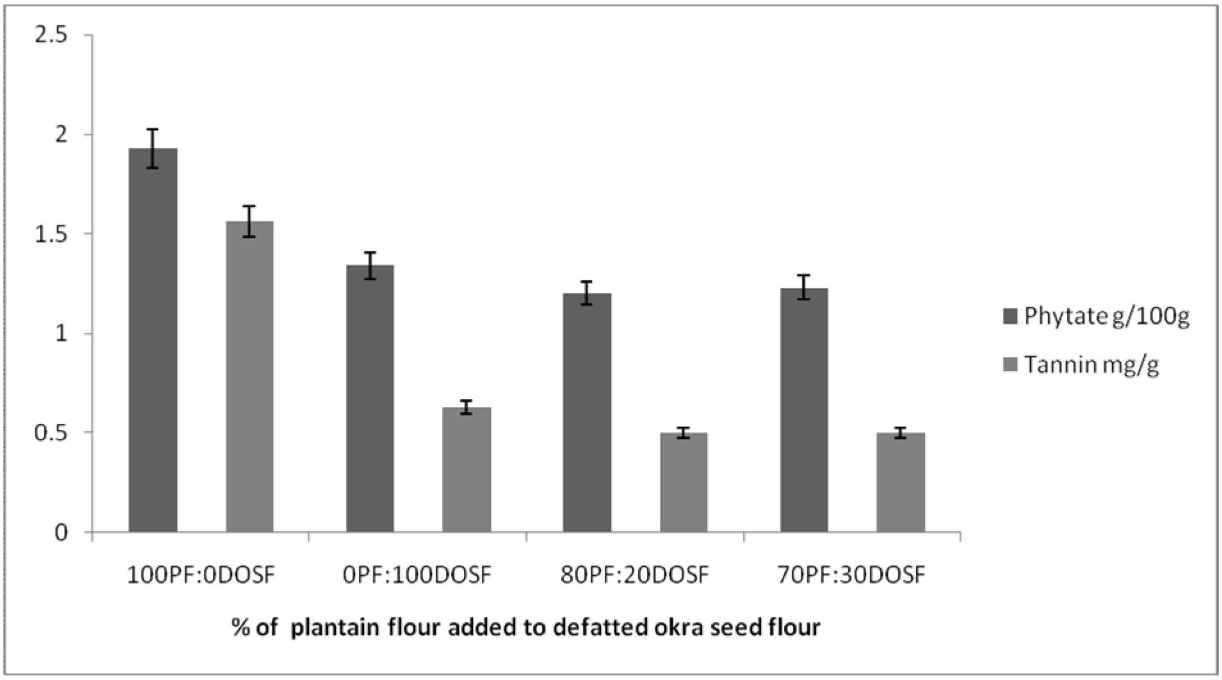

Figure 1 Phytate and Tannin content of plantain flour mixed with defatted okra seed flour

(Value = mean of triplicate. PF: Plantain flour, DOSF: Defatted okra seed flour)

Mineral

The mineral content is presented in table 3. 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. 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)**. The addition of defatted okra seed flour to the plantain flour resulted in significant ($P \leq 0.05$) increase in the minerals Zn and K content of the plantain flour; Zn, 0.10 – 0.59 mg/100g and K, 11.13 – 17.42 mg/100g and while Ca and Fe content of the plantain flour decreased significantly ($P \leq 0.05$) with the addition of defatted okra seed flour; Ca, 5.11 – 3.91 mg/100g and Fe, 3.30 – 2.84 mg/100g. This result agreed with the observation of **Abioye et al (2011)** in the fortification of plantain flour with soy bean flour. The increase/decrease in the mineral content of the plantain flour as a result of the addition of defatted okra seed flour could be attributed to the mineral content of the defatted okra seed flour.

Table 3 Mineral content of plantain flour mixed with defatted okra seed flour in mg/100g

%PF:DOSF	Calcium	Zinc	Potassium	Iron
100:0	5.11d	0.10a	11.13a	3.30c
0:100	3.49a	0.96d	16.82b	2.61a
80:20	4.40c	0.34b	16.50b	2.86b
70:30	3.91b	0.59c	17.42c	2.84b

Legend: Value represent mean of triplicate. Values with the same letter along the same row are not significantly different ($P \leq 0.05$). PF: Plantain flour, DOSF: Defatted okra seed flour

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 plantain flour (193.3) was far above the considered critical value of 15.0 **(Ferguson, 1988; WHO, 1996).** This indicated that the phytate content of the plantain flour will reduce the bioavailability of zinc to a critical level. The addition of defatted okra seed flour to plantain flour caused reduction in the phytate – zinc molar ratio of plantain flour but not below the critical level. The calculated calcium – phytate molar ratio of the plantain flour and the plantain flour mixed with defatted okra seed flour (0.45 – 0.61) were within the critical value of 6.0 **(Ferguson, 1988).** The solubility of phytate and proportion of zinc bound to the complex depend on the dietary calcium levels. Therefore phytate precipitation is not complete until dietary calcium - phytate molar ratios attain a value of approximately 6.0. At lower ratios, phytate precipitations are incomplete causing some dietary zinc to remain in solution **(Oboh et al, 2005).** The calculated [Ca][Phytate]/[Zn] molar ratio is considered a better index for predicting zinc bioavailability compared with the phytate - zinc ratio because of the calcium to phytate interaction **(Akindahunsi and Oboh, 1999).** The calculated [Ca][Phytate]/[Zn] molar ratio for the plantain flour mixed with defatted okra seed flour (0.02 – 0.04 mol/kg) were below the critical level (0.5 mol/kg), an indication of bioavailability of dietary zinc **(Akindahunsi and Oboh, 1999).** The values obtained for calculated [Ca][Phytate]/[Zn] molar ratio in this present work were lower to the value obtained for some okra varieties in Nigeria and some selected tropical vegetables **(Adetuyi, 2011; Akindahunsi and Oboh, 1999).** The zinc is more bio-available in the plantain flour mixed with defatted okra seed flour considering the lower values of the calculated [Ca][Phytate]/[Zn] molar ratio in comparison to the respective critical value.

Table 4 Calculated phytate - zinc, calcium - phytate and [Ca][Phytate]/[Zn] molar ratios of plantain flour mixed with defatted okra seed flour in %

%PF:DOSF	phytate : Zn	Ca : phytate	[Ca][Phytate]/[Zn]^{X}
100:0	193.33d	0.45a	0.25d
0:100	13.33a	0.45a	0.01a
80:20	34.62c	0.61b	0.04c
70:30	21.11b	0.42a	0.02b

Legend: ^{X} mol/kg, PF: Plantain flour, DOSF: Defatted okra seed flour

Functional properties

The bulk density and Least gelation concentration of plantain flour mixed with defatted okra seed flour is presented in Table 2. The bulk density of the plantain flour mixed with defatted okra seed flour decreased significantly ($P \leq 0.05$) from 0.795 g/cm^3 to 0.769 g/cm^3 as the percentage of okra seed flour increased. The reduction in the bulk density of the flour agreed with the report of other workers in the evaluation of maize-soybean flour blends **(Edema et al, 2005; Adetuyi, 2009).** The least gelation concentration increased significantly ($P \leq 0.05$) from 10 to 20 as the percentage of defatted okra seed flour increased. This result agreed with the observation of **Adetuyi et al, (2009)** in maize-soybean blend. The effect of the increase in the least gelation concentration is that more of the fortified flour is required for gelation which means more of protein will be incorporated into the food. The water absorption capacity and oil absorption capacity (WAC and OAC) are presented in figure 2. The WAC and OAC of the plantain flour increased significantly ($P \leq 0.05$) as the percentage of defatted okra seed flour added increased; WAC from 160 to 250, while OAC from 96.80 to 123.20. The increase in the WAC of the fortified flour as the defatted okra seed flour added increased agreed with the observation of **Sefa-Dedeh et al, (2002)** and **Adetuyi et al, (2009)** in the fortification of maize flour with soybean. The increase in the WAC and OAC 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 **Altchul and Wilcke (1985)** are conditions that facilitate binding and entrapment of water. Therefore the fortified flour due to high WAC could be used as thickener in liquid and semi liquid foods

(Fagbemi, 1999). The increase in protein also enhances the hdrophobicity and exposed more of the polar amino acid to the fat (Chau and 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 flavour retainer and increase the mouth feel of foods.

Table 2 Bulk density and least gelation concentration of plantain flour mixed with defatted okra seed flour

%PF:DOSF	Bulk Density (g/cm^3)	Least gelation concentration(w/v)
100:0	0.795c	10.00a
80:20	0.786b	20.00b
70:30	0.769a	20.00b

Legend: Value represent mean of triplicate. Values with the same letter along the same row are not significantly different (P≤0.05). PF: Plantain flour, DOSF: Defatted okra seed flour

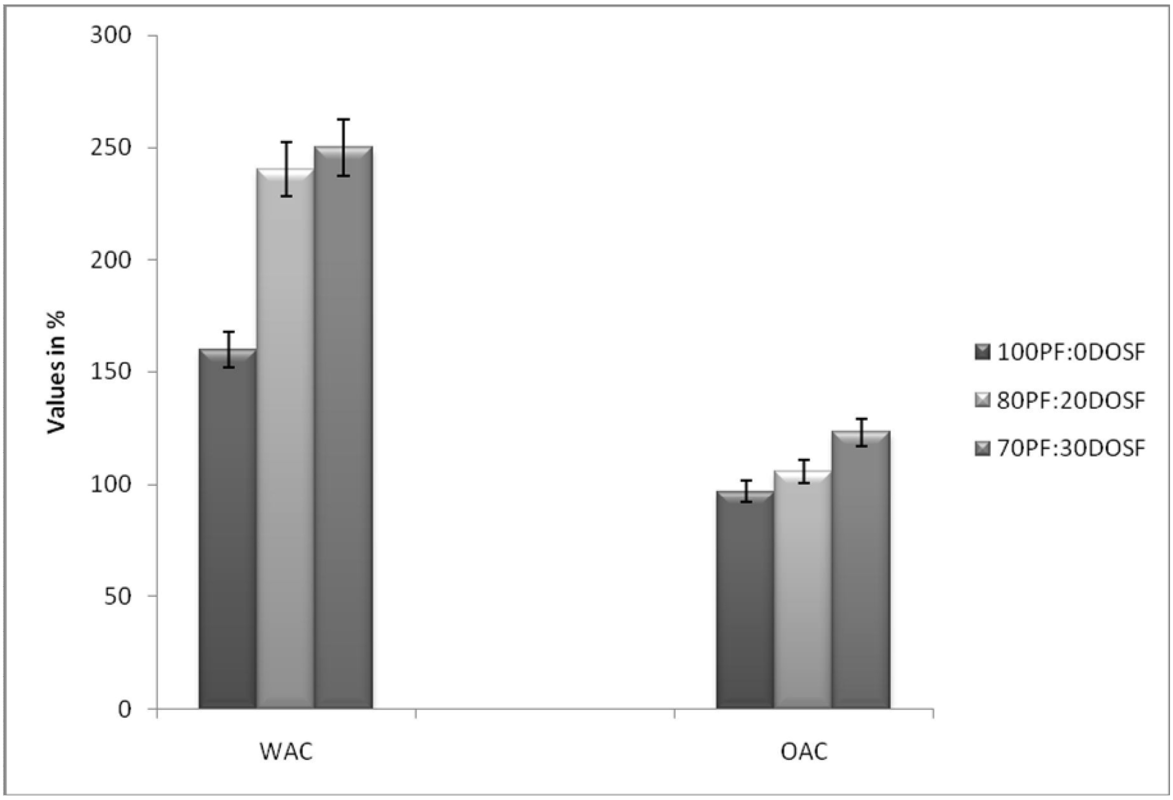

Figure 2 Water and Oil absorption capacity of plantain flour mixed with defatted okra seed flour (Value = mean of triplicate PF: Plantain flour, DOSF: Defatted okra seed flour)

CONCLUSION

The addition of defatted okra seed flour to plantain flour resulted in increase in the protein content and reduction in the fat content of the plantain flour. Fibre and ash content of the flour also increased. These nutrients become more available in the food prepared from the plantain flour. The increase in the least gelation concentration coupled with increase in the protein content of the resultant flour from the blend means more of the protein will be available in the food made from the plantain flour mixed with defatted okra seed flour. The zinc is more bio-available in the plantain flour mixed with defatted okra seed flour considering the lower values of the calculated [Ca][Phytate]/[Zn] molar ratio in comparison to the critical value of 0.5 mol/kg.

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