MICRONUTRIENTS, ANTI-NUTRIENTS AND MICROBIAL QUALITY OF BREAKFAST CEREALS PRODUCED FROM MAIZE, UNRIPE PLANTAIN, SOYBEANS AND DATES

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Abstract:

Breakfast cereals (BFCs) consumption is spreading and steadily replacing traditional diets due to its compositions and convenience for various consumers. This study assessed vitamins, minerals, anti-nutrients and microbial quality of BFCs produced from yellow maize, unripe plantain, soybeans and dates. These crops were processed into flours and formulated into blends of five samples at different percentages: Formulated samples were: A-100% maize; B-60:5:20:15; C-55:10:20:15; D-50:15:20:15 and E-45:20:20:15. Flour blends were mixed, moistened lightly kneaded, oven dried at 80 °C for 2 hours, crushed and lightly toasted. Vitamins, minerals, anti-nutrients and microbial contents of BFCs were determined using standard methods. . Results revealed that Vitamins A (98.12- 121.64 µg/100g), B_1 (0.17 – 0.21 mg/100), C (6.19 – 7.88 mg/100), and mineral contents including iron (3.11 – 3.82 mg/100), zinc (0.62 – 0.79 mg/100) and potassium (701.08 - 781.44 mg/100) concentrations of BFCs increased significantly with increasing addition of unripe plantain flour. The oxalate (0.61 – 0.67 mg/100), phytate (0.39 – 0.41 mg/100), tannin (0.12 – 0.13 mg/100) concentrations, and total bacterial count (0.25×10^4 - 1.75×10^4 CFU/g), total fungi count (0.00 – 0.50×10^4 CFU/g) and total coliform count (0.10 to 0.30×10^4 CFU/g) of BFCs were within recommended safe limits. This study demonstrated that supplementing yellow maize with unripe plantain flour in soybean-date-based BFCs can enhance the vitamins and minerals, yield low anti-nutrient and safe food products. Commercial breakfast cereal producers could incorporate unripe plantain flour, in maize-soybean-date blend for consumer healthier choice.

***Keywords**:* Anti-nutrient, breakfast cereals, date, microbial quality, micronutrients, unripe plantain.

Introduction

Breakfast cereals (BFCs) are ready-to-eat cereals, typically in form of flake , which can be consumed plain or with milk (Nkiru, Obianuju & Oladipo, 2019). BFCs are commonly referred to as cereals, morning cereals, or breakfast cereals (Abogunrin & Ujiroghene, 2022). Breakfast cereals has become an important component of diverse consumers food intake (Félix-Medina, Montes-Ávila, Reyes-Moreno, Perales-Sánchez, Gómez-Favela, Aguilar-Palazuelos & Gutiérrez-Dorado, 2020) and are sources of nutrients, including vitamins and minerals (Sumczynski, Kowalczyk & Słupski, 2023). Due to increasing awareness of nutrition, convenience, and economic factors, these breakfast cereals, along with bread, are progressively replacing many traditional breakfast staples that were previously consumed (Nkiru *et al*., 2019). Breakfast cereals products are ready-to-eat food items primarily derived from grains such as oats, maize, wheat, rice, and barley predominantly consumed in the morning (Fasuan, Ayodele & Olaniyi, 2021; Ariviani & Nastiti, 2024; Nkiru, Obianuju & Oladipo, 2019). Maize (Zea mays) serves as the primary raw material in the production of breakfast cereals (Qin *et al.*, 2022). Products derived from soybean protein have been employed as functional food components in nearly every food group available to consumers (Qin *et al.*, 2022). Dates consist of more than 70% sugar, of which are glucose, fructose, and a small amount of (Abogunrin & Ujiroghene, 2022). Yellow maize is a pro vitamin A fortified maize that has the potential of addressing vitamin A deficiency which is a major public health concern in Nigeria and Africa at large (Pillay, Derera, Siwela & Veldman, 2011). However, maize has a relatively low nutritional profile, particularly in lysine and micronutrients such as certain trace minerals (Barber, Watson & Drake, 2017; Dragana, Jane & Ivana, 2015). Therefore, enhancing the nutritional value of breakfast cereals by combining maize with other nutrient-rich food sources is advisable (Mbaeyi-Nwaoha & Uchendu, 2016). Plantain (*Musa paradisiaca*) is a large, perennial herb cultivated in tropical and subtropical regions, including Nigeria. Both ripe and unripe plantains are consumed in various forms, such as boiling, frying, roasting, or processing into flour for making 'amala' (Famakin, Fatoyinbo, Ijarotimi, Badejo & Fagbemi, 2016). Plantains are sources of iron, potassium, and vitamin A. However, they are naturally low in protein (Lamptey, Velayoudom, Kake, Uloko, Rhedoor, Kibirige, Ndour Mbaye, Sobgnwi & Kalra, 2019; Oluwajuyitan & Ijarotimi, 2019; Honfo et al., 2020). Soybeans are widely utilized because they have a higher nutritional content than other legume crops sucrose. Dates are also rich in fibers, vitamins, and minerals such as magnesium, iron, zinc, potassium. The incorporation of unripe plantain, soybeans, and dates into flake production offers a promising solution to the nutritional limitations of maize-based breakfast cereals.

Unripe plantain is rich in dietary fiber and micronutrients (Lamptey et al, 2019; Oluwajuyitan & Ijarotimi, 2019; Honfo et al, 2020). This study aimed to determine the vitamins, minerals, anti-nutrients and microbial quality of BFCs produced from yellow maize, unripe plantain, soybeans and dates.

Materials and Methods

Yellow maize, unripe plantain, soybeans and dates were purchased from a retail market in Ilaro, Ogun State, Nigeria. Other materials and equipment used were gotten from the Nutrition and Dietetics Kitchen, Federal Polytechnic Ilaro, Ogun State.

Sample Preparation

Processing of maize into maize flour

Maize was processed into maize flour using the method described by Anne *et al.* (2019). About 3 kg of yellow maize was sorted to remove spoilt grains, stones and other extraneous materials. The grains were winnowed, washed with potable water to remove dirt, steeped in portable water for 12 hours, drained and oven-dried at 60 ℃ for 10 hours. It was milled into flour using attrition milling machine that was fitted with sieved size of 0.4mm aperture to fine flour. The flour was kept at room temperature in plastic container with airtight lids and labelled for further use.

Processing of soybean into soybean flour

Two kilograms of soybean was processed according to the methods described by Akpara and Ogbogo (2015). Soybean was sorted, washed and steeped in water at a 1:2 weight-to-volume ratio for 12 hours, dehulled, oven dried at 60 ºC for 1 hour, milled using an attrition mill, flour was sifted through a 0.15 mm mesh screen. Soybean flour was packaged in airtight container, labelled and stored at room temperature for further use.

Processing of unripe plantain into unripe plantain

Unripe plantain flour was processed adopting the method described by Ndayambaje *et al. (*2019). One and the half kilogram of unripe plantain was rinsed in clean water, peeled with a knife, sliced into thin uniform sizes and blanched for 5 minutes to suppress the action of enzymes. It was oven dried at 60 ℃ for 14 hours, milled into powdered form and it was sieved using 0.4mm aperture into flour. The flour was kept at room temperature in plastic container with airtight lids and labelled for further use.

Processing of dates into date meal

The method described by Obiegbuna et al. (2017) was used with slight modification to process dates into date meal. Two kilograms of date fruit was sorted, washed, deseeded and cut into 2 mm sizes. The pulp was oven dried at 46 °C for 8hours and subsequently milled into fine powder in an attrition mill. The powder was sieved through 2mm mesh screen, packaged in air tight container and stored at 25 ºC temperature for further use.

Formulation of samples

Breakfast cereal was formulated from the blends of yellow maize flour. unripe plantain flour, soybean flour and date powder. Five samples of breakfast cereals were produced by using the graded levels presented on Table 1 and 100% yellow maize flour served as the control. Table 1 shows the formulation ratio of breakfast cereals .

Table1 Formulation of breakfast cereals.

Samples	Maize	Unripe plantain	Soybean	Date
A	100	0	0	0
B	60	5	20	15
C	55	10	20	15
D	50	15	20	15
E	45	20	20	15

Key: A (maize 100% control), B (maize 60%, unripe plantain 5%, soybean 20%, date15%), C (maize 55%, unripe plantain10%, soybean 20%, date 15%), D (maize 50%, unripe plantain15%, soybean 20%, date 15%) and E (maize 45%, unripe plantain20%, soybean 20%, date 15%)

Breakfast Cereal Production

The method described by Nkiru *et al.* (2019) was used for the production of breakfast cereals with slight modification. The breakfast cereal was made by mixing the composite flour of yellow maize. unripe plantain, soybean and date meal. Water was added to the mixture to form a batter which was poured thinly on cleaned flat greased stainless tray. The batter was oven dried at 80 °C for 2 hours until semi dried samples were obtained, crushed into small sizes with sharp knife, placed back

into the oven for further drying. The samples of breakfast cereal were allowed to cool, packaged in air-tight containers, labelled and used for laboratory analysis. Figure 1 shows the flowchart for production of breakfast cereals made from flour blends of yellow maize, unripe plantain, soybean and date meal.

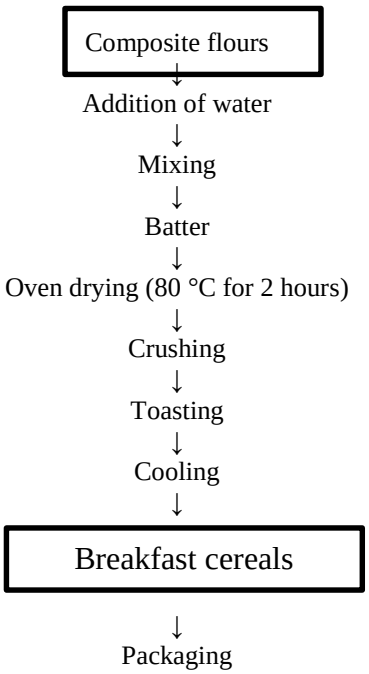

Figure1: Flowchart for the production of breakfast cereals

Chemical and microbial Analysis of Breakfast Cereals

Vitamin A was determined using the method described by Achinkann et al., (2013). Vitamins B_1 and C were determined according to the method described by Baraket et al. (1973) and modified by Okwu and Josiah (2006). Iron, zinc and potassium elements were measured with Atomic Absorption Spectrophotometer (Thermo scientific S Series Model GE 712354) after digesting with a perchloric – nitric acid mixture (AOAC, 2000). Phytate was determined using the method described by Maga (1982). The method of Swain (1979) was used for the determination of tannin contents of samples of breakfast cereal. Oxalate was determined using methods described by Day and Underwood (1986).

Microbial Determination Total plate count, total fungi count and total coliform count of breakfast cereal was determined following the method described by Ochei and Kolhaktar (2008).

Statistical Analysis

Data collected were subjected to statistical analysis using Analysis of Variance (ANOVA) to identify significant difference among sample means. The means were separated with the use of Duncan New Multiple Range Test (DMRT) with Statistical Package for Social Sciences (SPSS) version 23.0.

Results

Vitamin Contents of Breakfast Cereals

Table 1 shows the vitamin contents of breakfast cereals

Table 1: Vitamin Content of Breakfast Cereals

Samples	Vitamin A (µg/100 g)	Vitamin B_1(µg/100 g)	Vitamin C (µg/100 g)
A	98.13^{a} ±0.00	0.17^{a} ±0.00	6.19^{a} ±0.00
B	98.86^{a} ±0.01	0.18^{a} ±0.01	6.82^{a} ±0.01
C	100.82^{b} ±0.01	0.19^{b} ±0.01	7.0^{b} ±0.00
D	110.73^{c} ±0.00	0.19^{b}±0.00	7.36^{c} ±0.02
E	121.64^{d} ±0.01	0.21^{c} ±0.01	7.88^{d} ±0.00

Values are means of duplicate determination ± SD (Standard deviation). Means in the same column with different superscript are significantly different (p>0.05).
Key: *A (maize 100% control), B (maize 60%, unripe plantain 5%, soybean 20%, date15%), C (maize 55%, unripe plantain10%, soybean 20%, date 15%), D (maize 50%, unripe plantain15%, soybean 20%, date 15%) and E (maize 45%, unripe plantain20%, soybean 20%, date 15%)*

Mineral Composition of Breakfast Cereals

Results of the mineral composition of the breakfast cereal formulated from yellow maize-soybean blends flavoured with firmly ripe banana flour is shown on Table 2.

Table 2: Mineral Content of Breakfast Cereals

Samples	Iron (mg/100 g)	Zinc (mg/100 g)	Potassium (mg/100 g)
A	3.11^{a}±0.00	0.62^{a}±0.00	701.93^{a}±0.01
B	3.41^{b}±0.00	0.68^{b}±0.00	712.08^{b}±0.01
C	3.68^{c}±0.00	0.73^{c}±0.00	726.11^{c}±0.00
D	3.72^{d}±0.01	0.75^{c}±0.01	744.05^{d}±0.01
E	3.82^{e}±0.00	0.79^{d}±0.00	781.44^{e}±0.01

Values are means of duplicate determination ± SD (Standard deviation). Means in the same column with different superscript are significantly different (p>0.05).
key : *A (maize 100% control), B (maize 60%, unripe plantain 5%, soybean 20%, date15%), C (maize 55%, unripe plantain10%, soybean 20%, date 15%), D (maize 50%, unripe plantain15%, soybean 20%, date 15%) and E (maize 45%, unripe plantain20%, soybean 20%, date 15%)*

Anti-nutrient contents of Breakfast Cereals

The anti-nutrient contents of samples of breakfast cereals are presented on Table 3.

Table 3: Anti-nutrient contents of breakfast cereal

Samples	Oxalate (mg\g)	Phytate (mg\g)	Tannin (mg\g)
A	0.61^{a}±0.00	0.39^{a}±0.01	0.12^{a}±0.01
B	0.63^{ab}±0.00	0.39^{a}±0.00	0.12^{a}±0.00
C	0.65^{b}±0.02	0.40^{ab}±0.02	0.12^{a}±0.00
D	0.67^{b}±0.00	0.40^{bc}±0.01	0.13^{ab}±0.01
E	0.67^{c}±0.01	0.41^{c}±0.01	0.13^{b}±0.01

Values are means of duplicate determination ± SD (Standard deviation). Means in the same column with

different superscript are significantly different (p>0.05). Key: *A (maize 100% control), sample B (maize 60%, unripe plantain 5%, soybean 20%, date15%), sample C (maize 55%, unripe plantain10%, soybean 20%, date 15%), sample D (maize 50%, unripe plantain15%, soybean 20%, date 15%) and E (maize 45%, unripe plantain20%, soybean 20%, date 15%)*

Microbial Quality of Breakfast Cereals

The Microbial quality of breakfast cereals is presented on Table 4

Table 4: Microbial Quality of Breakfast Cereals

Samples	TBC (10^4 Cfu/g)	TFC (10^4 Cfu/g)	TCC (10^4 Cfu/g)
A	0.25^{a}±1.41	0.00^{a}±1.41	0.10^{a}±0.71
B	0.70^{b}±0.00	0.10^{ab}±1.41	0.15^{a}±1.41
C	1.15^{c}±0.00	0.20^{ab}±1.41	0.20^{a}±1.41
D	1.20^{b}±0.71	0.40^{bc}±0.00	0.25^{a}±0.71
E	1.75^{c}±2.12	0.50^{d}±2.82	0.30^{a}±1.41

Values are means of duplicate determination ± SD (Standard deviation). Means in the same column with different superscript are significantly different (p>0.05). A (maize 100% control), B (maize 60%, unripe plantain 5%, soybean 20%, date15%), C (maize 55%, unripe plantain10%, soybean 20%, date 15%), D (maize 50%, unripe plantain15%, soybean 20%, date 15%) and E (maize 45%, unripe plantain20%, soybean 20%, date 15%)

Discussion

Vitamin Contents of Breakfast Cereals

The vitamin A content ranges from 2.1 mg/100g to 7.8 mg/100 g. The values were increasing with increase in the percentage composition of unripe plantain. This could be as a result of the presence of beta carotene in the yellow maize. Edima-Nyah et al. (2019) reported a much higher values ranging from 11.30 to 21.15 mg/100 g in breakfast cereals from blends of local rice, African yam beans and coconut flour. Vitamin A is an essential vitamin and its deficiency in the body cause night blindness (Ojimelukwe et al., 2005). The US Recommended daily allowance (USRDA) for vitamin A is 5000 I.U. The vitamin A content of the breakfast cereals ranged from 98.12 µg to 121.64 µg . The control sample A containing 100% maize exhibited the lowest vitamin A content (98.12µg/100g).The result obtained from this study which is higher (70.07 to 74.01µg) than that reported by Ujong *et al*. (2023) of breakfast cereals made from the blend of yellow maize enriched with soybean and groundnut. Vitamin A is essential for young children to maintain healthy vision and immunological function. According to Ujong *et al*. (2023) yellow maize can supply 40– 50% of the adult Recommended Dietary Intake for vitamin A, making it an efficient source of vitamin A. Nevertheless, maize typically lacks other vital nutrients, sample B (60% maize, 5% unripe plantain, 20% soybean, and 5% date) showed a marginal increase in vitamin A (98.12 µg/100g) this is similar to the report by Ahmadu *et al*. (2023) who realized an increase in vitamin A content in their study by the substitution with soybean and date, this increase in this study may be as a result of the addition of the unripe plantain. However, sample E had a higher Vitamin B1 content (0.21 µg/100g) compared to sample A (0.164 µg/100g). Ahmadu *et al*. (2023) reported the vitamin B_1 (1.36 to 2.57 mg) of breakfast cereals made from the blend of millet flour supplemented with soybean and date fruit flour. The vitamin B_1 content indicated the possible effect of the extra substances on the micronutrient profile . The body uses thiamine as a co-enzyme in the metabolism of energy. Additionally, it helps young children and adolescents maintain a healthy mental attitude and treat beriberi. Thiamine is equally important for nerve signal transmission and muscle contraction. Vitamin C content was notably higher in sample E (7.88 µg/100 g), which included more unripe plantain, soybean and date, ingredients known for their ascorbic acid content. The increase in ascorbic acid content observed in all the substituted samples could be attributed to the addition of different levels of unripe plantain in the products. Ahmadu *et al*. (2023) reported a vitamin C content of 1.55 to 2.22mg which is lower when compare to the report from this study. Vitamin C is important in the prevention of scurvy and development of strong immune system in newborns, young children, and adults (Ahmadu *et al*., 2023).

Mineral Composition of Breakfast Cereals

Mineral analysis revealed that sample E, which contained the highest proportion of unripe plantain (20%) and soybean (20%), provided the most substantial amounts of iron (3.82 mg/100 g), zinc (0.79 mg/100 g), and potassium (781.44 mg/100 g). Iron content of the samples varied significantly ($p<0.05$) from each other. The sample E had the highest value (3.82 mg/100 g). While the sample A had the least iron content (3.11mg/100 g) . The values (3.11-3.82 mg/100 g) obtained in this study were high. However, the values of iron was consistent with the values reported by (Mbaeyi-Nwaoha and Uchendu , 2016) who realized an increase in iron content from 3.22 to 5.64 mg/100 g in their breakfast cereals made from fermented soybean paste and acha mixes. This suggests that plantain, dates and soybean may be important for increasing mineral content, which is especially important for correcting iron and zinc deficiencies that are common in Nigeria children. (Ijarotimi & Oluwalana , 2013). In contrast sample A, with a lower proportion of these ingredients, had the lowest mineral levels, underscoring the need for diversified ingredients to improve micronutrient density in breakfast cereals. The zinc content of the breakfast cereals varied from 0.68-0.75mg/100g. Sample E substituted with 20% unripe plantain, 20% soybean 15% date fruit flour had the highest zinc content while sample A had the least zinc value (0.62mg/100g). The result shows an increase in the amount of unripe plantain, soybean and date fruit flour added to the products. However higher values were reported by (Usman *et al.*, 2015) for breakfast cereals made from blends of African yam bean, maize ,and defatted coconut flour. Zinc is essential for every living cell which also aids in blood coagulation. Additionally, it is necessary for hormone regulation, cell growth and protein synthesis, wound healing, and reproduction. The

potassium contents of the samples which ranged from 701.93-781.44mg/100g increased significantly ($p<0.05$) as the levels of unripe plantain, soybean, date fruit flour increased in the products. There was a significant difference ($p<0.05$) between the samples in the potassium content. However the results shows that subsequent increase in the potassium content with increase in the levels of unripe plantain flours substituted for maize flour in the samples. The values for potassium were higher compared to that reported by (Ahmadu *et al*., 2023) in their study of breakfast cereals produced from millet flour, soybeans and date flour. Potassium is a crucial mineral that aids in fluid equilibrium and enables muscles to contract and nerves to react to stimuli.

Anti-nutrient contents of Breakfast Cereals

Oxalate, phytate, and tannin contents, were highest in sample E. Oxalates and phytate are known to reduce the bioavailability of essential minerals such as iron (Gibson, 2021). Oxalate contents of the sample ranged from 0.61 to 0.67mg/ 100g. In this study sample A had the lowest values of oxalate content. High anti-nutrient content suggests that further processing or ingredient modifications might be required to reduce these compounds and improve overall nutrient absorption. A moderate proportion of plant-based ingredients can balance nutrient content and anti-nutrient effects (Oluwafemi *et al.,* 2020). Oxalates is important in diet in reducing mineral absorption. Phytate and tannin contents.of the samples ranged from 0.39- 0.41% and 0.12-0.13%, respectively. Samples A and E have the lowest and highest values of phytate and tannin, respectively. The tannin contents of the current study were lower than the values (0.80 - 1.72) reported by Usman *et al. (2021*) of breakfast cereals made from blends of local rice , soybeans and defatted coconuts flour. Tannin are important to the diet and help improve blood pressure and reduce the risk of heart disease.

Microbial Quality of Breakfast Cereals

The total bacterial count in the breakfast cereals varied between 0.25 and 1.75 × 10^4 CFU/g, with noticeable differences across the samples. According to Anon (2001), a bacterial count of 10^4 CFU/g is deemed satisfactory, while counts surpassing 10^5 CFU/g indicate substandard quality. Based on this benchmark, the total bacterial counts recorded in the breakfast cereals fall within acceptable safety limits. The total fungal count spanned from 0.00 to 5.00 × 10^3 CFU/g, with with significant variations observed among the samples. Additionally, the total coliform count was recorded between 0.10 and 0.30 × 10^4 CFU/g, also exhibiting significant discrepancies. The microbial counts observed in this study conform to the safety standards set by the International Commission on Microbiological Specifications for Foods, which recommends microbial limits between 10^2 and 10^5 CFU/g for ready-to-eat products.

Conclusion

This study showed that ready-to-eat breakfast cereals could be produced from blends of yellow maize, unripe plantain, soybean, date flour and as sources of vitamins A, B_1 and especially vitamin C which are absent in some commercial products. Samples of breakfast cereal in the current study were sources of iron, zinc and potassium. Blends of flour and processing procedures employed in this study yielded samples of breakfast cereals with safe levels of anti-nutrients and high microbial quality.

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