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SENSORY EVALUATION AND ANTINUTRIENT PROFILE OF *Musa paradisiaca* (LINN.) FORTIFIED CHINCHIN

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Abstract
Food fortification for man's optimal derivation of nutrients is an already established nutritional approach for preventing and managing nutrition-related diseases, but it could also have unforeseen side effects. Consequently, this study evaluated the antinutrient profile and sensory properties of wheat flour chinchin fortified with Plantain, *Musa paradisiaca*. Four batches of wheat flour were prepared following established protocols; they were fortified with plantain to make chinchin in a ratio of 4:1, except for the control group. Group 1 served as the control; Group 2 was fortified with ripe plantain; Group 3 was fortified with unripe plantain; and Group 4 was fortified with an equal mixture of ripe and unripe plantains. The antinutrient contents of the chinchin were determined following established protocols, and the sensory attributes were evaluated by 30 panelists of consumers using a 5-point hedonic scale quantity analysis. Findings showed that unripe plantain-fortified chinchin has significantly ($p<0.05$) low oxalate, phytate and lectin contents. Fortification with plantain (ripe or unripe) significantly increased the saponin content of the chinchin. In conclusion, fortification of chinchin with *Musa paradisiaca*, most especially the unripe, positively modified antinutrient contents; has no adverse impact on sensory attributes, and could therefore be of health benefits to man.

Keywords: Antinutrient, Diseases, Fortification, *Musa paradisiaca*, Sensory

INTRODUCTION

Food fortification has gained prominent attention in the 21st century and has become a notable nutritional tool for improving human health and overall growth and development. It is an inexpensive, effective, and simple strategy for improving the nutritional quality of food. Functional foods (fresh and processed) have been reported to significantly contribute to a healthy body, immunity enhancement, and management of long-term illnesses (Sing *et al*., 2022). Dietary changes and/or modifications do not only affect one's current health, but also aid in predicting the onset and management of diseases such as hypertension, obesity, diabetes, and cancer, among others (Xiao *et al*., 2024). However, in order to maximize the nutritional advantages of food fortification, it is expedient to identify any adverse health effects that might arise from the consumption of fortified foods.

Musa paradisiaca, a monocotyledon plant, reported to as having a low-glycemic index, as well as rich in potassium, dietary fiber and resistant fiber in comparison with cereals (Ayodele and Erema, 2011). Its consumption is beneficial to diabetic patients (Akubor and Ishiwu, 2013).

Wheat is a cereal crop of global nutritional and economic relevance (International Grains Council, 2017). The International Grains Council (2017) estimated that over 700 million metric tons of wheat flour was processed for consumption in 2014/2015 globally. Chinchin is a fried, golden brown, crunchy wheat flour-based snack commonly available in all parts of Nigeria. It is one of the popularly eaten Nigerian snacks that are usually made with processed or refined wheat flour. It is consumed by all categories of people in the country, children, youths, and adults. However, reports exist that processed wheat-based products are low in quality nutrients, and nutritional improvement was recommended through fortification (Ficco and Borrelli, 2023). Globally, as of 2016, over 80 countries have legislation to fortify wheat flour, 14 countries have legislation to fortify maize products, and six countries have legislation to fortify rice (Food Fortification Initiative, 2016). It can then be inferred that by now, fortification of grains should be a global call. Antinutrients, which can be found at some level in almost all plants for varied reasons are of concern to nutritionists and dieticians when they exceed acceptable concentrations, and are being targeted in modern crops for reduction or total removal via genetic engineering. Since many of them have health-beneficial effects in humans (Soetan, 2008; Popova and Mihaylova, 2019); the reduction approach via food fortification could be a better option rather than complete elimination. This is because they do not pose any serious adverse effects on human if occurred within acceptable concentration range.

Based on the forgoing, *Musa paradisiaca* was considered a good choice to fortify wheat flour in chinchin production. This study consequently investigated the antinutrient factors and sensory attributes of *Musa paradisiaca* (plantain)-fortified chinchin with the aim to determine the impact of the fortification on both the nutrients and general acceptability of the product. It is hoped that the findings of the study will provide useful information on the nutritional quality of plantain-fortified chinchin, which could be explored in nutritional counseling.

MATERIALS AND METHODS

Materials

Golden Penny Prime wheat flour, Kings vegetable oil, Simas margarine, Dangote salt, Hollandia evaporated milk, Golden Penny Premium white granulated sugar, baking powder, egg, powered nutmeg, water, frying pan, knife, and cooking gas cylinder were all bought from Ibaka Market, Akungba-Akoko, Ondo State, Nigeria, latitude 7.4740°N and longitude 5.7379°N.

Chemicals

All chemicals and reagents used were of analytical grade. Isobutyl alcohol, sulfuric acid, potassium permanganate and hydrochloric acid were obtained from Sigma-Aldrich, USA while iron (III) chloride, sodium carbonate and magnesium carbonate were obtained from BDH, UK.

Sample collection

Fresh unripe bunch of plantain (*Musa paradisiaca*) was bought from Ibaka Market, Akungba-Akoko, Ondo State, Nigeria. The sample was identified and authenticated by a competent curator in the Plant Science and Biotechnology Department Herbarium (PSBH) Unit, Faculty of Science, Adekunle Ajasin University, Akungba-Akoko, Ondo State. It was assigned PSBH-251 as voucher specimen code and a sample deposited at the herbarium.

Sample preparation

The plantain cultivars were divided into two parts; one part was kept in a tied sack for seven days to get ripened, and was used as ripe plantain blend; while the other part was left open in a room in order to reduce exposure to heat and water, and was used as unripe plantain blend. On the eighth day, both the ripe and unripe plantain were thoroughly washed, peeled, sliced, and blended to a smooth texture to have the following plantain products; ripe blended plantain, unripe blended plantain, and an equal mixture of ripe and unripe blended plantains (see Table 1). Similarly, four batches of wheat flour designated as Group 1, Group 2, Group 3, and Group 4 (see Table 1) were prepared in bowls following the standard method for making chinchin reported by Lawan *et al*. (2024) with slight modifications. All solid ingredients were grinded into powdered form for convenience and ease of measurement with a small container graduated in milliliters.

Table 1: Groupings and summary of used ingredients

Ingredients (ml)	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Flour	124	124	124	124
Baking powder	0.3	0.3	0.3	0.3
Milk	2.5	2.5	2.5	2.5
Margarine	3.75	3.75	3.75	3.75
Salt	0.15	0.15	0.15	0.15
Sugar	5.63	5.63	5.63	5.63
Egg	16.25	16.25	16.25	16.25
Nutmeg	0.3	0.3	0.3	0.3
Water	31	-	-	-
Ripe plantain	-	31	-	15.5
Unripe plantain	-	-	31	15.5

Keys: Group 1 - Flour Chinchin; **Group 2** - Ripe Plantain Fortified Chinchin; **Group 3** - Unripe Plantain Fortified Chinchin; **Group 4** - Ripe and Unripe Plantain Fortified Chinchin

Note: Both liquid and powdered ingredients were measured with a small container marked in ml

Dry ingredients such as sugar, salt, and baking powder were measured and sieved into the bowls and mixed thoroughly to ensure homogeneity. Melted margarine was added and mixed thoroughly, while a mixture of egg and milk was also added and mixed thoroughly to form dough. Thereafter, 31 ml of plantain blends, which represents ratio 1:4 of the fortification (i.e. 25%) was added to the dough of the test groups, mixed and covered for two minutes. The dough was then placed on a board surface and kneaded until it became smooth and elastic. It was subsequently cut into cubes using a knife, followed by frying in a pan on low heat for 7 minutes until it became golden brown. Thus, the three different blends of plantain were used to fortify the different groups of wheat flour with the exemption of the control group, in a ratio of 4:1. The *Musa paradisiaca* (plantain)-fortified chinchin was drained of excess oil, packaged in plastic containers, and stored at 25^0C for antinutrient analysis and sensory evaluation.

Antinutrient analysis of fortified chinchin

The chinchin samples were grinded into fine powdery form without prior drying in the oven. The fine powder was subsequently used for the following antinutrient assays.

Determination of oxalate

Oxalate content was determined according to standard protocol of Arthur (2019). One gram (1 g) of the sample was soaked in 75 ml of 1.5 N of H_2SO_4 for 1 hour in a 250 ml conical flask and then filtered through a No 1 Whatman filter paper. Twenty-five milliliter (25 ml) of the filtrate was measured into a beaker, followed by 2 drops of methyl red as an indicator. The mixture was boiled and titrated hot at 80°C against 0.1 M $KMnO_4$ until a pink color that persisted for 15 seconds appeared.

Determination of phytate

Phytate content was determined according to established method of Sureshkumar *et al*. (2015). Four gram (4 g) of the sample was soaked in 100 ml of 2% HCl for 3 hours and then filtered through a No 1 Whatman filter paper. The filtrate (25 ml) obtained was placed in a conical flask, followed by the addition of 5 ml of 0.3% solution of ammonium thiocyanate as an indicator and 53.5 ml of distilled water to create a favorable acidic condition. The mixture was subsequently titrated against 0.00566 g/ml of iron (III) chloride solution containing 0.00195 g/ml of iron until a brownish yellow coloration that persisted for 5 minutes appeared.

Determination of saponin
The spectrophotometric method of Egbuna *et al*. (2018) was used for saponin determination. Two gram (2 g) of the sample was weighed into a 250 ml beaker and 100 ml of isobutyl alcohol (isobutanol) was added. The mixture was shaken for 5 hours using a shaker so as to ensure uniform mixing. The mixture was filtered with No 1 Whatman filter paper into a 100 ml beaker containing 20 ml of 40% saturated solution of magnesium carbonate ($MgCO_3$). The mixture obtained was again filtered through No 1 Whatman filter paper to obtain a clean colorless solution. One milliliter (1 ml) of the colorless solution was then taken into a 50 ml volumetric flask using a pipette, and 2 ml of 5% iron (III) chloride ($FeCl_3$) solution was added and made up to the mark with distilled water. This was allowed to stand for 30 minutes for color to develop, and the absorbance was read against the blank at 380 nm.

Determination of tannin
The protocol of Makkar and Goodchild (1996) was used to determine the level of tannin in the samples. Two grams (2 g) of the sample was weighed into a 50 ml sample bottle and 10 ml of 70% aqueous acetone was added and the bottle was properly covered. It was put in an ice bath shaker and shaken for 2 hours at 30^0C. The mixture was then centrifuged and the supernatant stored in a container that is kept in an ice for few minutes. Thereafter, 0.2 ml of the supernatant was taken into a test tube and 0.8 ml of distilled water was added. The standard tannin acid solutions were prepared from 0.5 mg/ml of the stock and the solution made up to 1 ml with distilled water. Folin ciocateaureagent (0.5 ml) was added to both the sample and the standard, followed by 2.5 ml of 20% Na_2CO_3. The solution was swirled using a stirrer and allowed to incubate for 40 minutes at room temperature. The absorbance was read at 725 nm against a reagent blank concentration of the same solution from a standard tannic acid curve that was prepared.

Determination of lectin
The hemagglutination assay method of lectin as described by Adamcova *et al*. (2021) was used to quantify the level of lectin in the chinchin. The assay was carried out in a standard U-bottomed microplate. The sample was serially diluted 2-fold as described by Bing *et al*. (1967), and 50 µl of the clarified lectin extract was mixed with (25 µl) of 2% rabbit red blood cell suspension and incubated for 30 minutes at 25 ^{0}C. Hemagglutination was observed with the naked eye and full agglutination was measured as the titer representing the reciprocal of highest dilution. The specific activity of the lectin is the titer of hemagglutination per mg of protein.

Evaluation of sensory attributes of fortified chinchin
The different chinchin samples were coded with three-digit numbers and alphabets, and given to 30 panelists (male and female), comprising of both staff and students of Adekunle Ajasin University, Akungba-Akoko, Ondo State in the ratio of 1:2 for evaluation. The following sensory attributes were evaluated; color, crispness, appearance, aroma, smoothness, and overall acceptability by the panelists. A 5-point hedonic scale (5 = strongly agree, 4= Agree, 2 = Maybe, 2 = Disagree, and 1 = Strongly disagree) was used for the review or assessment.

Statistical analysis information
The data obtained were subjected to Analysis of Variance (ANOVA) using GraphPad software version 5. Comparisons between different groups were carried out using one-way ANOVA with Turkey Multiple Range Test, and the level of significant difference was taken at 0.05, that is, 95% confidence.

RESULTS
Table 2 results show that chinchin fortified with unripe plantain (*Musa paradisiaca*) has oxalate, lectin and phytate contents (9.002±0.002 mg/g, 28.600±4.100 mg/g and 2.439±0.013 mg/g respectively) that are significantly different ($p<0.05$) from all other groups, except its phytate content that is not significantly different ($p>0.05$) from only the control group (2.469±0.003 mg/g). The results further show that chinchin fortified separately with unripe and ripe plantains have

saponin contents (68.198±8.198 mg/g and 48.649±0.000 mg/g respectively) that is significantly different from the conventional chinchin i.e. the control group (22.162±0.901 mg/g), but not significantly different from chinchin fortified with both ripe and unripe plantain blends (44.865±3.784 mg/g).

Table 2: Antinutrient contents of chinchin samples

Antinutrients	Group 1	Group 2	Group 3	Group 4
Phytate (mg/g)	2.469±0.003^{b}	3.188±0.008^{a}	2.439±0.013^{b}	3.303±0.007^{a}
Oxalate (mg/g)	14.520±0.114^{a}	10.792±0.013^{c}	9.002±0.002^{d}	12.321±0.013^{b}
Lectin (µg/g)	52.750±2.850^{a}	46.600±0.400^{a}	28.600±4.100^{b}	48.300±1.000^{a}
Saponin (mg/g)	22.162±0.901^{b}	48.649±0.000^{a}	68.198±8.198^{a}	44.865±3.784^{ab}
Tannin (mg/g)	0.601±0.160^{a}	0.759±0.117^{a}	0.902±0.376^{a}	0.707±0.193^{a}

Keys: Group 1 - Flour Chinchin; **Group 2** - Ripe Plantain Fortified Chinchin; **Group 3** - Unripe Plantain Fortified Chinchin; **Group 4** - Ripe and Unripe Plantain Fortified Chinchin.

Data are mean values of duplicate determinations ± standard deviation. Values not carrying the same superscript letters are significantly different ($p < .05$) from one another, while those carrying same superscript do not differ significantly from one another.

Moreover, Figures 1 to 6 reveals that there is no significant difference in appearance, smoothness, crispiness, aroma, color, and general acceptability respectively between the different chinchin groups.

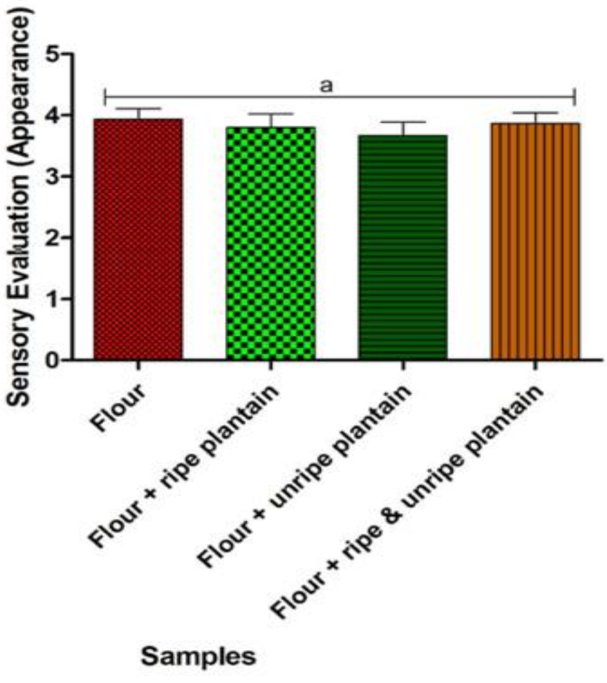

Figure 1: Appearance of plantain-fortified chinchin

Data which are not carrying the same alphabet(s) are significantly different (p < .05) from one another, while those carrying same alphabet(s) do not differ significantly from one another.

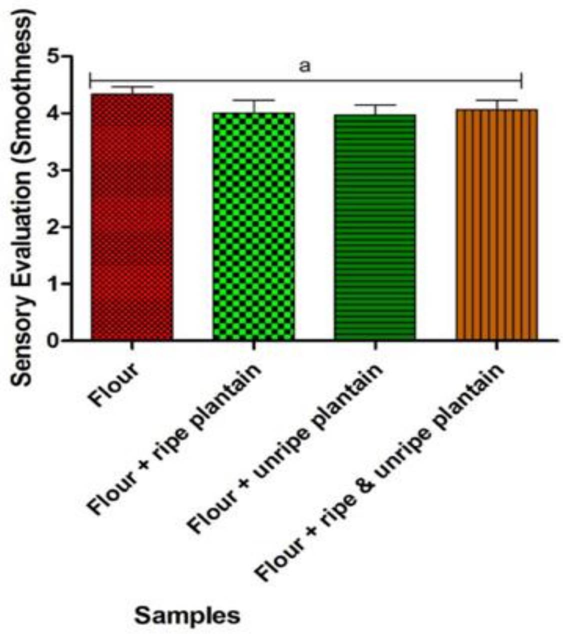

Figure 2: Smoothness of plantain-fortified chinchin
Data which are not carrying the same alphabet(s) are significantly different ($p < .05$) from one another, while those carrying same alphabet(s) do not differ significantly from one another.

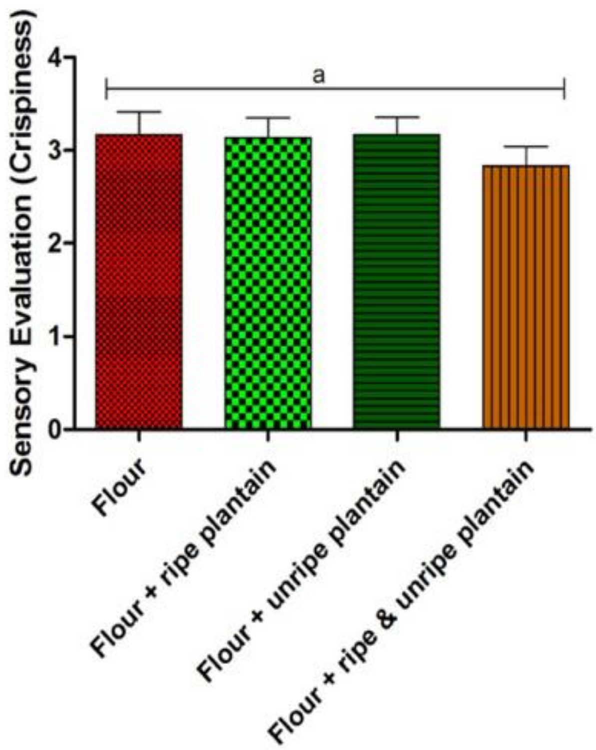

Figure 3: Crispiness of plantain-fortified chinchin
Data which are not carrying the same alphabet(s) are significantly different ($p < .05$) from one another, while those carrying same alphabet(s) do not differ significantly from one another.

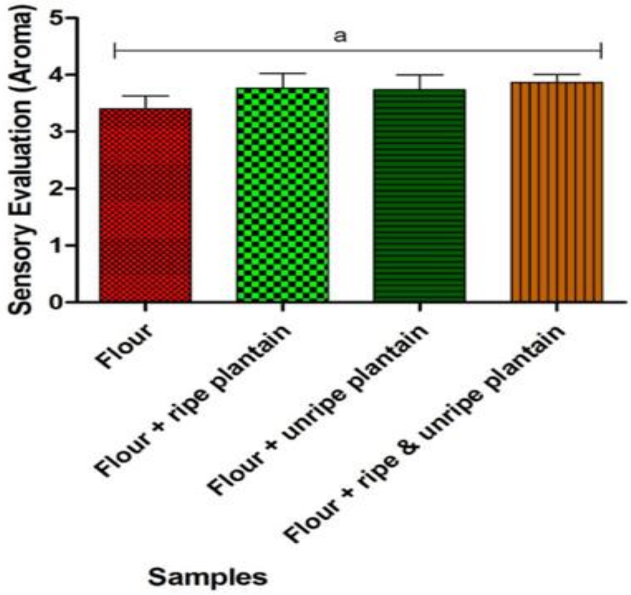

Figure 4: Aroma of plantain-fortified chinchin

Data which are not carrying the same alphabet(s) are significantly different ($p < .05$) from one another, while those carrying same alphabet(s) do not differ significantly from one another.

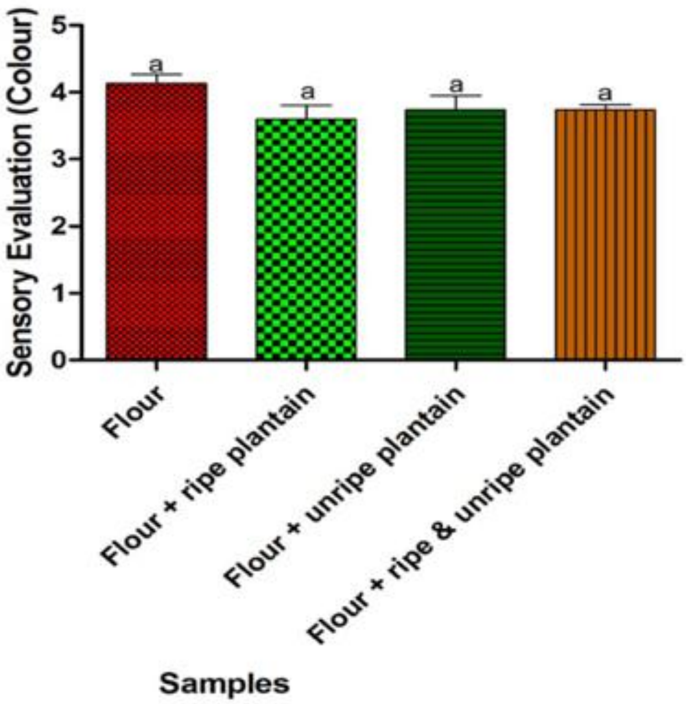

Figure 5: Color of plantain-fortified chinchin

Data which are not carrying the same alphabet(s) are significantly different ($p < .05$) from one another, while those carrying same alphabet(s) do not differ significantly from one another.

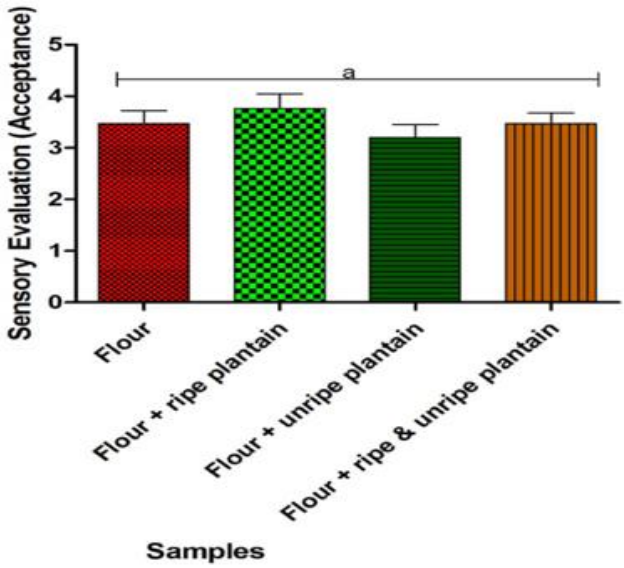

Figure 6: General acceptance of plantain-fortified chinchin

Data which are not carrying the same alphabet(s) are significantly different ($p < .05$) from one another, while those carrying same alphabet(s) do not differ significantly from one another.

DISCUSSION

Antinutrients have beneficial roles if occur within acceptable level that the body can tolerate, and some have been widely applied in nutrition and medicine as pharmacologically active agents (Popova and Mihaylova, 2019). They are chemical compounds with advantageous benefits to mankind when consumed wisely (Popova and Mihaylova, 2019). Therefore, the significantly low oxalate and lectin contents of unripe plantain (*Musa paradisiaca*)-fortified chinchin in comparison with the other groups as observed in Table 2, suggests no harmful potential thus, making the fortification a desirable one. Although, there is dearth of data on antinutrients of plantain-fortified chinchin, there are few related studies that can be compared with the findings of this study. Contrary to the above finding, Adebayo *et al*. (2023) found increased oxalate level in a raw wheat-plantain-velvet bean composite flour at varied concentrations. They found that oxalate level increased from 24.56±0.23 in 100% wheat flour to 448.79±0.29 mg/100 g in 150:105:45 wheat-plantain-velvet bean composite flour as the concentration of both plantain and velvet bean flour increased. The variation in findings may be due to their usage of velvet bean in addition to a high quantity of plantain for fortification in comparison with the small quantity of plantain used for fortification in this study. Also, the blanching and oven drying of their plantain and velvet bean, which were not done in this study, as well as, the difference in product analyzed (they analyzed raw composite flour, while in this study fried chinchin was analyzed) could be the reasons for the variation in findings.

Reports have shown that oxalic acid binds with calcium, magnesium, and iron to form insoluble salts/esters called oxalates that are not easily excreted after digestion. This consequently leads to many deleterious effects such as gastrointestinal tract irritation, kidney stones, inhibition of absorption of vital nutrients, and other biochemical disturbances on human's nutrition and health (Popova and Mihaylova, 2019; Olawoye and Gbadamosi, 2017). So, the low level of oxalate in the various fortified chinchin groups, most especially unripe plantain-fortified chinchin might make it beneficial to human. In other words, there might be little or no risk of having mineral absorption impairment because, according to Natesh (2017), lesser oxalate-mineral interaction is synonymous to more nutrients (e.g. minerals) availability for utilization.

The low level of lectin (Table 2) also presents unripe plantain-fortified chinchin as good choice for consumption. The low lectin content might be due to amplified lectin-fiber binding relationship (Cai *et al*., 2020), which might have been enhanced by the fortification process, since plantain has been repeatedly reported to be high in fiber (Nguimbou *et al*., 2020). Based on available literature, the low lectin content signals its potential usefulness in cancer management and blood glucose reduction due to lectin's antiangiogenic, antimetastatic, antiproliferative (Sinha and Khare, 2017) and insulin-stimulating effects (Food Fortification Initiative, 2016) when consumed minimally. Conversely, the high lectin content of the conventional chinchin and chinchin fortified with both ripe and unripe plantain blends raises serious concern. According to Gong *et al.* (2017), lectin can cause red blood cells to clump together, nausea, diarrhea, etc. when consumed in surplus. Reports have also suggested that lectin could bypass human defense mechanisms at a high level, by presenting the wrong immune system codes to breakdown the small intestine's wall surface (cause holes in the gut wall), initiate intestinal permeability/leaky gut syndrome (Karpova, 2016), and circulate round the body to cause autoimmune diseases like colitis, Crohn's disease, and Coeliac-Sprue among others (Popova and Mihaylova, 2019).

Moreover, phytic acid and saponin have been shown to reduce blood glucose and/or plasma cholesterol and triacylglycerols at low level (Popova and Mihaylova, 2019); therefore, the low phytate content of unripe plantain-fortified chinchin, further show its advantageous inherent-health benefits in comparison with other groups, which includes conventional chinchin. It is the excessive intake of phytate that has anti-nutritive effects due to its strong binding affinity with some minerals such as calcium, iron, magnesium, zinc, and copper, which makes them unavailable for absorption in the intestines (Ekholm *et al*., 2003). So, unripe plantain-fortified chinchin, which has lower phytate content than the control, might promote optimal nutrient absorption and minimize the risk of phytate-related nutritional disorders. Gemede (2014) corroborated this with his finding that moderately consumed phytate has blood lipid-reducing ability. Conversely, the observed increase in phytate level of ripe plantain-fortified chinchin (2.47±0.03 to 3.19±0.08 mg/g), and ripe and unripe plantain-fortified chinchin (2.47±0.03 to 3.30±0.07 mg/g) is consistent with the elevated phytate content (i.e. 0.002±0.001 to 0.005±0.001%) in chinchin supplemented with defatted peanut flour and orange peel flour at varying concentrations, reported by Bongjo *et al*. (2023). It is also in agreement with the finding of Adebayo *et al*. (17), who reported significant increase in phytate content (5.67±0.11 to 6.44±0.08 mg/100 g) of raw wheat-plantain-velvet bean composite flour.

Some antinutrients such as saponin and tannin initially believed to be completely harmful have been found to be beneficial to health even when sometimes high. According to Popova and Mihaylova (2019), it is the concentration-dependent effects of these bioactive substances that should be taken into consideration and not total elimination from foods. The levels of saponin and tannin in ripe, and unripe plantain-fortified chinchin (Table 2) do not indicate any adverse effect on health, and do cast any negative effect on their suitability for fortification and consumption. In a related study, Ezeigbo and Ezeigbo (2018) discovered that unripe plantain contains higher level of tannin than ripe plantain, whereas the opposite was the case for saponin content. They reported rich nutritional values in both ripe and unripe plantain just as discovered in this study although; the results of unripe plantain fortification (Table 2) seem to be better. Bongjo *et al*. (2023) also discovered significant increase in saponin content of chinchin supplemented with defatted peanut flour and orange peel flour at different concentrations just as observed in this study. Our finding is also consistent with that of Adebayo *et al*. (2023), who reported significant increase in saponin level of raw wheat-plantain-velvet bean composite flour (0.00±0.00 to 1.87±0.02 mg/100 g). Contemporary reports suggest that saponin can trigger the immune system to protect against cancer and reduce cholesterol level (Gemede, 2014). Furthermore, a high saponin diet can be used to inhibit dental caries and platelet aggregation, antidote against acute lead poisoning, and treatment of hypercalciuria (Shi *et al*., 2004). Therefore, the saponin content of the fortified chinchin can be seen as promising health-enhancer.

Similarly, the moderate increase in tannin content in unripe plantain-fortified chinchin makes it a preferred food to other chinchin groups, due to the well-documented pharmacological importance of this bioactive compound in literature. It is associated with accelerated blood clotting, reduced blood pressure, decreased serum lipid level, and modulation of immune responses. According to Lamy *et al.* (2016), at higher concentration, tannin is responsible for astringent and bitter flavor; and since the fortified chinchin was not bitter, its general acceptability is almost the same with the conventional chinchin (Figure 6). This reveals the fact that the saponin content is not high to the extent of posing any adverse effect on the sensory attributes.

The non-significant differences in appearance, smoothness, crispiness, aroma, color, and general acceptability (Figures 1 to 6) indicate that fortifying chinchin with various plantain blends in the ratio (i.e. 4:1) used for this study does not adversely affect its sensory characteristics, but rather maintains its appeal, attractiveness, pleasantness and desirability for patronage and consumption. This is in accordance with the findings of Onoja *et al*. (2011) on sensory attributes of wheat-based bread supplemented with fermented cowpea, cocoyam and plantain in a ratio of 70:25:3:2. The sensory attributes results (Figures 1 - 6) further suggests the potential acceptability of plantain-fortified chinchin by all, and that if recommended for consumption as a functional food for people suffering nutrition-related health challenges for remedial and/or therapeutic purposes and/or other consumers, it should be widely accepted with little or no persuasion due to its appealing sensory attributes. Thus, the abilities of unripe plantain to modified antinutrients level and preserve sensory characteristics provide further insight on the reported usage of plantain in the treatment/management of diabetes mellitus and related diseases by Ekpo *et al*. (2011).

CONCLUSION

Fortification of wheat flour chinchin with plantain (*Musa paradisiaca*), particularly with unripe plantain, moderately modified antinutrient contents in a manner that could benefit human's health without compromising sensory attributes. Therefore, both ripe, and unripe plantain-fortified chinchin emerge as desirable snacks and can be recommended as functional food for human.

ETHICAL CLEARANCE STATEMENT

Authors obtained ethical clearance from the Centre for Research and Development Unit of Adekunle Ajasin University, Akungba-Akoko; and also got the consent of the panelists to participate in this study.

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