EFFECT OF DIFFERENT PROCESSING TECHNIQUES ON THE CHEMICAL COMPOSITION OF FERMENTED MAIZE PRODUCT (*IPEKERE*)

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Abstract
Ipekere is a snack's fried like food product from maize which can be eaten in its natural state or with pap as breakfast in many homes. Different processing methods on the chemical composition of fermented maize product (ipekere) were carried out. The maize samples were prepared by wet-milling prior fermentation. The chemical composition (proximate, mineral and antioxidant contents) and antinutrient content of maize samples were determined. Fermentation enhanced the crude protein, fat and ash contents in all the samples while the crude fibre and the carbohydrate contents show a decrease from 1.54% to 0.3% and 28% to 12% for yellow maize machine-grinded and 1.5% to 0.5% and 34% to 18% for white maize hand-grinded. The phytate content decreased from 8.0 to 4.8 mg/g (yellow maize machine grinded), 6.0 to 3.6 mg/g (yellow maize hand-grinded), 6.4 to 4.0 mg/g (white maize machine grinded) and 5.0 to 4.2 mg/g (white maize blended) respectively. There was no significant difference in the tannin content. The mineral composition of the samples varied significantly. High antioxidant content 69% and 65% were obtained from white and yellow maize hand-grinded while yellow and white maize machine-grinded had the least value 20%. Fermented yellow maize and machine-grinding showed the best sample quality and processing method that could be employed in producing nutritious ipekere.

Keywords: Cereals, fermented foods, *Ipekere*, maize, proximate composition.

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1. INTRODUCTION

Different foods and food products are produced either by manual or mechanical techniques. Various approaches have been employed in food processing. Some of the processing techniques involve peeling, dehulling, washing, grating/grinding, fermenting, pressing, sieving, packaging, boiling, frying etc. In many developing countries today, varieties of foods are produced from cereals and legumes. They form bulk of staple foods in many homes with much concern on their nutritional balancing and economic purposes in reducing or alleviating malnutrition and hunger (Marina *et al*., 2013).

Traditionally, cereal foods play an important role in human diet of Africa origin where they are largely produced. They account for 77% of total caloric consumption (Taiwo, 2009). Nutritionally, cereals such as maize contain high levels of dietary fibre (12.19%) but relatively poor protein quality with limiting amount of essential amino acids, lysine and tryptophan and mineral profile, though it is very rich in vitamins A, C, and E, carbohydrates and essential minerals. Thus, there is need to enrich maize diets with both protein and micronutrient rich foods (Barber *et al.*, 2017).

Cereals can be processed into flour, as main raw materials used in the production of popular food products as complementary foods for infants feeding which are cost effective, cheap with high acceptability, sensory quality, long shelf life and affordability by the less affluent within the reach of wider population (Mbata *et al*., 2009).

There is need to formulate nutritious foods so as to avert protein/energy malnutrition through commercially produced foods preparation by fermentation, extrusion or other high technology processes (Afoakwa *et al*., 2007).

Consumption rate of maize and maize based products are grossly increasing in Nigeria and other developing countries. The could be attributed to eating habits as a result of poverty, which has become a major challenges in developing countries, whereby individual are unable to afford high quality foods for their household, this has caused many Nigerians in consuming less quality foods at the expense of what they need for a healthy life (Oladeji *et al*., 2014).

Though, a lot of researches are ongoing using different processing techniques in producing certain local foods as conventional approach in boosting economy of an individual with productive skills. Fermentation process has showed great effect on the physicochemical and microbiological quality of most food formulated from cereals/ legumes (Oyarekua and Eleyinmi, 2004).

Cereals form a major and most important source of the world's food with more significant impact in human diet throughout the world. Cereal grains account for the most important group of fermented foods in tropical Africa. The main cereals grown in Nigeria are maize, guinea corn, rice, millet and sorghum (Adebayo *et al*., 2010).

Maize (*Zea mays*) is an important cereal grain in the world. It serves as food for man, animals and for industrial purpose (Wakil and Daodu, 2011). Maize has the highest worldwide production of all grains crops, yielding 785million tons in 2012 with the largest producer - the United States of America producing 42%; Africa 6.5% with Nigeria being the largest African producer with nearly 8million tons (http://faostat.fao.org/). In the tropics, maize is a common cereal crop, a good source of carbohydrate, vitamins and minerals. It can be processed into a wide range of food items and snacks (Arotupin *et al*., 2019).

Maize can be processed into wide range of foods, snacks and beverages (Afoakwa *et al*., 2007; Arotupin *et al*., 2019). Though, preparations and uses of the maize grains varied from group to group in Nigeria, though at times with some similarities.

Traditionally, fermentation of cereal is initiated by microflora of the raw materials. Fermentation helps in food preservation, protein digestibility, positively enhance texture, aroma and improve the biological value of foods due to the enzyme a-amylase degrading the starch granules and consequently lowers the viscosity of the gruel (Achi, 2005; Chelule *et al.*, 2010).

Different processing methods such as fermentation are known during processing of cereals for the preparation of a wide variety of dishes in developing countries. Many African foods are fermented and processed before consumption and these constitute a significant component of African diet (Sanni and Adesulu, 2013).

Several maize based fermented products, such as *pap*, *akamu*, *ogi*, or *koko*, in West Africa, *togwa* in Tanzania, *banku* and *kenkey* in Ghana, *mahewu* in South Africa, *mawe* in Benin have been documented (Jepersen *et al*., 1994).

Some of the food snacks from maize include; *guguru* (pop-corn), *aadun* (maize snack), *kokoro* (corn cake), *donkwa* (maize-peanut ball) and *ipekere* (maize cake) (Arotupin *et al*., 2019).

These snacks are popular food items with a long history of consumption especially among the low income populace. In recent time, findings have shown that less information are available on the improvement of their nutritional quality (Aletor and Ojelabi, 2007).

Most maize snacks in Nigeria such as *ipekere* are prepared by frying in hot palm oil. Frying is the commonest of these processing methods. Frying is a unit operation used to alter the eating quality of food products. It is often selected as a method of choice for creating a unique flavor and texture in processed foods (Patterson *et al.*, 2004). The popularity of these fried snacks necessitates the need to improve their quality.

Ipekere, like other cereal-based foods is rich in carbohydrate, but low in protein and deficient in some essential amino acids particularly lysine which makes the product nutritionally deficient. The consumption of these snacks is becoming more popular in Nigeria, most especially in the South-Western part among children, rural dwellers and low income populace (Arotupin *et al.*, 2019).

Ipekere are ready-to-eat, convenient and inexpensive food products, containing digestive and dietary principle of vital importance. Optimization of different processing techniques during the production process can improve its quality with much health benefits on the consumers, which could reduce the dependence of the consumers on the ready-to-eat imported wheat (Akinoso *et al.*, 2011).

Though, little information is available on the nutritional composition of fermented maize grains for *ipekere* production. Therefore, this study was undertaken to determine the best processing techniques on the chemical composition of fermented maize sample for *ipekere* production.

2. MATERIALS AND METHODS

2.1. Samples collection and preparation: Healthy yellow and white maize were purchased from Oja-Oba market in Akure, Ondo State, Nigeria. The maize kernels were peeled off from the corn, sorted and washed. Approximately 300.0g each of the maize samples were weighed and processed by blending, machine grinding and hand grinding. The maize samples were kept separately in transparent fermenting vessels for 7 days at 28^{o}C ambient temperature.

2.2. Proximate determination: The proximate contents (moisture, ash, crude fibre, fat, crude protein and carbohydrate) of the raw and fermented maize samples were analyzed using the method described by AOAC (2012).

2.3. Determination of anti-nutrient content: The anti-nutrient content of the samples were determined according to the method described by AOAC (2012). The anti-nutrient content determined includes tannin and phytate.

2.4. Mineral determination: The analyses of micronutrients and macronutrients were carried out according to AOAC (2012). The mineral parameters determined were calcium, iron, zinc, magnesium and manganese using flame atomic absorption spectrophotometer (Model 372).

2.5. Quantitative determination of antioxidant properties of the samples: This was determined as described by Bao (2005). The antioxidant parameter determined was 1, 1-diphenyl-2-picrylhydrazyl (DPPH).

2.6. Data analysis: All analyses were carried out in triplicates. Data obtained were analyzed using analysis of variance (ANOVA). Duncan's Multiple Range Test was used to compare the mean difference using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago, USA). Significance was accepted at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Proximate composition

The proximate composition of the samples analyzed is represented (Figures 1-6). The fat, protein and ash contents of the fermented samples increased as the fermentation time progresses, the carbohydrate and crude fibre decreased while there was no significant difference in the moisture content of the fermented sample when compared with the raw sample. The fat content increased from 1.0 to 3.8% for yellow maize machine-grinded, 0.8 to 4.4% for yellow maize hand-grinded, 1.8 to 4.0% for yellow maize blended, 1.7 to 2.8% for white maize machine-grinded, 0.9 to 3.8% for white maize hand-grinded and 1.2 to 3.4% for white maize blended (figure 1). The highest protein and ash contents 7.6% and 0.98% were recorded from yellow maize blended at day 7 (Figures 2 and 3). The carbohydrate content decreased from 25.00 to 9.00% for yellow maize machine-grinded, 28.00 to 15.00% yellow maize hand-grinded, 25.00 to 16.00% yellow maize blended, 15.00 to 9.00% white maize machine-grinded, 26.00 to 18.00% white maize hand-grinded and 23.00 to 16.00% white maize blended (figure 4). High crude fibre content 0.3% was obtained from fermented yellow maize machine-grinded and yellow maize hand-grinded respectively (Figure 5). There was no significant different in the moisture content of both raw and the fermented samples (figure 6).

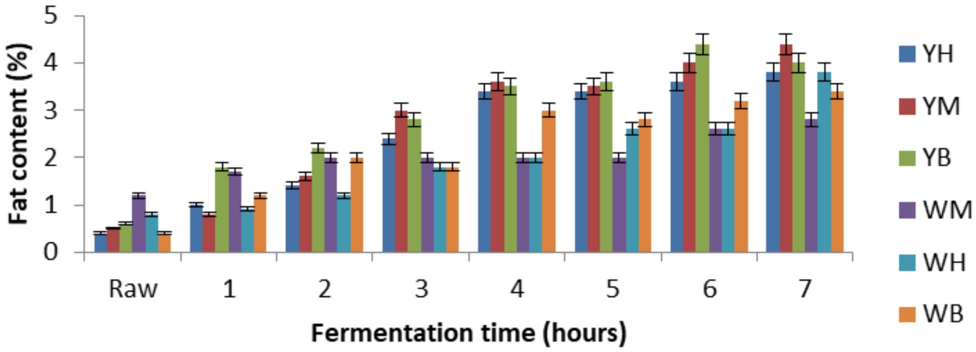

Figure 1: Fat content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

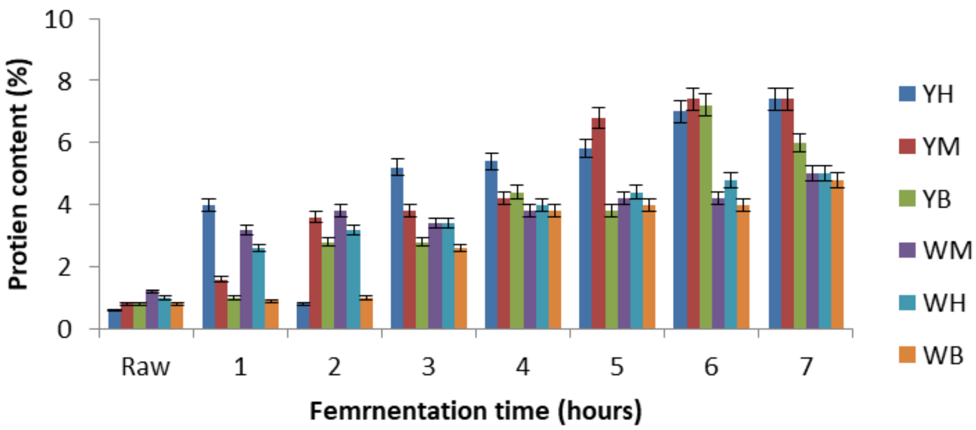

Figure 2: Protein content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

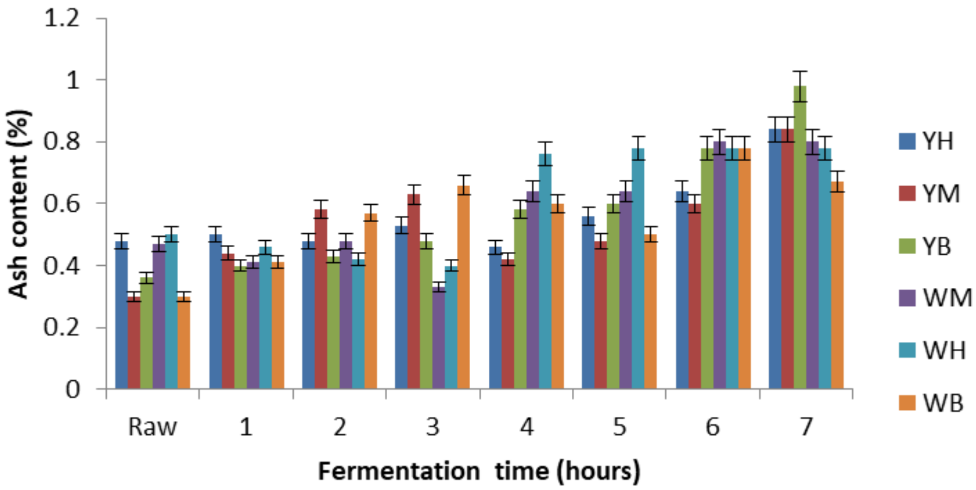

Figure 3: Ash content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

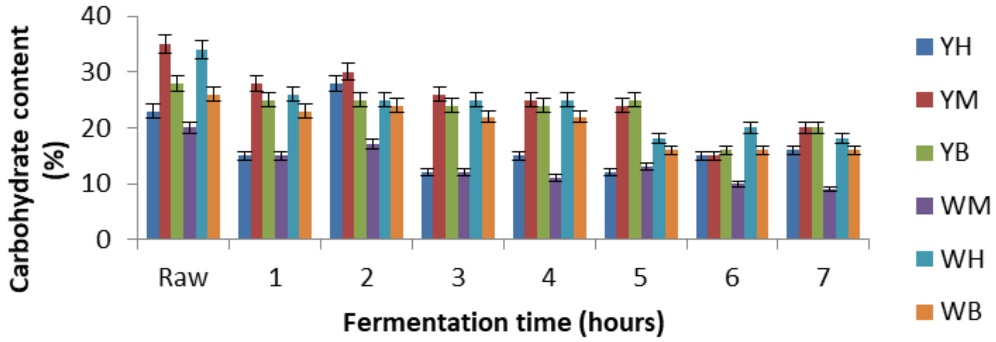

Figure 4: Carbohydrate content of the samples

Legend key*: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

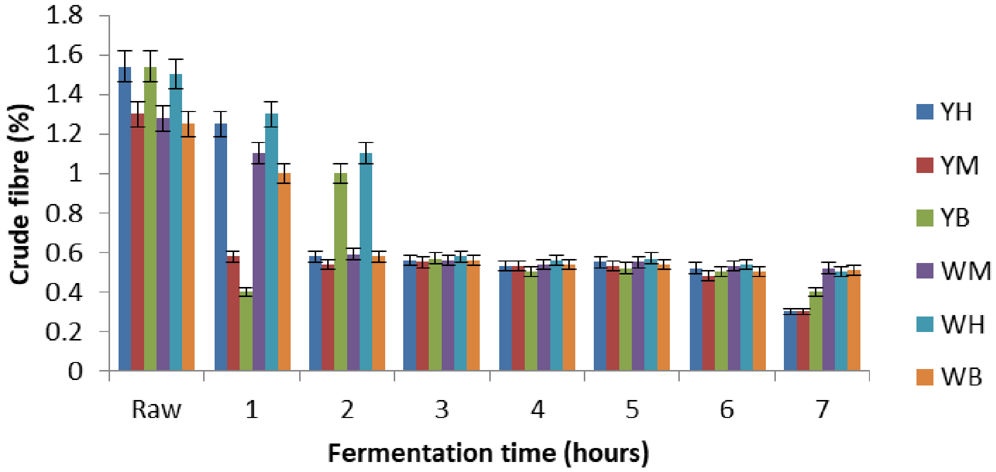

Figure 5: Crude fibre content of the samples

Legend key*: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

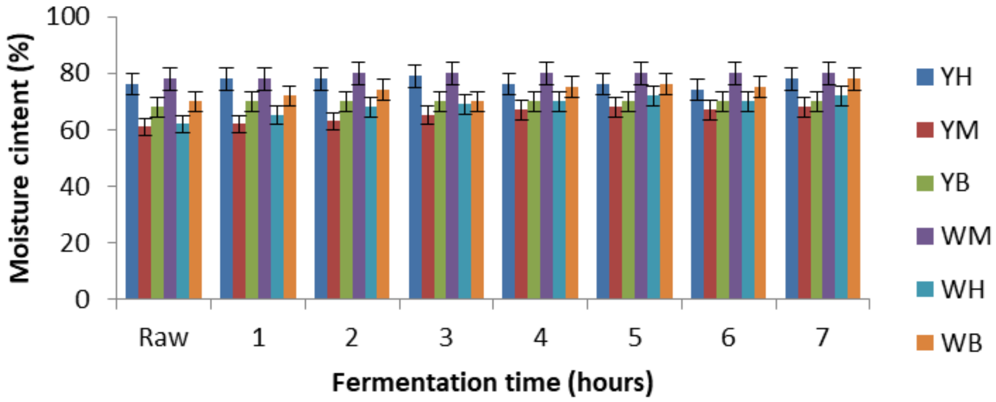

Figure 6: Moisture content of the samples

Legend key*: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

The proximate composition represents the total nutritional composition of foods. The chemical composition of foods depends on food substrate to be analyzed. The analysis could be dependent of the following parameters (protein, moisture, crude fibre, fat, ash and carbohydrate contents).

The decrease in ash content observed in this study could be due to general activities of the fermenting microorganisms who by enzymatic activity could breakdown most of these components into their absorbable forms. The decrease in ash content could be due to general enzymatic activities of the fermenting microorganisms in breaking down of most of these substrates into their absorbable forms (Wakil and Daodu, 2011). The decrease in fat content could be attributed to its utilization by fermenting micro-organisms. Microorganisms might oxidize the fat to yield considerable amount of energy for their activities. The increase in moisture content of fermenting substrates aids in the release of nutrients with increase in water activity which enhances the fermentation. Fibre is an important dietary component in preventing overweight, constipation, cardiovascular disease, diabetes and colon cancer. High dietary fiber content has been reported to impair protein and mineral digestion and absorption in human subjects (Ijarotimi, 2010; Modu *et al*., 2017). The reduction in crude fibre might be due to hydrolytic effect of various microbial enzymes degradation of the fibre during fermentation (Oyarekua, 2011). The observed increase in protein content of the fermented maize samples may be due to the increased growth and microbial proliferation in the form of single cell protein of the starter culture, the structural proteins that are an integral part of the microbial cell and the ability of the microorganisms to secrete protease and increase in bioavailability of amino acid during the fermentation process (Tortora *et al*., 2002; Oboh, 2006). The significant increase in the protein content of both white and yellow sprouted sweet maize when compared with the sprouted maize samples has been reported (Oluwalana, 2014). It had also been reported that heating at high temperature denatures the protein content of most fermented foods (Akinoso *et al.*, 2011). The decrease in ash content could be due to general activities of the fermenting microorganisms who by enzymatic activity could breakdown most of these components into their absorbable forms. The increase in the fat content of the fermented maize might be due to the contribution of fat globules form of the fermented grinded-maize slurry, secretion of microbial oil by microorganisms such as fungi during the fermentation. The total carbohydrate referred to as nitrogen free extract decreased, thus resulting in a high energy protein balanced food. The decrease in carbohydrate content of the fermented maize could be attributed to the selective utilization of carbohydrate as energy source by fermenting microorganisms and the action of microorganisms in the degradation of starch to sugars during fermentation (Gernah *et al.*, 2011). This degradation causes an improvement in the nutritive value, absorption and digestibility of the processed gruel for *ipekere* production.

3.2. Minerals composition

The mineral composition is represented in figure 7 to 11. High magnesium content 0.5 and 0.6mg/g were obtained from yellow maize hand-grinded and yellow maize machine-grinded (figure 7). The calcium content was relatively high in the raw sample and high zinc content in the fermented sample (Figures 8 and 9). White maize machine-grinded recorded high iron content 1.34% (figure 10). The fermented white maize hand-grinded and the fermented yellow maize blended had high manganese content 0.13% and 0.07% respectively (figure 11). The increase in the mineral content might be due to the reduction in the phytate during fermentation. Phytates are insoluble and form of salt with metals rendering these metals unavailable for absorption (Gilani *et al*., 2005). The reduction in the calcium and iron content of the maize sample during the fermentation might be as a result of their being used as cofactors and coenzymes during the course of metabolism (Dewey and Brown, 2003). Manganese is involved in over 300 metabolic reactions and is needed for bone, protein, making new cells, activating B vitamins, relaxing nerves and muscles, clotting blood, and in energy production (Guerrera *et al*., 2009). Potassium and magnesium in the fermented maize could help in the proper functioning of muscles by supplying more energy (Silva Dias, 2014). Phosphorus is an important constituent of every living cell. It is very essential in bone formation and other cellular reactions in the body (Berdanier and Zempleni, 2009).

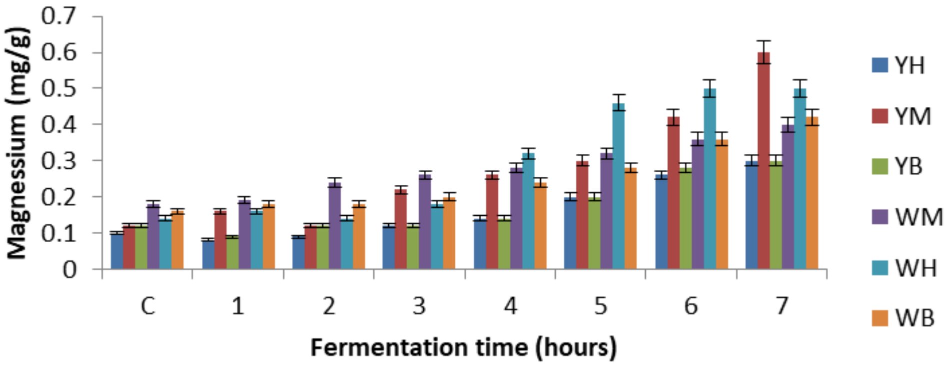

Figure 7: Magnesium content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

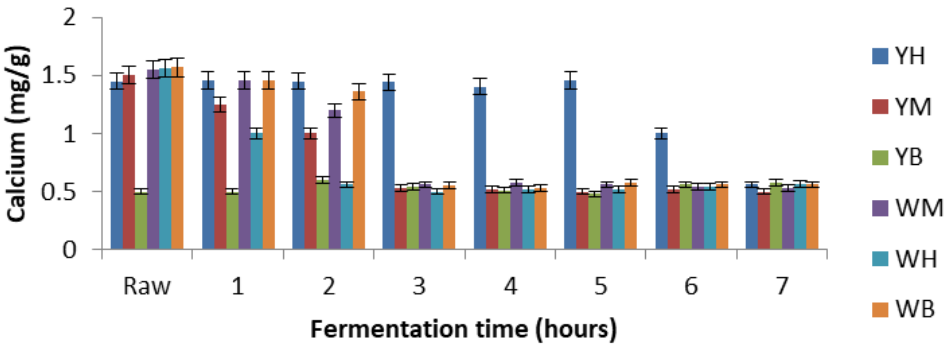

Figure 8: Calcium content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

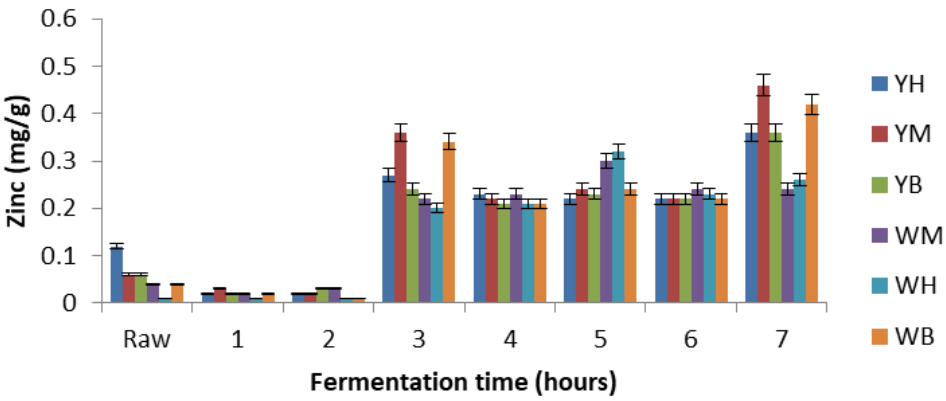

Figure 9: Zinc content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

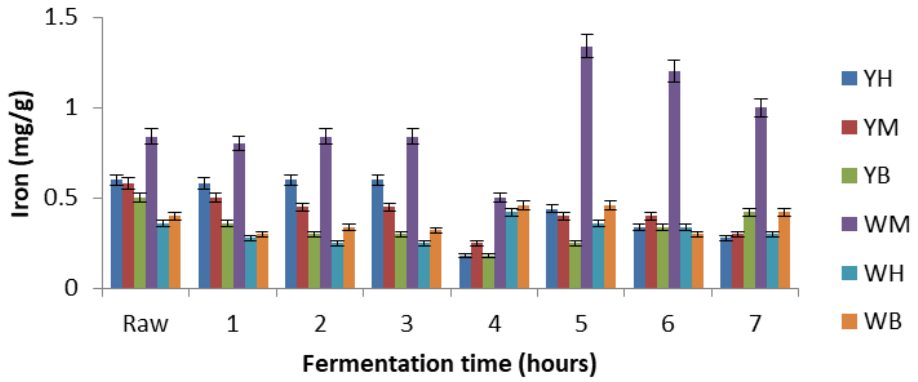

Figure 10: Iron content of the samples

***Legend key**: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

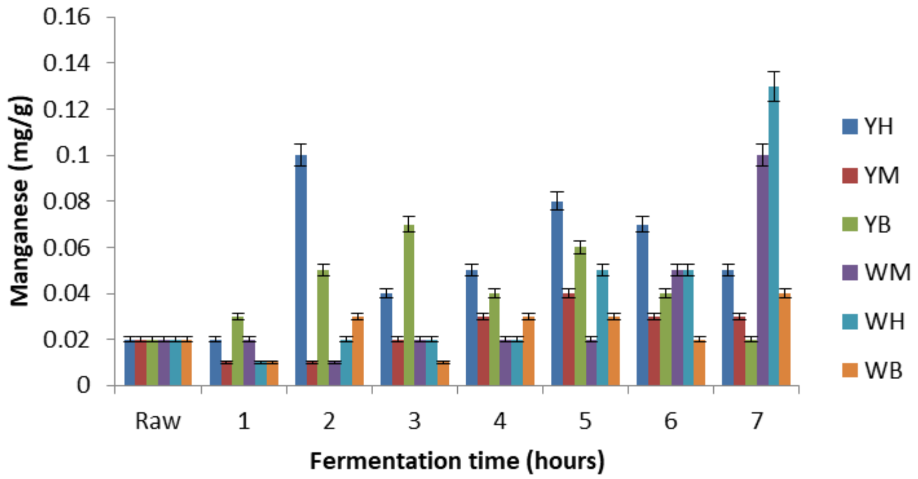

Figure 11: Manganese content of the samples

***Legend key**: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

3.3. Antinutrient composition

The phytate and tannin contents of the maize samples were represented (figures 12 and 13). High tannin and phytate contents 8.0% were obtained from raw white maize blended and fermented yellow maize hand-grinded with no significant difference in the raw and fermented up till day 3 of the fermentation process. Antinturients have the ability of decreasing the digestibility and palatability of protein because they form insoluble complexes with them and the amounts are insignificant to cause any hindrance to nutrient absorption from other foods (Fowomola and Akindahunsi, 2008). The reduction in the phytate during fermentation might be due to secretion of phytates bond, change in the pH which affects the attachment of water molecule and thus configuration of phytatic acid by altering the strong water molecules attached (D'souza, 2013). The reduction in phytate content of fermented cereal foods has been reported (Adegbehingbe *et al*., 2018). The increase in tannin content could be as a result of resultant antinutrient compound from microbial biomass.

The reduction in tannin content may be as a result of enzymatic activity of the organisms whose hydrolyzing ability is enhanced by fermentation. The reduction in the phytic acid content of formulated blends may be due to hydrolysis of phytate by the enzyme phytase into lower inositol phosphates which are believed to be activated during the germination and fermentation process.

The reduction in the phytic acid content of formulated blends may be due to hydrolysis of phytate by the enzyme phytase into lower inositol phosphates which are believed to be activated during the germination and fermentation process (Akanbi *et al*., 2010).

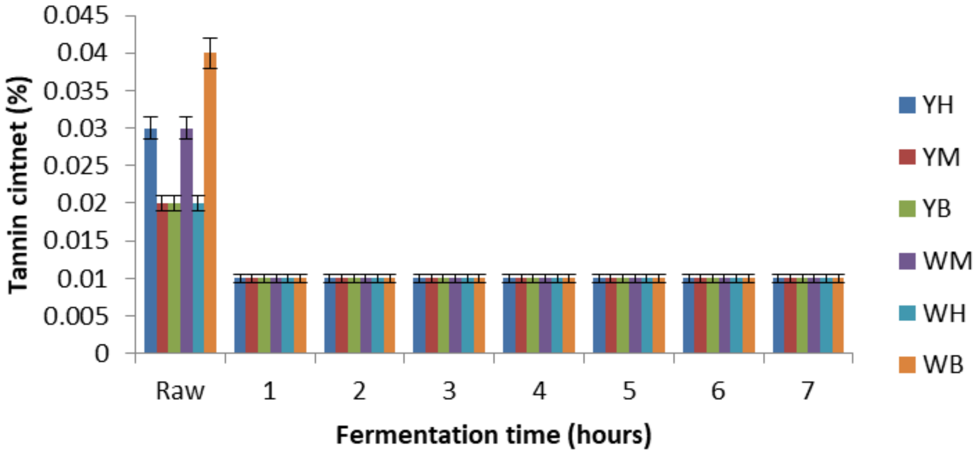

Figure 12: Tannin content of the samples

Legend key*: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

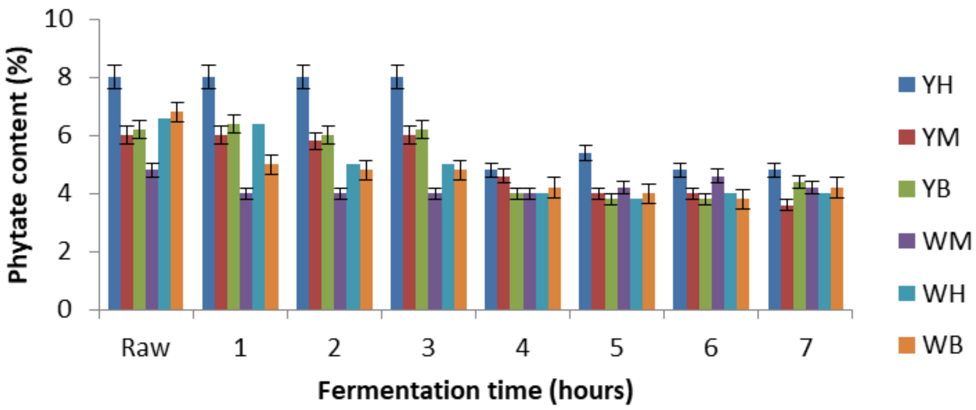

Figure 13: Phytate content of the samples

Legend key*: YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

3.4. Antioxidant content

Figure 14 shows the antioxidant content of the maize samples. The antioxidant content of the fermented samples decreased when compared with the raw sample. High antioxidant content 1,1-diphenyl-2-picrylhydrazyl (DPPH) 68% was obtained from the raw white maize machine-grinded while the least value 20 was obtained from fermented yellow and white maize machine-grinded respectively. Some plant crops are known and have been screened for diverse antioxidant activities but little or no information are available on the antioxidant of fermented maize. The presence of antioxidants in food products helps to scavenge the free radicals that might cause toxicity to human health. They are very helpful in alimentary digestion, cosmetics and pharmaceutical industry. The significant increase in the antioxidant components of the white maize hand-grinded might be attributed to the activities of fermenting microorganisms mostly the lactic acid bacteria capable of producing exopolysaccharides (Alfieri *et al.*, 2016). The difference observed in the antioxidant contents might be due to the nature of the fermenting substrate, fermentation medium and environmental conditions.

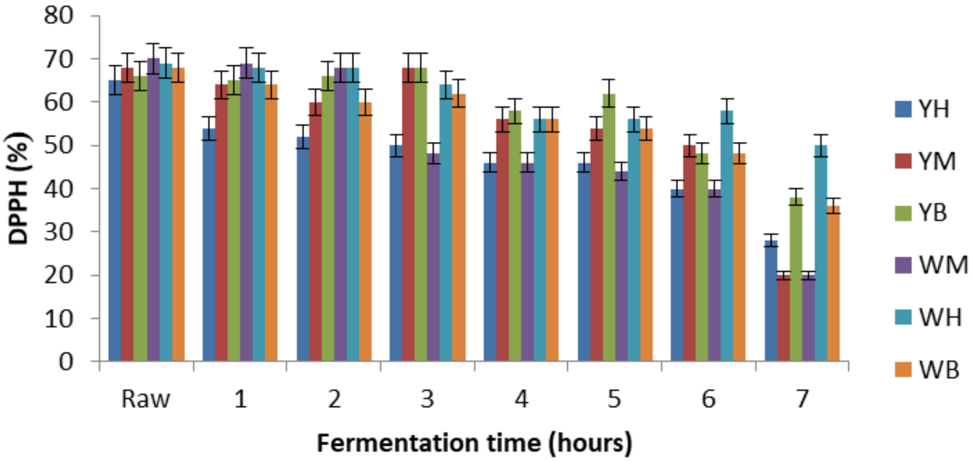

Figure 14: DPPH content of the samples

Legend key: *YH - Yellow maize hand-grinded, YM – Yellow maize machine-grinded, YB – Yellow maize, WH - White maize hand-grinded, WM – White maize machine-grinded, WB – White maize blended.*

4. CONCLUSION

This study reveals the nutritional composition of the processed fermented maize samples. It was observed that yellow maize hand-grinded and machine grinded had high nutritional balance when compared to the other samples. The suggested that, both manual and mechanical methods of yellow maize for the production of *ipekere* could be best adopted. Though it can be tedious, expensive and require special skills when large population demanding for the product. However, fermented yellow maize can be recommended as cheap grain for the production of local snacks and as complementary food for infant weaning.

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