EFFECT OF REFRIGERATED STORAGE ON THE QUALITY ASSESSEMENT, ANTIOXIDANT AND SENSORY COMPOSITIONS OF FUNCTIONAL "OGI" ENRICHED WITH DIETARY TIGERNUT (*Cyperus esculentus L)* FIBER EMULSION.

Abstract

"Ogi" is a porridge prepared from fermented maize, sorghum or millet in West Africa and very popular breakfast cereal and infant weaning food in Nigeria. The study aimed at investigating the effect of refrigerated temperature on some quality properties of ogi. The dietary tigernut fiber and "ogi" were prepared using standard methods. The dietary tigernut fiber was added to the "ogi" at different proportions (5 %, 10 %, 15 % and 20 %). Proximate, pH, total titratable acidity, antioxidant and sensory characteristics of the enriched ogi during four weeks refrigerated storage were assessed. The fat content of "ogi" increased with increasing tiger nuts fiber and storage periods of four weeks with the values ranged from (5.30 to 10.12 %), (5.30 to 11.45 %), (6.33 to 14.45 %), (6.53 to 16.34 %). The same trend of increase were observed for protein content of the enriched "ogi" with values of (8.90 to 17.01 %), (10.90 to 17.89 %), (10.93 to 18.88 %) and (10.99 to 19.86 %) for weeks one to four. The fiber content also concomitantly increased with inclusion of tigernut fiber and storage periods (0.90 to 1.97 %) and (1.09 to 3.43 %) for weeks one and four. The DPPH scavenging radical activity and total flavonoids of the samples increased as the storage periods increases. The sensory results showed that $\mathbf{O_{80}TG_{20}}$ and $\mathbf{O_{70}TG_{30}}$with moderate percentage of 20 % inclusion of tiger nut fiber were more acceptable by the panelists. The study established that ogi enriched with tiger nut fiber could serve as a cheap functional food recipe with high nutrient and antioxidant qualities, hence can be considered as nutritional intervention in the management and control of oxidative stress diseases in human.

Key words: "Ogi", tigernut fiber, refrigerated, antioxidant, functional food

1. Introduction

"Functional foods have been found to contain compounds that may reduce or inhibit the possibility of certain diseases or otherwise optimize health. These particular compounds are either naturally occurring in functional foods or be added by fortification or

enrichment. The categories of functional components include dietary fiber, fatty acids, isothiocyanates, carotenoids, flavonoids, phenolic acids, plant stanols and sterols, prebiotics and probiotics, soy protein, phytoestrogens, vitamins, and minerals. Fortification or enrichment of traditionally fermented food products is a vital procedure of increasing and improving the concentration, bioavailability and functionality of the nutritional content of the edible part of the plant food, particularly the cereals to the levels that consistently and significantly exceed the inherent nutrient content" (White and Broadley, 2005).

"Ogi is a fermented cereal pudding indigenously made from maize, sorghum or millet" (Inyang and Idoko, 2006). "In many parts of Nigeria and Africa gelatinized ogi is called pap and predominantly used as an indigenous infant weaning food and also breakfast food for adults in Africa" (Inyang and Idoko, 2006; Ogodo *et al*., 2015)."The traditional preparation of maize Ogi involves soaking of maize in water for three days followed by wet milling and sieving to remove bran, hulls and germs. The pomace was retained on the sieve and afterwards discarded as animal feed while the filtrate settle to give a semi-solid substance referred to as Ogi in Southwest, Nigeria" (Ajanaku *et al.,* 2012)."During steeping and sieving processes of the maize paste, many nutrients such as protein, vitamins, minerals are lost. However, loss of these nutrients can be minimized by removing sieving from the production processes" (Inyang and Idoko, 2006). "To improve the nutritional value of ogi, researchers have fortified it with plant protein such as African walnut, soy peptides, ginger, Bambara groundnut or animal protein sources (egg and milk)".(Ihuoma et al., 2021; Ogori et al., 2020; Olayiwola et al., 2017; Adeyemo and Abimbola, 2019) "In the recent time, local consumption pattern has moved towards the inclusion of different single or combined spices by the local processors with the view to improving the quality of the products. Spices are culinary herbs which have aromatic or pungent flavor. They are dried seeds, fruit, root or vegetable substances used in the preparation of foods to enhance the flavor and nutritional quality of such food. Some of the challenges facing the production of ogi are quality losses most especially the dietary fibre which occur at different stages of its production" (Awoyale *et al*., 2016). Therefore, food ingredients that could be added to alter its nutrient composition, prevent microbial contamination and at the same time impart color and taste are needed.

Tigernut (*Cyperus esculentus* L.) is an edible perennial grass like plant native to the Old World, and is a lesser-known vegetable that produces sweet nut-like tubers known as "earth Almonds". Cyperus esculentus had been reported to be a "health" food, since its consumption can help prevent heart disease and thrombosis and is said to activate blood circulation (Chukwuma, *et al.,* 2010). "It was also found to assist in reducing the risk of colon cancer" (Adejuyitan, *et al.*, 2009). This tuber is rich in energy content (starch, fat, sugar, and protein), minerals (phosphorus and potassium), and vitamins E and C (Belewu and Belewu 2007) thus making this tuber also suitable for diabetics and for those intent on losing weight (Borges *et al.*,2008). "The tubers contain about 25 % oil, which are resistant to peroxidation, 50 % digestible carbohydrates, 4 % protein and 9 % crude fiber. Dietary fiber and phenolic compounds are two plant food constituents that are associated with many health benefits and have been demonstrated to reduce risk for developing cancer and some chronic diseases" (Barberan and Andrés-Lacueva, 2012)."Therefore, the intake and the use of these compounds as functional ingredients to enrich foods have been increasing in order to provide health benefits to consumers. Dietary fiber has an essential role in intestinal health and appears to be significantly associated with a reduction of cholesterolaemia and modification of the glycemic response" (Schulze *et al*., 2004). "Furthermore, phenolic and dietary fiber compounds have potent antioxidant and free-radical scavenging properties that protect against oxidative damage to important biomolecules. All these properties are associated with the chemical structures of these compounds, which determine their subsequent physiological and nutritional properties as functional ingredients" (Dziki *et al.,* 2014). This work was designed to investigate the effect of tigernut dietary fiber on the nutrient quality and antioxidant compounds of fermented ogi during cold storage.

2. Materials and Methods

2.1 Sample collection

Maize (*Zea Mays*) were obtained from the Agricultural farm store of The Oke-Ogun Polytechnic Saki Oyo State, Nigeria. Authentication of the grains was done at the

Department of Crop Science, The Oke-Ogun Polytechnic Saki Oyo State, Nigeria. Tigernut (*Cyperus esculentus L.*) seeds were purchased from a local market in Saki, Oyo State, `

2.2. Sample Preparation

The maize grains were sorted to remove extraneous materials and unwholesome grains, after which the grains were washed and steeped in clean water for 48 h at room temperature. The water was decanted after 48 h and the maize was wet-milled into slurry using the Imex 100901231 Attrition mill (Europe). Sieving was done using a muslin cloth to separate the pomace from the filtrate.

For tigernut fiber extraction, 5 g of dried tigernut seeds was soaked in 50 ml of deionised water for 12 h, blanched at 95 ℃ for 5 min and filtered. Fibers were obtained by treating the bleached residue in 85 % ethanol with a defined ethanol/residue ratio at fixed time and temperature on a magnetic stirrer (IKAC MAC HS7). The mixture was filtered and the residue was recovered to undergo several other treatment cycles. The final residue was then sequentially rinsed with 95 % ethanol and acetone before drying in an oven at 50 ℃ for

24 h. The multiple leaching processes using ethanol allowed gradual removal of non-fibrous compounds from the ginger and thus enriching the residue in the fibers.

2.3. Reagents.

Except otherwise stated, all chemicals used were of analytical grade. Glass distilled water was used for the experiment.

2.4. Determination of physicochemical properties of the sample

2.4.1pH and total titratable acidity and total soluble solid

The pH of the samples was measured according to Association of Official Analytical Chemists (AOAC) method No. 943.02 (AOAC, 2020) with some slight modifications. The ogi sample (5 g) was weighed into an Erlenmeyer flask and 50 ml of distilled H_2O was added. The suspension was prepared by mixing for 10 min at 25°C. Then, the pH was measured using a Jenway-3505 pH-meter (Barloworld Scientific Ltd Essex, UK) with a glass electrode standardized by buffer solutions of pH 4 and pH 7, both at 25°C. Each batch was analysed in triplicate.

The measurement of titratable acidity was done according to method described by Manjula *et al*., (2012). Erlenmeyer flask used with a transfer pipette 20 ml sample and 1 ml of 2 % w/v solution of phenolphthalein. Content is titrated with 0.1 M NaOH solution to appearance the faint pink color that will not get lost for over 2 min.

The total soluble solid of the yoghurt samples were measured using an Abbe Mark II digital refractometer by placing 0.5 g syrup on the lens and reading the sample for temperature corrected brix.

2.5. Determination of the proximate composition of the sample

2.5.1. Moisture content

About 2 ml of the yoghurt sample was weighed into previously dried and weighed glass crucibles. The crucibles with the samples were then placed in a thermostatically controlled oven at 105° C till a constant weight of solid material was obtained after 5 h. The crucibles were then removed and cooled in a desssicator and then weighed. The moisture content of the samples was calculated by difference in weights and expressed as a percentage.

2.5.2. Crude ash content

About 2 ml of homogenized yoghurt sample was weighed into each of three previously dried and weighed porcelain crucibles and heated for about 20 min over a boiling water bath till they were visibly dry. The crucibles with their content were then transferred into a muffle furnace at 600° C and incinerated for 2 h. The crucibles were removed, placed in a desssicator to cool then weighed and the ash content was calculated and expressed as a percentage.

2.5.3. Crude protein content

About 2 ml of the sample was placed in a kjeldahl digestion flask containing a selenium based catalyst and 25 ml of concentrated H_2SO_4 added in a fume chamber until digestion was completed after 5 h. The digest was cooled and transferred into a 100 ml volumetric flask and made up to the mark with distilled water. 10 ml of the diluted digest was put in the steam distillation unit, which was previously flushed with distilled water. 18 mL of 40 % of NaOH was then added to the solution in the steam distiller. 25 ml of 2% boric acid pipette into a conicalflask and two drops of bromocresol green methyl red mixed indicator added. This mixture was placed under the condenser outlet of the distillation system, with the tip of the condenser completely immersed in it. The distillation was carried out until all the boric acid solution turned from pink to yellowish green. The solution in the conical flask was titrated against 0.1N HCl solutions and the end point recorded, the distillation processes were done with triplicate samples of the diluted digest, a blank was taken through the same procedure using distilled water in place of the sample.

2.5.4. Crude fat content

About 10 ml of each yoghurt samples was poured into a previously weighed Petri dish and dried over a water bath till most of the water had evaporated, the samples was then transferred to an oven and further dried at 105° C till a constant weighed was obtained. The weight of water loss and dried solids obtained were determined by subtraction and later used to calculate the total amount of fat on wet weight basis. 2 g of the dried sample was weighed into each of two paper thimbles, the thimbles were sealed and placed in the soxhlet extractors. About 150 ml of petroleum ether was poured into each of two previously dried and weighed round bottomed flasks attached to the extractors; extraction was carried out for 16 h. After this, the petroleum ether was recovered from the soxhlet with only small amounts left in the flask. The flasks were then removed and placed in an oven (with the door partially closed) for the ether to completely evaporate. The flasks were cooled in a desssicator, weighed and the fat content was calculated on a wet per weight basis using the water content determined after drying the wet sample.

2.5.5. Carbohydrate content

Total carbohydrate was determined by differences between 100 and total sum of the percentage of fat, moisture, ash, crude fiber and protein content and to calculate the result of the sample. The carbohydrate content of the samples was expressed as a percentage of the differences between the sum of the other chemical composition of the samples and 100.

2.6. Determination of Antioxidant activity of the yoghurt

2.6.1. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay

The DPPH radical scavenging abilities of the yogurts were measured according to the method of De Ancos *et al*., (1992) with some modifications. In brief, 50 µm DPPH radical solution (Sigma Aldrich, St. Louis, MO, USA) prepared in 95 % ethanol was added to an equal volume of the yogurt samples. The reaction mixtures were shaken vigorously and kept in the dark at room temperature for 30 min. After centrifugation (80009g, 10 min), the DPPH radical scavenging activity was measured at 517 nm with a microplate reader (BioTeck Inc., Winooski, VT, USA). Scavenging effect of DPPH radicals was calculated according to the following equation

$$\textbf{Inhibition (\%)} = {}^{(Acontrol - Asample)}\Big/_{A(control)x\ 100}$$

Where $A_{control}$ is the absorbance of the control reaction (containing all reagents except the test compound) and A_{sample} is the absorbance of the test compound. Ascorbic acid and butylated hydroxylanisol (BHA) at a concentration of 0.1 mg/mL were used as positive control

2.6.2. Ferric Reducing Antioxidant Power (FRAP)

Ferric reducing antioxidant power (FRAP) assay: The reducing power of the extracts was determined according to the method described by Oboh (2008) with some modifications. Briefly, 250 µL of each sample at different concentration were mixed with a phosphate buffer (500 µL, 0.2 M, pH 6.6) and potassium ferricyanide (500 µL, 1 %). The mixtures were then incubated at 50°C for 20 min. An amount of 500 µL of trichloroacetic acid

(10%) was added to each sample, and the mixtures were centrifuged at 1.006 × g for 10 min. After that, 750 µL of the upper layer were mixed with 750 µL distilled water and ferric chloride (50 µL, 0.1 %). The mixtures were incubated for 10 min in the dark. Absorbance was measured at 700 nm against a control that consisted of all the reagents without the test sample. All tests were performed in duplicate.

2.7. Determination of Flavonoid content

The method of Shodende and Oboh (2012) was adopted to" determine the total flavonoid content of the sample whereby 0.1 ml of extract was mixed with 4.9 ml distilled water and 0.3 ml of $NaNO_2$ was added. Approximately 0.3 ml of $AlCl_3$ and 2 ml 1 M NaOH were added at 5 min and 6 min, respectively. The volume was made up to 10 ml with distilled water. The mixture was thoroughly mixed using the vortex equipment and the absorbance was read at 510 nm. A calibration curve was prepared using a standard of catechin hydrate (R2 ¼ 0.9994) was used to prepare the calibration curve and the result was expressed as mg catechin equivalents per g of the sample".

2.8. Sensory attributes

Cooled samples that had been stored overnight, were subjected to sensory evaluation on a 9-point hedonic scale. The sensory panels consist of 50 students of Food science and Technology department, The Oke-Ogun Polytechnic Saki, Nigeria. Sensory evaluation of yogurt were carried out for different sensory attributes such as color, flavor, taste, texture and overall acceptability. The sensory scores of the developed yoghurt were done on a nine-point hedonic scale with 1 (dislike extremely) and 9 (like extremely).

2.9. Data analysis.

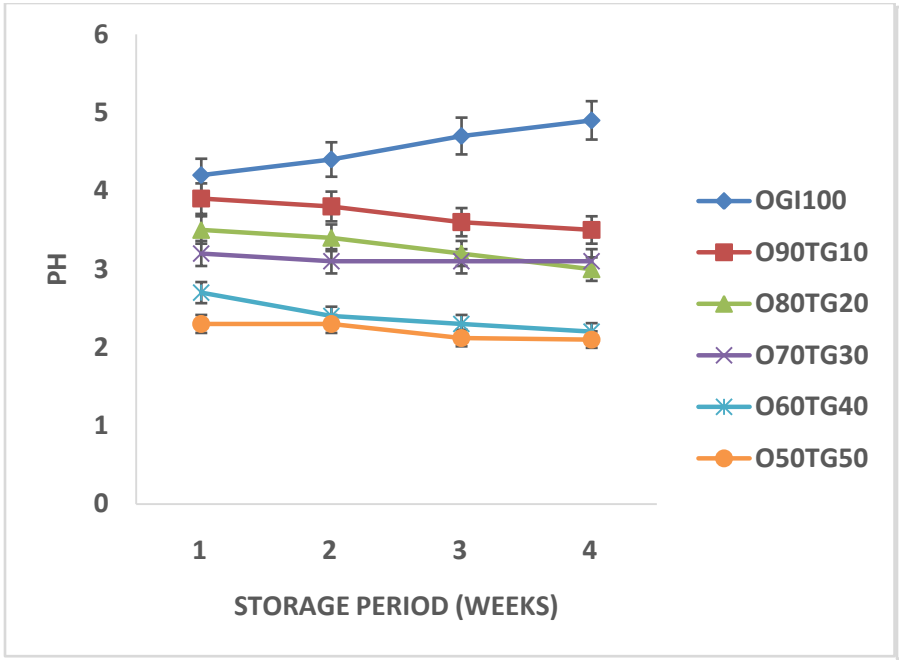
All the data obtained from three replications were analyzed as a completely randomized design procedure using the general linear model procedure of the SPSS version 23 statistical package program (SPSS, Inc., Chicago, IL). Duncan's multiple range test was used to measure the significant difference between means ($p < 0.05$).

3. Result and Discussion

3.1. pH and total titratable acidity and total soluble solid of ogi enriched with dietary tigernut fibre emulsion pulp.

Changes in the pH of all the ogi enriched with tigernut fibre is presented in figure 1. The values ranged from 4.2 to 4.9 for **(OGI_{100})** which revealed an increase in the pH during a storage of four weeks. However, a sequential decrease in the pH of other samples was noted during storage, for instance, it was observed that the value decreased from 3.90 to 3.50 and 3.50 to 3.00 for (**$O_{90}TG_{10}$**) and (**$O_{80}TG_{20}$**) respectively. The acidic pH of (**OGI_{100}**) was expected because fermented cereal products such as ogi usually have high acidity (Mulin, 2003). This is often associated with the actions of acid-producing microorganisms like the lactic acid bacteria during the fermentation process. The inclusion of tigernut fibre considerably decreased the pH value as the enrichment level increases. However, the pH values of all the samples were still at the acidic range though enrichment reduced the degree of acidity, it would however pose no danger to the storability of the products.

There was a significant decrease in the total soluble solids of the sample during the storage period. **(OGI_{100})** has total soluble solids of 0.5 to 2.5 ^{o}Brix while the TSS of **($O_{90}TG_{10}$)** and **($O_{80}TG_{20}$)** reduced from 2.3 to 0.5 ^{o}Brix and 2.2 to 0.4 ^{o}Brix respectively as shown in Figure 2. The TTA of **(OGI_{100})** slightly increased from 0.05 to 0.07% during storage period of the samples. The (**$O_{90}TG_{10}$**) and (**$O_{80}TG_{20}$**) increased from 0.08 to 0.11% and 0.09 to 0.14% as shown in figure 3. A steady decrease in pH and an increase in TTA during storage period of the samples might be as a result of continuous fermentation during storage and also as a result of the consumption of free sugar in the sample as reported by Omemu (2011).



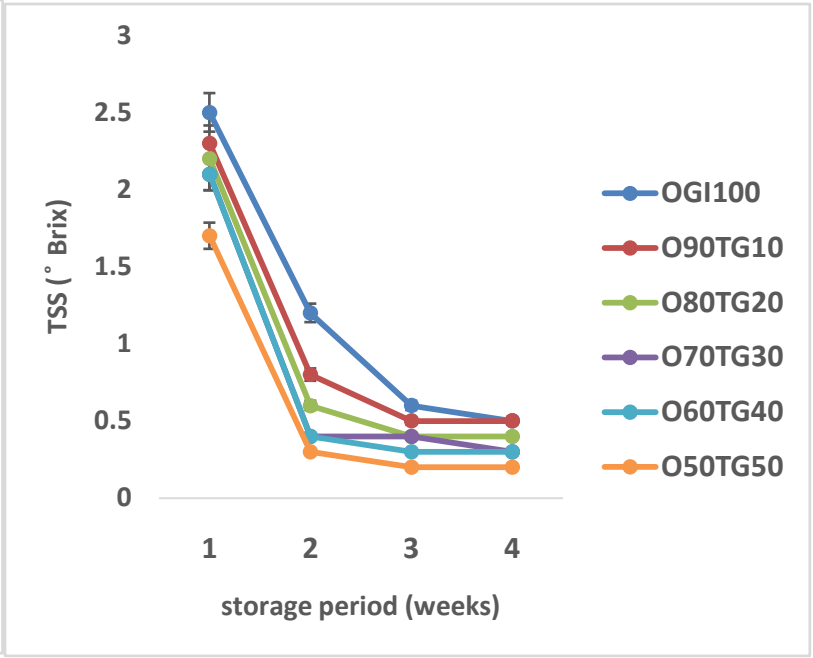


Fig. 1. Changes in the pH of ogi enriched with dietary tigernut fibre with pulp emulsion

Fig 2. Changes in the Total soluble solids of ogi enriched dietary tigernut fiber pulp emulsion

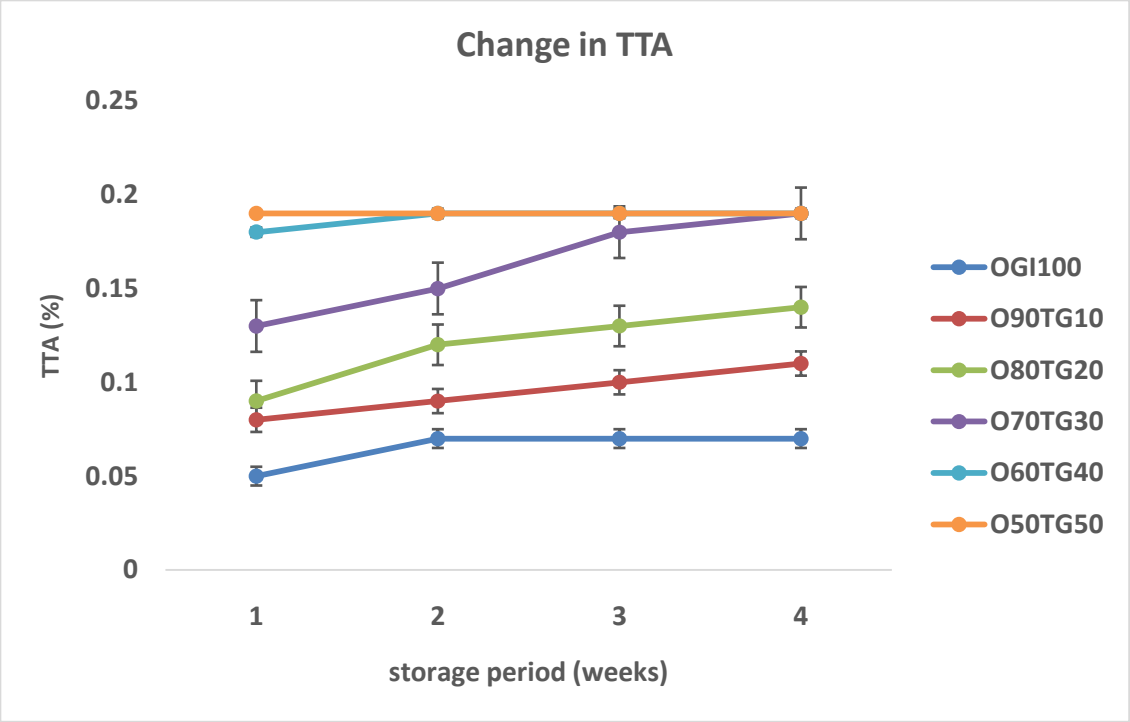


Fig 3. Change in the total titratable acidity of ogi enriched with dietary tigernut fiber pulp Emulsion

3.2. Moisture, fat, protein, ash, fiber and carbohydrates contents of ogi enriched with dietary tigernut fiber pulp emulsion

It was observed that there was a significant ($P < 0.05$) difference in the moisture content ofthe samples as shown in figure 4. The study showed that the control sample (OGI_{100}) has a moisture content ranged from 12.01 to 18.82 % while ($O_{90}TG_{10}$) and ($O_{80}TG_{20}$) has a moisture content ranged from 9.88 to 17.68 % and 9.67 to 16.12 %. The moisture content of all the samples decreased with increasing storage period. The enrichment of the ogi with the tigernut fibre, might have contributed to the significant decrease in the moisture content. The moisture content of the ogi enriched with tigernut fibre in this study is similar to 11.70 % to 12.00 % for ogi enriched with baobab fruit powder as reported by (Adejuyitan *et al*., 2012). However, the moisture content is higher to the value of 8.86% to 8.90% for ogi fortified with Bambara ground flour (Adeyemo and Abimbola, 2019). This decrease in moisture during the storage period indicates that they would have good keeping quality as food spoiling organisms thrive well where there is adequate moisture (Modu *et al*., 2013).

Changes in the fat contents of the ogi enriched with tigernut fibre are shown in figure 5. There was a significant ($P < 0.05$) difference in the fat content of the samples as the fat content increases during the storage period. The fat content for the sample at the week one ranged from 5.3 to 10.12 % for OGI_{100} and $O_{50}TG_{50}$, while the value ranged from 5.3 to 11.45 % for OGI_{100} and $O_{50}TG5_0$ at week two respectively. The increasing content of fat observed in this study may be attributed to high fat content value of about 30% reported to be present in the tigernut seed which is invariably transmitted into the fibre of the tigernut (Ogunlade *et al*., 2015). Tigernut has been reported to be rich in nutrients collectively with fat composition comparable with olive oil and this explains its significance in a balanced diet since it lowers the threat of heart diseases and lower cholesterol levels (Fabunmi *et al*., 2016, Arand *et al.*, 2015).

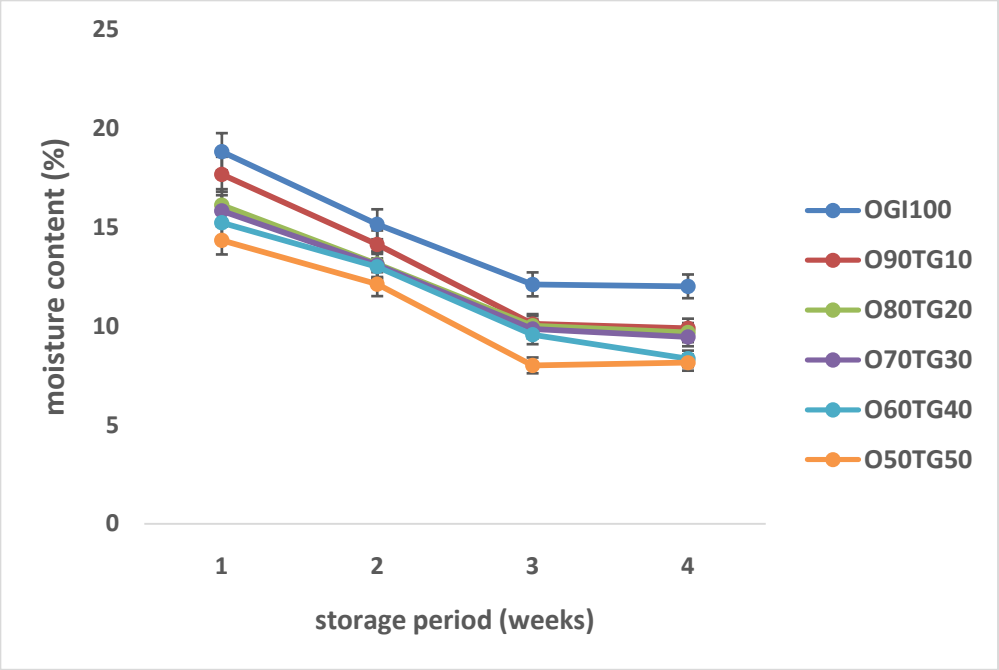


Fig 4. Changes in the moisture content of ogi enriched with tiger nut fiber

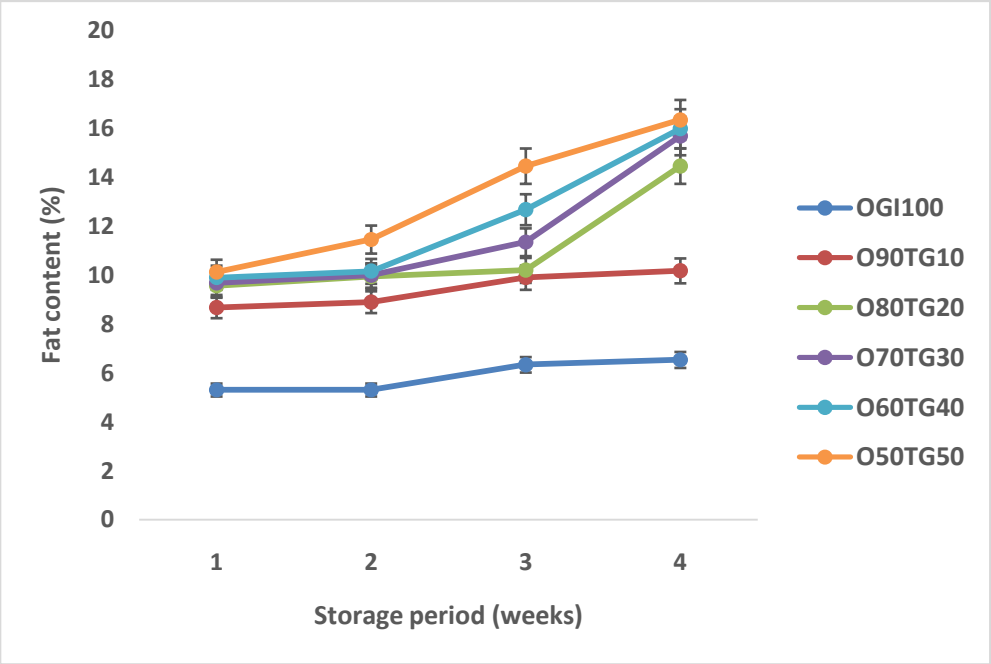


Figure 5. Changes in the fat content of ogi enriched with tiger nut fiber

The same trend of increase in the protein content of the samples as the storage period increases is as observed in this study is shown in figure 6. OGI_{100} showed an increase in value of protein from 8.90 to 10.99 % over a storage period of four weeks while O90TG10 and O80TG20 have a value of 13.89 to 16.79 % and 13.99 to 16.78 % respectively over the same period of storage. The values obtained in this study was higher than 2.15 to 8.02% for acha-tamba based ogi enriched with hydrolyzed soy peptides (Ogori et al; 2020). The result showed that the enrichment of the ogi with tigernut fibre has a pronounced effect on the ogi products. Tigernut has been reported to possess high amount of protein (Rosello-Soto *et al*., 2018). Hence, this explains the high protein observed in this study. Other researchers reported that the protein content of ogi may improve during storage as a result of metabolic activities of some microorganisms which release some extracellular enzymes into the ogi during storage (Oboh and Akindahunsi, 2003). The fibre content for OGI100 and O90TG10 were 0.9 to 1.09 % and 1.51 to 2.88 % respectively over a period of four weeks storage as shown in figure 7. The enriched ogi has higher content of fibre than the control sample (OGI100). The fibre was higher than 2.17 % obtained for maize ogi enriched with ginger and tigernut (Olaniran and Abiose; 2019). Tigernut has been reported to be high in dietary fibre content which could be effective in the cure of and prevention of numerous diseases such as colon cancer, coronary heart disease, obesity, diabetes, gastrointestinal disorder and losing weight(Gambo and Da'u, 2014; Adeyanju; 2011; Trimdad *et al.*, 2010; Borges *et al*., 2008).

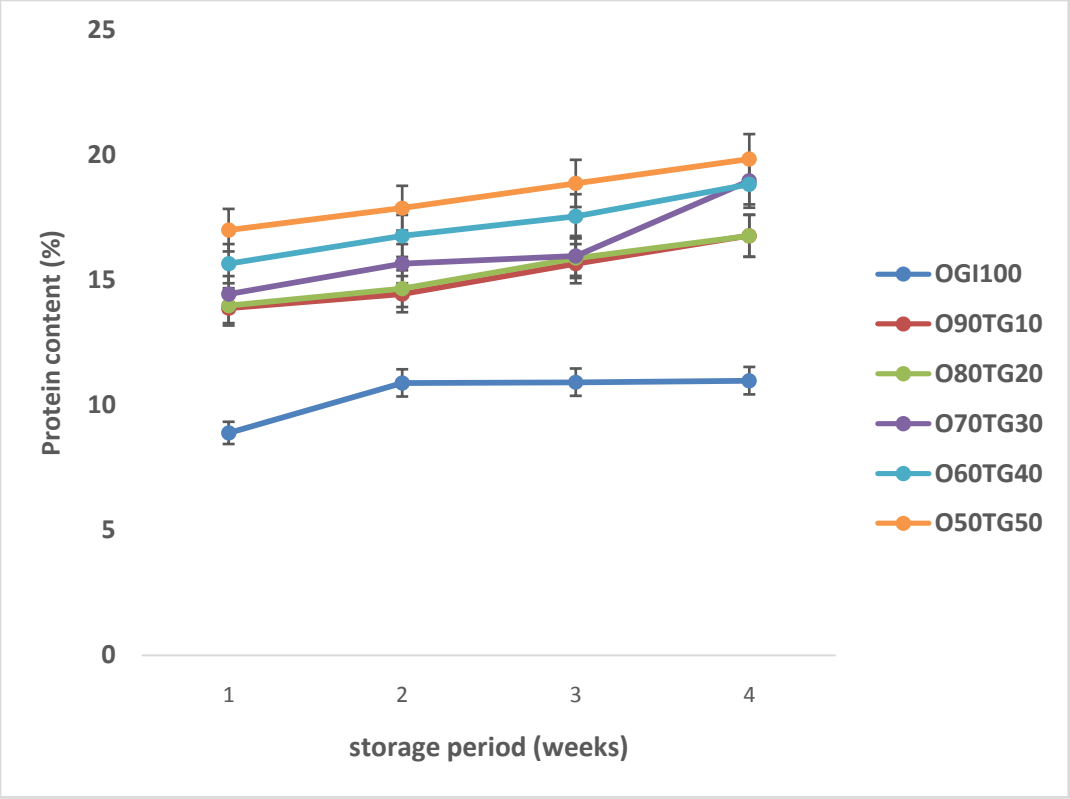


Figure 6. Changes in the protein content of ogi enriched with tigernut fibre

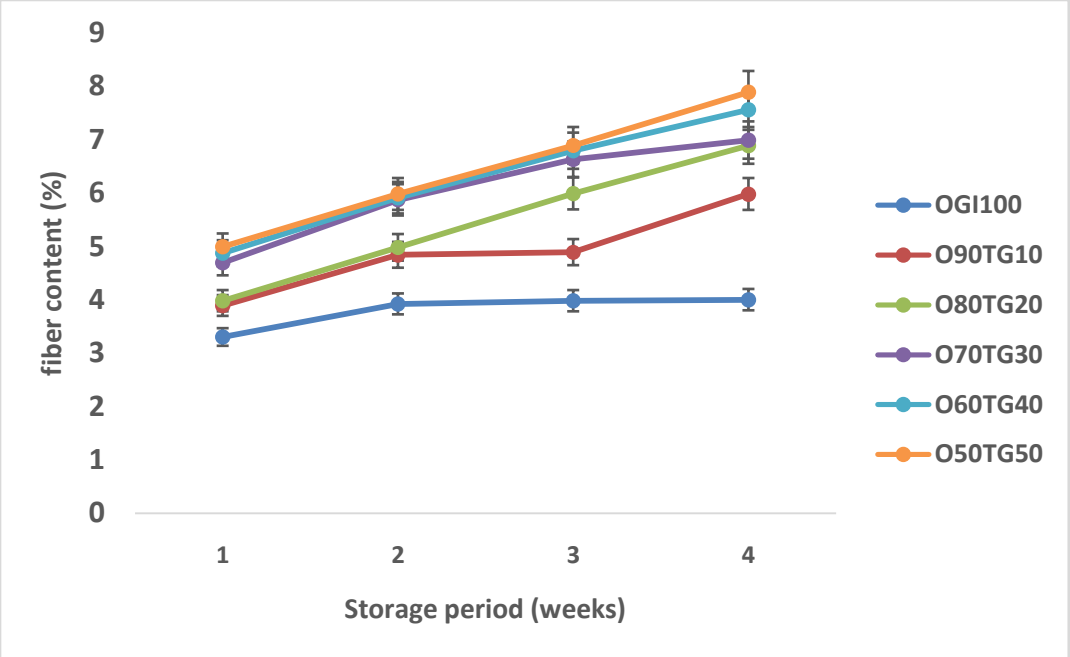


Figure 7. Changes in the fibre content of ogi enriched with tigernut fibre

The ash content of the samples increases as the storage period increases as shown in figure 8 for instance, the (OGI100) and (OGI90TG10) ash contents ranged from 0.9 to 1.09% and 1.51 to 2.88% over storage period of four weeks while the value ranged from 1.65 to 2.98% and 1.69 to 3.28% for O80TG20 and O70TG30 respectively over a storage period of four weeks. An increase in the ash content of the ogi in this study may be as a result of high ash content found in tigernut seeds. Ash content in a food sample is an indication of mineral elements and this indicates that the understudy ogi in this work contain high amount of minerals which could be of health benefit to the consumers. The carbohydrate content of the ogi samples is shown in figure 9. The OGI100 has carbohydrate content of 62.78 to 68.54 %. It will be observed that the carbohydrate content of the ogi samples decreased during the storage period. The carbohydrate content obtained in this study was lower than 73.04-81.92% for ogi enriched with turmeric and ginger (Adelekan et al; 2021). The inclusion of tigernutfibre to the ogi decreased the carbohydrate content of the samples.

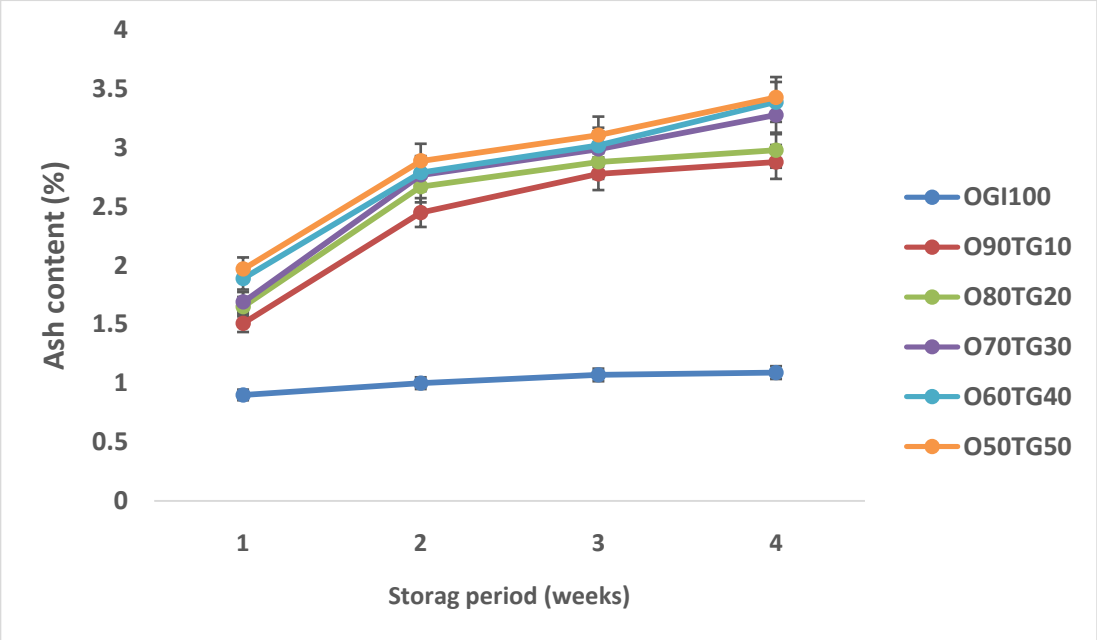


Figure 8. Changes in the ash content of ogi enriched with tigernut fibre

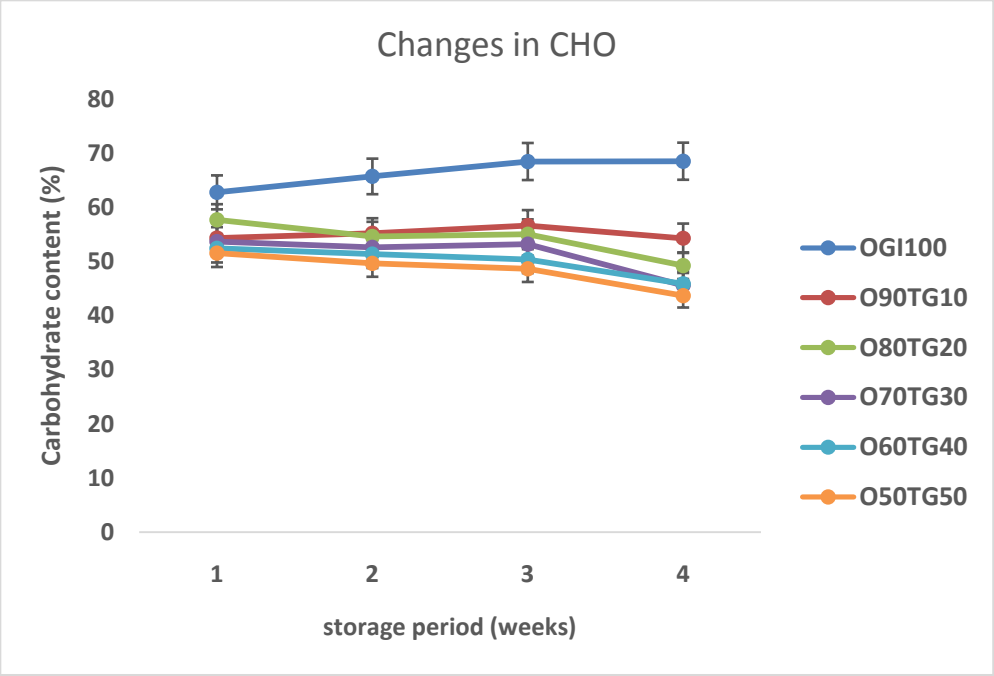


Fig 9. Changes in the carbohydrate content of ogi enriched with tigernut fibre

3.3. DPPH radicals, FRAP and Total flavonoid content of ogi enriched with dietary tigernut fiber pulp emulsion

Table 1 showed the DPPH free radical scavenging activity of the ogi enriched with tigernut. The DPPH of (OGI_{100}) ranged from 10.60 to 10.88% over a period of storage, while ($O_{90}TG_{10}$) and ($O_{80}TG_{20}$) ranged from 15.45 to 16.23% and 16.67 to 17.05% respectively. A progressive increase in the DPPH was observed as the level of enrichment increases as well as the storage period increases. Studies on the antioxidant activity of tigernut indicated that it could be utilized to mop up and scavenge free radicals and generate essential metabolic reactions (Ogunlade *et al*., 2015). It has also been suggested that addition of tigernut as an enrichment to a traditional diet like ogi would probably alleviate the symptoms associated with neurodegenerative and cardiovascular diseases (Sanche-Zapata *et al*., 2012). The ferric reducing property of ogi enriched with tigernut fibre is shown in Table 2. A progressive increase over a period of storage was observed in the FRAP content of the sample. The values obtained for (OGI100) ranged from 0.10 to 0.13$MgFe^{2+}$/100g while the values ranged from 0.14 to 0.19$MgFe^{2+}$/100g for ($O_{90}TG_{10}$) and ($O_{80}TG_{20}$) respectively.The total flavonoids content of the ogi enriched with tigernut fibre over a storage period is shown in Table 3. A significant ($P<0.05$) difference was observed among

the samples where (OGI100) has a value of total flavonoid ranged from 0.16 to 0.18mg/g while (O90TG10) and (O80TG20) have flavonoids ranged from 0.57 to 0.78mg/g and 0.82 to 0.98mg/g. It would be observed that the increase in the level enrichment increased the flavonoid content of the sample. It could therefore be concluded that enrichment with tigernut fibre improved the flavonoids content of ogi.

Table 1. Changes in the scavenging ability of DPPH for free radicals of ogi-enriched with tigernut fibre.

Samples	***DPPH (%)***			
WEEKS	***1***	***2***	***3***	***4***
OGI_{100}	$10.60^{f}\pm1.02$	$10.70^{f}\pm1,04$	$10.79^{f}\pm1.00$	$10.88^{f}\pm1.01$
$O_{90}TG_{10}$	$15.45^{e}\pm1.02$	$15.78^{e}\pm2.01$	$15.89^{e}\pm1.14$	$16.23^{e}\pm1.12$
$O_{80}TG_{20}$	$16.\ 67^{d}\pm0.02$	$16.78^{d}\pm1.11$	$16.99^{d}\pm1.11$	$17.05^{d}\pm.1.11$
$O_{70}TG_{30}$	$17.10^{c}\pm1.04$	$17.23^{c}\pm1.04$	$17.45^{c}\pm1.01$	$17.77^{c}\pm1.01$
$O_{60}TG_{40}$	$17.89^{b}\pm0.02$	$17.99^{b}\pm2.11$	$18.02^{b}\pm1.11$	$18.34^{b}\pm1.07$
$O_{50}TG_{50}$	$18.78^{a}\pm0.02$	$18.99^{a}\pm1.04$	$19.10^{a}\pm1.11$	$19.35^{a}\pm1.01$

Mean (±)Values with different alphabetical superscripts in a column differ (P > 0.05) significantly

Table 2. Changes in the ferric reducing activity power of ogi enriched with tigernut fibre.

Samples	***FRAP ($MgFe^{2+}$/100g)***			
WEEKS	***1***	***2***	***3***	***4***
OGI_{100}	$0.10^{f}\pm0.01$	$0.12^{f}\pm0.01$	$0.13^{f}\pm0.01$	$0.13^{f}\pm0.01$
$O_{90}TG_{10}$	$0.14^{e}\pm0.02$	$0.17^{e}\pm0.02$	$0.19^{e}\pm0.01$	$0.19^{e}\pm0.01$
$O_{80}TG_{20}$	$0.28^{d}\pm0.01$	$0.47^{d}\pm0.02$	$0.59^{d}\pm0.03$	$0.69^{d}\pm0.01$
$O_{70}TG_{30}$	$0.32^{c}\pm0.01$	$0.71^{c}\pm0.01$	$0.77^{c}\pm0.02$	$0.80^{c}\pm0.02$
$O_{60}TG_{40}$	$0.89^{b}\pm0.01$	$0.90^{b}\pm0.02$	$0.90^{b}\pm0.01$	$1.00^{b}\pm0.03$
$O_{50}TG_{50}$	$1.11^{a}\pm0.01$	$1.19^{a}\pm0.01$	$1.22^{a}\pm0.01$	$1.26^{a}\pm0.03$

Mean (±)Values with different alphabetical superscripts in a column differ (P > 0.05) significantly

4. **Table 3. Changes in the total flavonoids content of ogi enriched with tigernut dietary fibre.**

Samples	***TOTAL FLAVONOID CONTENT (mg/g)***			
WEEKS	***1***	***2***	***3***	***4***
OGI_{100}	0.16^{f}±0.01	0.16^{f}±0.01	0.18^{f}±0.02	0.18^{f}±0.02
$O_{90}TG_{10}$	0.57^{e}±0.02	0.69^{e}±0.01	0.72^{e}±0.01	0.78^{e}±0.03
$O_{80}TG_{20}$	0.82^{d}±0.01	0.87^{d}±0.01	0.88^{d}±0.01	0.94^{d}±0.02
$O_{70}TG_{30}$	0.95^{c}±0.02	1.02^{c}±0.01	1.09^{c}±0.01	1.12^{c}±0.01
$O_{60}TG_{40}$	1.17^{b}±0.01	1.19^{b}±0.01	2.12^{b}±0.01	2.18^{b}±0.04
$O_{50}TG_{50}$	2.44^{a}±0.02	2.67^{a}±0.01	2.78^{a}±0.03	2.89^{a}±0.04

5. **Mean (±)Values with different alphabetical superscripts in a column differ (P > 0.05) significant**

5.1.Sensory characteristics of ogi enriched with tigernut fibre.

The flavor of the samples increases with increase in addition of tigernut fibre as well as increase in the storage period. OGI_{100} has flavor value ranged from 5.55 to 5.75 while $O_{90}TG_{10}$ and $O_{80}TG_{20}$ ranged from 7.15 to 8.25 and 7.25 to 8.35 respectively as shown in figure 10. It would be observed that $O_{70}TG_{30}$ has the highest rating in term of flavor while $O_{50}TG_{50}$ was rated lowest. The texture of the samples also steadily improved with addition of enrichment though the ogi (OGI_{100}) has a better texture. However, ($O_{90}TG_{10}$) and ($O_{80}TG_{20}$) with rating of 7.60 to 7.99 and 7.2 to 7.99 compete favorably with control sample in terms of texture as shown in figure 11. In term of taste, ($O_{90}TG_{10}$) and (O80TG20) with the score rating of 8.130 to 8.49 and 7.25 to 8.69 was significantly different from that of (OGI100) with the score of 7.20 to 7.99. So, in term of taste, (O80TG20) was most preferred and followed by (O90TG10) as shown in figure 12. The color of (O90TG10), (O80TG20) and (O70TG30) was rated best among the samples with scores of 8.1 to 8.8, 8.3 to 8.8 and 8.5 to 8.8 as shown in figure 13. The color of the samples improved with addition of ginger fibre and with storage period. The overall acceptability of the sample

showed that O80TG20 was rated best with the score values ranging from 7.00 to 8.80 over a period of storage. It is followed by (O90TG10) with score value ranging from 7.66 to 7.95 as shown in figure 14. It could be concluded that preference in color, taste and acceptability for O90TG10 could be due to a moderate percentage of tigernut fibre. The trend of results observed in this study is in agreement with Adelekan *et al*., (2021) for fermented maize ogi enriched with turmeric and ginger.

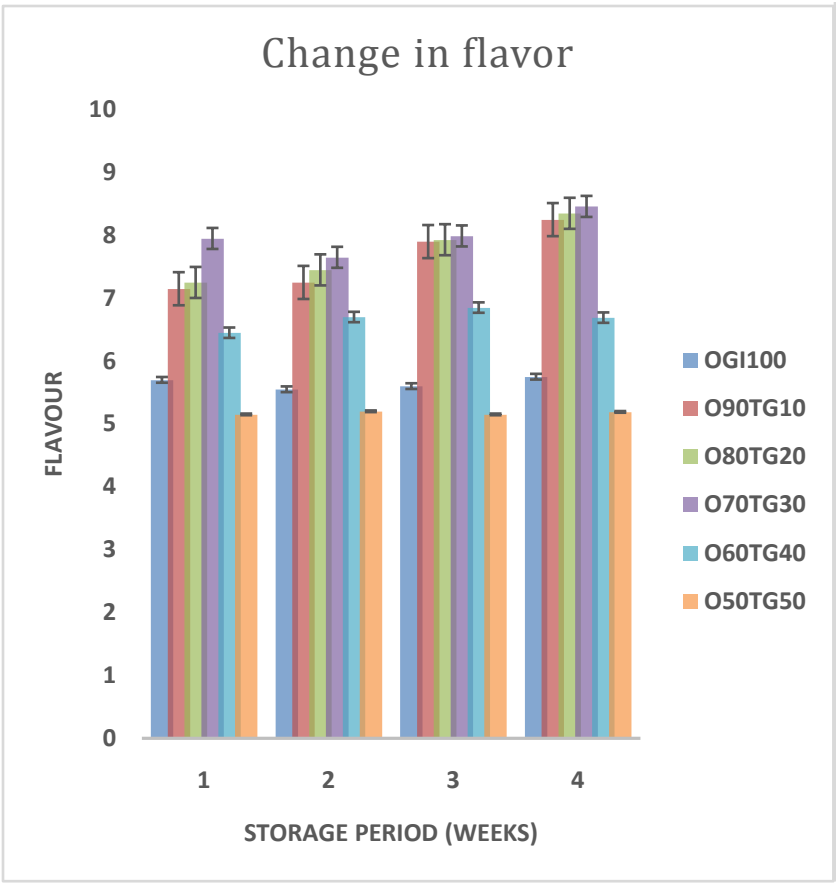


Fig. 10. Changes in flavor of ogi of ogi enriched with tigernut fiber

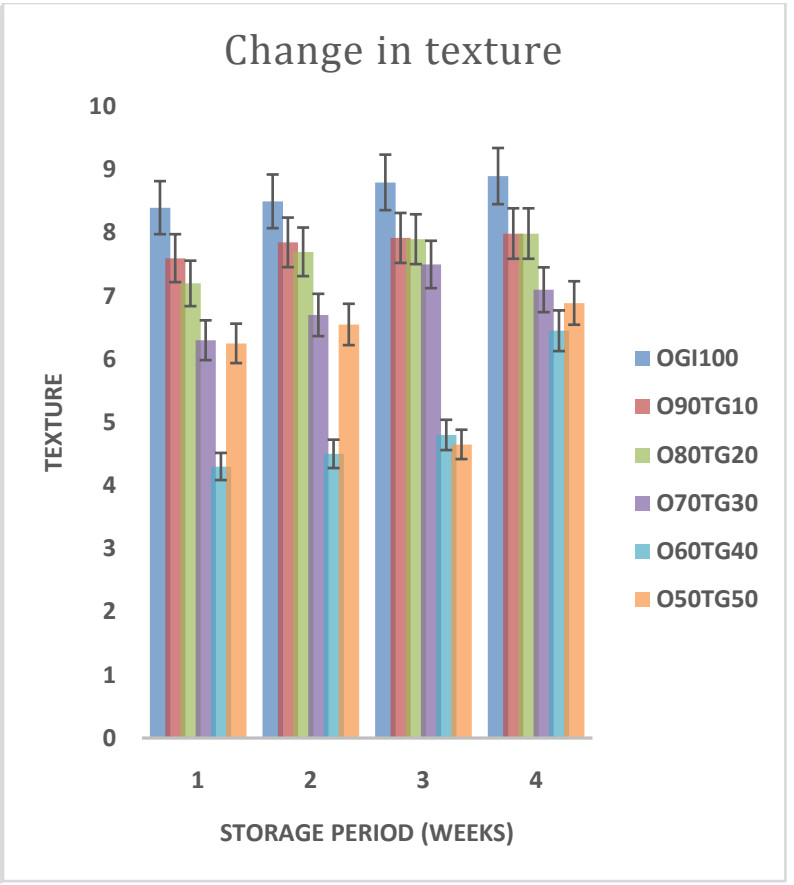


Fig. 11.Changes in texture of ogi enriched with tigernut fiber

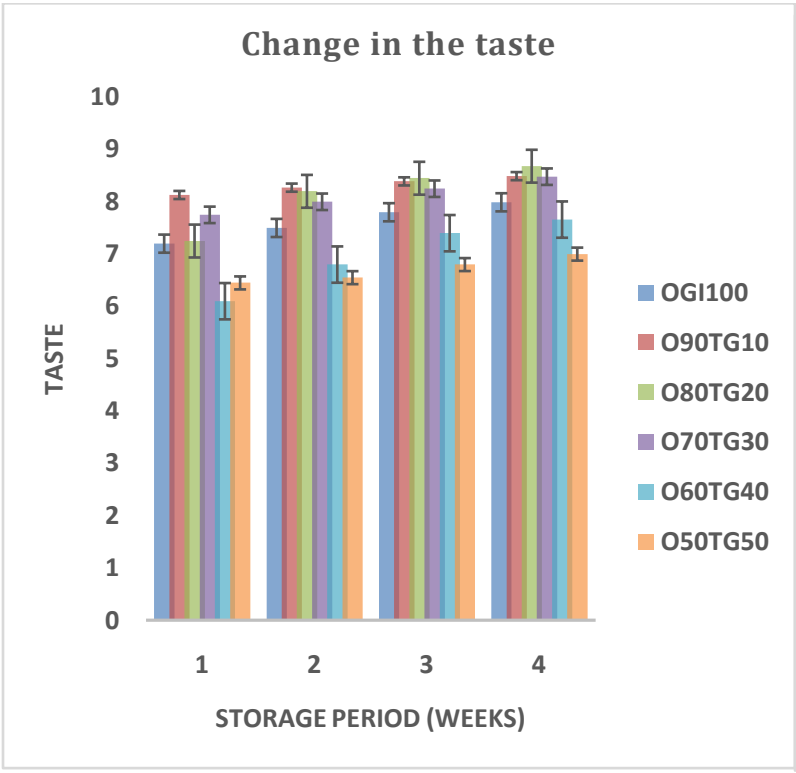


Fig 12. Changes in taste of ogi enriched tigernut fiber fiber

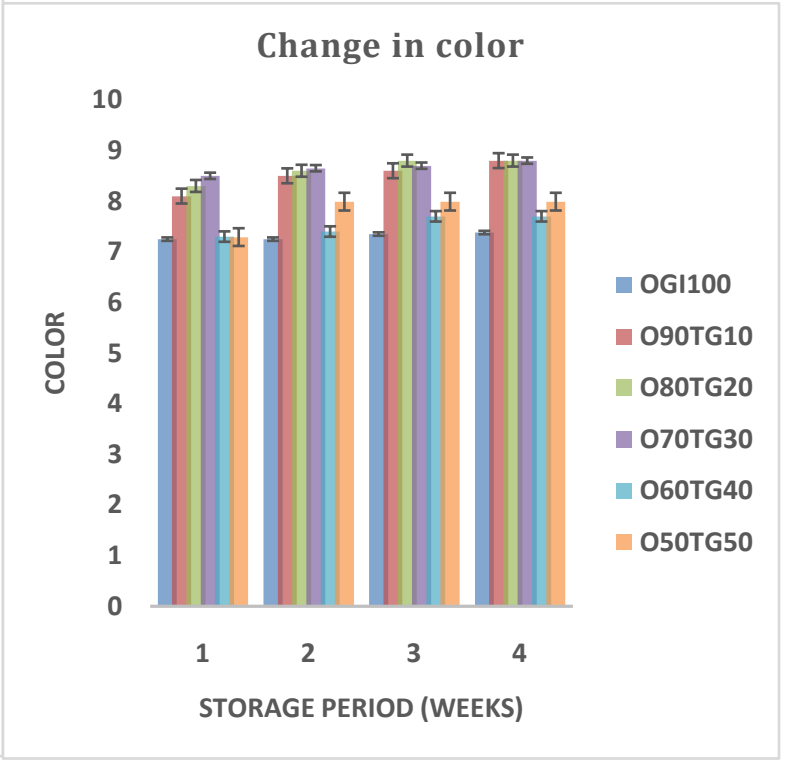


Fig 13. Changes in the color of ogi enriched with tigernut

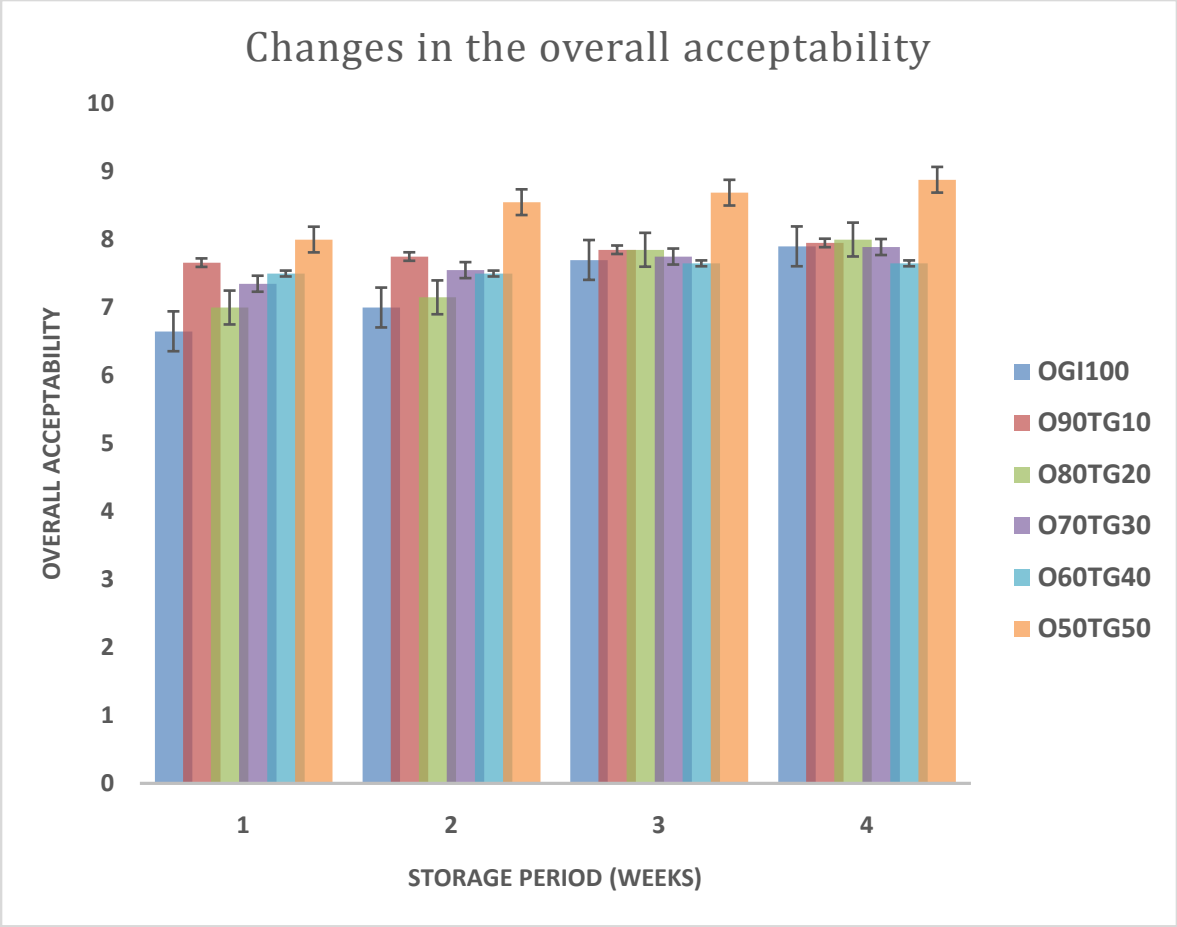


Fig 14. Changes in the overall acceptability of ogi enriched with tigernut fiber

4. Conclusion

This study established the effect of addition of tigernut fiber pulp emulsion on fermented ogi on the physicochemical, proximate, antioxidant and sensory properties of the products during storage period that last for four weeks. Addition of dietary fiber pulp emulsion improved the nutrient content of the ogi sample over the period of storage. The antioxidant composition of the samples also appreciably increased over the period of storage while the sensory evaluation showed that ogi enriched with 20 % dietary tigernut fiber pulp emulsionhas the highest acceptability with respect to color, taste, and flavor respectively. The boosting of the antioxidant in the samples through enrichment with dietary tigernut fiber could help in the prevention of oxidative stress and improve health status of the regular consumer.

Conflict of interest

The authors declared none

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Author contributions

AAO:conceptualization**,** Methodology and Data curation

AOA:Original draft preparation, Reviewing and Editing

ALA: Methodology, data curation and validation

OBF: Provision of study materials, reagents, materials and laboratory samples.

References

Adejuyitan, J.A., Otunola E.T., Akande. E.A., Bolarinwa. I.F. & Oladokun, F.M. (2009). Some Physicochemical properties of Flour obtained from fermentation oftiger nut (Cyperus esculentus) sourced from a market in Ogbomosho, Nigeria. *African Journal of Food Science, 3: 51-5524*

Adejuyitan, J. A,. Abioye, A.O., Otunola, E.T & Oyewole, Y.N. (2012). An evaluation of some properties of baobab fruit powder and ogi mixes. *Transnational Journal of Science and Technology 2 (7). 1-12*

Adejuyitan, J.A (2011). Tigernut processing: its food uses and health benefits. American Journal of Food Technology 6(3).197-201.

Adeyemo, S.M & Abimbola O.C (2019). Assessment of the nutritional qualities of a locally-produced weaning blend of sorghum ogi fortified with bambara groundnut flour. *The International Journal of Biotechnology 8 (2). 115-124*

Adelekan, A.O., Emmanuel A.A & Bolanle E.D (2021). Effect of enrichment with turmeric and ginger on some quality characteristics of fermented maize *Ogi. Croat. Journal of. Food Science and Technoogy. 13 (2)*

Ajanaku, K.O,.Ajanaku C.O,. Edobor-Osoh A & Nwinyi, O.C (2012). Nutritive value of Sorghum Ogi fortified with groundnut seed (*Arachis hypogaea L.*). *America Journal of Food Technology 7: 82-88*

Anand, S. S., Hawkes, C., de Souza, J, R., Mente, A., Dehghan, M., Nugent, R., Zulyniak, M. A., Weis, T., Bernstein, A. M., Krauss, R. M., Kromhout, D., Jenkins, D. J. A., Malik, V., Martinez-Gonzalez, M. A., Mozaffarian, D., Yusuf, S., Willett, W. C., & Popkin, B. M. (2015). Food consumption and its impact on cardiovascular disease: Importance of solutions focused on the globalized food system. *Journal of the American College of Cardiolog, 66* (14), 1590–1614.

Awoyale, W., Maziya-Dixon, B., Alamu, O.E & Menkir, A. (2016): Effect of packaging materials and storage conditions on the degradation of xanthophyll in yellow maize ogi powder. *Journal of Food Nutrition Research. 4 (8), 522-527.*

Barberan, T. F & Andrés-Lacueva, C. (2012). Polyphenols and Health: Current state and progress. *Journal of Agricultural and Food Chemistry 60(36). 8773-8775*.

Belewu, M.A. & Belewu, K.Y. (2007). Comparative physico-chemical evaluation of tigernut, soybean and coconut milk sources. *Int. J. Agric. Biol., 9: 785- 787.*

Borges, O., Gonçalves, B., de Carvalho, J.L., Correia, P & Silva, A.P (2008). Nutritional quality of chestnut (*Castanea sativa Mill*.) cultivars from Portugal. *Food Chemistry 106(3):976-84*

Chukwuma, E.R., Obiama, N. & Christopher, O.I. (2010). The phytochemical composition and some Biochemical effect of Nigerian Tigernut (Cyperus esculentus. L) tuber. *Pakistan Journal ofNutrition 9(7): 709-715*25

De Ancos B., Sgroppo, S., Plaza L& Cano M.P (2002). Possible nutritional and health- related value promotion in orange juice preserved by high - pressure treatment. J Sci Food Agriculture. 2002; 82: 790-796.

Dziki, D., Rozylo, R., Gawlik-Dziki, U & Swieca, M. (2014). Current trends in enhancement of antioxidant activity of wheat bread by the addition of plant materials rich in phenolic compounds. *Trends in Food Science and Technology, 40(1). 48–61*

Fabunmi, T. O., Adigbo, S. O., Odedina, J. N & Akinsanya, Y. I. (2016). Effects of tuber size, soaking hours and sprouting media on sprouting of tiger nut (*Cyperus esculentus* L. var. sativa) tubers. *Acta Agriculturae Slovenica, 107(2), 345*

Gambo A & Da‟u A (2014). Tiger nut (Cyperus esculentus): composition, products, uses and health benefits-a review. Bayero Journal of Pure and Applied Sciences 7(1). 56-61

Ihuoma, A., Chimebuka, V.E & Ndukwe, M (2021). Quality Assessment of Powdered Maize Ogi Fortified with African Walnut (*Tetracarpidium conophorum*) Flour. Microbiology Research Journal International 31(4). 28-51

Inyang, C.U & Idoko C.A (2006). Assessment of the quality of ogi made from malted millet. *African Journal of Biotechnology* 5. 2334-2337.

John O.O., Victoria, I & Mobolaji, A.B (2017). Bacteriological and Proximate Evaluation of Ginger-Fortified Fermented Maize (ogi). *America. Journal of Food Technology 12: 374-378.*

Manjula, K., Viswanath, C. & Suneetha, C. (2012). PhysicoChemical, Sensory and Microbial Quality of Yoghurt Fortified with Sapota Pulp. *International Journal of Material Sciences and Chemistry 11. 4-6*

Modu, S., Ibrahim, Z., Hajjagana, L., Falmata, A. S., Babagana, M & Bintu, B. P. (2013). Production and evaluation of weaning meal from fermented red maize fortified with cowpea. *Academia Journal of Food Research*, *1*(3). 50

Molin, G (2008). Lactobacillus plantarum: the role in foods and in human health. In: Farnworth, E. R. (ed.) Handbook of fermented functional foods. CRC press, Boca Raton. pp. 363

Oboh G (2008). Polyphenol extracts from Hyptis suaveolens leaves inhibit Fe2+ - induced Lipid peroxidation in brain. *International Journal of Biomedical Pharmacy Scencei.2:41-46*

Oboh, G. & Akindahunsi, A.A. (2003). Biochemical changes in cassava product (flour and *garri*) subjected to *Saccharomyces cerevisiae* solid media fermentation. *Food Chem.* 82. 599-602

Ogodo, A.C., Ugbogu O.C & Ekeleme U.G (2015). Bacteriological quality of commercially prepared fermented ogi (Akamu) sold in some parts of South Eastern Nigeria. *International Journal of Biomolecules, Agriculture and Food Biotechnology 9: 638-641*.

Ogori, A.F., Uzor, O.A, Lukas, H., Miroslava, C., Alexey, G., Alexey, L., Anna, D., Pigorev, I., Sergey, P & Mohammad, A.S (2020). Physicochemical, functional and sensory properties of acha-tamba based ogi enriched with hydrolyzed soy peptides. *Journal of Microbiology, Biotechnology and Food Science 9 (4). 824-830*

Ogunlade, I., Adeyemi, B.A & Aluko, O.G (2015). Chemical compositions, antioxidant capacity of Tigernut (Cyperus esculentus) and potential health benefits. *European Scientific Journal. 11(10).*

Olaniran A.F & Abiose S.H (2019). Proximate and antioxidant activities of bio-preserved *ogi* flour with garlic and ginger. *Food Research* 7.1936

Olayiwola, J.O, Inyang, V& Bello, M.A (2017. Bacteriological and proximate evaluation of ginger-fortified fermented maize (ogi). America Journal of Food Technology. 2017:12(6):374-378

Omemu, A. M. (2011). Fermentation dynamics during production of ogi, a Nigerian fermented cereal porridge. *Report and Opinion, 3(4), 8-17*

Rosell´o-Soto, E., Garcia, C., Fessard, A., Barba, F., Munekata, P., Lorenzo, J., & Remize, F. (2018). Nutritional and microbiological quality of tiger nut tubers (*Cyperus esculentus*) derived plant-based and lactic fermented beverages. *Fermentation, 5(1).3*

Sánchez- Zapata, E., Fernández- López J & Angel Pérez- Alvarez J (2012). Tiger nut (Cyperus esculentus) commercialization: health aspects, composition, properties, and food applications. Comprehensive Reviews in Food Science and Food Safety. 11(4). 366-77.

Schulze, M.B., Liu, S., Rimm, E.B., Manson, J.E., Willett, W.C & Hu, F.B (2004). Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. America. *Journal of Clinical. Nutrition. 80, 348-356*

Shodehinde, S.A & Oboh G (2012). In vitro antioxidant activities and inhibitory effects of aqueous extracts of unripe plantain pulp (Musa paradisiaca) on enzymes linked with type-2- diabetes and hypertension. *Journal of Toxic Environmental Health Science 4:65-75.*

Trinidad, T.P., Mallillin, A.C., Loyola, A.S., Sagum, R.S & Encabo, R.R (2010). The potential health benefits of legumes as a good source of dietary fibre. British Journal of Nutrition. 103(4). 569-74.

White, P.J&Broadley, M.R (2005). Biofortifying crops with essential mineral elements. *Trends Plant Science 10: 586-593*.