Original Research Article

**Quality evaluation of ready-to-eat flakes from malted yellow maize, defatted groundnut and sweet orange peel composite flour blends**

.

ABSTRACT

|  |
| --- |
| The study produced and evaluated ready-to-eat (RTE) Flakes from blends of malted yellow maize, defatted groundnut and sweet orange peel flours with the following formulation:MM1 (100:0:0%), MGS1 (90:5:5%), MGS2 (80:15:5%), MGS3 (70:25:5%), MGS4 (60:35:5%) and MGS5 (50:45:5%). Sample MM1 served as control. The samples were analyzed for their chemical, mineral, antioxidant, functional and sensory qualities using standard methods. The proximate composition of the RTE Flakes revealed a significant (p<0.05) increase in moisture (8.47-9.36%), ash (1.35-2.19%), crude fibre (4.12-5.31%), lipids (1.27-1.92%), protein (9.81-18.56) with a decrease in carbohydrate content (74.98-62.66%) as substitution with defatted groundnut increased. The mineral content of the RTE Flakes ranged from: calcium (42.80-72.88mg/100g), Potassium (70.12-122.63mg/100g), Zinc (2.49-5.69mg/100g) and Iron (4.06-9.55mg/100g). The antioxidant assay revealed 41.07-25.85% for DPPH, 66.71-38.19% for ABTs and 4.09-7.79mg/100g for FRAP. Sensory evaluation showed highest preference for sample MM1 (Control) followed by MGS4, MGS2, MGS1, MGS3 and then MGS5 in that order. However, all the samples were acceptable generally by the panelists. This study therefore demonstrated that malted yellow maize, defatted groundnut and sweet orange peel flour can be used for the development and production of RTE Flakes with improved nutritional and sensory attributes. |

*Keywords: RTE Flakes, Proximate composition, malted yellow maize, defatted groundnut, sweet orange peel flour, antioxidants*

1. INTRODUCTION

“Ready-to-eat flakes are processed grain mixtures that do not require additional cooking before being consumed by humans. They are lightweight, easy to ship, and have a reasonable amount of shelf stability. Ready-to-eat cereals (RTEC) meals have a high fiber content and have been adjusted to include vitamins B, iron, and calcium. Furthermore, eating RTEF has been linked to a higher chance of consuming amounts of vitamins and minerals exceeding daily recommended intakes, particularly calcium” (Olabinjo and Olumurewa 2020).Since cereals are relatively low in protein, low in fat, and have a high fiber content, they have long been employed as industrial raw materials. Cereals like sorghum and maize are high in minerals like Sulphur and include important amino acids like cysteine, tryptophan, and methionine. Legumes and oil seeds have very high levels of lysine; another necessary amino acid, but are relatively low in Sulphur-containing amino acids (Olabinjo and Olumurewa 2020).Legumes have recently been used by food scientists and processors into natural cereal formulations as nutrient diversification strategy and to help lower the prevalence of malnutrition among vulnerable populations.

*Zea mays L*., commonly referred to as corn in some regions, is a significant annual grain that is a member of the genus *Zea* and grass family Poaceae. A maize ear is made up of kernels, husk, and silks, which are its edible and inedible parts. Although there are many different types of corn farmed today, yellow corn is the most widely grown cereal grain crop globally (Syazana and Zulkifli, 2021). Unripe corn is often consumed either raw or cooked, whereas mature corn kernels are industrially processed to provide a variety of products used in food preparation, including corn flour, corn oil, and starch (Nawaz *et al*., 2018).

“Nutrients that are abundant in yellow maize kernels include proteins, lipids, carbohydrates, and certain important vitamins and minerals. Compared to rice and wheat, maize has a lower protein level but still has an energy density of 365 kcal/100g, with about 72% carbohydrate, 10% protein, and 4% fat” (Ranum *et al*., 2014). The fat content of yellow maize kernels aids in the retention of fat-soluble vitamins A, D, E, and K, which scavenge free radicals and act as antioxidants to protect against cancer (Kaul *et al*., 2019). Furthermore, the fat content of yellow corn kernels is significant since they contain 45–50% of the oil that is recovered from the germ of the corn kernels. According to Kaul *et al*. (2019); Syazana and Zulkifli, (2021) the extracted oil is useful in making maize oil, which may be utilized in cooking.

While there are other use for the maize plant, historically, people have cultivated it primarily for food, and as a result, the grains have become a staple in diets all around the world (D.-H. Elisa *et al.,* 2022).As a major source of calories and nutrients for 4.5 billion people worldwide, especially in rural Latin America and Africa, maize and its derivatives are now staple foods for many human populations (Palacios-Rojas *et al*., 2020,D.-H. Elisa *et al.,* 2022). “Because maize contains phytochemicals or secondary metabolites like carotenoids and phenolic compounds, its diversity is important for food security in addition to its nutritional value” (Guzzon *et al*., 2021; D.-H. Elisa *et al.,* 2022). “Consuming a diet high in phytochemicals is linked to a decreased risk of chronic illnesses including diabetes and cancer, which are prevalent issues in contemporary society” (D.-H. Elisa *et al.,* 2022).

“Groundnut (*Arachis hypogaea L*.), a self-pollinated allotetraploid leguminous crop in the Fabaceae family, is also known by the names peanut, monkey nut, earthnut, and goobers” (Janila *et al*., 2013). “Groundnut is a legume crop with the unusual growth characteristic of producing seeds in pods underground. As a commodity crop, they are farmed throughout the world in tropical and subtropical regions. China leads the world in groundnut production with 17.5 million metric tons, followed by India with 6.5 million metric tons, Nigeria with 3.9 million metric tons, and the United States with 2.8 million metric tons” (USDA 2021).According to Gulluoglu *et al*., (2016), “groundnut seeds provide an abundant supply of minerals (P, Ca, Mg, and K), vitamins (E, K, and B;the richest source of thiamine and niacin), protein (25–30%), oil (35–56%), and carbohydrates (9.5–19.0%). The crop is used in the production of lubricants, paints, food, feed, and pesticides, among other industrial items” (Variath and Janila 2017). Groundnuts are ideally positioned to be a source of plant-based protein due to their global availability. About half of the 40–50 million metric tons that were grown worldwide in recent years were crushed for oil, leaving 20–25 million metric tons of defatted peanut powder that contained roughly 50% protein (Dean 2021).Groundnuts can be eaten raw or used to make a variety of dishes. They can also be boiled, toasted, processed to make oil, groundnut cake, and peanut butter.

“Citrus fruits, which are members of the *Rutaceae* family, the Plantae kingdom, and the Citrus genus, are grown all over the world, including Nigeria” (Egbuonu and Osuji 2016). “Global citrus production stood at 158 million tonnes in 2019” (World Data Atlas, 2020). “Citrus fruits include tangerine (*Citrus reticulata*), grapefruit (*Citrus vitis*), lime (*Citrus aurantifulia*), lemon (*Citrus limonum*) and sweet orange (*Citrus sinensis*)” (Egbuonu and Osuji 2016). “In tropical and subtropical regions of the world, sweet oranges are a significant fruit” (Nwosu *et al*., 2022).In particular, sweet orange (*Citrus sinensis L.*) is a small evergreen tree that grows to a height range of 7.5-15 meters (Sharon-Asa *et al*., 2010).In addition to being consumed fresh, the fruits are also utilized to make frozen juice concentrate, canned orange juice, jams, and jellies, among other products. Large volumes of orange peel and pulp are produced by the orange processing industries as byproducts of the industrial extraction of orange juices (de Castro *et al*., 2020).Active phytochemicals found in citrus fruit have potential health benefits. It also offers a good amount of potassium, folic acid, vitamin C, and pectin (Shafiya *et al*., 2018). According to research on the deterrence of life-threatening diseases, citrus fruits, fruit extracts, and citrus flavonoids have a wide range of promising biological properties because of their phenolic profile and antioxidant properties (Shafiya *et al*., 2018). Despite the high quantities of vitamin C, dietary fiber, and certain bioactive compounds that may have favorable health effects, citrus peels and pulps are typically thrown away after juice extraction (Nwosu *et al*., 2022).Dietary fiber has been utilized to treat a number of gastrointestinal conditions and has been shown to have positive effects on cholesterol, the risk of colon cancer, and weight loss (Gill *et al*., 2020).

Therefore this study is aimed at producing RTE Flakes from malted yellow maize, defatted groundnut and sweet orange peel composite flours and evaluate it nutritional and organoleptic attributes.

2. material and methods

**2.1 Raw Material Procurement**

The yellow maize and raw dried groundnut seeds were purchased from Wurukum Market, Makurdi and transported to the CEFTER Food Processing laboratory in sacks for further processing. The sweet orange fruits was procured from Rail-way Market, Makurdi and also transported to the Food Processing Laboratory CEFTER in baskets.

**2.2 Preparation of Yellow Maize Flour**

Preparation of sprouted yellow maize flour was carried out as described by Olaoye *et al*., (2015) in fig.1 with slight modification. Whole maize grains was sorted to remove dirt and other extraneous materials, and then washed in clean water. Grains were soaked in water for 24 hrs and then drained. They were spread on jute bags, moistened and left to germinate for 48 hrs. The germinated grains were dried in a dehydrator at 65oC for 24 hrs after which ridicules and plumules were removed by winnowing. They were milled using hammer mill machine and sieved to obtain malted maize flour. The flour samples was packaged in nylon bag and stored at room temperature until use.

**2.3 Sweet Orange Peel Powder preparation**

Preparation of orange peel flour (SOP) SOP was produced as described by Obafaye and Omoba (2018) in fig.2. Ripe orange fruits was washed with distilled water, and peeled with hand knife. The peels were dried in a dehydrator at 400C for 48 hr. The dried peels was milled into flour, cooled and then sieved (150 mm mesh size) to obtain ripe sweet orange peel flour. The flour was stored at 40C inside an airtight polyethylene pack prior to use.

2.4 **Preparation of Groundnut Flour**

The method used by as described by Bongjo *et al.,* (2022) in fig.3 Groundnut seeds were manually washed by hand to remove foreign materials, such as dust, dirt, piece of stones and dried. The groundnut seeds were toasted for 15 minutes, cooled and dehulled then milled. The milled paste was then cold pressed to extract oil and then dried in a dehydrator at 600C for 48hrs, pulverized, sieved and packed in air tight container for further use.

**2.5 Production of flakes**

The flaking was done using the method by Olorunsogo and Adejumo (2023) with slight modification. The composite flours and sugar (8%) were weighed and mixed homogeneously using an electric blender and then water (80%) added and mixed into a dough. The samples were then subjected to pressure cooking at 900C for 1 hour and the samples were removed and allowed to cool down for 5 minutes. Each of the samples were rolled or pressed into flat, thin flakes using a rolling pin, and then were subjected to an electric oven(Maxi 6090 pipe 4b+2p basic Grey;made in Turkey) at temperature of 1500C for 30 minutes. On removal from the toasting machine, the flakes were allowed to cool down and later packed in different clean transparent, plastic packaging containers.

|  |
| --- |
| Yellow Maize Grains |

Sorting/cleaning

Steeping in water (24 hr)

Germination (48 hrs)

Drying (dehydrator) (600C, 24 hrs)

Sorting/winnowing

Milling

Sieving

|  |
| --- |
| Malted Yellow Maize Flour |

Fig.1 Flow chart for the production of malted yellow maize flour.

Source:Olaoye *et al*., (2015) modified slightly.

|  |
| --- |
| Sweet Orange Fruits |

Soaking and washing (clean tap water)

Peeling (hand knife)

Drying (Dehydrator) (60oC, 24 hrs)

Grinding

Sieving (0.2mm mesh)

Packaging and Storage

|  |
| --- |
| Sweet Orange Peel Flour |

Fig.2 Flow diagram for the production of sweet orange peel powder.

Source:Obafaye and Omoba (2018) (Modified)

|  |
| --- |
| Groundnut Seeds |

Cleaning/Sorting by hand

Toasting (15 mins)

Cooling

Dehulling

Milling

Cold pressing

Drying in dehydrator (600C, 24hours)

Pulverization

Sieving

|  |
| --- |
| Defatted Groundnut flour |

Fig.3 Flow diagram for the production of defatted groundnut flour.

Source:Bongjo *et al.,*(2022) (Modified)

|  |
| --- |
| Mixing composite flour with water |

Composite dough

Pre-cooking (1000C for 1hr)

Cooling

Flaking

Toasting (1500C for 30 mins)

Cooling/packaging

|  |
| --- |
| Ready-to-eat flakes |

Fig.4 flow process for the production of RTE flakes from composite flour.

**2.6 Blend formulation for ready-to-eat flakes from composite flour**

The 3 flours; Malted yellow maize, defatted groundnut flour and sweet orange peel flour were blended in different ratios as shown in Table 1.

Table 1. Blend formulation

Ingredient (%)

Sample Yellow maize Flour Defatted Groundnut Flour Sweet Orange Peel Flour

MM1 100 0 0

MGS1 90 5 5

MGS2 80 15 5

MGS3 70 25 5

MGS4 60 35 5

MGS5 50 45 5

**2.7 Determination of Proximate Composition of** **ready-to-eat flakes**

Proximate composition of ready-to-eat flakes was carried out in triplicates to test the moisture content, fat, crude protein, ash, and carbohydrate percentages using Association of Official Analytical Chemist (AOAC, 2012) methods.

**2.7.1 Determination of ash content**

Ash content was determined using incineration at 600 °C in a muffle furnace, according to the method described by Opega *et al*., (2016). Two grams of each grounded sample was weighed into a crucible and ignited tarred crucible (w1). The crucible and weighed sample were placed on a hot plate inside a fume cupboard to prevent smoke accumulation, the remaining residue was transferred to a preheated muffle furnace and maintain at 600 °C for 6 hours until the sample is reduced to light ash, the crucible was removed, placed in the desiccators, cooled and weighed (w2) and the ash content was calculated in equation (1) as follow:

W2−W1

% ash = × 100 (1)

2.0 g

**2.7.2 Determination of fat content**

Fat content was determined using the Soxhlet extraction method according to Opega *et al.,* (2016). Two grams (2 g) of the sample was weighed into a thimble (w1), a dry and cool boiling flask was weighed, filled with 300 mL petroleum ether (w2), and boiled at 60 °C with the extraction thimble in soxhlet apparatus, which was allowed to reflux for 6 hours. The thimble was carefully removed, while the extracted oil in the petroleum ether flask was dry between 105 - 110 °C for 1 hour. It was then be transferred from the oven to the desiccators, allowed to cool, weighed, and calculated in equation 3 as follow;

W2−W1

% fat = × 100 (2)

Weight of the sample (2.0 g)

**2.7.3 Determination of crude protein content**

The crude protein was determined using the micro–Kjeldahl method described by Prabhavathi *et al.* (2017). Two grams (2 g) were weighed along with 20 mL of distilled water into a micro –Kjeldahl digestion flask. It was shaken and allowed to stand for some time. One tablet of selenium catalyst and 20 mL tetra Oxo sulphate (VI) acids (H2SO4) was added. The flask was heated on the digestion block at 100 °C for 4 hours until the digest became clear. The flask was removed from the block and allowed to cool and the content was transfer into a 50mLvolumetric flask and diluted to the mark with water. Nitrogen in the distillate was determined by titrating with 0.014 M of H2SO4; the endpoint was obtained when the color of the distillate changed from green to pink.

Actual titre value −titre value of blank × 0.1 × 0.014 × 𝑐𝑜𝑛𝑣𝑒𝑟𝑠𝑖𝑜𝑛𝑓𝑎𝑐𝑡𝑜𝑟

% Crude protein = × 100

Weight of food sample (3)

**2.7.4 Determination of moisture content**

The moisture content of each sample was determined as described by Khalifa *et al*. (2017) using the vacuum oven method. Two grams of the grounded sample was rapidly weighed into a pre-weighed dried dish (w1) and weighed with the dish (W2). It was dried to a constant weight at 100 °C at a pressure that does not exceed 100 mHg for 5 hours. When the drying procedure was completed, the dish was placed in the desiccators to cool and reweighed (W3) and the recorded loss in weight, was the moisture. The percentage moisture was calculated as below;

 W1+W2

% moisture = × 100 (4)

W3−W1

Where;

W1 = Initial weight of the empty crucible

W2 = Weight of the crucible plus (+) the sample before drying

W3 = Final weight of crucible + sample after drying

% total solid (dry matter) = 100 % moisture

**2.7.5 Determination of crude fiber content**

A non-enzymatic method (Prabhavathi *et al*., 2017), was used to determined crude fiber content. Two grams of the dry sample was defatted with petroleum ether and boiled under reflux for 30 minutes with 200 mL of a solution containing 1.5 g of H2SO4 /100 mL of the solution. The solution was filtered through linen on a fluted funnel and wash with boiling water until the washing is no longer acidic. The residue was transferred to a beaker and boiled for 30 minutes in 200 mL of a solution containing 1.25 g of carbonate-free NaOH per 100 mL. Final residue was filtered through a thin but closed pad of washed and ignited asbestos in a porcelain crucible. It was dry in an electric oven, weighed, incinerated, cooled, and reweighed;

The loss in the weight after incineration x 100 was calculated as the percentage (%) of the crude fiber

Loss in weight (g)

% crude fibre = × 100

Original mass (2.0) (5)

**2.7.6 Determination of carbohydrate content**

Carbohydrate content was determined as described by Khalifa *et al.,* (2017) where the total proportion of carbohydrate in the sample was obtained by calculation, using the percentage weight method by subtracting the % sum of food nutrients: (% protein, % crude fiber, fat % and % ash %) from 100 %.

Where, percentage (%) of carbohydrates (=) (CF + CP + F + A + M – 100 %) where; CF = Crude Fibre, CP= Crude Protein, M = Moisture, F = Fat and A = Ash.

Note: Triplicate values were obtained for each sample.

**2.8 Determination of Mineral Composition**

The minerals were determined using the methods described by AOAC (2010), using atomic absorption spectrophotometer (AAS). Five ml of the sample was measured using a syringe into a 250 ml Erlenmeyer flask, acidified with nitric acid and evaporated to dryness using a steam bath. Fifteen ml of HNO3 was added and heated in a fume cupboard to a colourless solution after addition of 5 ml H2O2, at 400-450oC for 2 h. The ashed samples were adjusted to 50 ml in a volumetric cylinder with distilled water.

**2.8.1 Determination of iron content**

Five ml of the sample as prepared above was transferred into 50 ml volumetric flask. Then 10 ml of ammonium acetate buffer solution and 2 ml phenon-throline solution were added, and the mixture diluted to the mark with distilled water. The reagents were mixed thoroughly and allowed to stand for 10 min. for maximum colour development. Standard solution was prepared by measuring 1 g of pure iron wire into 100 ml conc. HNO3, in a water bath and was diluted to 1000 ml with distilled water. From this stock, standard solutions of 0.0, 0.5, 1.0, 2.0 and 4.0 ppm were prepared and used for equipment calibration. Total iron was determined with appropriate iron lamp.

**2.8.2 Determination of calcium content**

The samples were wet-ashed as described above. Five(5) ml of each of the sample digests was measured into a conical flask using a syringe and then pipetted 1.0 ml of SrCI2 solution containing 10,000 mg/ml to yield a 1,500 mg/ml of Sr2+ in the final solution. Calibration curve was prepared for the element using standard solution, which was prepared by dissolving 2.497 g of oven-dried CaCO3, diluted to 100 ml with de-ionized water. From this stock solution, calcium standard solutions were prepared with the concentrations of 0.0, 3.0, 8.0 and 9.0-ml. Calcium concentration in the sample was determined using AAS with calcium filter.

**2.8.3 Determination of zinc content**

Five ml of each of the samples were first digested with 20 ml of acid mixture (650 ml conc. HNO3; 80 ml percloric acid (PCA); 20 ml conc. H2SO4) and aliquot of the diluted clear digest was used for the measurement of absorbance with AAS using filters that match the element. The samples were heated until a clear digest was obtained and then diluted to the 500 ml mark with distilled water. Standard zinc solution was prepared by dissolving 1 g zinc metal in 20 ml HCl and diluted to 1,000 ml with deionized distilled water; (1 ml = 1 mg Zn).

Distilled water was acidified with 1.5 ml conc. HNO3 and left for one min. The instrument was zeroed. Standard was atomized and the burner adjusted both up and down and sideways until a maximum response was obtained, and absorbance of the sample determined. The actual zinc lamp was used for its determination.

**2.8.4 Determination of potassium content**

Potassium was determined using AAS as described by Nwuso *et al*., (2022). Five ml of each of the samples was first digested with 20 ml of acid mixture (650 ml conc. HNO3; 80 ml PCA; 20 ml conc. H2SO4) and aliquots of the diluted clear digest used for atomic absorption spectrophotometry, using filters that match the element. The samples were heated until clear digest was obtained and then diluted to the 500 ml mark with distilled water. Then, 91.0% (w/v) lithium chloride was added. A standard stock solution containing 100 mg/ml of K+ ions was prepared by dissolving 1.907 g KCl in water. The solution was made to 500 ml mark with distilled water. From the stock solution, a standard solution of 0.0, 2.0, 4.0 and 6.0 ppm were prepared, to which a standard stock solution of 1% lithium-chloride was added. The potassium standard was used to calibrate the instrument while the actual potassium concentration of the samples was determined using potassium filter at 385 nm.

**2.9 Determination of Functional Properties**

**2.9.1 Determination of Bulk Density (BD)**

The Bulk Density of the flake sample was determined by the method modified by Ogunlakin *et. al.,* (2012). A previously weighed measuring cylinder was filled with 20 g of the sample. The bottom of the cylinder was tapped gently but repeatedly on a laboratory bench to eliminate air spaces until there was no further reduction of the sample. The resulting volume was recorded and bulk density was determined by placing 20 g of the sample into the measuring cylinder and the volume was recorded without tapping. The cylinder with the sample was weighed and the bulk density of the samples was determined by:

BD (g/cm3) = $\frac{W\_{2}-W\_{1}}{V}$ (6)

Where,

BD = bulk density in g/cm3

W1 = weight of empty cylinder (g)

W2 = weight of cylinder + sample (g)

V = volume of the cylinder occupied by sample (cm3)

**2.9.2 Determination of water and Oil absorption Capacity (WAC/OAC)**

WAC and OAC were determined according to the modified method of Awofadeju *et al*., (2021). 1 g of each flour sample was weighed into a centrifuge tube. Using a waring whirl, 10 mL of distilled water was thoroughly mixed with the sample for 30sec. the sample was allowed to stand at room temperature for 30 min with gentle stirring after every 10 min during this period it was then centrifuged at 2000 rpm for 30 min, after which the supernatants were decanted and the volume taken. The same procedure was repeated using oil to determine the oil absorption capacity.

The WAC and OAC was determined as follows;

WAC/OAC (g/g) = $\frac{Volume of water or oil absorbed}{Dry weight of sample } x Density of water/oil$ (7)

Density of water = 1 g/mL

Density of oil = 0-907 g/mL

**2.9.3 Determination of Swelling Capacity (SC)**

The method modified by Awofadeju *et al*., (2021) was used. About 10 g of the sample was measured into a 300 ml measuring cylinder. Then 150 mL of distilled water was added to the sample and allowed to stand for 4 hours. The final volume after swelling was recorded and the percentage of swelling calculated as follows;

Swelling capacity (%) = $\frac{final volume-initial volume}{initial volume}×100$ (8)

**2.10 Determination of Anti-oxidants**

**2.10.1 Measurement of 2, 2-diphenyl-1-picrylhydrazyl radical scavenging activity**

The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity (RSA) was determined by the slightly modified method of Badr *et al.,* (2023). Briefly, 80 μL of 0.2 mM DPPH ethanol solution was added to 20 μL ofsample solution at different concentrations (50∼1,000 μg/mL) and allowed to react at 25oC. The control consisted of 20 μL of DMSO and 80 μL of 0.2 mM DPPH. The mixtures were incubated at room temperature for 10 min and then the absorbance was measured by ELISA at 492 nm. The DPPH radical scavenging ability of each sample is expressed as the half maximal inhibitory concentration on DPPH free radicals (IC50).

**2.10.2 Radicals scavenging ability (ABTs\_1)**

A spectrophotometry procedure described by Ferri *et al*., (2013) was used with some modification needed for application to both polymeric and low molecular weight substrates: instead of methanol, dioxane with a little admixture of water (10%) was used as a solvent, the time of interaction for some flake samples was prolonged to 24 h. In order to prevent auto-oxidation, the experiments were carried out under an inert atmosphere of argon using a degassed solvent.

A flake extract sample solution in dioxane (0.1 ml) was mixed with 3.9 ml of a 6 · 105 mol/l DPPH solution and the absorbance at 517 nm of the mixture was immediately measured using a Specord UV/VIS spectrophotometer. The decrease in DPPH concentration was plotted at different molecular ratios of reagents. As the change in absorbance of the DPPH solution without any additives was negligible for the time of the reaction needed for a steady state achievement (1–2 h), it was possible to calculate the number of DPPH radicals scavenged by one antioxidant molecule, in the case of flake by monomeric moieties, phenyl propane unit (PPU). The percentage of DPPH remaining at the steady state was plotted as a function of the molar ratio of the lignin sample tested to DPPH and from this graph the concentrations of the flake samples needed to decrease the initial DPPH concentration by 50% (EC50) were determined. Scavenging activity was characterized in terms of antiradical power, ARP, which was defined as an inverse value of EC50. On the basis of the efficient concentration, the efficient interaction stoichiometry was calculated as the number of DPPH moles reduced by one mole of related compounds. The reaction rate of the samples with DPPH was recorded using ESR spectroscopy with the ER-9 spectrometer. The interaction was carried out in dioxane solution (200C) in flake extract excess. Solutions of co-re-agents were mixed in the ESR measuring tube, and the change in the intensity of the third peak in the DPPH ESR spectrum was followed continuously. The number of paramagnetic centres inherent in polyconjugation systems of flake was calculated from the intensity of their singlet ESR spectra with g-value of 2.0030 and 2.0035, respectively.

**2.10.3 Ferric Reducing Antioxidant Power (FRAP)**

The method described by Senevirathna *et al*., (2021) was used. Briefly, in this method 90µL of FRAP reagent was mixed with 90µL of distilled water and 30Ml of sample or blank (distilled water or methanol). The final dilution of the test sample was 1/34 and readings were at 595nm on a spectrophotometer. Temperature was maintained at 370 C and the sample was measured every 15 s for up to 30min.

**2.11 Sensory Evaluation**

Sensory assessment was carried out on the RTE flake samples. The samples were encoded in identical containers and displayed. A hedonic scale of nine-points was used. The scale ranged from “Like Extremely (9)” to “Dislike Extremely (1)”. Each of the samples was rated for Taste, Aroma, Crispiness, Colour and Overall Acceptability. During the sensory test, after each assessment, panelists were told to drink water or rinse their mouths to clear the palate.

**2.12 Data Analysis**

Data was expressed as mean ± standard deviation. The data obtained were subjected to an analysis of variance (ANOVA) test to determine whether there was significant differences, and Duncan’s multiple range test (DMRT) was used to separate the means where there were significant differences.

3. results and discussion

**3.1 Proximate Composition of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

The proximate composition of ready-to-eat flake made from Malted maize, defatted groundnut and sweet orange peel flour is presented in table 2.

Proximate composition is fundamental to determine the major nutritional component and storage characteristics of food product. These include moisture, ash, crude fibre, lipids, crude protein and carbohydrates (calculated by difference).

**Moisture Content**: The moisture content of the flake samples varied from 8.47% to 9.36%, with MGS5 exhibiting the highest moisture content and MM1 (control) the lowest. These figures are significantly different (*P*=.05) across all samples. It can be observed that moisture content increased with increased defatted groundnut flour. This corroborate Nwakunite *et al.,*(2024) where “moisture content of flaked rice and kidney beans significantly increased with corresponding increase in the percentage addition of kidney bean flour. All the flake samples were below the recommended limits of 13-15% as safe moisture content levels for storage of food and cereal products” (USDA, 2017). The moisture content of a food is of importance to determining packaging and shelf life. Ready-to-eat flakes are generally low in moisture content. The low moisture levels of the flakes would ensure shelf stability during storage.

**Ash Content:** Ash content refers to the inorganic residue that remains after the combustion of materials. It is a key determinant of the mineral composition of food products such as calcium, magnesium, iron and potassium. It can help in accessing the nutritional profile and quality of food. The ash content of the flakes increased progressively with increased incorporation of defatted groundnut, ranging from 1.35% in the control sample MM1 (control) to 2.19% in MGS5. The ash content of the flake samples differed significantly (*P*=.05) from each other except for MGS2 and MGS1 which may be due to both samples having the same or similar mineral composition after processing treatment;malting and defatting. Those values were in agreement with the ones obtained by Ezegbe *et al.*, (2023) for maize-based flake snacks complemented with *Mucuna pruriens* seed flour which valued between 1.4-1.6% ash content. According to Adeyeye *et al.*, (2020), “the ash content gives an overall estimate of total mineral elements present in the food. Minerals are important components of the diet because they are building materials for bones, aid muscle & nerve function as well as regulating the body’s water balance” (Najjingo *et al.*2024).

**Fibre Content**: the fibre content of the flakes samples analyzed ranged between 4.12 to 5.67% with MM1 (control) having the least value (4.12%) while MGS2 had the highest value (5.67%). The values recorded differ significantly (*P*=.05) across all flakes samples. The observed trend indicate that the fibre contend increased with increased incorporation of partially defatted groundnut and Sweet orange peel flour except for MGS2. The same trend was reported by Malik *et al*., (2017) for corn-peanut flakes which had fibre content from 1.80 to 2.73%, however the value were lower than the formulated flakes in this study. The fibre content of the formulated flakes are also higher than those reported by Nwakunite *et al.,* (2024) for flaked rice complimented with kidney beans flour (1.66-4.67%). “The higher values recorded could be as a result of the sweet orange peels inclusion in the formulated flake samples. Dietary fiber is important and has several benefits in human metabolism such as improved bowel movement, reduced glucose spikes, increased satiety and prebiotic function therefore adequate intake is required” (Najjingo *et al,.*2024).

**Lipid content:** the lipid content of the formulated RTE flakes ranged from 1.27-1.92% with MM1 (control) having the lowest value while MGS5 recorded the highest value. The value were all significantly different (*P*=.05) within all the samples. These values are advantageously lower than those obtained by Malik *et al*., (2017) from corn-peanut flakes which figures ranged from 3.77-14.12%. Ezegbe *et al.*, (2023) also reported higher values for lipids (6.30-10.93%) from maize-based flaked snacks complemented with *Mucuna pruriens* seed flour. The distinct variation in lipid content can be due to partially defatting the groundnut before incorporating into the flake formulation. The low lipid content of the RTE flakes aligns well with current consumer preferences. This could enhance the marketability of the RTE flakes among health-conscious consumers, positioning it as a preferable snack option for those looking to reduce lipid/fat consumption as it is linked to weight gain and cardiovascular complications. The low lipid content of the RTE flakes also makes it less prone to rancidity which affects the taste and aroma negatively as well as degrades the nutritive value of food.

**Protein content:** The percentage crude protein of the formulated flakes varied between 9.81 and 18.56%. MM1 (control) had the lowest value (9.81%) while MGS5 had the highest value of 18.56%. There were significant differences (*P*=.05) in the crude protein content of the samples except for MM1 (control) and MGS1 which could be as a result of minimal inclusion of protein-rich (5% defatted groundnut flour in MGS1) and the presence of a low protein component (sweet orange peel flour) that resulted in negligible effect on the total protein content of MGS1. Increased quantities of defatted groundnut flour inclusion significantly increased the protein content of the RTE flakes. The result obtained corroborates Ezegbe *et al.*, (2023) who analyzed maize-based flake snacks complemented with *Mucuna pruriens* seed flour and reported increased protein content with increasing *Mucuna pruriens.* Malik *et al*., (2017) also reported the same trend, the addition of defatted groundnut flour in the formulation improved the protein level in corn flakes and this may help in reducing malnutrition in people consuming such products. Asi *et al.,* (2024) also analyzed corn flakes raw materials and reported that “the higher the proportion of pre-cooked red bean flour the lower the proportion of pre-cooked white corn flour, the higher the protein content in the flakes. Legumes significantly have a higher plant-based protein content compared to other plant-based ingredients. Therefore increasing the amount of defatted groundnut flour increases protein levels in the RTE flakes. Sufficient protein intake is necessary because proteins are one of the building blocks of body tissues and they are precursors of important biological molecules such as hormones and enzymes” (Najjingo *et al.*2024).

**Carbohydrate content:** the carbohydrate content of the formulated RTE flakes analyzed in this study are significantly different (p<0.05) ranging from 62.66 % (MGS5) as the lowest to 74.98 % (MM1; control) recording the highest value. However, the addition of sweet orange peel flour does not have a significant effect on the carbohydrate content of flakes despite the fact that sweet orange peel extract has been reported by Egbuonu and Osuji (2016) to have a carbohydrate value 54.17%. The trend indicates that as **defatted groundnut flour was incorporated into the flake blends,** the carbohydrate content decreased. This was in agreement with Nwakunite *et al.,* (2024) who recorded values of 53.69 to 69.91% for carbohydrate in flaked rice complimented with kidney beans flour. The carbohydrate content of the samples decreased significantly with increase in the percentage substitution of defatted groundnut flour. This could be attributed to the low composition of carbohydrate in legume compared to cereals. The values obtained were higher than those reported by Olabimjo *et al*.,(2020) for RTE flakes with formulation 30:10 (soybean: groundnut) had the highest Carbohydrate value of 54.25% and lowest value 46.42% for 10:30 soybean and groundnut blends respectively.

“Carbohydrate content is highly influenced by other proximate components; as the levels of other proximate components decrease, the carbohydrate content increases and vice versa” (Asi *et al.,* 2024). Higher carbohydrate values of RTF indicate that it is a good source of energy to the body.

Fig. 5 Samples of RTE Flakes produced from malted maize, defatted groundnut and sweet orange peel composite flour.

**Table 2. Proximate Composition of RTE Flakes from Maize, Groundnut and Sweet orange Peel Flour**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sample | Moisture (%) | Ash (%) | Fibre (%) | Lipid (%) | Protein (%) | Carbohydrate (%) |
| MM1 | 8.47a±0.06 | 1.35a±0.08 | 4.12a±0.05 | 1.27a±0.03 | 9.81a±0.05 | 74.98f±0.10 |
| MGS1 | 8.95c±0.02 | 1.61b±0.03 | 4.22b±0.04 | 1.50b±0.02 | 9.85a±0.05 | 73.87e±0.06 |
| MGS2 | 9.08d±0.04 | 1.67bc±0.02 | 5.67c±0.05 | 1.69c±0.03 | 11.91b±0.04 | 71.08d±0.12 |
| MGS3 | 8.65b±0.08 | 1.75c±0.03 | 4.80d±0.09 | 1.75d±0.01 | 13.88c±0.04 | 69.14c±0.13 |
| MGS4 | 9.23e±0.04 | 1.92d±0.06 | 5.03e±0.02 | 1.82e±0.01 | 15.89d±0.04 | 66.11b±0.08 |
| MGS5 | 9.36f±0.05 | 2.19e±0.05 | 5.31f±0.02 | 1.92f±0.05 | 18.56e±0.04 | 62.66a±0.07 |

Values are Mean ±Standard deviation of triplicate determination. Values with same superscript along the column are not significantly different (*P*=.05)

MM1-100% Malted maize, 0% defatted groundnut and 0% Sweet orange peel flour

MGS1-90% Malted maize, 5% defatted groundnut and 5% Sweet orange peel flour

MGS2-80% Malted maize, 15% defatted groundnut and 5% Sweet orange peel flour

MGS3-70% Malted maize, 25% defatted groundnut and 5% Sweet orange peel flour

MGS4-60% Malted maize, 35% defatted groundnut and 5% Sweet orange peel flour

MGS5-50% Malted maize, 45% defatted groundnut and 5% Sweet orange peel flour

**3.2 Mineral Composition of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

The mineral composition of the formulated RTE flakes are presented in table 3.

The result shows that the calcium content of the RTE flakes ranged from 42.80mg/100g to 72.88mg/100g. Sample MM1 (Control) flake recorded lowest value of 42.80mg/100g for calcium while sample MGS5 had the highest value of 72.88mg/100g.There was significant difference (*P*=.05) in the calcium content of the flake samples. There was significant increase with increased incorporation of defatted groundnut flour in the flake. The observed trend was reported by Bongjo *et al*.,(2023) for Chin-chin formulated with wheat, defatted peanut and orange peel composite flour where there was increase in the calcium content with increased addition of defatted peanut and orange peel flour. The values obtained in this study are lower compared to Bongjo *et al*.,( 2023) however higher than those reported by Olabinjo *et al*.,(2020) for RTE flakes from blends of maize, defatted soybeans, defatted groundnut, Moringa leaves and scent leaves where calcium content increased with increased defatted soybeans flour. Calcium is necessary in maintaining total body health and it also helps the development and strength of bones and teeth.

The Potassium (K) content of RTE flakes samples was relatively compared to other minerals analyzed in this study. The potassium content of the samples ranged from 70.12 to 122.63mg/100g. MM1 (Control) had the lowest value (70.12mg/100g) while sample MGS5 recorded the highest value of 122.63mg/100g. All samples were significantly different (*P*=.05) in potassium content with increased defatted groundnut and sweet orange peel flour. The observed trend was reported by Bongjo *et al*.,(2023) for chin-chin made from composite flour where there was a significant increase (p<0.05) in the potassium content as the level of incorporation of defatted peanut flour and Orange Peel Flour increased with higher values from 136.42-300.08mg/100g compared to those obtained in this study. Values recorded align with Olabinjo *et al*., (2020) for RTE flakes from blends of maize, defatted soybeans, defatted groundnut, moringa leaves and scent leaves. Potassium has been reported to play a vital roles in proper functioning and maintaining fluid balance of the essential organs; brain, heart, nerves and muscle (Asouzu *et al*., 2020). It has also been known to aid nerve impulse transmission and it is a vital cation of intracellular fluid (Bongjo *et al*., 2022).

Zinc content (Zn) of the RTE flakes formulation varied with significant differences (*P*=.05) among the samples. The zinc content values for all samples ranged between 2.49 and 5.69mg/100g. Sample MGS5 had highest value of 5.69mg/100g while sample MM1 (Control) had the lowest value of 2.49mg/100g.This result showed that there was significant increase (*P*=.05) in zinc content of the samples as the amount of defatted groundnut Flour and Sweet Orange Peel Flour incorporated into RTE Flake is increased. The zinc content values in this study are higher than those reported by Malik *et al*., (2017) for corn-peanut blended flakes (0.42-0.98mg/100g). Zinc is an essential micronutrient that aid protein formation in the body thus positively influencing blood formation, wound healing, growth, taste perception, and maintenance of all tissues and healthy immune system components of many enzymes.

The iron (Fe) content of the Flakes range from 4.06 – 9.55mg/100g and are significantly different (*P*=.05). Sample MGS5 had highest value (9.55mg/100g) of iron content while sample MM1 (Control) had the lowest value (4.06mg/100g). The varied values with increased incorporation of defatted groundnut flour, this could be attributed to the high iron content of groundnut as reported by (USDA, 2019) and values reported here followed the same trend as reported by Malik *et al*., (2017); Olabinjo *et al*., (2020) but are comparatively higher. The content of iron of the flake sample MGS5 shows that products would be beneficial nutritionally for children for the development strong bones, blood formation and body development.

**Table 3. Mineral Composition of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sample | Calcium (Ca)(mg/100g) | Potassium (K)(mg/100g) | Zinc (Zn)(mg/100g) | Iron (Fe)(mg/100g) |
| MM1 | 42.80a±0.01 | 70.12a±0.01 | 2.49a±0.03 | 4.06a±0.01 |
| MGS1 | 46.02b±0.02 | 78.56b±0.01 | 2.86b±0.01 | 4.75b±0.00 |
| MGS2 | 50.13c±0.03 | 86.19c±0.00 | 3.17c±0.02 | 5.40c±0.01 |
| MGS3 | 56.30d±0.03 | 91.24d±0.03 | 3.66d±0.02 | 6.03d±0.01 |
| MGS4 | 61.37e±0.02 | 105.04e±0.06 | 4.14e±0.02 | 7.89e±0.01 |
| MGS5 | 72.88f±0.02 | 122.63f±0.02 | 5.69f±0.02 | 9.55f±0.03 |

Values are Mean ±Standard deviation of triplicate determination. Values with same superscript along the column are not significantly different (*P*=.05)

MM1-100% Malted maize, 0% defatted groundnut and 0% Sweet orange peel flour

MGS1-90% Malted maize, 5% defatted groundnut and 5% Sweet orange peel flour

MGS2-80% Malted maize, 15% defatted groundnut and 5% Sweet orange peel flour

MGS3-70% Malted maize, 25% defatted groundnut and 5% Sweet orange peel flour

MGS4-60% Malted maize, 35% defatted groundnut and 5% Sweet orange peel flour

MGS5-50% Malted maize, 45% defatted groundnut and 5% Sweet orange peel flour

**3.3** **Functional Properties of Composite Flour from Maize, Groundnut and Sweet orange Peel Blends.**

The functional properties of flours describe the behaviour of the flours during preparation, processing and also predict how they will affect the taste, appearance and texture of the finished food products (Bongjo *et al.,* 2022). These properties are a function of the organoleptic, physical, and chemical properties of the food such as fat protein, fibre, and carbohydrate content (Aburime *et al.,* 2020). These properties are crucial in determining the overall quality of food products. The functional properties of the composite flour blends are presented in table 4.

**The bulk density (BD)** of the flours ranged from 0.59g/ml (MGS1) to 0.74 g/ml (MGS5).the bulk density of the flour increased with increased inclusion of defatted groundnut flour. All samples were significantly different (*P*=.05) except for MM1 (control) and MGS1. The same trend was reported by several authors including Bongjo *et al.,* (2022) who also observed increased in bulk density with increased incorporation of defatted peanut flour in composite flour. Kui *et al.,* (2014), reported flours made from legumes to have high bulk density. Suresh *et al*., (2015) also observed the same trend. The bulk density of flour is an indication of the heaviness of a flour sample. It is an important parameter that is used to determine requirements for food packaging and is a function of the moisture content and particle size of flours (Bongjo *et al.,* 2022).It is obvious that decreased proportion of malted Maize flour increased the bulk density of the composite flours. The high bulk density recorded suggests that the flour is suitability for use in food preparations.

**Water Absorption Capacity (WAC)** is an important functional property necessary in food formulations particularly those involving dough handling as it determines the extent to which the flour concerned can absorb water. The water absorption capacity decreased significantly (*P*=.05) from 1.68g/g (MM1; control) to 1.41g/g (MGS5) except for MM1 and MGS1.The principal chemical composition that enhances the water absorption capacities of flours are fiber, proteins, and carbohydrates (Suresh *et al*., 2015).The mentioned constituents contain hydrophilic parts that are polar or charged side chains. Therefore, the slight decrease in the WAC of the flour is due to the decrease in carbohydrate content which has hydrophilic ability despite increase in the fiber and protein content of the flour as the quantity of the high-protein-dense rich defatted groundnut flour and sweet orange flour were added.

**Oil Absorption Capacity (OAC)** of the formulated flour samples varied significantly different (*P*=.05), with values ranging from 1.42g/g in MM1 (control) to 1.15g/g in MGS5. Notably, MM1 exhibited the lowest OAC, while MGS5 had the highest. The trend observed align with Menon *et al*., (2015) where oil absorption capacity significantly decreased (*P*<.01) in composite flour variants as compared to the standard/control flour. The mechanism of oil absorption is principally attributed to the physical entrapment of oil and the binding of oil to a non-polar chain of protein (Menon *et al*., 2015) Therefore, the lower oil absorption capacity of composite flours samples might be due to the presence of high protein constituents of the defatted groundnut flours and the hydrophilic nature of those flours. OAC is the ability of the fat in flour to bind to the non-polar side chain of proteins. It is an essential functional property that contributes to enhancing mouth feel while maintaining the flavor of the food product.

**Swelling Index (SI)** The swelling index of the formulated composite flours ranged between 8.21 to 8.87%. The lowest value of swelling index was observed in MM1 (control) (8.21%) whereas the maximum in MGS5 (8.87%). Swelling index(SI) is an indicator parameter of the water absorption index of the flour granules interaction during heating (Menon *et al*., 2015) The swelling index of flours depends on size of particles, types of variety and types of processing methods or unit operations employed(Suresh *et al*.,2015). According to Menon *et al*., (2015), SI is a representation of non-covalent bonding between molecules within starch granules and also a factor of amylopectin ratio and α-amylose ratios.

**Table 4. Functional Properties of Composite Flour from Maize, Groundnut and Sweet orange Peel Blends.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sample | Bulk Density(g/mL) | Water Absorption Capacity(g/g) | Oil Absorption Capacity(g/g) | Swelling Index (%) |
| MM1 | 0.61a±0.00 | 1.68e±0.03 | 1.42e±0.02 | 8.21a±0.03 |
| MGS1 | 0.59a±0.00 | 1.67e±0.02 | 1.41e±0.01 | 8.15a±0.01 |
| MGS2 | 0.63b±0.00 | 1.59d±0.01 | 1.35d±0.01 | 8.36b±0.02 |
| MGS3 | 0.67c±0.00 | 1.52c±0.02 | 1.28c±0.02 | 8.53c±0.04 |
| MGS4 | 0.69c±0.00 | 1.48b±0.02 | 1.22b±0.02 | 8.72d±0.02 |
| MGS5 | 0.74d±0.00 | 1.41a±0.01 | 1.15a±0.01 | 8.87e±0.07 |

Values are Mean ±Standard deviation of triplicate determination. Values with same superscript along the column are not significantly different (*P*=.05)

MM1-100% Malted maize, 0% defatted groundnut and 0% Sweet orange peel flour

MGS1-90% Malted maize, 5% defatted groundnut and 5% Sweet orange peel flour

MGS2-80% Malted maize, 15% defatted groundnut and 5% Sweet orange peel flour

MGS3-70% Malted maize, 25% defatted groundnut and 5% Sweet orange peel flour

MGS4-60% Malted maize, 35% defatted groundnut and 5% Sweet orange peel flour

MGS5-50% Malted maize, 45% defatted groundnut and 5% Sweet orange peel flour

**3.4 Antioxidant Composition of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

The antioxidant results of the formulated RTE Flakes are presented in table 5. The antioxidant capacity of the sample formulations relative to the DPPH radical scavenging activity shows that the highest antioxidant potential according to this assay was recorded for MGS1(90% Malted maize, 5% defatted groundnut and 5% Sweet orange peel flour) formulation which was 52.52% dry weight while MGS5 recorded the least(25.85%) dry weight. All the formulations were significantly different (*P*=.05) at different levels of inclusion. It was observed that the level of DPPH radical scavenging activity reduced with increased substitution of defatted groundnut flour since the level of inclusion of sweet orange peel was consistent. The reduction in antioxidant capacity with increased substitution of defatted groundnut flour could be due to lower inherent antioxidant capacity of defatted groundnut flour compared to malted maize and sweet orange peel. The trend and values obtained in this study correlated with Rani *et al*., (2020) (19.26-46.69mgTE/100g) for biscuit fortified with orange peel powder at 20% substitution. The values reported by Badr *et al*., (2023) (16.95-36.52) for corn flakes produced from different levels of yellow corn flour and quinoa flour are however relatively low compared. The increase in the values of the formulated flakes with defatted groundnut flour and sweet orange peel is most likely attributable to the fact that groundnut and orange peel flour are very rich in antioxidant capacity

MGS1 compared to other formulations showed the highest antioxidant potential in ABTs (2, 2-azino-bis (3-ethybenzothiazoline-6-sulfonic acid)) radical scavenging activity (66.48%) while sample MGS5 recorded the least (38.19%). The flake formulations were significantly different (*P*=.05) across all the samples. ABTs assay is a crucial indicator of the health promoting potential of the RTE Flakes.

The results from the FRAP assay also showed that the highest antioxidant potential was given by MGS1) (7.79mg/100g dw) and the lowest by MGS2 (4.09mg/100g dw). All the samples were significantly different (*P*=.05). The values reported in this study are lower compared to those by Senevirathna *et al*., (2022) (21.03% dw) for extruded puffed breakfast cereals from purple sweet potato (*Ipomoea batatas* L.) and red rice. Antioxidant capacity measured by FRAP is often correlated with reduced risk of diseases such as cancer, cardiovascular diseases and neurodegeneration disorders.

This is due to the role of oxidative stress in the development of such diseases and the ability of antioxidants to counteract it.

**Table 5. Antioxidant Composition of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

|  |  |  |  |
| --- | --- | --- | --- |
| Sample | DPPH (%) | ABTs (%) | FRAP (mg/100g) |
| MM1 | 41.07e±0.31 | 57.71e±0.44 | 6.33d±0.19 |
| MGS1 | 62.52f±0.51 | 66.48f±0.21 | 7.79f±0.19 |
| MGS2 | 36.52d±0.81 | 47.18d±0.10 | 4.09a±0.11 |
| MGS3 | 32.34c±0.58 | 44.81c±0.14 | 5.39b±0.22 |
| MGS4 | 28.64b±0.60 | 41.87b±0.22 | 6.02c±0.07 |
| MGS5 | 25.85a±0.81 | 38.19a±0.06 | 7.00e±0.04 |

Values are Mean ±Standard deviation of triplicate determination. Values with same superscript along the column are not significantly different (*P*=.05)

DPPH-2, 2-diphenyl-1-picrylhydrazy.ABTs-2, 2-azino-bis (3-ethybenzothiazoline-6-sulfonic acid). FRAP-Ferric Reducing Antioxidant Power

MM1-100% Malted maize, 0% defatted groundnut and 0% Sweet orange peel flour

MGS1-90% Malted maize, 5% defatted groundnut and 5% Sweet orange peel flour

MGS2-80% Malted maize, 15% defatted groundnut and 5% Sweet orange peel flour

MGS3-70% Malted maize, 25% defatted groundnut and 5% Sweet orange peel flour

MGS4-60% Malted maize, 35% defatted groundnut and 5% Sweet orange peel flour

MGS5-50% Malted maize, 45% defatted groundnut and 5% Sweet orange peel flour

**3.5 Sensory Attributes of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

The sensory characteristics of the RTE flakes prepared were evaluated, and the results are presented in Table 6.

The preference scores of tastes ranged between 6.40 and 7.13. The MM1 (Control) and MGS2 were most preferred (with mean score of 7.13); however, all the samples were not significantly (*P*=.05) different in taste. These scores indicate a taste preference ‘like moderately” and “Like slightly”

The mean scores for aroma ranged from 6.53(MGS5) to 6.93 (MGS3). Sample MGS3 formulated flake was the most preferred in respect of aroma. Aroma is the main organoleptic determining factor that makes a product to be liked or disliked. However, there was no statistical difference (*P*> .05) between the control and the composite flakes produced. This implies that the composite RTE Flake compared favorably with the control sample MM1 (Control). This could be attributed to the great aromatic flavour imparted by orange peel flour as well as the defatted groundnut flour. The Panelists accepted all the formulated flakes since their mean score indicated ‘Like Slightly’ on the hedonic scale.

Crispiness represents the key textural attributes of dry snacks product; indicating freshness and high quality. Crispiness mean scores ranged between 5.80 and 7.80. Sample MM1 (7.80) recorded the highest mean followed by MGS1 (7.53).The result of the crispiness indicate ‘like moderately’ and “like slightly” as presented on the hedonic scale.

The mean scores for colour of all the RTE Flakes produced ranged from 6.47 to 7.47.Samples MGS1,MGS2 and MGS3 were not significantly different(p>0.05), sample MM1 was not statistically different(*P*>.05) from MGS4 while MGS5 was significantly different(*P*=.05) from all the samples. Sample MGS2 and MGS3 were the most preferred, followed by MGS1 then MM1. All the means score for colour represent “like moderately” and “like slightly” from the hedonic scale. colour is known as the only quality that consumers can base their purchasing decisions on.

The “overall acceptability” mean scores recorded by the RTE Flake samples ranged between 6.27 and 7.60 with sample MGS5 recording the lowest mean of 6.27 which indicates ‘like Slightly’ on the hedonic scale. The RTE Flake samples MGS4 and MGS2 compared more favorably with the control sample MM1 in terms of overall acceptability. The overall acceptability informs how much or less a product is accepted. Acceptability may not necessarily depend solely on the sensory attributes of the product but also on other determinants parameter such as physiological, behavioral and cognitive factors, related to the consumer.

**Table 6. Sensory Attributes of Flakes from Maize, Groundnut and Sweet orange Peel Flour Blends.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample | Taste | Aroma | Crispiness | Colour | Overall Acceptability |
| MM1 | 7.13a±1.46 | 6.67a±1.18 | 7.80c±1.08 | 7.00ab±1.13 | 7.60b±1.50 |
| MGS1 | 6.40a±2.23 | 6.67a±1.49 | 7.53bc±1.19 | 7.40b±0.83 | 6.80ab±1.66 |
| MGS2 | 7.13a±0.64 | 6.87a±0.99 | 7.20bc±1.21 | 7.47b±1.41 | 7.00ab±0.93 |
| MGS3 | 6.53a±1.25 | 6.93a±1.03 | 6.60ab±1.63 | 7.47b±1.41 | 6.47a±1.19 |
| MGS4 | 6.80a±1.52 | 6.73a±1.22 | 6.93ac±1.03 | 6.93ab±1.03 | 7.13ab±0.92 |
| MGS5 | 6.60a±1.06 | 6.53a±1.46 | 5.80a±1.93 | 6.47a±1.30 | 6.27a±1.22 |

Values are Mean ±Standard deviation of triplicate determination. Values with same superscript along the column are not significantly different (*P*=.05)

MM1-100% Malted maize

MGS1-90% Malted maize, 5% defatted groundnut and 5% Sweet orange peel flour

MGS2-80% Malted maize, 15% defatted groundnut and 5% Sweet orange peel flour

MGS3-70% Malted maize, 25% defatted groundnut and 5% Sweet orange peel flour

MGS4-60% Malted maize, 35% defatted groundnut and 5% Sweet orange peel flour

MGS5-50% Malted maize, 45% defatted groundnut and 5% Sweet orange peel flour

4. Conclusion

This study demonstrated that partially defatted groundnut and sweet orange peel flour have great potential in the production of high nutrient dense RTE Flake. The flake significantly improved the nutritional composition in terms of protein, crude fibre and ash while carbohydrate content decreased with increased substitution with defatted groundnut flour.

The mineral content also experienced a significant increase in term of calcium, potassium, zinc and iron therefore supporting proper bone health and nerve functions. The functional properties supply useful insight into texture, stability, and processing characteristics, which are essential for application in industrial optimization and quality control processes. Producing RTE Flakes from malted yellow maize and partially defatted groundnut-sweet orange peel flour blend has nutritional advantages over the 100% yellow maize flakes especially for individuals with health issues requiring protein, fibre, antioxidants and minerals rich foods and low content of carbohydrates.

The sensory result showed that all flake samples were acceptable by the panelist, however, samples MGS4 and MGS2 compared favourably with the MM1 (control). The study therefore indicates that the use of partially defatted groundnut flour for the production of RTE Flakes would greatly enhance its utilization for high protein dense snack. Utilization of sweet orange peel flour also has expanded the scope and utilization of sweet orange peel and in turn solved the problem of environmental pollution associate with the peels.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

Aburime L.C, Ene-Obong H.N, David-Oku E. (2020) Functional properties and sensory evaluation of ‘chinchin’ bread and biscuits produced from composite flours from African yam bean, orange fleshed sweet potatoes, plantain, cocoyam, maize and wheat.” *European Journal of Food Science Technology*, 8(4):46–64

Adeyeye, Emmanuel and Adesina, Adeolu and Olaleye, Abdul and Olagboye, s.A. and Olatunya, Ayomadewa. (2020). Proximate, Vitamins, Minerals Compositions Together with Mineral Ratios and Mineral Safety Index of Kilishi (Beef Jerky Meat*). Haya: The Saudi Journal of Life Sciences*. 05. 79-89.

AOAC (2012). Official Methods of Analysis of the Association of the Official Analytical Chemists.19thEd.published by AOAC Arlington. Virginia, USA.

Asi, S. A. S. L. C., Rosida, R., & Wicaksono, L. A. (2024). Characteristics of Healthy Cornflakes (Study of the Proportion of Pre-Cooked White Corn Flour: Pre-Cooked Red Bean Flour and the Proportion of tapioca). AJARCDE *Asian Journal of Applied Research for Community Development and Empowerment*, 8(3), 158-162.

Awofadeju, O. F. J., Ademola, I. T., Adekunle, A. E., Oyeleye, A. O. and Oyediran, R. I. (2021). Assessment of extrusion technique on physico-chemical property,microbial quality and anti-nutritional factors of extruded Ready-to-eat snacks *Nigerian Agricultural Journal* 52,(1),227-236

Badr, S.A, El-Waseif, M.A, Amr F, Salama, M.M, Ghanem, S.M & Kadry, M.M. (2023) Enhancing the Nutritional Value of Corn Flakes by Adding Quinoa Flour *Egyptian. Journal of Chemistry* 66(13), 1395-1406

Bongjo, N.B., Aondoaver, A.S.,Gbertyo, A.J.,Ayong Mary Assumpta Fulai, A,M.A & Nchung,L.(2022) Nutritional and Functional Properties of Wheat-Defatted Peanut-Orange Peel Composite Flour *European Journal of Nutrition & Food Safety,*14(12) 74-86.

Bongjo N.B, Ahemen S.A, Gbertyo J.A, Guyih D.M & Muyong M.G (2023) Chemical and organoleptic properties of Chinchin produced from flour blends of wheat, defatted peanut and orange peels. *Journal of Nutrition Health Food Engineering.*13 (1)20‒26.

 DOI: 10.15406/jnhfe.2023.07.00367

Dean L.L (2021) Peanut Protein-Processes and Applications. A Review. *Journal of Nutrition and Food Science 4: 031*

de Castro L.A., Lizi J.M., das Chagas E.G.L., de Carvelho R.A. and Vanin F.M. (2020). From orange juice by-product in the food industry to a functional ingredient: *Application in the circular economy.Foods,* 9 (5), 1-17

Domínguez-Hernandez Elisa, Gaytan-Martínez Marcela, Gutierrez-Uribe Janet Alejandra, Domínguez-Hernandez Martha Elena (2022). The nutraceutical value of maize (*Zea mays* L.) landraces and the determinants of its variability: A review *Journal of Cereal Science* 103:1-13

Egbuonu,A,C.C and Osuji*,* C.A (2016).Proximate Compositions and Antibacterial Activity of *Citrus sinensis* (Sweet Orange) Peel and Seed Extracts *European Journal of Medicinal Plants* *12(3): 1-7.*

Ezegbe, C.C., Onyekwulu, P.U., Mmuoh, .S. Okocha,K.S., & Igwe,N.P.(2023) Sensory Evaluation an Physiochemical Qualities of Maize-Based Flake Snacks complimented with Mucuna Prurins Seed Flour. *In e-Proceedings of the Faulty of Agriculture International Conference,* 189-195

Ferri, M., Gianotti, A., & Tassoni, A. (2013). Optimization of assay conditions for the determination of antioxidants capacity and polyphenols in cereal food components. *Journal of Food Composition and Analysis*, 3(2), 94-101

Gill S.A., Rossi M. and Whelan K. (2020). Dietary fibre in gastrointestinal health and disease. *National Review Gastroenterol. Hepatology,* 18**,** 101-116.

Gulluoglu, L., Basal, H., Onat, B., Kurt, C. &Arioglu, H. (2016). The Effect of Harvesting on some Agronomic and Quality Characteristics of Groundnut Grown in the Mediterranean Region of Turkey. *Field Crops Resources*, 21, 224–232.

Guzzon, F.,Arandia Rios, L.W., Caviedes Cepeda, G.M., C´espedes Polo, M., Chavez Cabrera, A., Muriel Figueroa, J., Medina Hoyos, A.E., Jara Calvo, T.W., Molnar, T.L., Narro Le´on, L.A., Narro Le´on, T.P., Mejía Kerguel´en, S.L., Ospina Rojas, J.G., V´azquez, G., Preciado-Ortiz, R.E., Zambrano, J.L., Palacios Rojas, N., Pixley, K.V. (2021) Conservation and use of Latin American maize diversity: pillar of nutrition security and cultural heritage of humanity. *Agronomy* 11: 172.

https://doi.org/ 10.3390/agronomy11010172.

Janila, P., Nigam, S.N., Pandey, M.K., Nagesh, P., & Varshney, R.K. (2013). Groundnut improvement: use of genetic and genomic tools, *Frontiers in plant science*, 4, 23

Kaul, J., Jain, K., & Olakh, D. (2019). An overview on role of yellow maize in food, feed and nutrition security. *International Journal of Current Microbiology and Applied Sciences, 8*(2), 3037-3048.

Khalifa, A., Alfalluos, H., Soheal, A., Wesam, A., Kollab, F. A. & Salem, M. E. (2017). Qualitative and Quantitative phytochemical Analysis and Antimicrobial Activity of Retama” Extract Grown in Zliten Libya. *International Journal of Medical Science and Clinical Inventions*, 4, 2861-2866

Kui Du S, Jiang H, Yu X, Lin Jane J.(2014) Physicochemical and functional properties of whole legume flour. LWT - *Food Science Technology*. 55 (1):308–313.

DOI: 10.1016/j.lwt.2013.06.001

Malik, A.A., Bhat, A.,FourH., Ahmad,N. & Gupta,P.(2017) Processing and Assessment of Quality Characteristics of Corn-peanut Flakes *International Journal. Food. Fermentation Technology 7(2): 287-294,*

Menon, L, Majumdar, S. D. & Ravi (2015). Development and analysis of composite flour bread *Journal Food Science Technology* 52(7):4156–4165

DOI 10.1007/s13197-014-1466-8

Najjingo, E., Byakika,S., Mukisa,I.M.(2024)Physical properties, nutritional profile, and consumer acceptability ofgluten-free breakfast flakes from cassava flour *Applied Food Research* 4(2) 100541

Nwakunite, L.C., Oyarebu, A.O., & Ezegbe, C.C. (2024). Production and Evaluation of Flakes from Rice (*Oryza sativa*) and Kidney Bean (*Phaseolus vulgaries*) Flour Blends. *In e-Proceedings of the Faculty of Agriculture International Conference* 416-422

Nwosu A.N., Nweze B.C. and Onwuchekwa A.I. (2022). Chemical composition of biscuits supplemented with orange peel and pulp flours. *Agro-Science*, 21 (2), 24-32. DOI: <https://dx.doi.org/10.4314/as.v21i2.3>

Nawaz,M.,Shah,N.,Zanetti,B.R.,Maugeri,M.,Silvestre,R.N.,Fatima,F.,Neder,L.,Valadi,H.(2018).Extracellular vesicles and matrix remodeling enzymes:the emerging roles in extracellar matrix remodeling,procession of diseases and tissue repair.*Cells*, 7(10),167

Obafaye, R.O and Omoba, O.S (2018) Orange peel flour: A potential source of antioxidant and dietary fiber in pearl-millet biscuit, *Journal of Food Biochemistry*. 2-8

<https://doi.org/10.1111/jfbc.1252>

Olabinjo, Oyebola Odunayo; Olumurewa, John Alaba Victor (2020). Qualities Evaluation of Extruded Ready to Eat Snack from Composite Non-Wheat Flours. *Scientific Modelling and Research*, 5(1): 14-24.

Ogunlakin, G.O.,Oke,M.O., Babarinde, & Olatunbosun,D.G.(2012). Effect of drying methods on proximate composition and physiochemical properties of cocoyam flour, 245-250

Olaoye O.A, Ubbor S.C, Okoro V.O, Lawrence L.G (2015). Performance of Malted Maize Flour as Composite of Wheat in the Production of Cake. *American Journal of Agricultural Science.*2 (3) 126-132.

Olorunsogo,S., & Adejumo,B (2023)Development and Optimization of Flakes fromSome Selected Locally Available Food Materials. IntechOpen

Opega, J. L., Orishagbebmi, C. O., Yusufu, P. A. & Ishaka, N. A. (2016). Proximate Composition, Mineral and Phytochemical Contents of Some Leafy Vegetables Native to Igala Kingdom Kogi State Nigeria. *International Journal of Biochemistry Research & Review*, 4, 1-11

Palacios-Rojas, N., McCulley, L., Kaeppler, M., Titcomb, T.J., Gunaratna, N.S., Lopez Ridaura, S., &Tanumbihardjo,S.A.(2020). Mining maize diversity and improving its nutritional aspects within agro-food systems*. Comprehensive reviews in Food Science and Food Safety*, 19(4), 1809-1834

Prabhavathi, R. M., Prasad, M. P.Jayaramu, M. (2017). Studies on Qualitative and Quantitative Phytochemical Analysis of Cissus quadrangularis. Pelagia Research Library. *Advances in Applied Science Research*, 4, 11-17.

Rani,V., Sangwan,V., Rani,V. & Malik,P. (2020) Orange Peel Powder: A Potent Source of Fiber and Antioxidants for Functional Biscuits *International Journal of Current Microbiology and Applied Sciences 9*(9),1319-1325

Ranum Peter, Juan Pablo Pe˜na-Rosas and Maria Nieves Garcia-Casal (2014) Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*, 1312; 105-112

Senevirathna, S.S.J., Ramali, N.S., Azman E.M.,Juhari,N.H. & Karim R.(2022). Production of innovative antioxidant-rich and gluten-free extruded puffed breakfast cereals from purple sweet potato (*Ipomoea batatas* L.) and red rice using a mixture designapproach, *Journal of Food Processing and Preservation,* 1-16

Shafiya Rafiq, Rajkumari Kaul, S.A. Sofi, Nadia Bashir, Fiza Nazir, Gulzar Ahmad Nayik(2018). Citrus peel as a source of functional ingredient: A review*Journal of the Saudi Society of Agricultural Sciences* 17, 351–358.

Syazana Shahabuddin Nur and Marina Zulkifli (2021). A Review: Influence of Processing Techniques on Nutritional Composition and Antinutritional Components of Corn (*Zea mays* L*.*) Kernels *Inaugural Symposium of Research and Innovation for Food (SoRIF*), 82-84.

Sharon-Asa L, Shalit M, Frydman A, Bar E, Holland D,Or E, Lavi U, Lewinsohn E, Eyal Y.( 2010) Citrus fruit flavor and aroma biosynthesis: Isolation, Functional Characterization, and Developmental Regulation of Cstps1, a key Gene in the Production of the Sesquiterpene Aroma Compoundvalencene. *Plant Journal*.36:664-674.

Suresh, D., Nethravathi, P.C., Lingardaju, K., Rajanaika, H., Sharma, S.C., & Nagabhushana,H. (2015).EGCG assisted green synthesis of ZnO nanopowder Photodegradative,antimicrobial and antioxidant activities*. Spectrochemica Acta Part A: Molecular and Biomolecular Spectroscopy*, 136, 1467-1474

USDA: United States Department of Agriculture/Foreign Agricultural Service, (2021). Citrus: World Production, Markets and Trade Reports. Available from: https://www.fas.usda.gov.

U.S. Department of Agriculrure, Agriculrural Research Service (2019). *FoodData Central* (FDC: 16087) accessed 12th April 2025

USDA (2017). Food Composition Database. Basic Report: 16096, Peanuts, virginia, oil-roasted, with salt. https://ndb.nal.usda.gov/ndb/foods/show/4834, Accessed Date November 20th 2024.

Variath, M. T. & Janila, P. (2017). Economic and Academic Importance of groundnut. In: Varshney R, Pandey M, Puppala N, Editors. The groundnut genome. Compendium of plant genomes. *Chemical Springer*, 3, 111 – 118.

Doi: 10.1007/978-3-319-63935.

World Data Atlas, (2020).World-Citrus fruit production quantity.https://knoema.com/ atlas/World/topics/Agriculture/Crops-Production-Quantity-tonnes/Citrus-fruit-production (Accessed December 1st 2024)