Production and Quality Evaluation of Functional Burgers From *Monodora myristica* (Gaertn.) Dunal and African Breadfruit

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ABSTRACT

Functional burgers were produced from *Monodora myristica*-African breadfruit blends and toasted African breadfruit seeds. Flour was produced from *Monodora myristica* seeds and the flour was defatted. African breadfruit seeds were divided into two parts; the first was processed into flour after parboiling and dehulling, and the second was toasted and dehulled. Composite flour was produced from *Monodora myristica* and African breadfruit in the ratio of MA90:10, MA80:20, MA70:30, MA60:40, and MA50:50 respectively. 100% wheat flour (WF100) was the control. The toasted breadfruit seeds were coated with *Monodora myristica*-African breadfruit blends and baked. The control was African breadfruit seeds coated with 100% wheat flour (SWF100). The proximate composition, and functional properties of the blends; proximate composition, mineral content, and sensory properties of the burgers were all determined using standard methods. Data were statistically analyzed using SPSS version 20. The crude protein, fiber, ash, fat, foaming capacity, and emulsion capacity, of the blends increased as *Monodora myristica* level increased but carbohydrate reduced. The blends' water and oil absorption capacities increased as African breadfruit flour increased. The protein, ash, fat, fiber, phosphorus, magnesium, calcium, and iron content of burgers increased with increased inclusion of *Monodora myristica* flour and carbohydrate reduced. Burgers from WF100 had the least value in all the nutritional attributes analyzed but the highest carbohydrate. The composite burgers had superior nutritional properties than 100% wheat flour burgers. They also compared favorably with SWF100 in all the sensory attributes assessed. Burgers produced from MA60:40 were most preferred in terms of overall acceptability.

Keywords: African breadfruit seeds, Composite flour, Functional properties, *Monodora myristica* seeds, Snack foods

INTRODUCTION

Snack foods such as cakes and sugar sweetened beverages are generally high in carbohydrates and fats (calories) but deficient in other nutrients (Hess and Slavin, 2018). They are foods or caloric beverages eaten between regular meals. The desire/motivation to snack depends on several factors such as hunger, social/food culture, and environment (Verhoeven *et al.*, 2015). However, most people do not eat "ordinary snacks" as a result of one ailment or another (Gomez-Favela *et al*., 2021). Furthermore, there is increased awareness of the importance of functional foods amongst consumers (Agiriga *et al*., 2023). Gomez-Favela *et al*. (2021) stated that functional foods helps to boost nutritional status and curb the development of degenerative diseases due to poor feeding habit amongst other factors. Nutrients of concern incorporated in local cheap crops could be used to guide the development of new "functional snack foods" as the popular ones in the market promote weight gain and are of poor nutrition.

Monodora myristica (Gaertn.) Dunal of the *Annonaceae* family is a valuable underexploited tree that thrives in the tropics (Agiriga *et al*., 2023). Its ultimate economically essential parts are the oil-rich seeds that are consumed in Sub-Saharan Africa (Agiriga *et al*., 2023). The sweet-scented seeds possess an impressive range of antioxidant properties (Agiriga and Siwela, 2018a). They are additionally rich in proteins (Agiriga and Siwela, 2018b) and thus, can serve as useful or vital constituents in the food processing industries. The plant protein can also be used to supplement the carbohydrate foods eaten regularly in many developing countries. Furthermore, *Monodora myristica* seeds are rich in dietary minerals (Nkwocha *et al.*, 2019), they could therefore be used as a cheap source of essential minerals in food preparation. Also, since they are rich in dietary fiber (Agiriga and Siwela, 2018a), they are crucial in the production of health beneficial foods otherwise known as functional foods. High-fiber foods are tied to reduced incidences of hemorrhoids, diabetes, high blood pressure, and obesity in people who consume them on a regular basis (Iwe *et al.*, 2016).

African breadfruit (*Treculia africana* Decne) from the *Moraceae* family is a vital legume and food security crop found mostly in the West and Central Africa (Ojimelukwe and Ugwuona, 2021). It has immense nutritional potential (Frances and Johnson, 2022). The evergreen tree bears around 20 to 30 pods that contain edible seeds, annually (Ojimelukwe and Ugwuona, 2021). African breadfruit is a local specialty meal for the urban dwellers and the rich in Nigeria, due to its nutritious seeds (Frances and Johnson, 2022). The seeds are domestically consumed boiled or toasted.

African breadfruit and *Monodora myristica* are vital in the preparation of food products with increased nutritional value. Their flour blends could be used to develop a healthy nutritious gluten-free snack. Gluten-free foods are in high demand by people suffering from celiac disease who have gluten intolerance and the market for gluten-free foods is continuously expanding (Dzandu *et al.*, 2023). Therefore, the production of functional gluten-free burgers from African breadfruit and *Monodora myristica* composite flour is a welcome development. These gluten-free burgers would be a delight for people suffering from gluten intolerance and they will also address nutrient insufficiencies and excesses. The aim of this study, therefore, is to develop and evaluate nutritious burgers from African breadfruit-*Monodora myristica* flour blends and toasted African breadfruit seeds. Burgers from toasted African breadfruit seeds coated with 100% wheat flour served as the control since the quality attributes of baked products created from composite flours must be comparable to those of products made from wheat flour (Noorfarahzilah *et al.*, 2014).

MATERIALS AND METHODS

Materials

Dried *Monodora myristica* seeds without any pest infestation or damage, were procured from Oja Oba (Kings Market) Ado-Ekiti, Ekiti State, Nigeria. African breadfruit seeds, all-purpose wheat flour, vegetable oil, eggs, baking powder, nutmeg, salt, sugar, and vanilla were purchased from a Nigerian Tuck shop in South Africa. Reagents of analytical grade from Sigma Aldrich Co., Ltd (Steinheim, Germany) were used for this study.

Sample preparation

Foreign materials like dry leaves and stones were removed from *Monodora myristica* seeds. Hulls were removed manually from the cleaned seeds with the use of mortar and pestle and the seeds were thereafter milled into fine flour to pass through a 100 mesh sieve (Gohi *et al.*, 2019) using an electric blender- KenStar super blender, model No: KS-988. African breadfruit seeds were washed thoroughly, and divided into two batches. The first batch was parboiled (100^{o}C for 15min) to facilitate dehulling and avoid adverse changes in the nutritional components of the kernel (Ihemeje *et al.*, 2022). They were subsequently dehulled manually. The dehulled seeds were oven dried at 60^{o}C till equilibrium and milled into fine flour using an electric blender. The second batch was toasted in a frying pan at 45°C for 15min with constant stirring (Okwunodulu *et al.*, 2019). They were allowed to cool to room temperature and dehulled manually. The flour samples and toasted African breadfruit seeds were stored in an airtight plastic container at room temperature for further analysis.

Defatting of *Monodora myristica* flour

Flour samples were defatted for 4h using Buchi 810 Soxhlet Fat Extractor (Flawil, Switzerland) with hexane solvent (Laroche *et al.*, 2019). Flour samples were dried in an air convection oven (Gallenkamp, England) at 60°C for 12h to reduce their moisture content (Oloyede *et al.*, 2016). Samples were thereafter packaged in polythene bags and kept in an airtight container in the refrigerator (4°C) for further analysis (Oloyede *et al.*, 2016).

Formulation of flour blends

The method of Dzandu *et al.* (2023) was adopted with slight modifications. Flour from 100% wheat flour- WF100 was used as control. *Monodora myristica* and African breadfruit flour were mixed in a Kenwood food processor (Model KM 201; Kenwood Ltd, Hampshire, UK) at full speed for 3 min. The composite flours formulated were as follows:

- 100% wheat flour (WF100)
- 90% *Monodora myristica* flour and 10% breadfruit flour (MA90:10)
- 80% *Monodora myristica* flour and 20% breadfruit flour (MA80:20)
- 70% *Monodora myristica* flour and 30% breadfruit flour (MA70:30)
- 60% *Monodora myristica* flour and 40% breadfruit flour (MA60:40)
- 50% *Monodora myristica* flour and 50% breadfruit flour (MA50:50)

The flour samples were packaged in airtight containers and kept in the refrigerator at 4°C for further analysis.

Preparation of burgers

Coating for the toasted African breadfruit seeds was formulated with the method of Ihemeje *et al.* (2022) with slight modification. The ingredients used are shown in Table 1. Eggs, salt, vanilla, and sugar, were whisked in a bowl and the mixture was poured into a clean bowl containing flour, baking powder, and nutmeg powder. The mixture was kneaded, cut into rectangular shapes, and used to coat the toasted breadfruit seeds (35g per seed). The coated breadfruit seeds were baked in the oven for 10min at a temperature of 160^{o}C. Breadfruit seeds coated with WF100 served as the control. Burger samples were named following their composite flours as SWF100, SMA90:10, SMA80:20, SMA70:30, SMA60:40, and SMA50:50.

Proximate and functional properties of flour blends

The protein, fat, fiber, ash, and moisture content of the flour samples were determined by the AOAC, (2015) methods. Carbohydrates were calculated by difference as 100 – (% moisture + % ash, + % fiber, + % fat, + % protein). Functional properties were determined using the methods described by Onwuka, (2018).

Quality evaluation of burger samples

The proximate and mineral compositions of burger samples were determined according to AOAC (2015). Sensory evaluation was carried out using twenty semi-trained panelists. Coded samples were rated for appearance, aroma, taste, mouthfeel, and overall acceptability using a 9-point hedonic scale which ranged from 1(dislike extremely), to 9(like extremely). Portable water was provided for rinsing the mouth in between the respective evaluations (Agu *et al.*, 2023).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, version 21, SPSS Inc., Chicago, IL, USA) and judged for significance at $P \leq 0.05$. Duncan's Multiple Range Test (DMRT) was employed to separate means.

RESULTS AND DISCUSSION

Proximate composition of flour blends

The proximate composition of the flour samples is presented in Table 2. WF100 had less protein, fat, ash, and fiber but more moisture and carbohydrates than the composite flours. This result is in agreement with the work of Ihemeje *et al.* (2022).

Moisture

The moisture content of the flour blends which ranged from 8.43% to 8.77% showed significant ($P \leq 0.05$) statistical differences. These values are comparable to 8.16% to 10.00% reported by Ihemeje *et al.* (2022) for wheat/African breadfruit flour blends. The differences in moisture content of the flour samples could be attributed to differences in crop variety, climatic/soil conditions, storage, and processing methods of the samples. The moisture content of the blends decreased with increased incorporation of *Monodora myristica* flour. This could be due to the low water absorption capacity (WAC) of *Monodora myristica* flour compared to breadfruit flour (Olatoye *et al.*, 2019; Ihemeje *et al.* 2022). The high water absorption capacity of breadfruit flour suggests the presence of high amount of hydrophilic carbohydrate in the flour blend (Olatoye *et al.*, 2019). Also, parboiling improved the WAC of breadfruit flour. However, the moisture content of all the flour samples was below 14% which is the acceptable limit (Ohizua *et al.*, 2017). This implies that the flour blends have a good shelf life. High moisture is linked with a short shelf life as it encourages microbial proliferation that leads to spoilage (Ohizua *et al.*, 2017).

Protein

The protein content of the flour blends ranged from 17.45 to 21.81% and differed significantly ($P \leq 0.05$). MA90:10 had the highest value because it contains a high level (90%) of *Monodora myristica* flour. *Monodora myristica* has been reported to be rich in high-quality protein which can be used to enhance protein quality in human nutrition (Agiriga and Siwela, 2018b). It is generally known that any plant food that provides more than 12% of its caloric value from protein is a good source of protein. There was a significant ($P \leq 0.05$) reduction in the protein content of the blends with increased incorporation of African breadfruit flour. It can be inferred from this result that *Monodora myristica* can be used to complement foods that have higher amounts of carbohydrates but low protein and also help reduce the incidences of protein energy malnutrition. Protein is responsible for the repair of worn-out tissues and bodybuilding.

Fat

There was a significant ($P\leq 0.05$) difference in the fat contents of the flour blends which ranged from 24.41% to 37.01%. These values are higher than that of soybean flour (15.85 % to 19.49%) (Anwar *et al.*, 2016). The result shows that breadfruit flour is low in fat and the incorporation of *Monodora myristica* increased the fat content of the blends. *Monodora myristica* is an oil seed with a fat content of 46.36% (Agiriga and Siwela, 2018a). Although high fat could increase the risk of rancidity, *Monodora myristica* fat has been established to be non-drying and free from rancidity (Agiriga *et al.,* 2023). However, low-fat levels in flour samples are known to increase shelf life (Iwe et al., 2016). Fat is important in diets because it promotes fat-soluble vitamin absorption and maintains the palatability of food.

Fibre

The fiber content of the blends ranged from 4.25% to 7.24% and differed significantly ($P\leq 0.05$). Fiber values increased with an increase in *Monodora myristica* flour. This could be because *Monodora myristica* is rich in dietary fiber (Agiriga and Siwela, 2018a). Crude fiber is a type of plant cell wall material that is insoluble (Iwe *et al.*, 2016). The blends are good sources of fiber and can be used in the preparation of functional products. Consumption of high-fiber products has been linked to lower chances of colon cancer and reduced constipation (Gomez-Favela *et al.,* 2021).

Ash

The ash content of the flour blends differed significantly ($P\leq 0.05$) and ranged from 2.94% to 3.43%. Godswill, (2019) made the same observation and found significant differences in the ash content of various flour blends, with the maize-millet blend having the highest ash value. The ash content of the blends increased significantly ($P\leq 0.05$) with an increased quantity of *Monodora myristica* flour. This may be attributed to the increased amount of minerals such as calcium and iron. Ohizua *et al.* (2017) also reported that the ash content of unripe cooking banana, pigeon pea, and sweet potato flour blends increased at higher pigeon pea flour substitution. Ash measures of the total amount of minerals within a food (Godswill, 2019). This means that *Monodora myristica* flour can improve the mineral content of a food material.

Carbohydrates

The carbohydrate content of the flour blends ranged from 21.74% to 42.02% and differed significantly ($P\leq 0.05$). The carbohydrate content of the blends increased as the percentage inclusion of breadfruit flour increased. This may be because breadfruit flour contains a high amount of starch and sugar (Frances and Johnson, 2022). However, Ihemeje *et al*. (2022) reported that the addition of breadfruit flour in increasing proportion resulted in a decrease in the carbohydrate content of wheat-breadfruit flour blends.

Functional properties of flour samples

Results of the functional properties of the flour samples are shown in Table 3. Sample WF100 had the least water absorption capacity, oil absorption capacity, emulsion capacity and foaming capacity, and these values differed significantly from the flour blends.

Bulk density

The bulk density of the flour blends did not differ significantly ($P \geq 0.05$) and ranged from 0.56g/cm^3 to 0.57g/cm^3. However, Ohizua *et al.* (2017) reported that bulk density which varied from 0.48g/ml to 0.92g/ml increased as the incorporation level of unripe banana flour and sweet potato flour increased in unripe cooking banana, pigeon pea, and sweet potato flour blends. Particle size differences may be the cause of variations in the bulk density of the flours (Oppong, *et al.,* 2015). Bulk density is an index of the heaviness of a flour sample. It is important for ascertaining packaging requirements and material handling in the food industry (Oppong, *et al.,* 2015). The low bulk density of the flour blends makes them suitable for use in the preparation of many foods especially complementary foods for infants. According to Ohizua *et al.* (2017), high bulk diminishes the caloric and nutrient intake of a child thereby making the child unable to consume enough food to satisfy his/her energy nutrient requirements.

Water absorption capacity

The water absorption capacity (WAC) of the composite flours ranged from 162% to 169%. These values are much lower than the values-400% to 600% for jackfruit flour (Eke-Ejiofor *et al*., 2014). WAC of flour partly depends on its protein content and particle size (Oppong, *et al.,* 2015). The WAC of the flour blends increased gradually though not significantly ($P \geq 0.05$) with an increase in breadfruit flour. The same observation was made by Ihemeje *et al.* (2022). This may be attributed to the low protein and high carbohydrate contents of breadfruit flour as carbohydrates have been reported to greatly influence the WAC of foods (Ihemeje *et al.,* 2022). Also, gelatinization of carbohydrates and swelling of crude fiber during boiling of African breadfruit seeds may have enhanced water absorption. Ayoade *et al.* (2015) reported that WAC was low in roasted African breadfruit seeds compared to boiled samples. All the flour blends showed favorable WAC, making them suitable ingredients in the development of ready-to-eat foods, soups, gravies, and baked products.

Oil absorption capacity

The oil absorption capacity (OAC) of the flour blends ranged from 186% to 244%. These values are higher than 130 to 156% reported by Chandra et al. (2015) for various composite flours analyzed. OAC increased significantly ($P \leq 0.05$) with increased levels of breadfruit flour. This can be as a result of boiling of the African breadfruit seeds. Flours processed by boiling had significantly higher ($P \leq 0.05$) oil absorption capacity (Iwe *et al.,* 2016). Increased inclusion of *Monodora myristica* flour reduced the OAC of blends. Olatoye et al. (2019) also reported that the addition of *Monodora myristica* flour decreased the OAC of vanilla-*Monodora myristica* flour blends. This could be a result of the high fat content of *Monodora myristica* (Agiriga and Siwela, 2018a). Chandra *et al.* (2015) reported that high fat content in flours adversely affects the OAC of composite flours. OAC measures the ability of food material to absorb oil and is mainly attributed to the physical entrapment of oil and the binding of lipids to the nonpolar chain of a protein (Oppong, *et al.,* 2015). It is an important parameter in new food product development as it improves the flavor and mouth feel of food (Chandra *et al.,* 2015). OAC is a critical assessment of flavor retention, therefore the high OAC of the flour blends makes them better flavor retainers and favors their use in food processes that require mixing of oil such as baking.

Emulsion capacity

The emulsion capacity (EC) of the flour blends ranged from 35.80 to 45.20%. These values are lower than 97.2% reported for defatted *Moringa* seed flour (Ogunsina *et al.*, 2014).

Processing methods significantly impact EC (Iwe *et al.*, 2016). The EC of the flour blends increased significantly ($P \leq 0.05$) at all levels of substitution with *Monodora myristica* flour. The relatively higher EC of MA90:10 (45.20%) could be as a result of the high soluble protein content that forms the protective barrier around fat droplets thus preventing their coalescence (Ohizua *et al.*, 2017). It may also be due to the globular nature of the major protein. EC shows the highest volume of oil that can be amalgamated by protein dispersion (Iwe *et al.*, 2016). The high EC of the flour blends suggests that they are more digestible and therefore suitable for use as ingredients in infant food formulations (Godswill, 2019). They will also be useful as food additives/extenders, for binder formulation and stabilization of colloidal foods since their strong emulsions cannot easily separate into small lumps. Furthermore, the flour blends can be combined with wheat flour in food preparations for easy digestion since their values are much higher than that of WF100 (18.02%).

Foam capacity

Foam capacity (FC) refers to the amount of interfacial area that can be created by the protein in the flour (Chandra *et al.*, 2015). It is used to measure the ability of the flour to foam which depends on the presence of the flexible protein molecules that decrease the surface tension of water (Chandra *et al.*, 2015). The FC of the flour blends increased with an increase in *Monodora myristica* flour inclusion from 36.00% to 47.20%. This was expected since the protein content of *Monodora myristica* flour is considerably higher than breadfruit flour. It can also be attributed to the defatting process of *Monodora myristica* flour. Ihemeje *et al.* (2022) reported that defatting improved the FC of breadfruit flour. FC of flour blends is influenced by the specific types of flour used and their proportions in the blend.

Proximate composition of burgers

Results of the proximate composition of the burgers is shown in Figure 1. SWF100 had the least protein, fat, fiber, ash, and the highest carbohydrate content.

Moisture

There was no significant difference ($P \geq 0.05$) in the moisture content of composite burgers which ranged from 8.16% to 8.20%. However, values ranging from 8.16 to 8.24% were reported, as the moisture content of snacks produced from blends of wheat and African breadfruit flours (Ihemeje *et al.*, 2022). Oguntoyinbo *et al.* (2021) found that cookies made from composite flours of wheat and banana peel had moisture content, ranging from 4.93 to 5.63%. Differences in the raw materials utilized, as well as environmental and experimental conditions, can explain the variation in moisture content.

Protein

The protein content of the composite burgers ranged from 18.48 to 22.83. The protein content of snacks in this study is comparable to those reported by Ihemeje *et al.* (2022) in a similar study. Protein is an indispensable nutrient in the human diet and helps repair worn-out tissues. The increased protein content of the composite burgers will contribute significantly to the recommended daily requirement for protein (25–30g/day) for ages 15 and 19 years WHO (2015). This implies that frequent consumption of this snack may help to alleviate the problem of protein deficiencies in children and adults.

Fat

The fat content of the composite burgers which ranged from 24.95 to 37.03% was higher than 12.60 to 16.70% reported by

Ndife *et al.* (2020) for chin-chin produced from maize, soybean and orange fleshed sweet potato flour blends and 8.94%-20.52%, reported by Taiwo *et al.* (2017) for wheat-sorghum date cookies. The differences in the crop materials utilized could be responsible for the varying results. Although high-fat content could be undesirable in ready-to-eat snacks as it can promote rancidity, leading to the development of unpleasant sensory properties, it has already been established and documented that *Monodora myristica* fat is non-drying and free from rancidity (Agiriga *et al.*, 2023). Moreover, fat increases the absorption of fat-soluble vitamins and offers vital fatty acids, and crucial volatile chemicals for flavor and sensory properties (Agu *et al.*, 2023). Therefore, high fat is an added advantage to the nutritional properties of the burger samples.

Ash

Ash content is a measure of total mineral content in food and an important quality parameter in terms of nutritional labeling as well as processing properties of various food products (Bilge *et al*., 2016). Ash content (3.02 to 3.75%) of composite burgers was higher than 2 to 2.73% reported by Olatoye *et al.* (2019) for cookies produced from *Monodora myristica*-vanilla flour blend. In a related study, Bashir *et al.* (2022), reported ash content, 3.68 to 5.04% for finger millet-wheat composite biscuits. The variations in these results could be attributed to variations in the raw materials and blending proportions. Ash values of the composite burgers indicate that they have increased mineral content.

Fiber

There was a significant ($P \leq 0.05$) increase in the fiber content (4.99 to 7.36%) of the composite burgers. SMA90:10 had the highest fiber value. This agrees with the study of Bashir *et al*. (2022) who reported an increase (3.28–5.52%) in the fiber content of biscuits produced from finger millet-wheat composite flour. Still, their values were lower than the ones obtained in this study. Although crude fiber has a very small nutritional value, it assists in the increased utilization of nitrogen, absorption of some other micronutrients, and providing bulk for peristaltic activity in the intestine (Iwe *et al.*, 2016). It also helps one lose or maintain weight because eating fiber-dense foods helps one feel full (Gomez-Favela *et al.*, 2021).

Carbohydrates

The carbohydrate content (20.87 to 40.36) of the composite burgers, was lower than 52.65% to 64.71% reported for wheat-sorghum date cookies (Taiwo *et al.*, 2017). This may be attributed to differences in the raw materials used. The increased addition of *Monodora myristica* flour resulted in a decrease in the carbohydrate content of the burgers. Olatoye *et al.* (2019) also reported that the substitution of African nutmeg for vanilla resulted in reduced carbohydrate and energy contents of cookies. The low carbohydrate content of the burgers will help to curb incidences of overweight and obesity as most commercial snacks sold in the market contain mainly carbohydrates. Carbohydrates contribute to the energy value of food formulations.

Mineral composition of burgers

The mineral composition of the burgers is shown in Figure 2. Macro and microelements are necessary for normal physiological functions. Their deficiency causes serious metabolic abnormalities and their increase leads to toxicity (Ohizua *et al.*, 2017). The most abundant macro-minerals in the composite burgers were phosphorus, calcium, and potassium. On the other hand, Agiriga and Siwela, (2018a) reported that the most abundant macro-minerals in the plant samples they analyzed were potassium, phosphorus, and magnesium. The mineral content of a plant depends on its species and cultural practices adopted during planting (Ohizua *et al.,* 2017). SWF100 had the lowest values of all mineral elements analyzed. The implication of the mineral content of the composite burgers is that they could serve as a nutrient supplement and in the formulation of infant food.

Magnesium

There was a significant difference ($P \leq 0.05$) in the magnesium content of the composite burgers which ranged from 144.28mg/100g to 175.26mg/100g. It was observed that the inclusion of an increased quantity of *Monodora myristica* flour improved the magnesium content of all the composite burgers. The values obtained for magnesium in this study were higher than the values (88.62mg/100g to 178.05mg/100g) reported for maize-soybean-orange fleshed sweet potato chin-chin (Ndife *et al.,* 2020). They are also higher than 122.00mg/100g to 134.00mg/100g reported by Agu *et al.* (2023) for biscuits produced from blends of whole wheat, soy *okara,* and tiger nut residue flours. The varied results may be a result of differences in the raw materials used. Magnesium is an activator of a variety of enzyme systems and a regulator of nerve electrical potential. Because the burgers have a large amount of magnesium, they could be an ideal snack for both men and women.

Sodium

The sodium content of the composite burgers (6.40mg/100g to 10.45mg/100g) varied significantly ($P \leq 0.05$). These values are higher than 1.02 to 1.08mg/100g reported by Ihemeje *et al.* (2022) for snacks produced from wheat and African breadfruit (*Treculia africana*). Differences in the raw materials utilized may be the reason for the varied results. The result showed a decrease in the sodium content of the burgers as the incorporation of *Monodora myristica* flour increased. *Monodora myristica* is known as a poor source of sodium. This may account for the decrease in sodium content of the composite burgers. Sodium is required for nerve and muscle functioning but over-consumption can lead to kidney damage and increased chances of high blood pressure (Agu *et al.,* 2023). The sodium content of the composite burgers was low. Low sodium is necessary for the system due to its support for cell functionality without promoting heartbeats or high blood pressure (Agu *et al.,* 2023).

Calcium

The calcium content of the composite burgers significantly ($P \leq 0.05$) increased from 197.54mg/100g to 216.58mg/100g with increased inclusion of *Monodora myristica* flour. These values are higher than 70.00 to 150.00mg/100g reported by Oguntoyinbo *et al.* (2021) for cookies produced from wheat and banana peel composite flours. The U.K. Department of Health recommends a nutrient intake of 1000mg/day of calcium for adults and 550 mg/day for infants and children (Cormick and Belizan, 2019). Thus, to meet this recommendation, the burgers should be consumed with other calcium-rich or fortified beverages such as milk. Calcium aids in the development of bones and provides skeletal bones with support and rigidity. Increased calcium intake may protect against the development of type 2 diabetes (Adeleke *et al.,* 2019).

Iron

There was a significant ($P \leq 0.05$) increase in the iron content of the composite burgers from 49.06 to 82.63mg/100g with increased inclusion of *Monodora myristica* flour. Oguntoyinbo *et al.* (2021) also reported a significant ($P \leq 0.05$) increase in iron content (1.36 to 4.76mg/100g) of cookies produced from wheat and banana peel composite flour with increased inclusion of banana peel. Iron is an essential trace element that plays vital roles such as hemoglobin formation and oxidation of fats, protein, and carbohydrates (Agu *et al.,* 2023). The WHO (2015) daily recommended intake of iron for children (6–59 months) is 5.8mg/100g. Hence, children can get the required iron by consuming burger samples with other foods.

Phosphorus

The phosphorus content of the composite burgers (245.85 to 421.17mg/100g) differed significantly ($P \leq 0.05$). These results were higher than 78.23 to 139.17mg/100g recorded for chin-chin made from blends of maize, soybean, and orange fleshed sweet potato (Ndife *et al.*, 2020). The variation in the results could be attributed to the differences in the raw materials used. The phosphorus content of composite burgers increased with an increase in *Monodora myristica* flour. A study by Adeleke *et al.* (2019) found that *Monodora myristica* flour has a high mineral content, including phosphorus, calcium, magnesium, and zinc. This suggests that snacks made from *Monodora myristica* flour will be a good source of these minerals. However, the mineral content of snacks from different flour blends depends on the specific blend used and their processing methods. Phosphorus is needed for several metabolic processes, including energy production and control (Adeleke *et al.,* 2019).

Potassium

The potassium content of the composite burgers differed significantly ($P \leq 0.05$). The result showed that increased incorporation of breadfruit flour led to an increase in the potassium content of the burgers. This may be because African breadfruit is a rich source of potassium (Ihemeje *et al.*, 2022). Ihemeje *et al.* (2022) also reported that the potassium content of snacks produced from wheat and African breadfruit increased with an increase in the addition of African breadfruit flour. Potassium is an essential nutrient necessary in the synthesis of amino acids and proteins in man.

Sensory properties of burgers

The results of the sensory evaluation of burgers are shown in Figure 3. Sensorial data revealed that composite burgers compared favorably with the burgers produced from 100% wheat flour in all the sensory attributes.

There was no significant difference in the appearance and mouthfeel ($P \geq 0.05$) of the burgers but their taste, aroma, and overall acceptability differed significantly ($P \leq 0.05$).

It was observed that all burgers were generally accepted by panelists, but SMA60:40 with a mean sensory score of 7.58 for overall acceptability was the most acceptable. Overall acceptance expresses how the panelists accept the product generally. All the burgers had a mean overall acceptability score of 7.0 and above. Ndife *et al.* (2020) considered a product with an overall acceptability score of 7.0 and above as being accepted by the consumer. The baking conditions (temperature and time variables), the state of the snack constituents, such as fiber, starch, and protein, and the amounts of absorbed water during dough mixing, all contribute to the outcome of the overall acceptability.

The aroma and taste of the burgers SMA90:10 and SMA80:20 were the most preferred. This could be a result of the high content of *Monodora myristica* flour. *Monodora myristica* is naturally sweet-scented (Agiriga and Siwela, 2018a) and could therefore serve as a suitable substitute for commercial food flavoring agents. Olatoye *et al.* (2019) reported that *Monodora myristica* flour was an adequate substitute for vanilla in the production of cookies. Also, Nkwocha *et al.* (2019) noted that *Monodora myristica* seed has an aromatic fragrance, which makes it suitable as a spicing agent in both African and continental cuisines in Nigeria. The rich fat content of *Monodora myristica* (Agiriga and Siwela, 2018a) and sugar from African breadfruit could be responsible for the preference of the taste of burger samples SMA90:10 and SMA80:20. Taste refers to the sweet sensation caused in the mouth by contact with the food sample (Ndife *et al*., 2020) and this perception of sweetness is influenced by the interaction of sugar and fat. Both fat and sugar are important factors in the perception of creaminess and pleasantness (Leohr and Kjellsson, 2020) which are ingredients of sweetness of a food sample.

CONCLUSION

Functional burgers can be produced from *Monodora myristica*-African breadfruit flour blends. The burger samples would serve as functional foods because of their high protein, and fiber content in addition to other nutrients. Sensorial results revealed that the composite burgers were compared favorably with burgers coated with 100% wheat flour in all the sensory attributes assessed. Substitution of *Monodora myristica* flour with African breadfruit flour at a ratio of 60:40 yielded the most acceptable nutritious burgers. The production and consumption of *Monodora myristica*-African breadfruit burgers is highly recommended because of its nutrient composition and good organoleptic attributes.

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Table 1. Ingredients used for the preparation of coating material

Ingredient	Quantity
Flour	500g
Vegetable oil	75g
Egg	50g
Baking powder	30g
Nutmeg	15g
Salt	10g
Sugar	15g
Vanilla	10g

Table 2. Proximate composition of flour blends

Samples	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrates
WF100	9.03±0.00[a]	10.69±0.98[e]	1.59±0.04[e]	1.25±0.07[f]	1.98±0.06[d]	75.46±0.65[a]
MA90:10	8.43±0.33[b]	21.81±1.15[a]	37.01±0.01[a]	7.24±0.06[a]	3.43±0.04[a]	21.74±0.06[f]
MA80:20	8.51±0.01[b]	20.73±0.07[ab]	36.44±0.03[a]	6.62±0.00[b]	3.31±0.04[ab]	24.22±0.31[e]
MA70:30	8.60±0.08[b]	19.63±0.89[bc]	32.43±0.18[b]	5.95±0.07[c]	3.18±0.25[abc]	30.21±0.30[d]
MA60:40	8.68±0.11[ab]	18.54±0.28[cd]	28.42±0.59[c]	5.37±0.10[d]	3.06±0.00[bc]	36.10±0.14[c]
MA50:50	8.77±0.04[ab]	17.45±0.44[d]	24.41±0.58[d]	4.75±0.00[e]	2.94±0.06[c]	42.02±1.57[b]

Means bearing different superscripts in the same column are significantly ($p<0.05$) different

Table 3. Functional properties of flour blends

Samples	Bulk density (g/cm^3)	Water absorption capacity (%)	Oil absorption capacity (%)	Emulsion capacity (%)	Foaming capacity (%)
WF100	0.82±0.00[a]	77±1.84[b]	92.00±2.83[e]	18.02±1.70[e]	12.78±1.13[e]
MA90:10	0.57±0.08[b]	162±3.04[a]	186.00±9.90[d]	45.20±0.28[a]	47.20±0.07[a]
MA80:20	0.56±0.01[b]	164±24.04[a]	200.6±0.47[cd]	42.90±1.27[ab]	44.40±1.73[ab]
MA70:30	0.56±0.16[b]	165±14.14[a]	215.20±1.70[bc]	40.50±1.06[bc]	41.60±0.08[bc]
MA60:40	0.56±0.00[b]	167±0.28[a]	229.8±1.13[ab]	38.10±1.56[cd]	38.77±1.63[cd]
MA50:50	0.56±0.01[b]	169±7.07[a]	244.00±18.39[a]	35.80±1.13[d]	36.00±4.24[d]

Means bearing different superscripts in the same column are significantly ($p<0.05$) different

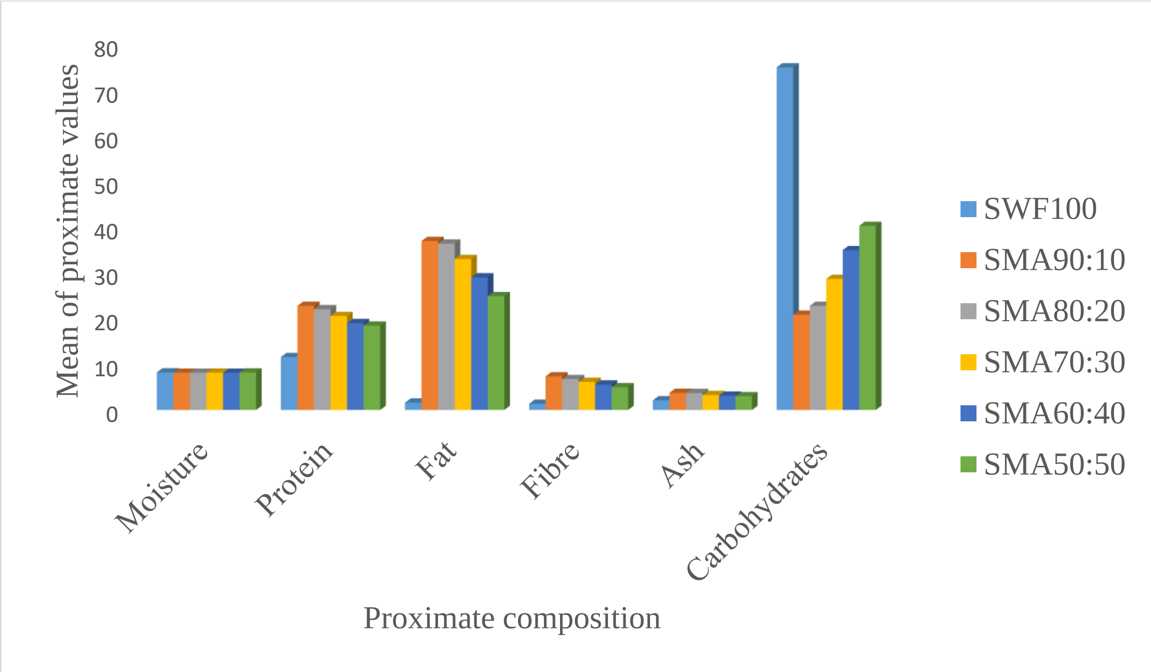

Figure 1. Proximate composition of burger samples

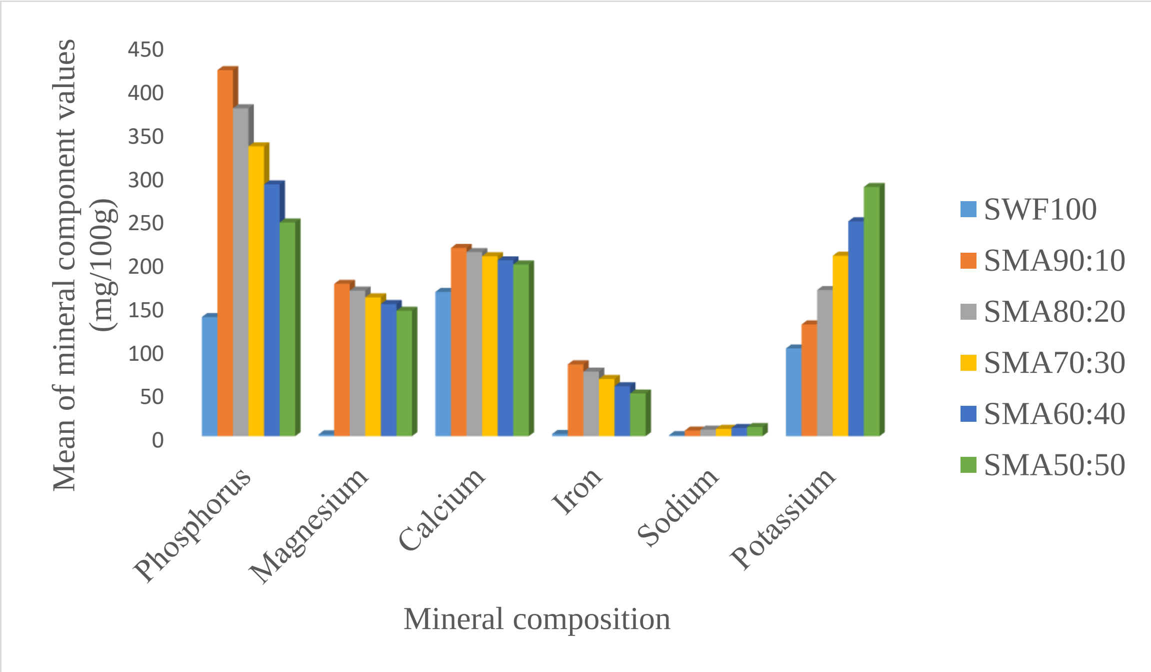

Figure 2. Mineral composition of burger samples

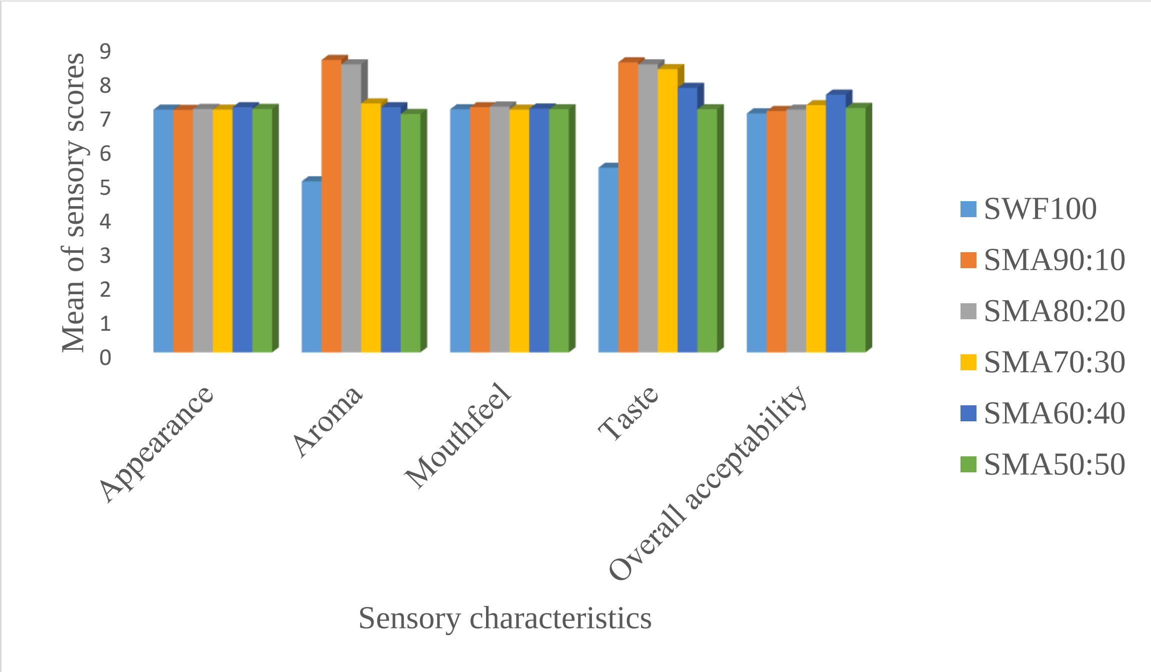

Figure 3. Mean sensory scores of burger samples