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Nutritional, Anti-Nutritional and Sensory Evaluation of Snacks Produced from Germinated Maize/Bambara Groundnut (Vigna Subterranean) Flours

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ABSTRACT

Background: Bambara nut, an underutilized legume is rich in protein and can improve the nutritional quality of snacks. This study evaluates the nutritional and sensory properties of muffins produced from germinated maize and Bambara groundnut flours. **Methods:** Maize and Bambara groundnut seeds were germinated (72 hours), oven-dried and milled. The composite flours from the germinated flours were combined with soya oil, tiger-nut milk, date and carrot powder to produce four samples of muffins. The samples were chemically analyzed for proximate, mineral, beta-carotene, and anti-nutrient contents. Then, sensory evaluation was carried out among 20 mothers (20-30) using a 5 hedonic scale. ANOVA and Duncan Multiple Range Test were also used to analyze the data. **Results:** Protein, fiber and carbohydrate contents of the muffins ranged from 7.63-9.23%, 0.05-0.08% and 70.63-71.55%, respectively. It was found that germination significantly increased protein and iron content of muffins but reduced zinc, calcium, and beta-carotene contents (P<0.001). The muffins contributed above 22% of the RDA regarding energy for children. Muffins produced from the blends provided higher level of protein, calcium, iron and beta-carotene compared to those made from whole wheat flour. There was a significant reduction in anti-nutrient contents of the muffins and germinated flours. The muffin produced from the 80% maize and 20% Bambara nut flour was rated best in terms of nutritional value, taste, and texture. **Conclusion:** Bambara nut flours could be used to produce nutritious snacks which would contribute to daily energy and protein needs of children.

Keywords: *Food processing; Germination; Legume; Infant food.*

Introduction

Undernutrition among young children is worse during the complementary feeding period and is linked to poor complementary foods, infections, and inadequate feeding among other things (Anato *et al.*, 2022). Infancy stage is a critical period of rapid growth and development requiring extra energy and nutrient (World Health Organization and United Nations Children's Fund (UNICEF), 2021). WHO recommends that 1-2 nutritious snacks should be given to infants (12-24 months)

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in between meals to support their daily energy and nutrient needs (World Health Organization, 2022). Moreover, ignorance of mothers and unavailability of nutritious snacks made especially for children has been a major challenge. Most available snacks are wheat-based and may predispose consumers, particularly children, to allergic reactions (Mazandarani *et al.*, 2022, Ricci *et al.*, 2019). Apart from these health reasons, the hike in prices of wheat-based products due to the existing global crisis, particularly the COVID-19 pandemic and Russia-Ukraine war (Hassen and El Bilali, 2022), informs renewed efforts towards use of non-wheat flours or partial replacement of wheat flour in the production of snacks. Attempts have been made over the years to produce composite flours from other cereals such as corn and rice and pseudo-cereals. Snacks produced from these non-wheat based flours tend to be high in commercial sugars and fat but low in proteins, vitamins, and other nutrients (Desai *et al.*, 2021, Kozik, 2021, Rico *et al.*, 2021). Processed snacks also contain significant quantities of preservatives, sweeteners, and other ingredients. Researches have confirmed that enriching cereal/grain-based flour with a variety of ingredients improves the nutritional value of cereal-based snacks. The trend is to enrich cereal-based flour snacks with diverse legumes (Bolarinwa and Oyesiji, 2021, Feyera, 2021, Gangola *et al.*, 2021, Mitelut *et al.*, 2021) and nuts (Arise *et al.*, 2021, Jabeen *et al.*, 2022, Oyeyinka *et al.*, 2021) as well as fruits and vegetables rich in vitamin A. Snacks can serve as additional sources of vitamins and minerals during complementary feeding stage (Abdel-Aal *et al.*, 2022), particularly for children residing in Sub-Saharan African countries where low consumption of nutrient dense foods has been reported (Daba *et al.*, 2021).

Maize (*Zea mays*) is the most common cereal and contains potassium, magnesium, iron, B vitamins, vitamin C and E (Shah *et al.*, 2016). Yellow maize is rich in beta-carotene, and Bambara groundnut (*Vigna subterranean L. Verdc*) is an under-utilized legume mostly grown in sub-Saharan Africa. Moreover, Bambara groundnut has various names such as ‘*jugo*’ beans (South Africa), *‘ntoyo ciBemba*’ or ‘*Katoyo*’ (Republic of Zambia), *Congo groundnut* (Congo), ‘*Nzama’* (Malawi), and *Nyimo beans* (Zimbabwe) (Okonkwo and Opara, 2010). The groundnut’s protein contains appreciable amount of essential amino acids such as lysine and methionine (Arise *et al.*, 2021). Date palm fruit (*Phoenix dactylifera L*) is also a sweet edible fruit rich in nutrients and antioxidants (Iftikhar *et al.*, 2015). Carrots are rich in carotenoids, and tiger nut (*Cyperus esculentus*) is an underutilized crop with rich nutrient profile (Adejuyitan, 2011).

Malting is a process that involves changes in nutritional, biochemical, and sensory characteristics of the food (Nkhata *et al.*, 2018). It is used in processing of cereals to improve nutritional quality, as it results in reduction of anti-nutritional factors (Laxmi and Chaturvedi, 2015, Oghbaei and Prakash, 2016). Healthy snacks should be made suitable for infants above six months to complement other meals in meeting their daily nutrient and energy requirements. Therefore, this study aims at producing and evaluating muffins for older infants using malted maize/Bambara groundnut flour blends combined with tiger nut, carrot, and date palm fruit powder. Availability of nutritious snacks produced from locally available ingredients would reduce the burden of protein energy malnutrition (PEM) in Nigeria.

Materials and Methods

Source of materials

The maize and Bambara groundnut were purchased at Idi-Araba market, Lagos, and dates and tiger nuts were purchased from a local seller in Lagos. Other baking materials were purchased from a local store. Constant Electronic Kitchen Scale (Model: 14192-2038B) was used to measure the quantities of the samples and ingredients. A 500 g weight was used to calibrate the scale.

Production of germinated maize

Raw maize was sorted to remove dirt and

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unwholesome grains. About 1.9 kg of maize seeds was washed in water. Then, the grains were steeped in tap water (1:3 w/v) at room temperature (28 ℃)) in a plastic bucket for 12 hours. After that, the grains were spread in a single layer on moist jute bags at room temperature (28 ℃) for 72 hours. Tap water was sprinkled on the grains at 12 hour intervals, and the malted grains were dried in a hot air oven (Ignis ACF040-MB) at 50-60 ℃ for 18-20 hours. Following that, the rootlets were manually removed and the dried malted grains were milled into flour using an attrition mill (MUNSON SK-30-SS). The resultant flour was sifted through a 60 mesh sieve, packed in zip lock bags, and stored at room temperature.

Production of germinated Bambara nut flour

Bambara seeds were sorted to remove stones and dirt. About 1.9 kg of Bambara seeds was steeped in clean tap water (1:3w/v) for 12 hours at room temperature. Then, the seeds were rinsed and allowed to drain before spreading evenly on a clean wet jute bag and were left for 72 hours to germinate. During germination, water was sprinkled on the seeds every six hours and the seeds were rinsed in running tap water twice daily to reduce fungal contamination. The jute bag was also washed twice daily after rinsing rotten or mold seeds were sorted out and thrown away. After 72 hours, germinated seeds were dried in a digital hot air oven at 60 ℃ for 18 hours. Then, the seeds were dehulled and the rootlets were detached and milled into flour using an attrition mill. The resultant flour was sifted through sieve, packed in zip lock bags, and stored at room temperature until it was used.

Production of date flour

Date palm fruits were sorted to remove immature, overripe, and damaged ones. The seeds were removed, and the pulp was dried, milled, and sieved.

Production of tiger nut milk

Fresh tiger nuts were washed and blended several times with water into slurry in a Phillips blender (HR-2102). The slurry was pressed using muslin cloth to extract the milk.

Preparation of muffins

The muffins were made using a modified procedure with slight modifications (Jabeen *et al.*, 2022). Wheat and composite blends of maize and Bambara nut flour were combined as indicated in **Table 1**. The composite flours were then used with the ingredients listed (**Table 2**) to prepare muffins as described in the flowchart (**Figure 1**).

Chemical analysis

Each sample was analyzed for protein, fat, moisture, ash, fiber, beta-carotene, phytate, hemaglutinin, and trypsin inhibitor (The association of official analytical chemists (AOAC), 2016) while carbohydrate was by different. Iron, zinc and calcium were determined using Atomic Absorption Spectrophotometry (AAS) after digestion.

Sensory evaluation

Muffin samples were evaluated by a panel of twenty semi-trained panelists from Surulere Local Government, Lagos, Nigeria for attributes of appearance, taste, texture, aroma and overall acceptability on a hedonic scale of 1-5 where 1=dislike extremely and 5=like extremely.

Table 1. Wheat and composite blends of maize and Bambara nut flour.

Type of flours	Samples (%)				
	A	B	C	D	E
Wheat flour	100	-	-	-	-
Germinated maize flour	-	80	70	60	
Germinated Bambara flour	-	20	30	40	
Unprocessed maize flour	-	-	-		80
Unprocessed Bambara flour	-	-	-		20

Table 2. Ingredients for the production of muffins.

Ingredients	Quantity
Composite flour	100 g
Baking soda	1/4 teaspoon
Date flour	50 g
Salt	1/8 teaspoon
Tiger nut milk	60 mls
Soya oil	40 mls
Egg	1 medium size
Carrot powder	48 g
Vanilla extract	1/2 teaspoon

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Combine composite flour, date flour, salt, and baking soda in a bowl

↓

Combine eggs, soya oil, tiger nut milk, and vanilla extract in a bowl and add them to flour and mix to form batter

↓

Fold in carrots and Pre-heat oven to 170 ℃

↓

Put the muffin liners into the muffin pan

↓

Divide the batter evenly into liners and bake at 200 ℃ for 35-50 mins

↓

Take them out of the oven and allow them cool

Figure 1. Flowchart for the production of muffins.

Chemical analysis

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Data analysis

The statistical analysis was undertaken using SPSS software version 20. Descriptive analysis such as means and standard deviation were performed and ANOVA was used to detect significant differences at P-value<0.05 among proximate, mineral, beta-carotene, anti-nutrients, and sensory attributes of the five samples of muffins. Duncan Multiple Range test was employed to separate the means.

Results

Proximate composition of muffins made from germinated Maize-Bambara groundnut blends

Table 3 presents the proximate composition of muffins made from germinated Maize-Bambara groundnut blends, tigernut milk, date palm, and carrot powder. The five muffin products had significantly different protein contents compared with Germinated Maize (60%); Bambara nut flour C (40%) (GMBC) had the highest value (9.23%) and the lowest value (7.63%) recorded in the Whole Wheat Flour muffin (WWF). It was observed that the protein contents of the muffins increased with the addition of Bambara groundnut flour (8.68 - 9.23%).

Mineral contents of muffins produced from Maize-Bambara groundnut blends

The muffins (GMBA, GMBB, GMBC) prepared from germinated maize and Bambara nut had a significantly higher level of iron, calcium and beta-carotene content compared to the muffin (WWF) made from 100% WWF (**Table 3**). Calcium and beta-carotene contents of the muffins made from composite flour increased with increased substitution levels of Bambara nut flour. The muffins had high beta-carotene contents compared to the unprocessed and processed maize and Bambara nut flours. Germination increased zinc and beta-carotene contents of maize and Bambara nut flour. The germinated maize flour had higher levels of zinc (1.31 mg/100g), calcium (204.70 mg/100g), and beta-carotene (275.50 ug/100g) contents compared with the unprocessed maize flour (**Table 3**).

Contribution of serving portion muffin (45g) to Recommended Dietary Allowance (RDA) for infants (6-24 months)

The contribution of 45 g portion of the prepared muffin to the RDA of energy, protein, beta-carotene, and iron was above 22% (**Table 4**). Low values were found for calcium (6.7-10.0%). The

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muffin that contributed the highest protein to the recommended daily protein allowance was the 60:40 germinated maize and Bambara nut mix. Muffins produced from the blends produced higher protein, calcium, iron and beta-carotene compared to those made from WWF. This affirmed the superiority of cereal-legume mix to cereal-based products.

Table 3. Proximate composition of muffins produced from Maize-Bambara flour blends (dry weight).

Sample	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Total ash (%)	Carbohydrate (%)	Energy (kcal)
WWF	21.42^{b}	7.63^{f}	13.66^{a}	0.05^{d}	2.71^{ab}	71.55^{a}	439.66
GMBA	22.24^{ab}	8.68^{e}	13.32^{bc}	0.62^{d}	2.72^{ab}	70.93^{a}	438.32
GMBB	22.11^{ab}	9.03^{d}	13.33^{b}	0.72 ^{d}	1.83^{b}	71.40^{a}	441.69
GMBC	21.09^{b}	9.23^{c}	13.15^{c}	0.80^{d}	2.87^{ab}	70.38^{ab}	436.79
UMBF	23.03^{d}	8.92^{d}	13.34^{b}	0.71^{d}	2.91^{ab}	70.63^{ab}	438.26
UBF	10.58^{c}	17.14^{b}	3.95^{d}	2.49^{b}	3.14 ^{a}	58.82^{d}	339.39
GBF	10.32^{c}	19.40^{a}	3.97^{d}	2.85^{a}	3.44^{a}	55.29^{e}	334.49
UMF	11.03^{c}	8.63^{e}	3.01^{e}	1.71^{c}	2.55^{ab}	69.60^{b}	340.01
GMF	11.21^{c}	9.22^{c}	3.15^{e}	1.80^{c}	2.71^{ab}	65.27^{c}	326.31

Minerals	Iron (mg/100g)	Zinc (mg/100g)	Calcium (mg/100g)	Beta-carotene (ug/100g)
WWF	4.09^{d}	1.70^{b}	74.3^{i}	423.02^{e}
GMBA	6.58^{a}	1.52^{c}	85.4^{h}	440.92^{d}
GMBB	4.56^{c}	1.71^{b}	101.9^{g}	458.91^{c}
GMBC	5.91^{b}	1.61^{bc}	111.5^{f}	471.71^{b}
UMBF	6.12^{b}	1.82^{a}	193.4^{c}	480.10^{a}
UBF	4.02^{d}	1.10	182.8^{d}	158.94 ^{i}
GBF	2.88^{e}	1.23^{d}	174.6^{e}	165.86^{h}
UMF	4.53^{c}	1.09^{e}	197.8^{b}	268.64^{g}
GMF	2.98^{e}	1.31^{d}	204.7^{a}	275.50^{f}

Means on the same column with different superscripts are significantly different; **WWF**: 100% whole wheat flour; **GMBA**: 80% germinated maize flour, 20% germinated Bambara groundnut flour A; **GMBB**: 70% germinated maize flour, 30% germinated Bambara groundnut flour B; **GMBC**: 60% germinated maize flour, 40% germinated Bambara groundnut flour C; **UMBF**: unprocessed maize (80%) and Bambara groundnut flour (20%); **UBF**: unprocessed Bambara groundnut flour; **GBF**: germinated Bambara groundnut flour; **UMF**: unprocessed maize flour; **GMF**: germinated maize flour.

Table 4. Contribution of serving portion (45 g muffin) to RDA for infants (6-24 months).

Nutrients	WWF	GMBA	GMBB	GMBC
Protein (g)	3.43	3.91	4.10	4.20
RDA (g), %RDA	15, 22.9	15, 26.1	15, 27.3	15, 28.0
Energy (kcal)	197.84	197.24	198.80	196.55
RDA (kcal), %RDA	700, 28.3	700, 28.2	700, 28.4	700, 28.1
Zinc (mg)	0.77	0.68	0.77	0.72
RDA (mg), %RDA	3, 25.7	3, 22.7	3, 25.7	3, 24.0
Calcium (mg)	33.44	38.43	45.86	50.18
RDA (mg), %RDA	500, 6.7	500, 7.7	500, 9.2	500, 10.0
Iron (mg)	1.84	2.96	2.05	2.66
RDA (mg), %RDA	8, 23.0	8, 37.0	8, 25.6	8, 33.3
Beta-carotene (μg)	190.36	198.41	206.50	212.27
RDA (μg), %RDA	500, 38.1	500, 39.7	500, 41.3	500, 42.5

WWF: 100% whole wheat flour; **GMBA**: 80% germinated maize flour, 20% germinated Bambara groundnut flour A; **GMBB**: 70% germinated maize flour, 30% germinated Bambara groundnut flour B; **GMBC**: 60% germinated maize flour, 40% germinated Bambara groundnut flour C; **RDA:** Recommended Dietary Allowance; %**RDA**: Proportion of the daily energy or the nutrient requirement provided by one serving of muffin.

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Anti-nutrient contents of muffins produced from Maize-Bambara groundnut blends

The result of the anti-nutrient analysis is shown in **Table 5**. Unprocessed Bambara nut flour had the highest content of anti-nutrients which was reduced through processing. There was a notable reduction in the levels of phytate (8.00-3.40 mg/100 g) and tannin (3.20-1.40 mg/100 g) of muffins produced from processed flours. Phytate content increased with increased incorporation of Bambara nut flour. Moreover, the reductions in phytate and tannin occurred concurrently with an increase in trypsin (0.28-0.49 Tiu) inhibitor and hemagglutinin (2.47-2.88 HU) content and Bambara groundnut flour. The WWF sample recorded the lowest level of hemagglutinin (2.29 HU) and trypsin inhibitor (0.15 TIU) contents, but highest level of phytate (8.00 mg/100g) and tannin (3.20 mg/100 g) contents.

Table 5. Anti-nutrient contents of muffins produced from Maize-Bambara groundnut blends.

Samples	Phytate (mg/100 g)	Tannin (mg/100 g)	Trypsin Inhibitor (Tiu)	Hemaglutinin (HU)
WWF	8.00[e]	3.20[b]	0.15[h]	2.29[g]
GMBA	6.30[ef]	2.30[c]	0.28[gh]	2.47[g]
GMBB	4.90[efg]	1.70[d]	0.37[fg]	2.70[f]
GMBC	3.40[fg]	1.40[d]	0.49[ef]	2.88[ef]
UMBF	2.30[g]	1.00[e]	0.56[e]	2.94[e]
UBF	88.00[a]	3.70[a]	21.92[a]	52.98[a]
GBF	74.00[b]	3.00[b]	15.9[b]	43.77[b]
UMF	65.50[c]	2.30[c]	9.35[c]	23.98[c]
GMF	50.00[d]	1.70[d]	5.82[d]	18.32[d]

Means on the same column with different superscripts are significantly different. Means with superscripts 'a' are highest in magnitude, followed by other means with other letters in a descending order; **WWF**: 100% whole wheat flour; **GMBA**: 80% germinated maize flour, 20% germinated Bambara groundnut flour A; **GMBB**: 70% germinated maize flour, 30% germinated Bambara groundnut flour B; **GMBC**: 60% germinated maize flour, 40% germinated Bambara groundnut flour C; **UMBF**: unprocessed maize (80%) and Bambara groundnut flour (20%); **UBF**: unprocessed Bambara groundnut flour; **GBF**: germinated Bambara groundnut flour; **UMF**: unprocessed maize flour; **GMF**: germinated maize flour.

Sensory properties of muffin samples

The muffins made from WWF and the GMBA were the most acceptable in terms of taste and appearance (**Figure 2**). On the other hand, the muffins made from GMBC were the least acceptable.

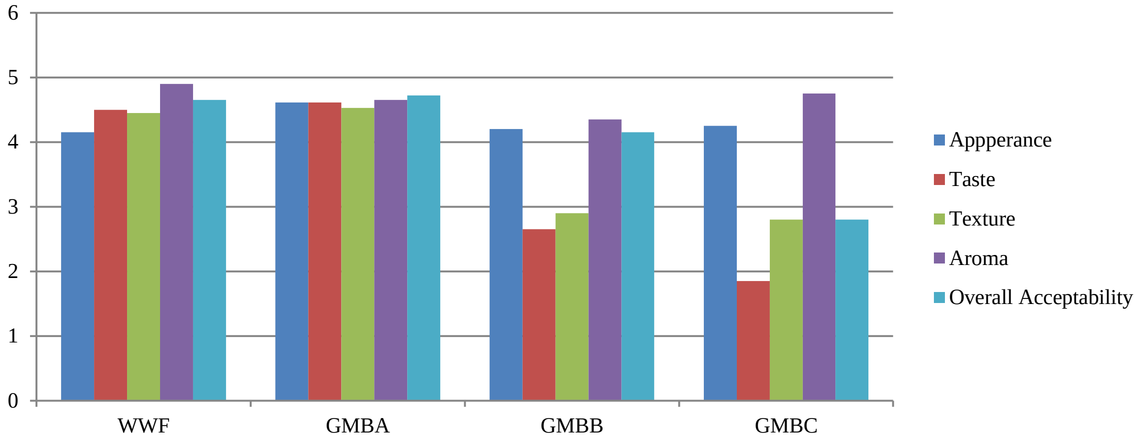

Figure 2. Sensory analysis of muffin samples.

WWF: 100% whole wheat flour; **GMBA**: 80% germinated maize flour, 20% germinated Bambara groundnut flour A; **GMBB**: 70% germinated maize flour, 30% germinated Bambara groundnut flour B; **GMBC**: 60% germinated maize flour, 40% germinated Bambara groundnut flour C.

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Discussion

Proximate composition of muffins made from germinated Maize-Bambara groundnut blends

The protein contents of the muffins increased with the addition of Bambara nut flour. This finding concurred with a previously mentioned study which reported an increase in protein contents of cupcakes made from rice/corn-based composite flour with increased addition of chickpea flour (3.97-14.66 g/100 g) (Jabeen *et al.*, 2022). The protein contents of gluten-free muffins also increased with increasing the levels of legume flour (Jeong *et al.*, 2020). When snacks were produced from composite flours of Bambara groundnut, unripe plantain and turmeric increased protein contents was the result (Adegunwa *et al.*, 2017). This finding was attributed to the increase in the added quantity of Bambara groundnut. Doughnuts produced from blends of wheat flour and Bambara groundnut flour showed higher protein contents with increased substitution levels of Bambara groundnut flour (Adebayo-Oyetoro *et al.*, 2017). Another study on kokoro reported an increase in the protein contents of kokoro made from Maize-Bambara flour blends (Arise *et al.*, 2021). The products from 70:30 (Maize:Bambara) had the highest protein content (32.30%).

Mineral contents of muffins produced from Maize-Bambara groundnut blends

Calcium contents of cookies prepared from wheat, Bambara nut, and ripe banana were higher than those made from 100% wheat which were lower in iron content (Arise *et al.*, 2021). The poor calcium content recorded in this study might be as a result of the quantity of tiger nut milk used. Second, maize which is the major ingredient is poor in calcium. Also, some of the minerals might have been lost during germination and baking. With reference to some research reports, the inclusion of legumes such as chick pea (Jabeen *et al.*, 2022) and sprouted soy (Agrahar-Murugkar *et al.*, 2016) to WWF in cupcake production increased iron, calcium, and zinc contents. However, the iron contents of cupcakes (18.6 mg/100 g) produced by Jabeen's group were higher than the iron contents of the muffins (4.09-6.58 mg/100 g) in the present study. This might be due to the use of almond (60%, 48% and 40%), chickpea and flaxseed flour as major ingredients with 5-8% sorghum flour for the production of the cupcakes. The high beta-carotene content of the muffins observed in this study could be attributed to the type of ingredients used in the production of the muffins such as dates and carrots. Date fruit is very rich in antioxidant flavonoids such as beta-carotene (Adejuyitan, 2011). In this study, germination process resulted in the increased levels of zinc, calcium and beta-carotene. This finding is not in agreement with another study that reported reductions in the levels of zinc and beta-carotene in maize and pigeon pea, respectively, after germination process (Anaemene and Fadupin, 2021). The result of lower iron values in germinated samples was also reported elsewhere (Mbaeyi-Nwaoha and Obetta, 2016). Thus, there is need to enrich the snacks made from processed flours with mineral mix to make up for the nutrients lost during the process of germination as well as heating.

Contribution of serving portion muffin (45g) to RDA for infants (6-24 months)

Consumption of the muffins could provide at least 22% of the daily protein, iron, beta-carotene, and energy required by children to meet the increased need for their rapid growth and development. Maize-Bambara nut muffins enriched with tiger nut milk, carrot, and date powder could contribute to reductions in the prevalence of PEM and hidden hunger among children. Shriver reported that produced snacks accounted for 28%, 32% and 26% of total daily energy, carbohydrates, and fat intakes, respectively (Shriver, 2018).

Anti-nutrient contents of muffins produced from Maize-Bambara groundnut blends

The reductions in phytate and tannin recorded in this study in malted maize and Bambara nuts were in line with the findings of other works (Atudorei *et al.*, 2021, Feyera, 2021). Sometimes, germination results in the reduction

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of anti-nutritional factors (Oghbaei and Prakash, 2016, Rico *et al.*, 2021, Zhang *et al.*, 2015). It involves changes in nutritional, biochemical, and sensory characteristics of the food (Feyera, 2021). These changes are strongly linked to the activities of endogenous phytase (Kozik, 2021) making germinated foods higher in nutritional quality compared to non-germinated seeds (Zhang *et al.*, 2015).

Sensory properties of the muffin samples

It was observed that taste and acceptability decreased with increased substitution of Bambara nut flour as found in other muffin-based works (Darkwa *et al.*, 2021, Jeong *et al.*, 2020), which showed a direct relationship between acceptability and quantity of Bambara nut used in the production of the snacks. This may imply that though legume flour improves the nutritive value of cakes and other snacks, the sensory properties are negatively affected. Legumes have strong off-flavour and bitter taste; high concentrations should not be used in snack production (Bravo-Núñez and Gómez, 2021). It is assumed that sweet flavours should mask these off-flavours. The quantity of dates powder used might be a factor to consider. Furthermore, it is possible to produce snacks that are acceptable in terms of taste by supplementing wheat flour with sorghum flour and using date as a sweetener instead of sugar. Organoleptic properties are very important for consumers' acceptance of new products (Guiné, 2022). Acceptability of products is a strong determinant of sales and consumption rates. Production is not complete till the product gets to the final consumer. Therefore, further research is needed regarding the improvement of the textural characteristics while maintaining the nutritional value of muffins prepared with Bambara nut flour.

Conclusion

Germination increases the protein and iron contents of Maize-Bambara groundnut flours but reduces zinc, calcium and beta-carotene contents. The addition of Bambara nut, tiger-nut milk, date, and carrot powder improves the nutritional quality of maize-based muffins. The Maize-Bambara nut muffin provides the appreciable proportion of the recommended daily allowances for protein, energy, zinc, iron, and beta-carotene but a low amount of calcium. This study also established that germination has a significant effect on the reduction of phytate and tannin levels of maize and Bambara nut flours. Muffins produced from germinated maize (80%) and Bambara nut (20%) flour were compared favorably with a 100% wheat-based muffin in acceptability. Nutritious snacks of acceptable taste and texture can be produced from 80% germinated maize, 20% germinated Bambara groundnut flours, tiger-nut milk, date and carrot powder.

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Conflicts of Interest

The authors declared no conflict of interests.

Authors' contributions

Anaemene DI and Arisa N conceptualized and designed the research. Adeoti D conducted the research while Anaemene D and Arisa N supervised the experiment. The statistical analysis was performed by Anaemene D. Adeoti D wrote the first draft of the work while Arisa N and Anaemene D revised the manuscript. All the authors read and approved the final manuscript.

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