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EVALUATION OF PROXIMATE COMPOSITION, FUNCTIONAL AND COLOUR ATTRIBUTES OF ENRICHED MAIZE FLOUR FOR THE PRODUCTION OF *KOKORO* USING MIXTURE DESIGN

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ABSTRACT

The nutritional composition of maize flour as a raw material for the production of snacks consumed can be enriched by partial substitution with other local available crop products. This study evaluated the feasibility of partially replacing maize flour with coconut and ginger flours for potential use in making of *kokoro* snack. Composite flours were produced from maize, ginger and coconut flours using D-optimal mixture design with 13 experimental runs. Proximate composition, functional properties and colour attribute of the composites were determined using standard laboratory procedures. Data obtained were analysed using Design Expert version 6.0.8. Results showed that wettability, swelling capacity and solubility index of the functional properties were significantly affected (P<0.05) by interaction effects of the maize and coconut flour. Fat content was significantly affected (P<0.05) by the interaction of maize and ginger flour. The colour attributes (redness, yellowness and lightness) were not significantly affected (P>0.05) by either the main or the interaction effect of the flours on the composites. The variations obtained in the properties investigated could be harnessed for the production of enriched *kokoro* snack.

Keywords: Maize flour, proximate composition, functional properties, colour, mixture design

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INTRODUCTION

Maize (*Zea mays* L.*)* also known as the poor man's nutria cereal is one of the most important staples in the world (USDA, 2014; Girai *et al*., 2018). It is used for food, feed and other industrial applications but as a food crop. It is the world's highest supplier of calories after wheat (Girai *et al*., 2018). According to Kaul *et al.* (2019), 30% of the calories for approximately 4.5 billion people in developing countries is supplied by maize. It is a major source of starch (corn starch) and maize flour which are major ingredients in home cooking and in many industrialized food products (Mishra *et al.,* 2012). It is also a major raw material for the production of many indigenous snacks such as *kokoro*, *aadun*, *donkwa* and *masa.* produced and consumed in various regions of Nigeria. Nigeria is a major producer of maize in Africa (FAOSTAT, 2017) and over 75% of maize production is used for human consumption. Hence, maize is an essential crop for food security in Nigeria.

Coconut (*Cocos nucifera Lin.*), the most extensively grown and used nut in the world, is among the top ten most useful and abundant trees in the world (Olajuyin *et al.*, 2019). It is commonly called 'tree of life' or 'tree of abundance' because it has multipurpose utilization in nutrition, medicine, cosmetics, etc. (Rethinam, 2019). Coconut is naturally low in digestible carbohydrates, contains no gluten, and is loaded with health-promoting fibre and other biologically active components such as sugars, proteins, amino acids, vitamins and minerals (Karandeep *et al.*, 2019; Raczyk *et al.*, 2021), hence it is a source of basic nutritional benefits to man (Makinde and Eyitayo, 2019). Coconut flour is a soft, flour-like product made from the pulp of a coconut fruit. Coconut flour can provide not only value-added income to the industry, but also a nutritious and healthy source of dietary fibre (Trinadad *et al.,* 2006). It is worthy to note that the simple carbohydrates and high fibre contents of coconut yield flours is less disruptive to blood sugars because of its low glycemic index (Ramaswamy, 2014: Makinde and Eyitayo, 2019).

Ginger (*Zingiber officinale)* is a spice believed to be indigenous to South East Asia, from where it has spread to other regions of the world (Rupasinghe and Gunathilake, 2015). According to Sangwan *et al.* (2014), India is the largest producer of ginger roots while other major producers include Nigeria, Sierra Leone, Jamaica, China and Haiti. Ginger contains several chemical compounds such as essential oils, vitamins and minerals that have multiple pharmacological effects, cardiotonic effects, gastro-intestinal actions thermogenic, and antibiotic activities (Zhao *et al.*, 2011: Sangwan *et al.*, 2014). Ginger is used as a seasoning material as well as taste enhancer in the production of food, drinks, confectioneries, alcoholic and non- alcoholic beverages (Sangwan *et al.*, 2014).

The nutritional composition of maize flour as a major raw material for the production of *kokoro,* a local snack consumed in Nigeria could be enhanced by partial substitution with other local available crops such as coconut and ginger flours. The use of coconut and ginger flours in the food industry will enhance the diversification and utilisation of coconut and ginger as raw materials for food production. Compositing flours influences their nutrient composition as well as their functionality as potential food ingredient, hence, this study evaluated the proximate composition, functional properties and colour attributes of maize, coconut and ginger composite flours.

MATERIALS AND METHODS

Source of Raw Materials

Dried yellow maize grain, coconut and ginger were purchased from Osiele market in Abeokuta, Ogun State, Nigeria.

Processing of maize flour

Dried maize grains was manually sorted, cleaned to remove stones, winnowed to blow away the chaff and damaged grains, and then decorticated. The cleaned and decorticated maize grains was dry-milled in a locally-fabricated attrition mill to produce the maize flour, which was allowed to cool before it was sieved to obtain a particle size of 750 µm (Otunola *et al.,* 2012).

Processing of coconut flour

Coconut flour was produced according to the method described by Afoakwah *et al.* (2019) with slight modifications for the production of the flour. Mature and dehusked coconuts were manually cracked and deshelled to obtain the endocarp. The endocarp was sliced into small sizes of 5-10 mm using a kitchen knife and washed thoroughly in clean water to remove foreign and unwanted materials. The sliced coconut kernels were subjected to size reduction using a laboratory hammer mill (Fritsch, D-55743 Idar-oberstein-Germany). The resultant meal was manually squeezed in a muslin cloth alongside addition of warm water to remove the coconut milk. The residue obtained was dried at 55 ^{0}C for 5 h. The dried residue was then milled into flour.

Processing of ginger powder

Ginger roots used were cleaned, peeled, cut into small pieces, washed and dried at 60^{0}C for 10 h in an oven (Model T12H Genlab, England). Dried ginger was milled and sieved using 150 µm to obtain a powder.

Preparation of maize- coconut-ginger composite flour (MCGF)

Different composites of the mixtures of maize flour, coconut flour and ginger powder were prepared by using D-optimal Design for three component mixtures which gave a total of thirteen (13) experimental runs (Table 1).

Table 1: Composition of the different formulations based on experimental design (%)

Runs	Maize flour (%)	Coconut flour (%)	Ginger flour (%)
1	73.75	23.75	2.50
2	73.00	25.00	2.00
3	75.00	21.00	4.00
4	75.00	22.00	3.00
5	72.25	24.25	3.50
6	71.00	25.00	4.00
7	73.00	25.00	2.00
8	71.00	25.00	4.00
9	73.00	23.00	4.00
10	72.00	25.00	3.00
11	75.00	23.00	2.00
12	75.00	21.00	4.00
13	74.25	22.75	3.00

Analyses

Determination of proximate composition

Moisture, crude protein, fat, crude fibre and total ash of the composite flours were determined by the method of AOAC (2005). Carbohydrate was calculated by difference.

Determination of Functional properties of the composites

Bulk density of the blends

The bulk density of each of the flour samples were determined according to the method of Nwosu *et al.* (2010). A weighed sample (10 g) was put in a calibrated 50 ml measuring cylinder. Then later, the bottom of the cylinder was tapped repeatedly unto a firm pad on a laboratory bench until a constant volume was observed. The packed volume was recorded. The bulk density was calculated as the ratio of the sample weight to the volume occupied by the sample after tapping.

$$\text{Bulk Density (g/ml)} = \frac{\text{weight of sample (g)}}{\text{volume of sample (ml)}}$$

Dispersibility of the blends

The method described by Kulkarni *et al.* (1991) was used. Ten grams of each flour sample was weighed into a 100 ml-measuring cylinder. Distilled water was added up to 100 ml volume. The sample was vigorously stirred and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100 to give a difference that is taken as percentage dispersibility.

Water absorption capacity of the blends

Water absorption capacity were determined according to the methods of Onwuka (2005). One gram of each sample was weighed into a clean conical graduated centrifuge tube and mixed thoroughly with 10 ml distilled water using a platform tube rocker for 30 s. The sample was allowed to stand for 30 min at room temperature, after which it was centrifuged at 3500 rpm for 30 min. After centrifugation, the volume of the free water (supernatant) was read directly from the graduated centrifuge tube. The absorbed water was converted to weight (in grams) by multiplying by the density of water (1 g/ml). The water absorption capacity was expressed in grams of water absorbed per gram of flour sample.

Absorbed water = total water - free water.

Oil absorption capacity of the blends

This was determined by the method described by Onwuka (2005). About 1 g of the sample was measured and 10 ml refined corn oil was weighed into a dry, clean centrifuge tube. Approximately 10 ml of refined corn oil was poured into the tube and properly mixed with the flour. The suspension was centrifuged at a speed of 3500 rpm for 15 min. The supernatant was thereafter discarded and the tube content was re-weighed. The gain in mass was recorded as the oil absorption capacity of the sample.

Swelling capacity of the blends

The swelling capacity was determined using the procedure described by Takashi and Sieb (1988). About 1 g of sample was weighed into a weighed centrifuge tube. Thereafter, 10 ml distilled water was added and shaken properly and heated in a water bath at 60^{o}C for 30 min, with constant mixing and then allowed to cool. The sample was centrifuged at 3000 rpm for 15 min; the supernatant was decanted and the sediment paste was weighed. The swelling capacity was calculated by the formula:

$$\%\ \text{Swelling Capacity} = \frac{\text{Weight of sediment paste}}{\text{Weight of the sample (dry basis)}} \times 100$$

Determination of colour attributes

The colour intensity of the flour blends were measured using a Konica Minolta Colour Measuring System (Chroma meter CR-410, Minolta LTD, Japan) as described by Kajihausa *et al.* (2020). The lightness (L^*), redness (a^*) and yellowness (b^*) values were obtained after calibrating the instrument using a white tile. Three replicate readings were taken for each flour blends and the average value reported. The results were expressed in accordance with the CIELAB system, where:

L* is the lightness [L =0 (black), L = 100 (white)],

a* (-a = greenness, + a = redness)

b* (-b values = blueness, + b* value = yellowness)

Statistical Analysis

Data obtained for proximate composition, functional properties, and colour analyses were analyzed statistically for significant effect of independent variable on the responses at 5% level, using analysis of variance (ANOVA). The effect of ingredient combination and optimization procedure was investigated using Design expert version 6.0.8 based on simplex centroid design. Models were generated and significant effect of the ingredient combination at 5% level was determined.

RESULTS AND DISCUSSION

Proximate composition of maize-coconut-ginger composite flours

Variation in the moisture, ash, protein, fat, fibre and carbohydrate contents as coconut flour and ginger flour included varied (Table 2). Moisture content of MCGF decreased as inclusion of coconut flour increased, but increase in maize and ginger addition resulted to an increase in moisture content (Table 2). The coefficient of determination for moisture content was able to predict more than 60% (Table 3). The moisture content of the flour is important for two reasons, firstly the higher the moisture content the lower the dry solids in the flour and secondly, flours with moisture content greater than 14% are not stable at room temperature. High moisture in foods could enhance the activities of spoilage microorganisms which in turn reduces quality and shelf life of food products. Hence, the low moisture content observed in this study would enhance the shelf stability of the flour blends.

The mean values of the fat contents ranged between 16.36% and 19.98% (Table 2). The regression model developed (R^2) for fat content was able to predict more than 90% predictive accuracy (Table 3). Increase in fat contents was observed as coconut flour substitution increased. However, addition of maize and ginger reduced the fat content. This observation was earlier reported by Makinde and Eyitayo (2019) and Afoakwah *et al.* (2019) on partial substitution of wheat flour with coconut flour. Fat plays a significant role in the shelf life of food products and as such relatively high fat content could be undesirable in flour products. This is because fat can promote rancidity in foods, leading to development of unpleasant and odorous compounds (Ihekoronye and Ngoddy, 1985). The interaction between maize flour and ginger flour exerted a negative significant influence on the fat content of MCGF composites (Table 3).

Table 2: Proximate Composition of Maize-coconut-ginger Composite Flours at Different Experimental Runs

Flour Sample	Moisture content (%)	Fat content (%)	Protein content (%)	Ash content (%)	Fibre content (%)	Carbohydrate content (%)
$M_{73.75}C_{23.75}G_{2.50}$	10.78	18.41	9.86	1.48	8.77	50.72
$M_{73}C_{25}G_{2}$	10.71	18.6	10.27	1.47	9.57	49.39
$M_{75}C_{21}G_{4}$	11.09	16.36	9.63	1.46	8.80	52.66
$M_{75}C_{22}G_{3.}$	11.32	16.88	9.78	1.39	8.50	51.79
$M_{72.25}C_{24.25}G_{3.50}$	10.82	19.24	9.98	1.54	9.23	49.21
$M_{71}C_{25}G_{4}$	10.72	19.98	10.22	1.56	9.94	47.59
$M_{73}C_{25}G_{2}$	10.89	18.55	10.43	1.51	9.55	49.07
$M_{71}C_{25}G_{4}$	10.86	19.92	10.22	1.55	9.37	48.10
$M_{73}C_{23}G_{4}$	11.14	18.85	9.82	1.49	8.89	49.82
$M_{72}C_{25}G_{3}$	11.13	19.21	10.35	1.54	9.76	48.02
$M_{75}C_{23}G_{2}$	11.38	18.90	9.94	1.48	8.97	49.35
$M_{75}C_{21}G_{4}$	11.61	16.40	9.64	1.47	8.87	51.99
$M_{74.25}C_{22.75}G_{3}$	11.48	16.87	9.84	1.41	8.92	51.49

* Values are means of duplicate

*Where M; Maize flour (%), C; Coconut flour (%), G; Ginger flour (%)

Table 3: Regression models relating responses and independent variables for proximate composition

Parameters	Moisture content	Fat content	Protein content	Ash content	Fibre content	Carbohydrate content
A	11.82	17.10	9.87	1.41	8.82	50.64
B	10.49	18.06	11.13	1.59	11.12	47.58
C	8.68	33.72	9.36	2.15	10.23	38.24
AB	-0.55	4.75	-1.68	-0.084	-3.43	1.84
AC	2.65	-28.50*	-0.21	-0.90	-2.12	26.31
BC	4.23	-14.16	-1.40	-0.94	-5.08	13.99
R^2	0.62	0.93	0.95	0.76	0.85	0.91

*Significant at $p < 0.05$. A= linear effect of maize flour, B = linear effect of coconut flour, C= linear effect of ginger flour, AB= interaction of maize and coconut flour, AC= interaction effects of maize and ginger flour, BC= interaction effects of coconut flour and ginger flour

Generally, the protein content of flour is one of the parameters that gives an indication of the nutrient quality of the flour. Flours are usually fortified with high protein flours to provide needed nutrition (Zhao *et al.*, 2011). The protein contents increased as coconut flour inclusion increased but, it decreased as substitution of maize and ginger flour increased (Table 2). The coefficient of determination (R^2) of the model predicting protein contents of the flour composites was 0.95 indicating over 90% predictive accuracy (Table 3). Proteins' unique physicochemical properties in foods play an important role in determining the functionality of flours which is also determined by the structure of proteins at different levels (Akharume *et al.,* 2021). Protein's influence on flour functionality may be due to the presence of hydrophilic and hydrophobic parts and as such depending on the type of amino acid present; whether polar or non-polar, it could determine the hydration properties of flour (Suresh *et al.,* 2015).

The mean values of ash contents as ranged from 1.39% - 1.56% (Table 2). The ash content of a food material could be used as an index of mineral constituents of the food because ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of an oxidizing agent (Sanni *et al.*, 2005). The regression model developed (R^2) for ash content was able to predict more than 70% (Table 3), indicating a predictive accuracy. Minerals play a role for the maintenance of the overall mental physical wellbeing and the development and maintenance bones, tissues teeth, and muscles (Ohizua *et al.,* 2017).

Fibre contents increased as coconut flour addition increased but decreased as inclusion of maize flour and ginger flour increased. The mean value of fibre contents ranged from 8.50% – 9.94% (Table 2). The regression model developed (R^2) for fibre content was able to predict more than 80% indicating a predictive accuracy (Table 3). These findings show that maize and ginger flour are not a good source of dietary fibre compared to coconut flour. One possible implication of using higher fibre coconut flour in food applications will be to help raise the fibre content of the food products and offer some important health benefits such as prevention of constipation and colon cancer, reducing low density lipo-protein cholesterol levels (LDL) (Hossain *et al.,* 2016).

Carbohydrate increased with increased in inclusion of maize flour but decreased as inclusion of coconut flour and ginger flour increased (Table 2). The significance of this is that MCGF with higher maize flours will have a higher glycemic index in comparison with other composites with higher coconut flour. Glycemic index is a measure of the rate of release of sugar by the food and absorption of sugar in the human body. This index is less affected by the amount of protein and fat in foods (Lal *et al.*, 2021).

Functional properties of maize-coconut-ginger composite flours

The term "functional property" as applied to food ingredients, is defined as any property, aside from nutritional attributes, that influences the ingredient's usefulness in food. Bulk density of the composites ranged from 0.55 g/ml to 1.20 g/ml (Table 4). The bulk density of the composite flour was found to be function of the linear and interactions effects of the independent variables. Interactions of maize flour and coconut flour as well as maize flour and ginger flour had a significant ($p<0.05$) effects on the bulk density (Table 5). This might be due to variations in particle size and true densities of the compositing flours. Increase in coconut flour and ginger flour resulted in a low bulk density, but a high value was observed as maize inclusion increased (Table 4). Bulk density is a property of materials which measures the heaviness of flour and other food products and thus, influences the packaging material, material equipment handling and industrial food applications of flours (Adegunwa *et al.*, 2015). High bulk density which is a good physical attribute that determines high ease of dispersibilty and reduction in paste thickness could indicate the suitability of flour for food use (Awolu *et al.*, 2017). The composites with low bulk density could be used for *kokoro* that would be desirable for children and can also be harnessed for complementary or weaning foods. The coefficient of determination (R^2) of bulk density was 0.99 (Table 5). Awolu *et al.* (2017) reported that the best R^2 value to obtain a good fit model was between 0.80 and 1.0. However, R^2 values > 0.60 could also indicate a fair fit of the model, hence, reliable in making predictions as reported by Sarifudin *et al.* (2020).

Wettability shows how proficient a flour sample will be distributed. The wettability properties of the composite blends ranged from 24.50 to 26.50 s (Table 4). The increase in the addition of coconut and ginger flour resulted in an increased wettability but inclusion of maize flour was found to lower the wettability time of the composite blends (Table 4). The coefficient of determination for water absorption capacity was 0.80 (Table 5). Ibanga and Oladele (2008) and Ubbor and Akobundu (2009) reported that flour samples that will disperse faster in water are the ones with the lowest wettability. Also, a higher value of wettability indicates lower reconstitution properties (Ubbor and Akobundu, 2009). Therefore; the wettability results implied that, coconut flour and ginger flour required longer time than the maize flour sample before it is completely wet or reconstituted. Interaction effect of maize and coconut flour had a significant ($p< 0.05$) on wettability (Table 5).

Dispersibility which is a measure of the capacity of starch flour to reconstitute in water ranged from 71.75 to 74.50 (Table 4). The higher the dispersibility, the better the starch flour reconstitute in water (Kulkarni *et al.,* 1991). An increase was observed as inclusion of maize and coconut flour increased but decreased as ginger flour inclusion increased. The result observed in this study indicated that maize flour and coconut flour will disperse easily and faster than ginger flour in aqueous solution or during food processing, and this is similar to the findings of Ayinde *et al.* (2012).

Water absorption capacity (WAC) can be described as the ability of flour to bind with water. (Singh, 2001). It also plays an important role in bulkiness and consistency of food products and can be influenced by gelation and hydrophilicity of starch (Asaam *et al.,* 2018). The water absorption capacity of the flour blends varied from 123.92% to 150.84% (Table 4). The increase in the addition of ginger flour resulted in a decrease in water absorption capacity but inclusion of maize and coconut flour increase water absorption. The coefficient of determination for water absorption capacity was 0.82 (Table 5). The low water absorption capacity observed in the composite flour as maize flour increased means inability to bind water with ease. High water absorption may also assure the product cohesiveness and this is a functional characteristic mostly important for ready-to-use foods such as biscuits and cookies but may also be important for dough making which is a stage in the production of *kokoro*. The higher water absorption capacity of these MCGF flours suggests that it can be used in bakery products.

Oil absorption capacity (OAC) describes the ability of a food material to be bound to oil. This parameter may also be influenced by the characteristic of the constituents of flour in terms of their hydrophobic components which aid in the absorption of oil (Muhammad *et al.,* 2013). Increase in ginger flour and coconut flour resulted in decrease in oil absorption but a high value was observed as maize flour inclusion increased (Table 4). The oil binding capacity of food protein depends upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity (Suresh and Samsher, 2013). The oil absorption capacity helps in facilitating appropriate flavour and mouth feel, thereby making the flours suitable for bread, bakery products and fried snacks (Saima *et al.,* 2015).

Swelling power or capacity can be described as a hydration property of flour after dispersing it in excess water for a specified period (Yagalema *et al.,* 2013). It is used to measure the ability of undisrupted granules to absorb water at high temperature. The swelling capacities of the composite flour samples were in the range 167.60% to 213.38% (Table 4). An increase in maize flour and ginger flour resulted in decrease in swelling capacity, in other words a high value was observed as coconut flour inclusion increased. However, the extent of swelling may be influenced by the fat composition of the flour which could have blocked the matrix of the fibre, thereby reducing access to water. The interaction effects of maize flour and coconut flour had a significant effect ($p<0.05$) on swelling capacity (Table 5).

Table 4: Mean values of the functional properties of composite flour at different experimental runs

Flour sample	BD (g/ml)	DIS (%)	WET (sec)	WAC (%)	OAC (%)	SC (g/ml)	SI
$M_{73.75}C_{23.75}G_{2.50}$	1.20	74.50	26.00	127.25	123.25	204.99	1.75
$M_{73}C_{25}G_2$	0.55	73.50	26.00	129.84	143.75	212.25	2.25
$M_{75}C_{21}G_4$	0.60	72.50	24.50	139.25	127.75	193.56	2.05
$M_{75}C_{22}G_{3.}$	0.58	72.50	25.50	143.37	133.75	184.00	2.25
$M_{72.25}C_{24.25}G_{3.50}$	0.56	73.00	25.50	125.62	122.88	196.31	2.75
$M_{71}C_{25}G_4$	0.56	71.75	25.50	124.01	130.38	194.38	3.75
$M_{73}C_{25}G_2$	0.58	73.50	26.00	129.13	146.00	213.38	3.05
$M_{71}C_{25}G_4$	0.57	72.50	25.50	124.18	129.63	211.00	2.75
$M_{73}C_{23}G_4$	0.58	72.50	26.50	123.92	148.00	167.60	1.25
$M_{72}C_{25}G_3$	0.57	73.50	26.50	124.94	138.38	206.43	3.00
$M_{75}C_{23}G_2$	0.59	74.00	24.50	150.84	155.13	183.38	2.50
$M_{75}C_{21}G_4$	0.60	72.50	24.50	144.33	128.88	191.50	2.25
$M_{74.25}C_{22.75}G_3$	0.59	73.00	26.00	150.75	134.00	193.00	1.25

* Values are means of duplicate

Where M; Maize flour (%), C; Coconut flour (%), G; Ginger flour (%)

* *BD= bulk density, DIS= dispersibility, WET=wettability, OAC = oil absorption capacity, WAC = water absorption capacity, SC= swelling capacity, SI= solubility index.*

Table 5: Regression Models Relating Responses and Independent Variables for Functional Properties

Parameters	BD (g/m)	DIS (%)	WET (sec)	WAC (%)	OAC (%)	SC (g/ml)	SI (%)
A	0.45	72.71	21.43	185.39	141.64	201.42	4.80
B	0.34	72.97	24.98	121.49	123.31	281.34	6.04
C	-0.70	67.29	15.69	70.41	396.31	-9.66	-0.76
AB	1.13*	4.13	9.55*	-64.43	68.77	-186.95*	-13.20*
AC	2.18*	6.36	22.99	-23.93	-432.85	268.55	-3.68
BC	2.37	4.92	15.93	87.22	-370.08	72.67	-1.78
R^2	0.99	0.71	0.80	0.82	0.53	0.78	0.75

*Significant at $p < 0.05$, A= linear effect of maize flour, B = linear effect of coconut flour, C= linear effect of ginger flour, AB= interaction of maize and coconut flour, AC= interaction effects of maize and ginger flour, BC= interaction effects of coconut flour and ginger flour

* Where BD= bulk density, DIS= dispersibility, WET=wettability, OAC = oil absorption capacity, WAC = water absorption capacity, SC= swelling capacity, SI= solubility index

Solubility is indicative of water penetration ability into starch granules of flours (Ikegwu *et al.*, 2010). The solubility of the composite flours ranged between 1.25 % and 3.75 % (Table 5). Solubility is an indication of the existence of strong bonding forces probably due to high amount of protein and fat that might form inclusion complexes with amylose (Pomeranz, 1991). The presence of coagulated proteins and lipids could result in reduction of water absorption capacity of flours which may lead to reduced swelling and consequently reduced solubility (Asaam *et al.,* 2018). According to Asaam *et al.* (2018), the presence of coagulated proteins and lipids will enhance formation of complexes with amylose thereby hindering its solubility. The increased inclusion of coconut flour increased the solubility index of the composite flour, while further addition of maize and ginger flour reduced it. The interaction of maize and coconut flour had a significant effect ($p<0.05$) on solubility index. This might be due to the high solubility in coconut flour than maize flour, therefore could be suitable for use as ingredient in other food products like.

Colour attributes of maize-coconut-ginger composite flours

The chromatic parameters L* (whiteness or brightness darkness), a* (greenness-redness), and b* (blueness-yellowness) have been widely used to describe colour changes during thermal processing of agricultural products; they have been related to the types and quantities of some components present in those products (Bahloul *et al.,* 2009). Colour attributes of the composite flour from maize, coconut and ginger flour, lightness, redness and yellowness ranged from 78.48 to 80.63; 0.77 to 1.23; 16.15 to 18.2, respectively (Table 6). The mean value of redness of composite flours decreased as maize flour and ginger flour inclusion increased, but an increase was observed as coconut flour was included. Yellowness increased alongside with increased maize flour and ginger flour but decreased with an increase in coconut flour (Table 6). However, interactions of maize flour and coconut flour had no significant ($p > 0.05$) effects on the lightness, redness and yellowness. The coefficient of determination (R^2) of lightness was 0.78 (Table 7).

Table 6: Mean values of the colour attributes at different experimental runs

Flour Sample	Lightness	Redness	Yellowness
$M_{73.75}C_{23.75}G_{2.50}$	79.48	1.12	16.45
$M_{73}C_{25}G_{2}$	78.48	0.94	16.15
$M_{75}C_{21}G_{4}$	79.51	0.77	17.51
$M_{75}C_{22}G_{3.}$	80.46	0.82	17.25
$M_{72.25}C_{24.25}G_{3.50}$	79.09	0.96	17.77
$M_{71}C_{25}G_{4}$	78.93	0.93	18.23
$M_{73}C_{25}G_{2}$	79.61	1.05	16.62
$M_{71}C_{25}G_{4}$	78.99	1.23	17.63
$M_{73}C_{23}G_{4}$	79.85	0.95	17.74
$M_{72}C_{25}G_{3}$	78.61	1.02	16.88
$M_{75}C_{23}G_{2}$	80.63	1.13	16.79
$M_{75}C_{21}G_{4}$	78.99	0.93	17.70
$M_{74.25}C_{22.75}G_{3}$	79.66	0.99	17.70

* Values are means of duplicate
Where M; Maize flour (%), C; Coconut flour (%), G; Ginger flour (%)

Table 7: Regression models relating responses and independent variables for colour attributes

Parameters	Lightness	Redness	Yellowness
A	81.51	1.11	17.01
B	76.27	0.89	15.63
C	84.11	2.03	19.75
AB	4.27	0.30	0.76
AC	-13.65	-2.65	-1.65
BC	0.44	-0.88	4.17
R^2	0.78	0.66	0.83

*Significant at ($p < 0.05$). A= linear effect of maize flour, B = linear effect of coconut flour, C= linear effect of ginger flour, AB= interaction of maize and coconut flour, AC= interaction effects of maize and ginger flour, BC= interaction effects of coconut flour and ginger flour

Optimization of composite flour

Numerical optimization option was employed to select the best combination of flour blend that would be acceptable for the production of *kokoro* snack. The desirability function was generated after limiting the preferred goal of blend variables and responses based on minimum moisture content, fat content and redness of the flour blends and maximum protein content, bulk density, dispersibility, water absorption capacity and swelling capacity while the maize flour, coconut flour and ginger flour were allowed to be in range. According to the desirability function, the software generated three solutions of process variables with the predicted values of responses. The predicted optimum condition at maximum desirability index of 0.70 (70%) was obtained at 73% of maize, 25% coconut flour and 2% ginger flour with following responses: moisture content (10.90%), protein content (10.23%), fat content (9.41%), bulk density (0.66 g/ml), water absorption capacity (129.31%), dispersibility (73.70%), swelling power (2.08%), redness (4.34) and lightness (9.08).

CONCLUSION

From this study, it can be concluded that incorporation of coconut flour and ginger flour into maize flour brings variations in the proximate composition, functional properties and colour attributes of maize-coconut-ginger composite flours. Wettability, swelling capacity and solubility index of the functional properties are significantly affected by interaction effects of the maize and coconut flour. Fat content is significantly affected by the interaction of maize and ginger flour. The colour attributes (redness, yellowness and lightness) are not significantly affected by the main or interaction effect of the flour blends. The significant changes in some of these properties revealed that maize composites with coconut and ginger could be potentially used to produce enriched *kokoro* snack as well as other maize-based snacks.

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