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Production and optimization of physical and chemical properties of cookies from mixture of malted sorghum, whole wheat and tiger nut flours Randomized Trials

Charles Ngwuja Ishiwu[1], *Ekpeno Sunday Ukpong[2] and Homa Fyne-Akah[2]

Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.[1]
Department of Food Science and Technology, Madonna University, Akpugo Campus, Enugu State, Nigeria.[2]

Abstract— Cookies from the blends of malted sorghum flour, whole wheat flour and tiger nut flour were produced and evaluated. The experimental design used was a mixture design which was carried out using Design Expert. A total of 14 samples of the composite flour and one control (100% whole wheat flour) were obtained and used to bake the cookies. The functional properties were determined in the flours. Proximate composition, energy value, sensory evaluation and physical qualities of the cookies were also evaluated. The protein content of the baked cookies ranged from 7.63- 11.68%, the highest value was found in the control. There were also significant differences in fat (1.76-8.74%), fibre (0.98-2.57%), ash (0.95-5.56%) and calorie (346.68-396.54 kCal/100g) of the baked cookies. Cookie made from the blends of 50% malted sorghum, 35% whole wheat and 15% tigernut flours had the highest value of fibre which did not differ significantly from cookie made from the blends of 45% malted sorghum flour, 35% whole wheat flour and 20% tigernut flour which had the highest value of ash. The result of the physical properties showed that the diameter of the cookies ranged from 3.21-3.55 cm, the smallest value was found in the control. No significant differences existed in thickness but there were significant differences in spread ratio (3.18-4.12), breaking strength (400-850 g) and colour. All cookies baked with the composite flours were accepted by the judges and comparable with that of the control.

Keywords—Quality of cookies, malted sorghum, tigernut, composite flour, optimization.

1. Introduction

Cookies are snacks made from unpleasant dough that when baked in the oven is converted into mouth-watering products [1]. The major flour for baking of cookies is refined wheat flour and this is because of its unique gluten content [3,4]. However, refined wheat flour is high in starch but low in other important nutrients such as dietary fibre, minerals and proteins which were destroyed to a greater amount during the refining process [5]. Furthermore, wheat is not cultivated in sufficient amount in many tropical countries of the world including Nigeria due to climatic reason, thus, its use is always expensive and uneconomical in these tropical countries. This has resulted in researches on composite flour technology where flours from roots, tubers and other cereals that are abundant in the tropics are used to replace parts of wheat flour. Flours produced solely from wheat or any of these staples have low nutritional value than when they are made with composite flours [6].

Sorghum (Sorghum vulgare) is one of the cereal crops that is abundant in many tropical countries such as Nigeria [7]. However, its use is limited due to its low nutritional value and the presence of antinutritional factors such as trypsin inhibitor, cyanogenic glucoside, tannin, phytic acid, and oxalate which are reported to account for the poor protein digestibility and mineral absorption of sorghum [8,9]. Many studies have shown that malting decrease these antinutritional factors and make the nutrients in cereals and legumes to be bioavailable [10,11].

Tigernut (Cyperus esculentus) comes from the family of Cyperaceae and it yields rhizomes and somewhat spherical tubers at the base. It is one of the crops that is under-utilized as the tubers are either eaten raw or roasted. The chemical composition of tigernut flour showed that its flour contains moderate amount of protein (9.7%), high quantity of fat (36%), high quantity of dietary fibre (5.62%) and mineral such as potassium (255 mg), sodium (235 mg), calcium (140 mg), phosphorus (121 mg), magnesium (56.3 mg) and manganese (38.41 mg) per 100 g but low in carbohydrates (40-47%) [12,13]. These nutrients are very essential to health and they have been reported not to be significantly adversely affected during milling [14,15]. Dietary fibre for instance, has been shown to improve digestive function, regulate blood sugar, reduce heart disease, lessen the risk of type 2 diabetes and helps to prevent some types of cancers [15]. The 2010 Americans Dietary Guidelines for example emphasized on increase dietary fibre intake [16].

Acceptable and very much liked composite flour cookies have been previously reported. There are previous works on cookies from composite flour such as wheat flour and malted barley bran [17], high fibre biscuit using blends of African breadfruit flour, maize flour and coconut grit [18], wheat-sorghum flours [19,20,21]. In the present work, the composite flours from malted sorghum flour, whole wheat flour and tigernut flour were mixed at different ratios using mixture design and used to bake the cookies. The aim was to analyse and compare the sensory, physical and chemical qualities of these cookies with that of conventional wheat flour. The study sought to produce highly nutritious and cheaper cookies by more inclusion of locally sourced and underutilized flours since the maximum amount of whole wheat flour in the composite flour was 40%. This will not only increase the utilization of tigernut and sorghum but will also encourage their cultivation by the farmers to earn more income.

2. Materials and Methods

2.1 Sources of materials

Wheat grains were bought from Ogige market in Nsukka, Enugu State. Tigernut was gotten from Ogbete main market, Enugu. Sorghum grains were procured from Eke Agbani Market, Nkanu West, Enugu State, Nigeria.

2.2 Methods

2.2.1 Production of malted sorghum flour

The process began by sorting of the sorghum grains and was followed by washing and steeping of the grains in potable water for 12 h. In order to prevent fermentation, the steeped water was changed after every 4 h interval. After steeping, the grains were drained and spread thinly on a layer of sterile jute bag, laid on slab, covered with another layer of sterile jute bag and left for 48 h to germinate at ambient temperature (29±2 0C). The grains were moistened by sprinkling with potable water at every 4 h interval during this germination period. The germinated grains were washed and dried in oven (Gulfex Scientific DHG 9202, England) at 50 0C for 12 h and after which the radicles and plumules were removed with stainless steel knife. The grains were ground into flour, sieved (0.45 mm sieve) and stored in dry plastic cans until used.

2.2.2 Production of tigernut flour

The roots were cleaned, sorted, washed with potable water, drained and oven-dried (Gulfex Scientific DHG 9202, England) at 50 0 for 12 h and ground into flour.

2.2.3 Production of wheat flour

This was done by sorting which was followed by washing and draining off the water. The grains were next dried in oven (Gulfex Scietific DHG 9202, England) at 50 0C for 12 h, ground into flour and sieved (0.45 mm sieve).

2.2.4 Formulation of composite flour

The experimental design was a mixture design which was done with Design Expert (Version 8.0.7.1). It was composed of three flours namely whole wheat flour (WF), malted sorghum flour (SF) and tigernut flour (TF) which were thoroughly mixed using a Panasonic blending machine (MX-AC 2105) in the range of 40-50% for SF, 30-40% for WF, and 10-20% for TF to get 14 samples as shown in Table 1. Wheat flour (100 % WF) served as control.

2.2.5 Determination of functional properties

This was carried out on the composite flours and the control. The foam stability (FS) determination was by Onwuka [22] method, the water absorption capacity and oil absorption capacity were determined by the AOAC [23] method, the emulsion capacity determination was by Yasumatsu et al. [24] method, and the least gelation concentration (LGC) was evaluated using Chandra et al. [25] method.

2.2.6 Preparation of cookies

The recipe was made up of the composite flour (100 g), margarine (55 g), whole egg (50 g), granulated sugar (45 g), skimmed milk powder (25 g), baking powder (5 g) and salt (1 g). Cookies were prepared using a modified recipe of cookie production as described by Ishiwu [6]. The margarine was mixed manually with granulated sugar in a stainless steel bowl to a creamy consistency. Liquid whole egg was beaten to foam after which it was poured into the mixture and the mixing continued for 2 min. The other dry ingredients which included salt, milk powder, composite flour, baking powder, and flavour were blended together after which they were mixed with the cream to form a dough. The dough was kneaded to plastic consistency, rolled out with a rolling pin and cut to the preferred shape. The cut pieces were placed over perforated tray and baked at 150 °C for 10 min. The well baked cookies were removed from the oven, cooled to room temperature, packed in polyethylene bags and stored at room temperature (29±2 0C) in air tight container for other studies.

2.2.7 Proximate composition of the cookies

The crude protein (Kjeldahl N x 6.25), fat (solvent extraction with petroleum ether), crude fibre, ash and moisture contents were determined according to the methods of AOAC [26]. The carbohydrate was calculated by difference. The energy value was calculated by Atwater formula using the factors of 4.0 for carbohydrate and protein and 9.0 for fat.

2.2.8 Physical properties of cookies

The breaking strength was determined by Ikuomola et al. [17] method, the diameter, thickness, and spread ratio of the cookies were determined by Bala et al. [27] method. The colour characteristics of the cookies were analysed using a colour spectrophotometer (Konica Minolta Chroma meter, CR-410). The Chroma meter was calibrated with white standard. L*, a*, and b* values were evaluated in duplicate and the mean was calculated. The results were expressed such that:

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

a* (−a* = greenness, +a* = redness)
b * (−b* values = blueness, +b* value = yellowness)

Table 1: Blending Ratios of Composite Flours

Blend Number	Malted Sorghum Flour (SF) (%)	Whole Wheat Flour (WF) (%)	Tigernut Flour (TF) (%)
1	50.000	40.000	10.000
2	45.000	35.000	20.000
3	48.333	33.333	18.333
4	50.000	30.000	20.000
5	43.333	38.333	18.333
6	46.667	36.667	16.667
7	45.000	35.000	20.000
8	50.000	35.000	15.000
9	40.000	40.000	20.000
10	50.000	30.000	20.000
11	40.000	40.000	20.000
12	50.000	40.000	10.000
13	45.000	40.000	15.000
14	48.333	38.333	13.333
15	0.000	100.000	0.000

2.2.9 Sensory evaluation

Seventeen (17) partially trained judges were randomly selected. The cookies were assessed for colour, taste, aroma, texture and crispness on a 9- point hedonic scale as described by Ihekoronye and Ngoddy [28] from like extremely to dislike extremely. The general acceptability was calculated with weighted arithmetic mean as described by Ukpong et al. [29] given the following weight to each attribute: Appearance 20 %, taste 15 %, aroma 15 %, texture 25 % and crispness 25 %.

2.2.10 Statistical analysis

Analysis of Variance (ANOVA) was carried out on the proximate, functional, sensory and physical attributes of the cookies using Statistical Package for Social Sciences (SPSS, Version 20.0 for windows, SPSS Inc. Illinois, USA). Mean separation was carried out using Least Significant difference (LSD) and Duncan Multiple Range test at $p < 0.05$. Design Expert was used to carry out the regression analysis of the results and those response variables that met the conditions for model adequacy were fitted into mathematical models. The software was also used to generate the colour and 3D-surface of the response variables.

3. Results and Discussion

3.1 Functional properties

The results of the functional properties of the composite flours are presented in Table 2. The functional properties indicate the potential application of such flours in the food. Water absorption capacity (WAC) signifies the ability of a substance to interact with water in an environment of small amount of water [25]. According to Chandra et al. [25], the leaching of the amylose fraction of starch and its dissolution in the liquid medium increase the WAC. The WAC of the control was 91.24% but in the other composite flour samples, they ranged from 90.45-98.34%, the highest was found in blends that comprised of 40% SF: 40% WF:20% TF. These values fall within the range reported by Adebowale et al. [19] on wheat-sorghum composite flours. These high values of WAC are desirable in doughs and baked goods such as cookies since it helps to increase the size of the baked goods [17].

The oil absorption capacity ranged from 0.46-0.58 g oil/g flour, which were lower than the results (1.18-1.64 g oil/ g flour) reported by Taiwo et al. [21] for wheat-sorghum date cookies. The variation could be due to the differences in the formulation. The highest values were found in control and sample containing 50% SF:20% WF: 20% TF as well as the one with 50% SF: 40% WF: 10% TF. The oil absorption capacity of flours is governed by the type and composition of amino acids and the arrangement of the hydrophobic groups in the protein structure [30]. High oil absorption capacity may enhance the flavour and mouth feel of the products made from such flours.

The emulsion capacity of the control was 0.35%, but in the composite flours it ranged from 0.26-0.44%. The emulsion capacity of a flour is influenced by the hydrophobic effects of protein [30]. High emulsion capacity and stability are advantageous in products such as cakes and frozen desserts. The foam stability ranged from 2.67-3.45%, the highest value was found in composite flour that contained 40% SF: 40% WF: 20% TF. The least gelation concentration (LGC) indicates the gelation ability of the flour and the lower the LGC the better the gelling ability of the flour [25]. The LGC ranged from 6.0-8.0%. There was no significant difference between the composite flours and the control ($p>0.05$).

3.2 Proximate composition

The results of the proximate composition of the cookies are presented in Table 3. The moisture contents were generally low (less than 10%) and ranged from 4.81-9.26%, the highest was found in cookies made from composite flour with 43.5% SF: 38.3% WF: 18.3% TF. These range of values were lower than the moisture range of 10.24-11.24% reported by Adebowale et al. [19] for wheat-sorghum composite biscuit. Low moisture content is desirable in cookies because it enhances prolong shelf-life by discouraging microbial spoilage.

The protein content ranged from 7.63-11.68%, the highest was found in the control which was significantly different ($p<0.05$) from the others. These low values of protein of the cookies baked with the composite flours could be due to the addition of malted sorghum flour and tigernut flour which are not good sources of protein. The protein content of the present study was lower than the range of 11.21-15.64% reported by Ikuomola et al. [17] for wheat-malted barley bran cookies but fall within the range of 7.06-11.84% reported by Adebowale et al. [19] for wheat-sorghum biscuit.

The fat content of the control was 4.95% but in the cookies baked with composite flours, they ranged from 1.76-8.74%. The highest value was found in cookie baked with 43.3% SF: 38.3% WF: 18.3% TF. Furthermore, the fat content of the cookies baked with composite flours that contained 48.8% SF: 33.3% WF: 18.3% TF (6.0%) as well as that of 40% SF: 40% WF: 20% TF (7.2%) were also significantly higher than that of the control. These values are higher than the range of 0.65-5.0% reported for pearl millet cookies by Florence et al. [5] as well as the range of 2.29-3.82% reported by Adeyeye [20] for sorghum-wheat flour cookies. The reason for these variations could be because of the high content of fat in the tigernut flour [13].

Increase have revealed discoveries that are a lot more fragile and less predictable than was the situation with the discoveries on SSBs. A sensible end is that dietary fat has a humble causal association with body weight which is of a lower greatness than that seen with SSBs.

Table 2: Functional Properties of Composite Flour

SAMPLE	WAC (%)	OAC (g/g)	EC (%)	FS (%)	LGC (%)
$S_{50.0}W_{40.0}T_{10.0}$	$98.12^{l}\pm0.14$	$0.55^{e}\pm0.01$	$0.33^{c}\pm0.01$	$3.35^{k}\pm0.01$	$6.00^{a}\pm0.00$
$S_{45.0}W_{35.0}T_{20.0}$	$92.23^{d}\pm0.01$	$0.48^{b}\pm0.01$	$0.44^{j}\pm0.01$	$3.27^{ij}\pm0.01$	$6.00^{a}\pm0.00$
$S_{48.3}W_{33.3}T_{18.3}$	$96.54^{i}\pm0.14$	$0.46^{a}\pm0.01$	$0.36^{fg}\pm0.01$	$2.67^{a}\pm0.01$	$6.00^{a}\pm0.00$
$S_{50.0}W_{30.0}T_{20.0}$	$94.34^{f}\pm0.01$	$0.57^{fg}\pm0.01$	$0.38^{h}\pm0.01$	$3.17^{g}\pm0.01$	$6.00^{a}\pm0.00$
$S_{43.3}W_{38.3}T_{18.3}$	$91.17^{b}\pm0.00$	$0.49^{c}\pm0.00$	$0.42^{i}\pm0.01$	$2.88^{d}\pm0.01$	$6.00^{a}\pm0.00$
$S_{46.7}W_{36.7}T_{16.6}$	$96.34^{h}\pm0.14$	$0.56^{ef}\pm0.01$	$0.37^{gh}\pm0.01$	$3.23^{h}\pm0.01$	$6.00^{a}\pm0.00$
$S_{45.0}W_{35.0}T_{20.0}$	$90.45^{a}\pm0.01$	$0.48^{b}\pm0.01$	$0.44^{j}\pm0.01$	$3.26^{i}\pm0.01$	$6.00^{a}\pm0.00$
$S_{50.0}W_{35.0}T_{15.0}$	$97.77^{k}\pm0.01$	$0.55^{ef}\pm0.00$	$0.29^{b}\pm0.01$	$2.69^{b}\pm0.01$	$8.00^{a}\pm0.00$
$S_{40.0}W_{40.0}T_{20.0}$	$98.34^{m}\pm0.01$	$0.46^{a}\pm0.01$	$0.26^{a}\pm0.01$	$3.44^{l}\pm0.01$	$8.00^{a}\pm0.00$
$S_{50.0}W_{30.0}T_{20.0}$	$94.34^{f}\pm0.01$	$0.58^{g}\pm0.01$	$0.38^{h}\pm0.01$	$3.18^{g}\pm0.01$	$8.00^{a}\pm0.00$
$S_{40.0}W_{40.0}T_{20.0}$	$98.23^{m}\pm0.01$	$0.48^{b}\pm0.01$	$0.29^{b}\pm0.01$	$3.45^{l}\pm0.01$	$8.00^{a}\pm0.00$
$S_{50.0}W_{40.0}T_{10.0}$	$96.64^{j}\pm0.14$	$0.57^{fg}\pm0.01$	$0.34^{de}\pm0.01$	$3.26^{i}\pm0.01$	$6.00^{a}\pm0.00$
$S_{45.0}W_{40.0}T_{15.0}$	$98.14^{l}\pm0.01$	$0.47^{ab}\pm0.01$	$0.37^{gh}\pm0.01$	$3.28^{j}\pm0.01$	$6.00^{a}\pm0.00$
$S_{48.3}W_{38.3}T_{13.3}$	$96.34^{h}\pm0.14$	$0.47^{ab}\pm0.01$	$0.32^{c}\pm0.01$	$2.68^{a}\pm0.01$	$8.00^{a}\pm0.00$
$S_{0.00}W_{100.0}T_{0.00}$	$91.24^{c}\pm0.01$	$0.58^{g}\pm0.01$	$0.35^{ef}\pm0.01$	$2.88^{d}\pm0.01$	$8.00^{a}\pm0.00$

Values with the same superscript along each column are not significantly different at $p < 0.05$.
Where: WAC= water absorption capacity; OAC= oil absorption capacity; EC= emulsion capacity; FS= foam stability; LGC= least gelation concentration.
S= Malted Sorghum Flour; W= Whole Wheat Flour; T= Tigernut Flour.

The fibre content was in the range of 0.98-2.57% which fall within the WHO recommended levels of fibre of not more than 5% [31]. The control also had high fibre content (1.37%) and the possible reason for this could be due to the fact that whole wheat flour was used. The highest significant value was found in cookie baked with the composite flour that contained 50% SF: 35% WF: 15% TF which also showed no significant difference ($p>0.05$) with the one with 45%SF: 40% WF: 15% TF and that of 45% SF: 35% WF: 20% TF. High fibre content in food is desirable because it improves digestive function, regulates blood sugar, lessens the risk of type 2 diabetes and helps to prevent some types cancers [15].

Fit summary of design Expert suggested special cubic mixture model. ANOVA indicated that the model was signified. Other terms that were significant include linear (A= malted sorghum flour, B= whole wheat flour and C= tigernut flour), mixture, AC, BC and ABC. Lack of fit was insignificant, and its p-value was 0.186, R-Squared = 0.85 and R2adj = 0.72. These results were high and high values of these terms make the model adequate. The final regression equation for fibre in terms of actual component is presented in Eq.1.

$$\text{FIBRE} = 14.73A + 22.22B + 58.56C - 1.48AC - 1.89 + 0.04ABC \qquad \text{Eq1}$$

Where A= malted sorghum four; B= whole wheat flour; C= tiger nut flour

Table 3: Proximate Composition of Cookies

Sample	Protein (%)	FAT (%)	MC (%)	Fibre (%)	Ash (%)	CHO (%)	Calorie (kCal/100g)
$S_{50.0}W_{40.0}T_{10.0}$	$8.15^{g}\pm0.01$	$2.94^{b}\pm0.01$	$6.86^{bc}\pm0.01$	$0.98^{a}\pm0.01$	$2.94^{e}\pm0.01$	$78.13^{e}\pm0.01$	$371.58^{e}\pm0.24$
$S_{45.0}W_{35.0}T_{20.0}$	$7.93^{c}\pm0.01$	$1.76^{a}\pm0.01$	$7.41^{cd}\pm0.01$	$2.56^{hi}\pm0.01$	$5.56^{i}\pm0.01$	$74.78^{c}\pm0.01$	$346.68^{a}\pm0.13$
$S_{48.3}W_{33.3}T_{18.3}$	$7.63^{a}\pm0.01$	$6.00^{e}\pm1.41$	$6.31^{b}\pm0.01$	$1.78^{d}\pm0.01$	$4.50^{g}\pm0.01$	$73.78^{bc}\pm1.31$	$379.64^{f}\pm7.52$
$S_{50.0}W_{30.0}T_{20.0}$	$7.88^{b}\pm0.01$	$3.88^{c}\pm0.01$	$9.00^{f}\pm1.41$	$1.98^{e}\pm0.01$	$1.00^{a}\pm0.01$	$76.26^{d}\pm1.60$	$371.48^{e}\pm6.21$
$S_{43.3}W_{38.3}T_{18.3}$	$7.98^{d}\pm0.01$	$8.74^{g}\pm0.01$	$6.48^{b}\pm0.01$	$2.53^{h}\pm0.01$	$2.78^{d}\pm0.01$	$71.49^{a}\pm0.01$	$396.54^{h}\pm0.13$
$S_{46.7}W_{36.7}T_{16.6}$	$10.74^{j}\pm0.01$	$4.90^{d}\pm0.14$	$7.62^{cd}\pm0.01$	$1.39^{b}\pm0.01$	$0.95^{a}\pm0.01$	$74.40^{c}\pm0.11$	$384.66^{fg}\pm0.76$
$S_{45.0}W_{35.0}T_{20.0}$	$8.14^{fg}\pm0.01$	$1.85^{a}\pm0.01$	$6.11^{b}\pm0.01$	$2.56^{hi}\pm0.01$	$4.71^{h}\pm0.01$	$76.63^{d}\pm0.07$	$355.73^{b}\pm0.10$
$S_{50.0}W_{35.0}T_{15.0}$	$10.86^{k}\pm0.01$	$1.90^{a}\pm0.14$	$8.74^{ef}\pm0.01$	$2.57^{i}\pm0.01$	$3.88^{f}\pm0.01$	$72.05^{a}\pm0.14$	$348.74^{a}\pm0.76$
$S_{40.0}W_{40.0}T_{20.0}$	$8.15^{g}\pm0.01$	$5.56^{de}\pm0.01$	$8.56^{ef}\pm0.01$	$1.76^{cd}\pm0.01$	$1.92^{b}\pm0.01$	$74.05^{c}\pm0.01$	$378.84^{f}\pm0.01$
$S_{50.0}W_{30.0}T_{20.0}$	$9.37^{i}\pm0.01$	$2.89^{b}\pm0.01$	$8.87^{ef}\pm0.01$	$2.28^{g}\pm0.01$	$2.44^{c}\pm0.01$	$74.15^{c}\pm0.01$	$360.09^{bc}\pm0.24$
$S_{40.0}W_{40.0}T_{20.0}$	$8.07^{e}\pm0.01$	$7.20^{f}\pm0.14$	$7.52^{cd}\pm0.01$	$2.15^{f}\pm0.01$	$2.35^{c}\pm0.01$	$72.71^{ab}\pm0.17$	$387.92^{g}\pm0.65$
$S_{50.0}W_{40.0}T_{10.0}$	$8.13^{fg}\pm0.01$	$3.40^{bc}\pm0.14$	$8.06^{de}\pm0.01$	$1.36^{b}\pm0.01$	$2.86^{de}\pm0.01$	$76.19^{d}\pm0.11$	$367.88^{de}\pm0.76$
$S_{45.0}W_{40.0}T_{15.0}$	$8.34^{h-}\pm0.01$	$1.93^{a}\pm0.01$	$4.81^{a}\pm0.01$	$2.55^{hi}\pm0.01$	$3.85^{f}\pm0.01$	$78.52^{e}\pm0.01$	$364.81^{cd}\pm0.01$
$S_{48.3}W_{38.3}T_{13.3}$	$8.11^{f}\pm0.01$	$3.85^{c}\pm0.01$	$9.26^{ef}\pm0.01$	$1.74^{c}\pm0.01$	$2.78^{d}\pm0.01$	$74.25^{c}\pm0.01$	$364.13^{cd}\pm0.01$
$S_{0.00}W_{100.0}T_{0.00}$	$11.68^{l}\pm0.01$	$4.95^{d}\pm0.01$	$6.86^{bc}\pm0.01$	$1.37^{b}\pm0.01$	$2.94^{e}\pm0.01$	$72.20^{a}\pm0.14$	$380.07^{f}\pm0.74$

Values with the same superscript along each column are not significantly different at $p < 0.05$.
Where MC= moisture content; CHO= carbohydrate; S= Malted Sorghum Flour; W= Wheat Flour; T= Tigernut Flour.

From Eq.1 the main effect of adding any of the three flours during the making of the cookies increased the fibre content of the finished product. It was observed based on the values of the coefficients that tigernut contributed to the highest increase in the fibre of the cookies than the whole wheat, while the whole wheat contributed to the fibre increase more than the malted sorghum flour. The interaction of malted sorghum and tiger nut flours decreased the fibre content of the cookies in a similar way the interaction effect of whole wheat and tiger nut flour lowered the fibre content of the cookies.

The ash content indicates the mineral content of the food. The control's ash content was 2.94% but those of the samples were in the range of 0.95-5.56% for the cookies baked with the composite flours. The highest value was shown by that of 45% SF: 35% WF: 20% TF. Furthermore, cookies baked with 48.3% SF:33.3% WF:18.3% TF, 45% SF: 35% WF: 15% TF, 50% SF: 35% WF: 15% TF and 45% SF: 40% WF: 15% TF were all significantly higher ($p<0.05$) than that of the control. Interestingly, these results were higher compared to the range reported by Ikuomola et al. [17] for wheat-malted barley bran composite cookies and the range of 1.81-2.45% for wheat-sorghum date cookies reported by Taiwo et al. [21]. These high values of ash could be due to the addition of tigernut flour. High content of ash suggests that the cookies will provide more minerals to the body when consumed. Special cubic mixture model was suggested by fit summary printout. ANOVA showed that the model was significant. The linear terms were not significant since their p-value = 0.9290, therefore was not included in the mathematical model. The only significant terms were AB and ABC. A, B and C represent the malted sorghum, whole wheat and tiger nut flour respectively in the cookies. Lack of fit was not significant and had p-value (0.1474) which is greater than 0.05. The model for ash is presented in Eq.2.

Ash = 13.11AB - 75.61ABC **Eq2**

Where A= malted sorghum four; B= whole wheat flour; C= tiger nut flour

The equation implies that the interaction effect of malted sorghum and wheat flours increased the ash content of the cookies while the interaction effect of the three flours did not, instead it lowered the ash content of the cookies.

The carbohydrate contents ranged from the 71.49-78.52%, and the control had carbohydrate content of 72.20%. This result was higher than the range (52.65-60.37%) reported by Taiwo et al. [21] for wheat-sorghum date cookies.

The caloric value of the control was 380.07 kCal/100 g but in the cookies baked with the composite flours, the caloric values ranged from 346.68-396.54 kCal/100 g. Cookies baked with 43.3% SF: 38.3% WF: 18.3% TF and that of 40% SF: 40% WF: 20% TF had significantly higher ($p<05$) calorie than the control. This result was higher than the energy values range of (348-382 kCal/100 g) reported for pearl millet cookies [5]. This could be because the fat content of the present work is also higher and that could have affected the calorie value since 1 g of fat contributes about 9.0 kCal of energy. Fit summary of the software suggested specific cubic and ANOVA for the specific cubic mixture model revealed that the model was significant (p-value = 0.0341). All the linear terms were significant (p-value = 0.0419). Another significant term was AB. Lack of fit was not significant. Its p-value = 0.7125, R-Squared = 0.7951 and R2adj = 0.6195. These values are high, making the model fit. All the flours had influence on increasing the calorie but only the interaction effect of malted sorghum flour (A) and wheat flour (B) in the cookies had influence on the caloric value. The effect of flour blend on the calorie content of the cookies is shown in Eq. 3.

Calorie = 379,85A + 366.04 + 368.65C + 69.27AB **Eq. 3**

Where A= malted sorghum four; B= whole wheat flour; C= tiger nut flour

3.3 Physical properties

The results of the physical properties are presented in Table 4. The thickness ranged from 0.86-1.05 cm and no significant differences ($p>0.05$) existed amongst the different samples and the control which agreed with the finding of Adebowale et al. [19] for wheat-sorghum composite biscuits. This range however, was higher than the range of 0.68-0.93 reported by Adeyeye [20] for wheat-sorghum cookies and this could be due to the inclusion of tigernut flour. Significant differences ($p<0.05$) existed in diameter, spread ratio, breaking strength and colour of the various samples. The diameter ranged from 3.21-3.55 cm and the lowest diameter was found in the control while the highest was found in the cookie baked with 50% SF:40% WF: 10% TF.

The spread ratio of the control was 3.29 but they were in the range of 3.18-4.12 in the composite flour cookies. The results of the spread ratio fall in the same range reported by Adeyeye [20] for wheat-sorghum cookies. The diameter and spread ratio give indication on the quality of the flour used in the baking as well as the ability of the dough to rise [27]. Increase in spread ratio is caused by increase in water absorption capacity of the dough and this is brought about by increase in hydrophilic sites [32]. High spread ratio is required in cookies [33]. Thus, cookies baked with 50% SF: 40% WF: 10% TF which had both the highest diameter and the spread ratio should be the most preferred by the consumers. Interestingly, this agrees with the result of sensory (Table 5) where the same sample was most accepted.

The breaking strength of the control was 650 g but in the cookies containing composite flour, it ranged from 400-850 g. Breaking strength is the least force that can break the cookies. The breaking strength of the cookies is greater than the range of 290.26-169.33 g reported by Ikuomola et al. [17] for wheat flour- malted barley bran cookies. Furthermore, by comparing the controls of the two studies, the one of this study is also higher and this may be as a result of the whole wheat flour used as against the refined wheat flour by Ikuomola et al. [17]. The protein-starch interaction caused by hydrogen bonding makes cookies to be hard [17]. ANOVA showed that the model was significant and linear model was suggested, having p-value = 0.0161, lack of fit was not significant and it exhibited p-value of 0.2334.

Table 4: Physical Properties of Cookies

Sample	Diameter (cm)	Thickness (cm)	Spread ratio	Breaking strenth (g)	Colour		
					L*	a*	b*
$S_{50.0}W_{40.0}T_{10.0}$	$3.55^{d}\pm0.12$	$0.86^{a}\pm0.07$	$4.12^{b}\pm0.22$	$400^{a}\pm10$	$38.68^{fg}\pm0.52$	$3.07^{ab}\pm0.16$	$5.23^{cd}\pm0.14$
$S_{45.0}W_{35.0}T_{20.0}$	$3.24^{a}\pm0.03$	$0.88^{a}\pm0.12$	$3.73^{ab}\pm0.46$	$750^{f}\pm15$	$38.10^{cd}\pm0.04$	$3.70^{e}\pm0.16$	$3.66^{a}\pm0.54$
$S_{48.3}W_{33.3}T_{18.3}$	$3.46^{bcd}\pm0.05$	$0.88^{a}\pm0.13$	$3.91^{ab}\pm0.54$	$700^{e}\pm15$	$38.45^{def}\pm0.04$	$3.71^{e}\pm0.17$	$5.08^{bc}\pm0.31$
$S_{50.0}W_{30.0}T_{20.0}$	$3.23^{a}\pm0.16$	$1.02^{a}\pm0.01$	$3.18^{a}\pm0.16$	$850^{h}\pm10$	$38.15^{cde}\pm0.19$	$3.46^{cd}\pm0.04$	$5.10^{bc}\pm0.15$
$S_{43.3}W_{38.3}T_{18.3}$	$3.31^{abc}\pm0.04$	$0.90^{a}\pm0.07$	$3.68^{ab}\pm0.25$	$700^{e}\pm20$	$37.25^{a}\pm0.11$	$3.42^{cd}\pm0.15$	$4.71^{bc}\pm0.14$
$S_{46.7}W_{36.7}T_{16.6}$	$3.50^{cd}\pm0.06$	$1.05^{a}\pm0.09$	$3.33^{ab}\pm0.35$	$850^{h}\pm20$	$37.49^{ab}\pm0.09$	$3.19^{ab}\pm0.03$	$6.08^{e}\pm0.16$
$S_{45.0}W_{35.0}T_{20.0}$	$3.23^{a}\pm0.06$	$1.01^{a}\pm0.06$	$3.73^{ab}\pm0.14$	$750^{f}\pm15$	$38.00^{cd}\pm0.23$	$3.72^{e}\pm0.04$	$3.64^{a}\pm0.28$
$S_{50.0}W_{35.0}T_{15.0}$	$3.50^{cd}\pm0.25$	$1.01^{a}\pm0.06$	$3.47^{ab}\pm0.05$	$750^{f}\pm30$	$37.86^{bc}\pm0.05$	$3.43^{cd}\pm0.08$	$5.79^{de}\pm0.22$
$S_{40.0}W_{40.0}T_{20.0}$	$3.36^{bcd}\pm0.03$	$0.96^{a}\pm0.96$	$3.51^{ab}\pm0.38$	$650^{d}\pm35$	$38.97^{g}\pm0.21$	$2.97^{a}\pm0.07$	$4.47^{b}\pm0.31$
$S_{50.0}W_{30.0}T_{20.0}$	$3.24^{a}\pm0.04$	$0.98^{a}\pm0.04$	$3.19^{a}\pm0.10$	$800^{g}\pm10$	$38.17^{cdef}\pm0.01$	$3.46^{cd}\pm0.00$	$5.12^{bc}\pm0.48$
$S_{40.0}W_{40.0}T_{20.0}$	$3.37^{abcd}\pm0.06$	$0.96^{a}\pm0.07$	$3.51^{ab}\pm0.19$	$700^{e}\pm20$	$38.92^{fg}\pm0.24$	$2.99^{a}\pm0.01$	$4.72^{bc}\pm0.18$
$S_{50.0}W_{40.0}T_{10.0}$	$3.51^{cd}\pm0.32$	$0.94^{a}\pm0.04$	$4.10^{b}\pm0.17$	$500^{b}\pm20$	$38.69^{fg}\pm0.04$	$3.04^{ab}\pm0.07$	$5.23^{cd}\pm0.08$
$S_{45.0}W_{40.0}T_{15.0}$	$3.33^{abcd}\pm0.21$	$0.92^{a}\pm0.18$	$3.71^{ab}\pm0.74$	$600^{c}\pm30$	$38.40^{def}\pm0.06$	$3.08^{ab}\pm0.11$	$5.95^{e}\pm0.28$
$S_{48.3}W_{38.3}T_{13.3}$	$3.48^{bcd}\pm0.21$	$0.95^{a}\pm0.10$	$3.90^{ab}\pm0.36$	$750^{f}\pm20$	$38.45^{def}\pm0.02$	$3.05^{ab}\pm0.07$	$5.06^{bc}\pm0.40$
$S_{0.00}W_{100.0}T_{0.00}$	$3.21^{a}\pm0.11$	$0.98^{a}\pm0.05$	$3.29^{ab}\pm0.28$	$650^{d}\pm10$	$38.16^{cdef}\pm0.49$	$3.26^{bc}\pm0.08$	$5.06^{bc}\pm0.32$

Values with the same superscript along each column are not significantly different at $p<0.05$.
Where MC= moisture content; CHO= carbohydrate; S= Malted Sorghum Flour; W= Wheat Flour; T= Tigernut Flour.

Non-significant lack of fit is desirable for the model to fit. The R-squared = 0.5280 and R2adj = 0.4422.

Thus, the concluding equation for breaking strength in terms of actual components is given in Eq.4

Breaking strength =8.69 – 3.31B + 24.42C **Eq. 4**

Where A= malted sorghum four; B= whole wheat flour; C= tiger nut flour

From Eq.4, both malted sorghum flour (A) and tiger nut flour (C) had positive coefficients of +8.69 and +24.42 respectively, while wheat flour (B) had negative coefficient (-3.31). The implication of this was that inclusion of both malted sorghum and tiger nut flours in the cookies increased the breaking strength with tiger nut flour having greater effect than malted sorghum flour. However, inclusion of wheat flour in the cookies reduced the breaking strength.

The colour of the cookies is a very important quality that stimulates appetite and influences consumer's choices. The brown colour of the cookies is as a result of Maillard reaction and caramelization which are influenced by amino acids, reducing sugar, oven temperature and the duration of baking. Significant differences ($p<0.05$) existed in the L*, a* and b* values between the control and the other cookies baked with the composite flours. The L* value of the control was 38.18, but it was in the range of 37.26-38.97 in cookies baked with the composite flours. This showed that the colour was not white but tilted more towards black. The a* value was 3.26 in the control and in the range of 2.97-3.72 in cookies baked with the composite flours. The b* value was 5.06 in control and in the range of 3.64-6.08 in cookies baked with composite flours. The positive values of a* and b* indicate that redness and yellowness of the cookies.

3.4 Sensory evaluation

The results of the sensory evaluations are presented in Table 5. All the variables tested by the judges got scores above 6.0, meaning that the cookies were acceptable and liked moderately. The appearance ranged from 6.71-7.82, taste values ranged from 6.65-7.76, aroma ranged from 6.82-7.88, texture was in the range of 6.35-7.35, and crispness was in the range of 5.76-7.53. The general acceptability of the control was 6.85 but they were in the range of 6.51-7.50 in cookies baked with the composite flours. Cookies baked with 50% SF: 40% WF: 10% TF was the most accepted though the value did not differ significantly from the control ($p>0.05$).

Table 5: Sensory Evaluation

SAMPLE	APPEARANCE	TASTE	AROMA	TEXTURE	CRISPNESS	GENERAL ACCEPTABILITY
$S_{50.0}W_{40.0}T_{10.0}$	$7.47^{ab}\pm1.07$	$7.47^{ab}\pm1.18$	$7.88^{b}\pm0.78$	$7.35^{a}\pm1.41$	$7.47^{bc}\pm1.59$	$7.50^{b}\pm0.99$
$S_{45.0}W_{35.0}T_{20.0}$	$7.29^{ab}\pm1.16$	$7.29^{ab}\pm1.36$	$7.76^{b}\pm0.97$	$6.88^{a}\pm1.22$	$6.59^{abc}\pm1.81$	$7.09^{ab}\pm1.07$
$S_{48.3}W_{33.3}T_{18.3}$	$7.53^{ab}\pm1.28$	$7.47^{ab}\pm1.23$	$7.71^{ab}\pm1.05$	$7.18^{a}\pm1.47$	$6.94^{abc}\pm1.64$	$7.31^{ab}\pm1.21$
$S_{50.0}W_{30.0}T_{20.0}$	$7.41^{ab}\pm1.12$	$6.88^{ab}\pm1.32$	$7.24^{ab}\pm1.20$	$6.76^{a}\pm1.82$	$6.24^{abc}\pm1.92$	$6.85^{ab}\pm1.30$
$S_{43.3}W_{38.3}T_{18.3}$	$7.24^{ab}\pm1.25$	$6.82^{ab}\pm1.33$	$7.41^{ab}\pm1.42$	$6.94^{a}\pm0.97$	$6.24^{abc}\pm1.56$	$6.88^{ab}\pm1.01$
$S_{46.7}W_{36.7}T_{16.6}$	$7.41^{ab}\pm1.12$	$6.88^{ab}\pm1.50$	$7.71^{ab}\pm0.99$	$6.88^{a}\pm1.36$	$6.18^{ab}\pm1.59$	$6.94^{ab}\pm1.04$
$S_{45.0}W_{35.0}T_{20.0}$	$7.06^{ab}\pm1.20$	$7.12^{ab}\pm1.32$	$7.53^{ab}\pm1.13$	$6.76^{a}\pm1.09$	$6.35^{abc}\pm1.73$	$6.89^{ab}\pm1.00$
$S_{50.0}W_{35.0}T_{15.0}$	$7.82^{b}\pm1.38$	$7.06^{ab}\pm1.35$	$7.59^{ab}\pm1.50$	$6.65^{a}\pm2.03$	$7.41^{bc}\pm1.54$	$7.28^{ab}\pm1.29$
$S_{40.0}W_{40.0}T_{20.0}$	$7.12^{ab}\pm1.22$	$7.47^{ab}\pm1.13$	$7.24^{ab}\pm1.09$	$6.53^{a}\pm1.42$	$6.82^{abc}\pm1.29$	$6.97^{ab}\pm0.94$
$S_{50.0}W_{30.0}T_{20.0}$	$7.24^{ab}\pm1.25$	$6.53^{a}\pm1.51$	$7.00^{ab}\pm1.23$	$6.35^{a}\pm2.06$	$5.76^{a}\pm2.17$	$6.51^{a}\pm1.51$

$S_{40.0}W_{40.0}T_{20.0}$	$6.88^{ab}\pm1.22$	$7.47^{ab}\pm1.13$	$7.06^{ab}\pm1.03$	$6.65^{a}\pm1.54$	$6.76^{abc}\pm1.25$	$6.91^{ab}\pm0.89$
$S_{50.0}W_{40.0}T_{10.0}$	$7.29^{ab}\pm1.21$	$7.41^{ab}\pm1.23$	$7.65^{ab}\pm2.00$	$7.35^{a}\pm1.41$	$7.53^{c}\pm1.63$	$7.44^{b}\pm1.00$
$S_{45.0}W_{40.0}T_{15.0}$	$6.71^{a}\pm1.31$	$7.47^{ab}\pm1.38$	$7.06^{ab}\pm1.14$	$6.47^{a}\pm1.38$	$6.29^{abc}\pm1.69$	$6.71^{ab}\pm1.11$
$S_{48.3}W_{38.3}T_{13.3}$	$7.24^{ab}\pm1.19$	$7.76^{b}\pm0.90$	$7.71^{ab}\pm1.11$	$7.18^{a}\pm1.38$	$7.12^{bc}\pm1.36$	$7.34^{ab}\pm0.95$
$S_{0.00}W_{100.0}T_{0.00}$	$7.18^{ab}\pm1.19$	$6.65^{a}\pm1.46$	$6.82^{a}\pm0.88$	$6.85^{a}\pm1.49$	$6.76^{abc}\pm1.67$	$6.85^{ab}\pm1.06$

Values with the same superscript along each column are not significantly different at $p < 0.05$.
Where MC= moisture content; CHO= carbohydrate; S= Malted Sorghum Flour; W= Wheat Flour; T= Tigernut Flour

3.5 Optimization

Optimization of the response variables (breaking strength, fibre, ash and calorie) that exhibited significant models was carried out first by numerical and then followed by graphical (Fig.1). All the responses that exhibited significant models and have been expressed in form of mathematical model were assigned equal importance on the basis of their effect on quality of the cookies. The response variables goals were set in range and the combined response values that gave desirably of 1 was selected. For numerical optimization, the cookies made using the following flour blend which gave desirably of 1 was selected; malted sorghum flour A (49.00%), whole wheat flour B (34.00%), tigernut flour C (17.00%) with the corresponding breaking strength (728.498 g), fibre (2.104%), ash (3.017%) and calorie (367.06/100g) as optimum quality for the cookies was selected and also presented graphically.

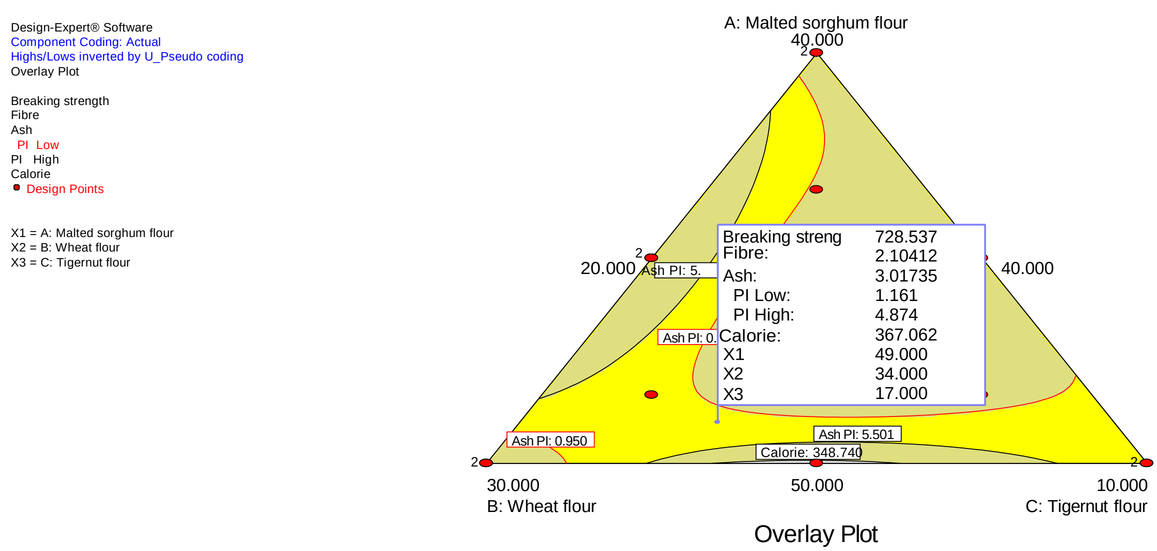

Fig. 1: Graphical optimization

4.Conclusion

This research work has successfully investigated the use of composite flour from malted sorghum, whole wheat and tigernut to produce cookies with enhanced nutritional and sensory qualities. The findings of this study showed that composite cookies had an enhanced physical, chemical and acceptable sensory scores when compared to conventional cookies made from wheat flour alone except in protein content. Thus, the malted sorghum-whole wheat- tiger nut cookies could be of health benefit to consumers. The most suitable cookie in terms of fibre and ash contents was the cookie from the blends of 50% malted sorghum flour, 35% whole wheat flour and 15% tigernut flour. The physical and sensory attributes of the cookies from this research were also comparable to the conventional cookies. The flour mix of 49.00% malted sorghum flour, 34.00% whole wheat flour and 17.00% tigernut flour yielded the cookie with optimum quality parameters of breaking strength, fibre, ash and calorie. Commercialization of this novel product could also be beneficial to industries and can boost the economy of tropical countries where these grains are grown.

5.`References

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