International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 12-12-2023, Accepted: 29-12-2023, Published: 15-01-2024
Volume 9, Issue 1, 2024, Page No. 12-20

Quality assessment of pancakes produced from wheat and tigernut composite flour

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Abstract
Physiochemical, functional, and proximate composition of composite flour made from wheat and tigernut was evaluated. Proximate composition and sensory properties of pancakes made from the composite flour was also evaluated. Wheat and tigernut flour was combined in the ratios of 100:0, 85:15, 70:30, 55:45, 40:60 and coded as samples A, B, C, D and E respectively. Sample A (100% wheat flour) served as the control. pH, titratable acidity and viscosity of the composite flour ranged from 4.02 - 4.48, 0.03 - 0.05 %lactic acid, 27.73 - 28.32 Pa.s respectively. Sugar content was 1.00 ºBrix across all samples. Oil and water absorption capacity, loose and packed bulk density, swelling power and solubility index, least gelation concentration, and foam capacity respectively, ranged from 2.04 – 2.75 and 1.32 – 1.62 g/g, 0.45–0.50 and 0.78–0.88 g/ml, 3.63 – 5.72 g/g and 33.95–44.95%, 0.02 -1.10%; and 15 – 25%. Moisture, ash, fat, crude protein, crude fibre and carbohydrate content of the flour ranged from 4.22– 5.04, 1.95 – 1.97, 4.10 – 18.20, 9.26 – 11.72, 2.3 – 4.16 and 63.32–76.61%respectively, with energy content of 381.18 - 457.08 Kcal/100g. Tigernut substitution to the flour led to significant increase ($p<0.05$) in fat, protein, carbohydrate and energy, while moisture and fibre decreased significantly. Pancakes moisture, ash, crude fibre, protein fat and carbohydrate content were 35.0 - 38.4, 0.64 - 2.15, 7.76 - 13.10, 7.50 - 18.40, 16.70 - 27.50 and 9.36 - 27.26% respectively, with energy content of 296.40 - 351.70 kcal /100g. Degree of likeness of the sensory attributes: aroma, colour, taste (sweetness), hardness, smoothness and overall acceptability were between like slightly and like moderately. Tigernut flour can be added to wheat flour at varying ratios of up to 30% in pancake making as it improved its nutritional value and had high degrees of likeness.

Keywords: Tigernut and wheat flour, pancakes, physicochemical and functional properties, proximate composition, and sensory properties

Introduction

Tigernut (*Cyperus esculentus*) is a creeping perennial plant which belongs to the sedge family (*Cyperaceae*). It is native to most tropical and temperate regions of the world (Rubert *et al.,* 2017; Bazine & Arslanoğlu, 2020) [41, 14]. It is majorly produced in Africa, Madagascar, Middle-East, Southern Europe and Indian subcontinent, the leading producing nations are Nigeria, Niger, Togo, Benin, United States, Iran, Iraq and Morocco. It is actually not a nut and it is called other names such as nutgrass, Chufa, nutsedge, earth almond, etc. (Samuel, 2016) [46]. There are three cultivars of tigernut; yellow, brown and black cultivars. The cultivars possessed different physicochemical properties (Ayo *et al.,* 2016; Nina *et al.,* 2019; Aşare *et al.,* 2020) [11, 33, 10] and functional properties (Nina *et al.,* 2019; Ismaila *et al.,* 2020) [33, 20]. The major factors that account for the chemical variation in tigernut are genetic makeup, production location (Ihenetu *et al.,* 2021) [19], environment and growing conditions (Duman, 2019) [16]. The tuber can be oval, ovoid or oblong (Asare *et al.,* 2020) [10] and can be eaten raw, dry or processed (Bazine & Arslanoğlu, 2020) [14].

Tiger nut is an underutilized tuber rich in many essential nutrients including proteins, carbohydrates, vitamins, minerals (Mohdaly, 2019) [30], phytochemicals, oil and fibre, (Ihenetu *et al.,* 2021) [19]. The tuber is reported to have numerous nutritional and health benefits (Bazine and Arslanoğlu, 2020) [14]. Different varieties of tigernut exhibit distinct nutritional profiles (Ismaila *et al.,* 2020) [20]. Its composition includes 45.73% carbohydrates, 30.01% oil, 5.08% protein, 2.23% ash, and 14.80% crude fibre (Sabah *et al.,* 2019) [45]. Different cultivars show variations in protein content, with the yellow and black varieties reported at 7.90% and 10.25%, respectively. Tigernut also contains essential fatty acids and essential amino acids in significant quantities (Ismaila *et al.,* 2020) [20]. The tuber is a source of various sugars, including disaccharide D-saccharose, which yields D-glucose, D-galactose, D-xylose, and D-arabinose upon hydrolysis. Yellow varieties have a total sugar content ranging from 10.09% to 12.64%, and fructans can constitute up to 13.49% of the tuber (Marchyshyn *et al.,* 2021) [26]. Tigernut is also a good source of calcium, sodium, phosphorus, potassium, iron, zinc, and copper (Ismaila *et al.,* 2020). Active ingredients in tigernut include sterols, alkaloids, tannins, saponins, resins, and vitamins E and C (Marchyshyn *et al.,* 2021) [26]. The phytochemicals present in tigernut, such as flavonoids, phenolic acids, and phenylethanoid glycosides, are exceptional and have potential applications in drug production and therapeutic diets (Mayer, 2019) [28].

Milling of tigernut into into flour is used to modify its appearance, develop its natural flavour, stimulate the digestive juices, make it easily digestible, increase *in-vivo*-bio-availability, destroy harmful microorganisms, improve its nutritional quality and prevent decomposition (Ndubuisi, 2009) [32]. Dry milling of tigernut produces flour rich in fibre and many essential nutrients. Adebayo and Arinola (2017) [1] recommended the use of tigernut in baking and the production of complementary foods. Several nutritional and health benefits were reported in using tigernut flour. Tiger nut flour has a unique sweet taste, which is ideal for different uses. It is a good alternative to many other flours like wheat flour, as it is gluten-free and good for people who cannot take gluten in their diets. It is also used in the confectionery industry (Ahmadzadeh *et al.*, 2006) [5].

Wheat is the most important stable food crop for more than one third of the world population and contributes more calories and proteins to the world diet than any other cereal crops (Kumar *et al.*,2011) [23]. Many countries including Nigeria has historically imported wheat to meet its high domestic demand, as the wheat plant can only thrive in subtropical regions. To address the escalating cost of wheat imports and reduce dependency on them, there is a critical need for diversification in the food sector (Marta *et al*, 2023) [27]. One significant factor driving this necessity is the gluten content found in wheat flour. Gluten, a protein inherent in wheat, plays a crucial role in dough characteristics, providing cohesiveness, viscosity, and elasticity, while also influencing water absorption capacity (Ortolan *et al*., 2017) [41]. However, the presence of gluten in food can lead to complications for certain individuals, particularly those with celiac disease, a genetic digestive disorder affecting around 1% of the global population. This percentage remains consistent across age groups and races. Gluten can also trigger other disorders like non-celiac gluten sensitivity, dermatitis herpetiformis, gluten ataxia, and wheat allergy (Bascuñán *et al*., 2017) [13]. Given these health concerns associated with gluten, there is a compelling need for alternative flours to replace wheat flour in food production. A widely consumed wheat-based product that can be modified to be gluten-free is pancakes (Adonu *et al*., 2022) [4].

Pancakes are starch-based products prepared by pouring batter onto a hot solid surface and cooking until solid (Messaoudi and Fahloul, 2018) [29]. Pancakes, quick and flat snacks, are typically crafted from wheat flour. High-quality pancakes exhibit optimal swelling power, necessitating the use of fresh dough to meet quality standards. Commonly enjoyed as a convenient and speedy homemade breakfast, pancake batter consists of a blend of flour, milk, eggs, sugar, and baking powder, cooked on a pan (Marta *et al*, 2023) [27]. Despite the increasing popularity of gluten-free options, many such products often lack satisfactory sensory qualities (Ren *et* al., 2020) [42]. Numerous studies have explored the development of gluten-free pancake formulations (Adonu *et al*., 2022, Marta *et al*, 2023) [4, 27].

This study was aimed at evaluating the physciochemical, functional and proximate composition of wheat-tigernut flour and the proximate and sensory properties of pancakes produced from the flour blends. The result will provide knowledge on the nutrients composition of wheat-tiger nut flour composite flour blend. Such information will expand the scope of knowledge on the utilization of tigernut flour in various food applications especially in pancakes.

Materials and methods

Raw materials and chemicals

Tigernut tubers, wheat and the ingredients for pancake production were purchased from Mile I market in Port Harcourt, Rivers State Nigeria.

Chemical reagents

The chemical, reagents and equipment used for this study are of analytical grade and obtained from the Department of Food Science and Technology, Rivers State University

Preparation of the flours: Tigernut, wheat and composite flours

Tigernut flour was prepared using the method described by Ade-Omowaye *et al*. (2008) [3] with some modifications. Two (2 kg) of tigernut tubers were cleaned, sorted, washed with water mixed with 1% NaCl for decontamination. It was then oven dried at at 60°C for 12 h, milled and sieved through 100 ųm aperture size sieve and the resultant flour was packaged in ziploc bag and stored for further use.

Wheat flour was produced according to the method described by Offia and Onwubiko, (2015) [37] with slight modifications. Whole wheat grains were sorted, washed oven dried at 80°C for 6 h, and dry milled with a grinding machine to obtain whole wheat flour. The flour was sieved through a 100 ųm aperture size sieve, packaged in ziploc bag and stored till required for analysis.

The wheat and tigernut flour were mixed in the following ratios: 100:0, 90:10, 80:20, 70:30, 60:40 for samples A, B, C D and E. Sample A with 100% wheat flour served as control. The flour blends were homogenised using a Kenwood mixer (A90IE, Kenwood Haunt Hampshire, England) to achieve uniform blends and stored in well labelled ziploc bags till needed for analysis.

Production of wheat-tigernut pancakes

The recipe and method of pancake preparation with slight modification was adopted from the recipe of Ola *et al*., (2020) [39]. The batter was made with the different ratios of the flour blends and a mixture of ingredients: sugar (9 g), salt (1.5 g), baking powder (2 g), margarine (50 g) egg beaters (39 g) and water (110 ml). Melted margarine and egg was thoroughly mixed in a bowl before the addition of thoroughly mixed the dry ingredients consisting of flour, sugar, baking powder and salt to the wet ingredients to make a fine batter. About 20 ml of the batter was fried at a time in a preheated frying pan sprayed with vegetable oil. Both sides were cooked for about 3 min each until it turned brown with bubbles on the top. The cooked pancake was removed from heat and allowed to cool for further analysis.

Determination of pH, titratable acidity, total soluble solids and viscosity of the composite flour

pH, titratable acidity (as % lactic acid), Total Soluble Solids (°Brix) and viscosity was determined using AOAC, (2012) [9] standard method. The samples (2 g) were homogenized in 20 mL of distilled water and filtered into a beaker. The pH meter (Jenco 6177) after calibration and stabilization with standard buffer of pH 4.0 and 7.0, was used to determine the sample pH. Thereafter, 3 drops of phenolphthalein were added as the indicator and the mixture was titrated against 0.1 M NaOH. Acidity was expressed as % lactic acid with each ml of the 0.1 M NaOH equivalent to 0.09 of lactic acid. A drop of the dissolved samples was placed on the prism of a clean refractometer and the sugar content (soluble sugar) was read from the scale (°Brix). Viscosity of 10 g of the composite flour slurry in 100 mL of distilled water was determined using Rotary Viscometer (NDJ-85, China).

Determination of the functional properties of the wheat-tigernut composite flour

Water and oil absorption capacity

The method described by Elkhalifa et al., (2005) [17] was used to determine the water absorption capacity of the composite flour samples. To 1 g of sample in a pre-weighed

15 mL centrifuge tubes, was added 10 ml of distilled water and thoroughly wetted using a vortex for 2 min. After 30 min of standing at room temperature the sample was centrifuged at 3000 rpm for 25 min at 20°C. The supernatant was decanted and the centrifuge tube containing sediment weighed. Water absorption capacity (grams of water per gram of sample) was calculated by dividing the weight of sediment by the sample weight. The oil absorption capacity, OAC, (grams of oil per gram of sample) was determined following the same procedure, except that soy oil was used in place of distilled water.

Bulk density

Bulk density determination was by method as described by Maninder *et al.,* (2007) [25]. The samples were filled gently into a 10 ml graduated cylinders, the bottom of the cylinders was tapped gently on a laboratory bench until there were no more diminution of sample level at the 10ml mark. The volume occupied by the sample was noted and the bulk density (g/ml) was expressed as weight of sample (g) divided by volume of sample (ml).

Solubility and swelling index

The swelling Power and Solubility were determined using the method by Robertson *et al* (2000) [43]. It involved weighing 1 g of the flour sample into a flask followed by the addition of 15 ml distilled water and shake thoroughly. Thereafter, it was sent to the water bath at a set temperature of 100^0C for 1 h. After heating, it was cooled under running water; then transferred into a previously dried and weighed centrifuge tube and centrifuged for 30 min at 2000rpm. After centrifuge, the swollen volume was read directly from the tube. The clear portion were transferred into a previously ignited weighed metal can, and dried in the oven at 105^0C for 1 hour after then cooled in the desiccator and weighed.

Dispersibility

Dispersibility of the samples was determined using the method described by Kulkarni *et al*. (1991) [22]. Ten gram (10 g) of each of the samples was weighed and placed in a 100 ml measuring cylinder followed by the addition of distilled water up to the 100 ml mark. The sample was vigorously stirred, mixed and next allowed to settle for 3 h. The volume of the settled particles was recorded and percentage dispersibility calculated.

Least Gelation Concentration (LGC)

Sample concentration is prepared between with 2-20% W/V of water inside test tubes. The test tubes are heated in a water bath for 1 hour at temperatures above 65 ℃. The test tubes are brought out and cooled for 2 hours in a refrigerator (4℃), the test tubes are then inverted. The least gelation concentration is determined as that concentration when the sample from the inverted test tubes does not slip or fall.

Foam capacity

A flour sample weighing two grams was introduced into 50 ml of distilled water at a temperature of 30±2°C within a 100 ml measuring cylinder. The mixture was stirred and adequately shaken to create foam, and the foam's volume after 30 seconds was documented. The Foam Capacity (FC) was quantified as the percentage increase in volume (Adejuyitan *et al*., 2009) [2].

Sensory evaluation of wheat-tigernut pancakes

The sensory evaluation of the pancakes was by the method of Obinna-Echem *et al.,* (2023) [35]. A 20-man s panellist made of staff and students of Food Science and Technology who are not allergic to any of the raw materials were used to evaluate colour, aroma, hardness, taste, smoothness and overall acceptability of the pancakes. A 9-point hedonic scale where: 9 = liked extremely, 8 = liked very much, 7 = liked, 6 = liked slightly, 5 = neither liked nor disliked, 4 = disliked slightly, 3 = disliked moderately, 2 = disliked very much and 1 = disliked extremely was used.

Statistical analysis

Analyses were carried out in duplicates. Data obtained were subjected to Analysis of Variance (ANOVA). Difference between means were evaluated using Tukey's multiple comparison tests at 95% confidence level using Minitab (Release 18.1) statistical software English (Minitab Ltd. Conventry, UK).

Results and discussion

Physicochemical properties of wheat-tigernut composite flour

The physicochemical properties of the composite flours (wheat and tigernut flour blends) are shown in Table 1 with the following parameters assessed: pH, TTA, Viscosity and Sugar. The pH values varied significantly ($p>0.05$) and ranged from 4.02 - 4.48 for sample B and D respectively. The pH of Sample C was comparable to the control (Sample A). Other researchers have reported the pH of tigernut flour to be 6.23 (Obinna-Echem *et al*., 2020) [36], 6.52 (Ndiaye *et al*., 2022) [31] and 6.80 (Kouame *et al*., 2022) [21]. With an increment in tigernut flour substitution, there was a resulting increase in the pH of the composite flours. This relationship was also observed in a study by Ade-Omowaye *et al*. (2008) [3]. The values for the total titratable acidity (TTA), viscosity and total soluble solid were not significantly different ($p>0.05$). TTA ranged from 0.03 - 0.05 %Lactic acid for sample B and E respectively. The acidity is within the range reported by Ade-Omowaye (2008) [3] as 0.024–0.057%. Viscosity ranged from 27.73 - 28.32 Pa.s with sample D having the lowest and sample E having the highest. The viscosities of Samples B and E compared favourably with the control. The viscosity exhibited by wheat-tigernut flour blends shows that the samples have good water binding capacity (Oke *et al*., 2019) [38] and are suitable for bakery products. All the samples had total soluble solid content of 1.00 °Brix, revealing that tigernut substitution did not affect the sugar content of the flours. In a study by Adejuyitan *et al*. (2009) [2], fermentation of tigernut tubers increased their sugar content while roasting was observed to reduce the total sugar content of tigernut flour (Ndiaye *et al*., 2022) [31]. Depending on nutritional requirements, Tigernut flour can be processed to yield desired results.

Table 1: Physicochemical properties of wheat-tigernut composite flour

Sample	pH	Titratable acidity (%Lactic acid)	Viscosity (Pa.s)*	Total soluble solids (^{0}Brix)*
A	4.20±0.01^c	0.04±0.00^a	28.32±0.12	1.00±0.00
B	4.02±0.01^d	0.03±0.00^b	28.32±0.21	1.00±0.00
C	4.26±0.01^c	0.04±0.00^a	27.76±0.48	1.00±0.00
D	4.48±0.03^a	0.04±0.00^a	27.73±0.20	1.00±0.00
E	4.37±0.02^b	0.05±0.00^a	28.30±0.08	1.00±0.00

Values are means ± standard deviation of duplicate samples
Values with the same superscript along each column are not significantly different at p >0.05.
*Values are not significantly different (p>0.05)
A = 100% Wheat and 0% tigernut flour.
B = 85% Wheat and 15% tigernut flour.
C =70% Wheat and 30% tigernut flour.
D =55% Wheat and 45% tigernut flour.
E = 40% Wheat and 60% tigernut flour.

Functional properties of the wheat-tigernut composite flour

Presented on Table 2 is the functional properties of the tigernut composite flour. The oil absorption capacity of the samples ranged from 2.04 – 2.75 g/g for 100% wheat flour and sample E (60% wheat and 40% tigernut flour) respectively. The determination of oil absorption capacity (OAC) is important since oil acts as a flavour retainer and improves mouthfeel (Kwaghsende *et al*., 2019) [24] and depicts the rate at which protein binds to fat in food systems. The slight increase in the OAC indicates that the addition of tigernut flour improved the oil absorption capacity of the composite flours. Oil absorption capacity is useful in formulation of foods such as sausages and bakery products like pancakes (Hasmadi *et al*., 2020, Akinwande *et al*., 2023) [18, 7]. Increase in OAC on tigernut flour substitution was also observed by Ayo *et al*., (2018) [12] with Acha flour, and Kwaghsende *et al*., (2019) [24]. The water absorption capacity of the samples ranged from 1.32 – 1.62 g/g. Water absorption capacity is the amount of water absorbed by food in order to achieve a desired consistency (Dada *et al*., 2023) [15], The capacity of flour to assimilate water was noted to exhibit a noteworthy correlation with its starch content (Ola *et al*., 2020) [39]. This outcome implies that the incorporation of tigernut flour could be applicable in the production of baked goods.

The bulk density of the flours was 0.45–0.50 g/ml and 0.78–0.88 g/ml for loose and packed bulk density respectively. The packed bulk density is higher than that reported by Ade- Omowaye *et al*. (2008) [3] and Kwaghsende *et al*., (2019) [24] (0.57–0.64 g/ml and 0.90–1.0 g/ml respectively). Bulk density is typically influenced by the particle size of the flour, starch content and its initial moisture content, and in turn it significantly impacts the specifications for packaging, material handling, and wet processing applications within the food industrial sector (Hasmadi *et al*., 2020, Kwaghsende *et al*., 2019) [18, 24]. High bulk density, as observed in the packed bulk density of the composite flours, is generally preferred due to its advantages in easy dispensability and the reduction of paste thickness (Hasmadi *et al*., 2020) [18]. The loose bulk density was slightly lower than the control. However, low bulk density finds advantaged application in the formulation of weaning foods (Hasmadi *et al*., 2020) [18].

The least gelation concentration (LGC), denoting the minimum protein concentration at which a gel persists when the tube is inverted, served as a metric for assessing gelation capability (Hasmadi *et al*., 2020) [18]. The least gelation concentration is employed to evaluate the protein's capacity to create a gel. There was no significant difference (P>0.05) in the LGC which ranged from 0.02 -1.10%. Besides sample C (70% Wheat and 30% Tigernut flour blend), the LGC values were the same (0.20%) for all samples. The lower the least gelation concentration, the better is the gelling ability of the protein ingredient in a food system (Hasmadi *et al*., 2020) [18]. A study by Dada *et al*., (2023) [15] observed an increase in LGC in composite flour formulated with African yam bean and tigernut flours.

The dispersibility which is a measure of the reconstitution ability of flour in water (Oke *et al*., 2019) [38] ranged from 36 – 37%. This is in contrast to that reported by Oke *et al*., (2019) [38] which ranged from 70.39–79.39% with tigernut substitution at 30% having the highest dispersibility. Swelling power is a measure of swollen starch granules during heating which in turn affects food eating quality (Oke *et al*., 2019) [38]. There was no significant difference (p>0.05) in the swelling power that ranged from 3.63 – 5.72 g/g. Similar values were reported by Dada *et al*., (2023) [15] for composite flour of wheat, African yam bean and tigernut (3–5%) while Oke *et al*., (2019) [38], reported a higher value of 10.45–19.96% for wheat-tigernut flour blends. The solubility index ranged from 33.95–44.95%. Swelling power (SP) and solubility index (SOI) are inversely related (Amoakoah Twum *et al*., 2015) [8]. The result obtained for foam capacity was higher than the findings of Kwaghsende *et al*., (2019) [24] and ranged from 15 – 25%. Flours produce foams due to surface active proteins and foaming capacity is a measure of the amount of the interfacial area created by protein during foaming (Hasmadi *et al*., 2020) [18].

Table 2: Functional properties of the wheat-tigernut composite flour

Samples	OAC g/g*	LGC*	WAC g/g	LBD g/ml*	PBD g/ml*	Dispersibility (%)*	SP g/g*	SOL(%)*	FC (%)
A	2.04±0.11	0.20±0.00	1.53±0.06^a	0.50±0.02	0.85±0.04	36.00±0.00^b	5.22±1.78	33.95±3.61	25.00±0.00^a
B	2.35±0.03	0.20±0.00	1.62±0.03^a	0.45±0.01	0.86±0.08	36.00±0.00^b	5.72±1.41	37.85±4.45	25.00±0.00^a
C	2.17±0.06	1.10±0.27	1.46±0.01^{ab}	0.46±0.00	0.88±0.01	36.00±0.00^b	3.63±0.73	44.95±0.35	20.00±0.00^b
D	2.11±0.12	0.20±0.00	1.32±0.01^b	0.48±0.02	0.78±0.05	37.00±0.00^a	4.25±0.16	44.60±5.80	15.00±0.00^c
E	2.75±0.76	0.20±0.00	1.34±0.08^b	0.49±0.02	0.80±0.02	36.00±0.00^b	4.06±1.02	39.40±8.49	15.00±0.00^c

Values are means ± standard deviation of duplicate samples

Values with the same superscript along each column are not significantly different at p >0.05.
*Values did not differ significantly (p >0.05)
OAC-Oil absorption capacity, LGC- least gelation concentration, WAC-water absorption capacity. LBD- Loose Bulk Density, PBD - Packed Bulk Density, SP–Swelling Power, SOL–Solubility Index, FC–Foam Capacity.
A= 100% wheat and 0% tigernut flour.
B= 85% wheat and 15% tigernut flour.
C=70% wheat and 30% Tigernut flour
D=55% wheat and 45% Tigernut flour.
E= 40% wheat and 60% tigernut flour.

Table 3: Proximate composition (%) and energy content **(**kcal/100g) of wheat-tigernut composite flour

Sample	Moisture*	Ash *	Crude fibre	Protein	Fat	Carbohydrate	Energy
A	4.55±0.08	1.95±0.01	4.16±0.06^{a}	11.72±0.02^{a}	7.70±1.41^{cd}	69.93±1.36^{b}	395.88±7.21^{c}
B	5.04±0.08	1.96±0.01	2.84±0.08^{b}	9.46±0.00^{bc}	4.10±0.71^{d}	76.61±0.72^{a}	381.18±3.48^{c}
C	4.44±0.50	1.95±0.00	1.66±0.13^{c}	9.26±0.51^{c}	11.05±2.05^{bc}	71.65±1.18^{b}	423.07±11.7^{b}
D	4.55±0.21	1.97±0.01	2.38±0.68^{bc}	11.72±0.01^{a}	14.00±0.71^{ab}	65.40±1.17^{c}	434.44±1.67^{ab}
E	4.22±0.25	1.97±0.01	2.30±0.14^{bc}	10.00±0.00^{b}	18.20±0.14^{a}	63.32±0.04^{c}	457.08±1.10^{a}

Values are means ± standard deviation of duplicate samples
Values with the same superscript along each column are not significantly different at p>0.05.
*Values are not significantly different (p>0.05

Table 4: Proximate composition (%) and energy content (kcal/100g) of wheat-tigernut pancakes

Sample	Moisture	Ash	Crude fibre	Protein	Fat	Carbohydrate	Energy
A	35.0±0.00^{c}	2.15±0.07^{a}	13.18±0.60^{a}	18.40±0.04^{a}	21.09±0.75^{c}	10.16±0.02^{c}	303.99±6.90^{a}
B	35.63±0.31^{c}	1.77±0.02^{ab}	7.77±0.26^{b}	7.50±0.00^{e}	19.78±0.38^{c}	27.26±0.17^{a}	317.05±2.61^{a}
C	38.45±0.42^{a}	0.85±0.00^{c}	11.70±2.76^{ab}	16.10±0.00^{b}	23.30±0.14^{b}	9.36±2.83^{c}	311.52±10.06^{a}
D	38.38±0.24^{a}	0.64±0.21^{c}	7.87±0.12^{b}	14.80±0.00^{d}	16.80±0.70^{d}	21.51±1.28^{b}	296.40±1.18^{a}
E	36.75±0.14^{b}	1.37±0.17^{b}	8.25±0.07^{ab}	15.90±0.00^{c}	27.50±0.38^{a}	10.15±0.44^{c}	351.70±1.66^{a}

Values are means ± standard deviation of duplicate samples
Values with the same superscript along each column are not significantly different at p>0.05.
A = 100% Wheat and 0% tigernut flour.
B = 85% Wheat and 15% tigernut flour.
C =70% Wheat and 30% tigernut flour.
D =55% Wheat and 45% tigernut flour.
E = 40% Wheat and 60% tigernut flour

Proximate composition of wheat-tigernut composite flour

Proximate composition of the composite flour samples is displayed in Table 3. The proximate analysis of food involves identifying the primary constituents of the food, which includes moisture, lipids, ash, protein, carbohydrate and fibre (Onwuka, 2018) [40]. The ash and moisture content of the flours did not vary significantly (P>0.05) at a mean of 1.95 – 1.97% for ash and 4.22 – 5.04 for moisture. The Ash content depicts the comprehensive quantity of minerals found in food substances following the application of heat (Amoakoah Twum *et al*., 2015) [8]. Low moisture content is important in the keeping quality of flour. High moisture content promotes spoilage due to oxidation reactions microbial and insect growth which can affect the quality of the tigernut composite flour (Amoakoah Twum *et al*., 2015) [8]. Crude fibre content of the samples ranged from 1.66 – 4.16% with sample A having significantly (p<0.05) the highest value and sample C had the least value. Decrease in fibre content contradicts that observed by Ade-Omowaye *et al*. (2008) [3]. The protein (9.26 – 11.72%), fat (4.10 – 18.20%), carbohydrate (63.32 – 76.61%) and energy content (381.18 – 457.08 Kcal/100g) of the flour samples were significantly different (p<0.05) from each other. Protein content of the flours are within the range reported by Ade-Omowaye *et al*. (2008) [3] and in another study by Amoakoah Twum *et al*., (2015) [8]. An increase in fat, protein and energy content was observed with increased substitution in tigernut flour. This increment could be attributed to the high fat content of tigernut flours (Ndiaye *et al*., 2022, Kouame *et al*., 2022) [31, 21]. Tigernut fat is reported to contain essential fatty acids which promote good health acting as an antioxidant, anti-arthritic, anti-inflammatory, atherosclerotic and anticonvulsant (Ayo *et al*., 2018, Kouame *et al*., 2022) [12, 21]. This progressive increase in fat was also reported by Ayo *et al*., (2018) [12] with Acha flour and Ade-Omowaye *et al*. (2008) [3]. Tigernut is known to be rich in carbohydrate and an excellent source of energy.

Proximate composition of pancakes produced from wheat-tigernut composite flour

The proximate composition of the pancakes was evaluated and presented on Table 4. The moisture content of the pancakes ranged from 35.0 – 38.4% for sample A and D respectively. While the moisture content of sample B was comparable to the control (100% wheat), samples C and D were significantly (p <0.05) higher than the other samples. This is consistent with the finding of Ola *et al*., (2020) [39] where composite flour with tigernut substitution at 30% recorded the highest moisture content of 39.53%, but lower than the report of 46 -59% reported by Obinna-Echem *et al*., (2023) [35] for cocoyam-soybean pancakes. Moisture content of the pancakes is a function of the water added during the preparation of the batter. The ash content ranged from 0.64 to 2.15% with sample D (55% wheat and 45 % tigernut flour) significantly (p<0.05) the lowest and sample A (100% wheat) having the highest ash content. This was lower than the report for cocyam-tigernut and tigernut-cowpea pancakes by Obinna-Echem *et al*., (2021) [34] and Obinna-Echem *et al*., (2023) [35]. The higher the ash content the more the mineral component of the sample as ash as an indicator of mineral content. Protein content of the samples varied siginifcantly (p<0.05) amongst the samples. The values ranged from 7.50 - 18.4% with sample B (100% wheat flour) as the lowest and sample A having the highest value. These values were higher than those of tigernut-cowpea pancakes (6.18 – 10.55%) (Obinna-Echem *et al*., 2021) [34]. Differences in other ingredients used can account for these variations. The pancakes had fat content between 16.70 and 27.50 %. Sample E had significantly (p<0.05) the highest fat content and of pancake. The ability of the batter to absorb oil during frying and the quantity of oil used can contribute to the fat content of the pancakes. Crude fibre content ranged from 7.76 – 13.10% for sample A and B respectively. This was comparable with tigernut pancake (7.74%) but lower for tigernut-cowpea pancakes (Obinna-Echem *et al*., 2021) [34]. Crude fibre is important in the absorption of some micronutrients and bowel movement (Akajiaku *et al*., 2018) [6]. Carbohydrate content ranging from 9.36 – 27.26%, Samples C and E compared favourably with the control but reduced significantly (p>0.05) from Samples B and D (27.26 and 21.51 % respectively). The carbohydrate content of the pancakes was lower than those of their flour counterpart. The increase in the other components: moisture, protein, fat and crude fiber resulted in decrease in the carbohydrate content of the pancakes. The energy content ranged from 296.40 – 351.70 Kcal/100g for sample D and E respectively. Tigernut substitution had no significant (p>0.05) effect on the energy content of the pancakes. The energy value was lower than those of the flour probably due to increase in moisture.

Sensory properties of pancakes produced from wheat-tigernut composite flour

Assessors' degree of likeness for the aroma, colour and taste of the samples are shown in Figure 1 while Figure 2 shows the degree of likeness for hardness, smoothness and overall acceptability. The degree of likeness for sensory attributes; aroma, colour and taste ranged from 6.85 – 7.15, 6.60 – 7.15 and 6.80 – 7.55 respectively. The values are indicative of liked slightly to liked moderately. Hardness, smoothness and overall acceptability were in the range of 6.45–7.10, 6.35 – 7.40 and 6.63 – 7.07 representing like slightly to like moderately. There was no significant difference (p<0.05) in the degrees of likeness of each attribute amongst the samples. However, the frequency for each scale of likeness for each attribute amongst samples showed that 60% of the Assessors, liked sample D moderately and that was significantly (p<0.05) higher than others for the aroma. For colour and hardness, sample E and C had 45% of the degree of likeness for like moderately while for taste sample A had 45% for liked very much. Sample A and C had 30% of the degree of likeness for like slightly. All the analysed samples had varying degrees of likeness that was between like slightly and like very much.

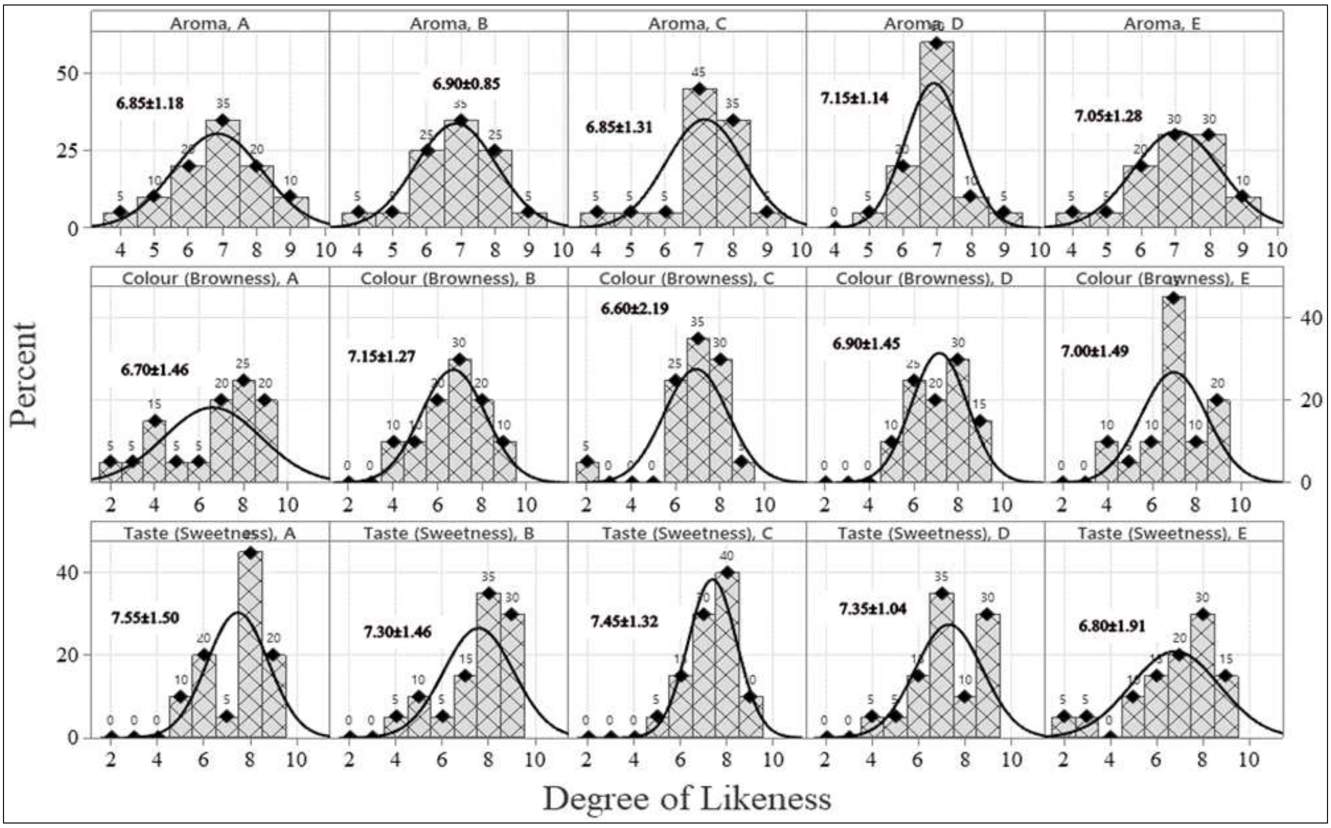

Fig 1: Histogram and frequency of the degree of likeness for aroma, colour and taste of the wheat-tigernut pancakes

The Bars represent the frequency (%) of the degree of likeness of each attribute per sample
Means ± standard deviation of degree of likeness by 20 Assessors are displayed
A = 100% Wheat and 0% tigernut flour.
B = 85% Wheat and 15% tigernut flour.
C =70% Wheat and 30% tigernut flour.
D =55% Wheat and 45% tigernut flour.
E = 40% Wheat and 60% tigernut flour

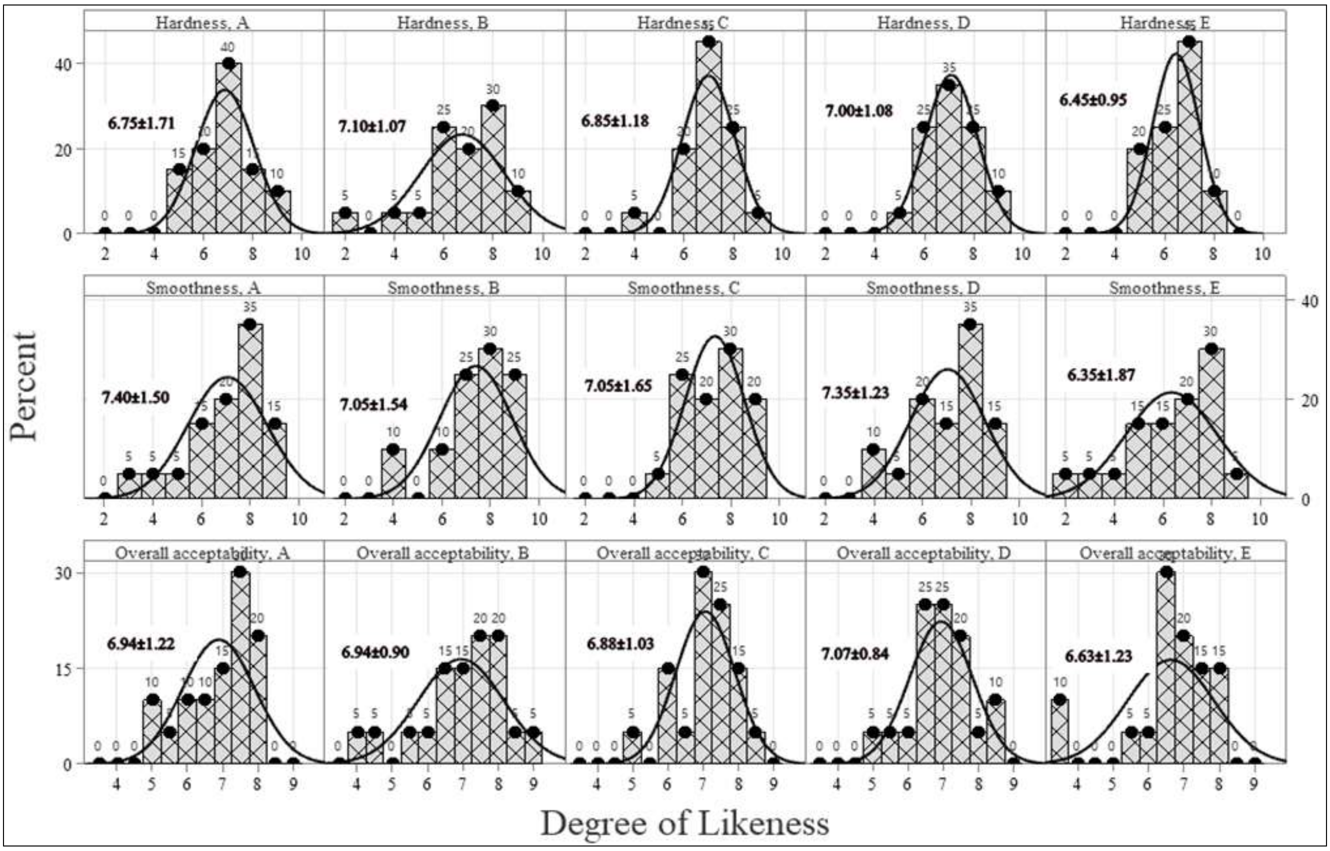

Fig 2: Histogram and Frequency of the Degree of Likeness for Hardness, Smoothness and Overall Acceptability of the Wheat-Tigernut Pancakes

The Bars represent the frequency (%) of the degree of likeness of each attribute per sample
Means ± standard deviation of degree of likeness by 20 Assessors are displayed
A = 100% Wheat and 0% tigernut flour.
B = 85% Wheat and 15% tigernut flour.
C =70% Wheat and 30% tigernut flour.
D =55% Wheat and 45% tigernut flour.
E = 40% Wheat and 60% tigernut flour

Conclusion

The study conclusively reveals that the physicochemical properties of the flour was unaffected by tigernut flour substitution with the pH slightly tending towards alkalinity on increasing substitution and very low TTA. Functional properties which depict the influence of a food ingredient in a particular food system showed that Tigernut flour substitution improved the oil absorption capacity which is of importance in bakery products. The flours have good and comparable water binding and gelling capacities with high bulk density which facilitate easy dispersability. The wheat-tigernut composite flour and the produced pancakes had increased fat, protein and energy content, so was the This energy-rich pancakes were liked to varying degrees by the sensory panel. Tigernut substitution produced a stable and enriched composite flour that can be a great source of energy and the different substitutions can be used in the production of quality and healthy bakery products especially pancakes while saving economic costs.

Acknowledgements

The authors acknowledge the technical assistance of Mrs Brown, Seline; Mrs Wokocha, Amarachi and Miss Owunna, Ruth of the analytical laboratory of Food Science and Technology, Rivers State University, Port Harcourt Rivers State, Nigeria.

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