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Research Article

Effects of Incorporation of Cauliflower (*Brassica oleracea var. botrytis*) Flour on the Physiochemical Properties of Chin-Chin

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ABSTRACT
This study aimed to assess the impact of cauliflower flour (CF) on the physiochemical properties of chin-chin snacks. Composite flours were prepared by blending wheat flour (WF) and cauliflower flour (CF) at varying ratios: Blend of wheat flour and cauliflower flour, WCF1 (100% WF: 0% CF), WCF2 (90% WF: 10% CF), WCF3 (80% WF: 20% CF), WCF4 (70% WF: 30% CF), WCF5 (60% WF: 40% CF), and WCF6 (50% WF: 50% CF), with 100% wheat flour as the control. The flour blends were analyzed for functional properties, while the chin-chin snacks were evaluated for nutritional and sensory characteristics. In terms of functional properties, the bulk density of the flour blends ranged from 0.63–0.69 g/ml, with WCF1 (100% WF) showing the highest value. The cauliflower flour increased water absorption, with WCF6 having the highest absorption rate (329.13%). In proximate analysis, the moisture content of the chin-chin samples ranged from 4.40–11.54%, with WCF6 having the highest (11.54%). Fibre content also increased, with WCF6 showing the highest value (0.57%). Additionally, the mineral and vitamin content of chin-chin samples from composite flours exceeded that of the control. Sensory evaluation revealed a significant difference ($P<0.05$) in attributes, with WCF2 (90% WF: 10% CF) receiving the highest overall acceptability score. The results suggest that, blends of wheat and cauliflower flour at a 90:10 ratio can be used to improve the nutritional profile of chin-chin snacks.

Keywords: Cauliflower; Chin-chin; Physicochemical properties; Proximate analysis; Wheat flour

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INTRODUCTION

Malnutrition is becoming more common in Nigeria due to poverty, low food production, lack of macronutrients and micronutrients in food, inadequate nutrition education and lack of knowledge about plant foods such as vegetables (Ilo *et al.,* 2025). A vegetable must meet certain requirements, such as accessibility, market availability, low cost, ease of cultivation, and preparation, in order to combat malnutrition (Ebert, 2020). It is important to use and consume more vegetables to reduce the prevalence of malnutrition in Nigeria and around the world. Many attempts have been made to improve the quality and functionality of snacks such as chin-chin by adding nutritional and functional ingredients to their basic recipes. Chin-Chin is a fried snack quite popular across Nigeria and most part of Western Africa (Adeyeye *et al.,* 2020). It is known as *atchomon* in Togo and Benin, *achomo* in Ghana, and croquette in Cameroon. It is similar to the Scandinavian snack Klenat, a crunchy, donut-like baked or fried dough of wheat flour, and other customary baking items (Akubor, 2004). The majority of West African children grew up eating and creating

Chin-Chin (as opposed to cookies) with their "mummy" or relatives, despite the fact that there are no reliable historical accounts of this food (Gbadamosi, 2012). Consider Chin-Chin as the cookie-like treat with smaller bites and stronger flavors. Chin-chin is prepared using wheat flour, butter, milk and eggs to form a stiff paste and then deep fried until golden brown. Chin-chin can sometimes be prepared by baking instead of frying (Adegunwa *et al.,* 2014). Chin-chin is a snack that encourages flexibility in terms of the ingredients and manufacturing methods. Chin-chin is a popular snack made from flour, sugar, butter, eggs, and other ingredients (Obarisagbon & Okechukwu, 2025). While these ingredients do provide some nutrients, chin-chin is generally considered a high-calorie, low-nutrient food. One of the main nutritional deficiencies in chin-chin is the lack of fiber. Most chin-chin recipes do not include any high-fiber ingredients such as whole grains or fruits, which can lead to a lack of fiber in the diet. Fiber is important for digestive health, as it helps to regulate bowel movements and lower the risk of certain diseases such as heart disease and diabetes. Many chin-chin recipes include a significant amount of sugar, which can contribute to weight gain, high blood sugar levels, and other health problems if consumed excessively. Excessive sugar consumption has been linked to an increased risk of heart disease, obesity, and other health problems. Chin-chin is also high in fat and calories, which can contribute to weight gain and other health problems if consumed excessively (Obinna-Echem, *et al.,* 2024). While fat is an important nutrient, it is important to consume it moderately as part of a balanced diet. Thus, even though chin-chin can be eaten occasionally, it is crucial to incorporate into it a balanced diet that also includes a variety of nutrient-rich foods including fruits, vegetables, whole grains, lean proteins, and healthy fats.

The nutritional value of the chin-chin can be fortified with plant-based vegetables such as cauliflower. Plant-based foods like vegetables are important protective foods and have great benefits in maintaining good health and preventing disease. Vegetables contain beneficial nutrients that can be used to strengthen and repair body tissues. Vegetables are important for maintaining the body's alkaline reserves (Mohammed *et al.,* 2023). It is very valuable because it contains a lot of vitamins and minerals. Vegetables contain significant amounts of vitamins A, B, and C.

Cruciferous vegetables like cauliflower (*Brassica oleraceae* var. *Botrytis*) which is one of the several vegetables in the species Brassica oleracea, the Brassicaceae family is an annual plant that reproduces by seed. Brassica vegetables, which have been eaten across the world, include several commercially intriguing crops such as cabbage, broccoli, cauliflower, and turnips (Artes-Hernandez *et al.,* 2023). A high intake of these veggies is linked to a lower risk of cancer, heart disease, and degenerative illnesses (Ribeiro *et al.,* 2015). Compared to other vegetables, cauliflower has higher antioxidant potential which makes them very interesting crops. It is considered as a rich source of dietary fiber and it possesses both antioxidant and anticarcinogenic properties (Mishra *et al.,* 2023). They are also strong sources of important vitamins, carotenoids, fiber, soluble sugars, minerals, and phenolic compounds (Paciulli, 2015). Cauliflower is gradually being accepted as a new plant vegetable in Nigeria due to its many nutrients and health advantages. (Mbah *et al.,* 2012).

Wheat has been ranked as the most popular cereal grain in the world since it is a staple food enjoyed by people all over the world (Gammoh *et al.,* 2018). Starch in wheat provides a valuable source of carbohydrates (Iqbal *et al.,* 2022). In order to make treats like pies, pizza, biscuits, and cookies, wheat flour is typically utilized. Wheat contains antioxidants (Li *et al.,* 2015; Starzyńska-Janiszewska *et al.,* 2019). The antioxidant qualities of wheat are significantly influenced by its protein level (Punia *et al.*,2019). In general, consumption of whole grains is associated with the prevention of diseases caused by oxidative stress, such as cancer, as most of the bioactive compounds are found in ground fractions rich in whole grains, bran, or germ (Esfandi *et al.,* 2019). Starch and protein are found in the endosperm of wheat, while bran and germ contain dietary fiber, minerals and phytochemicals that are important for human nutrition and health (Punia *et al.,* 2019). Wheat is rich in vitamins, especially vitamin E and the vitamin B group (primarily niacin), with the exception of vitamin C which is not normally found in grains. As consumers' preferences across the globe tilt towards consuming healthier snacks, incorporating cauliflower in chin-chin could be a beneficial way of improving nutritional value and variety of snacks. By blending wheat flour with cauliflower, the carbohydrate content of chin-chin may reduce, making it a more nutritionally acceptable snack.

MATERIALS AND METHODS

Procurement of materials

The materials used were purchased from Ogige Market in Nsukka, Enugu state, Nigeria. They include wheat flour, sugar, margarine, baking powder, egg, nutmeg, milk, and vegetable oil. Cauliflower was purchased from Jos, Nigeria.

Sample Preparation

Processing cauliflower flour

The cauliflower was selected and washed with clean water to remove sand and debris, and then cut into pieces with a knife and then blanched for 2-3 minutes at 80-85$°C$ to deactivate enzymes that can cause discoloration and off-flavours. After blanching, the cauliflower was drained for one minute and allowed to cool. The blanched cauliflower at 60$°C$.The cauliflower was ground to a fine powder using a disc mill. The fine powder was passed through 200mm mesh sieve and packed in air-tight containers for further analysis.

Cauliflower
↓
Selection and cleaning
↓
Cutting
↓
Blanching
↓
Drain
↓
Cool
↓
Drying
↓
Milling
↓
Sieve
↓
Cauliflower flour

Figure 1. Production of cauliflower flour
Source: Rodriguez-Chavez *et al.* (2021)

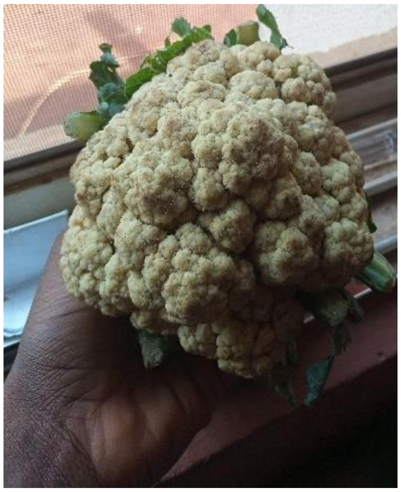

Plate 1. Raw cauliflower

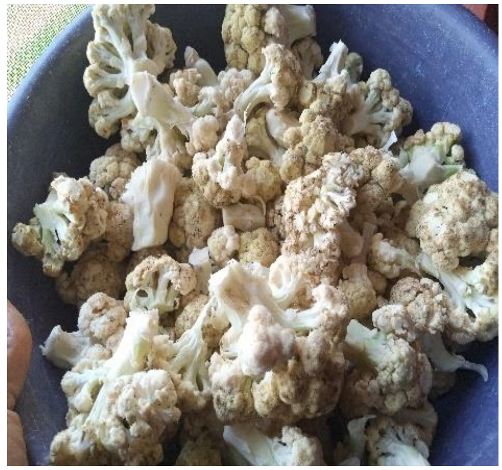

Plate 2. Cauliflower florets

Plate 3. Dehydrated cauliflower florets

Plate 4. Milled Cauliflower into flour

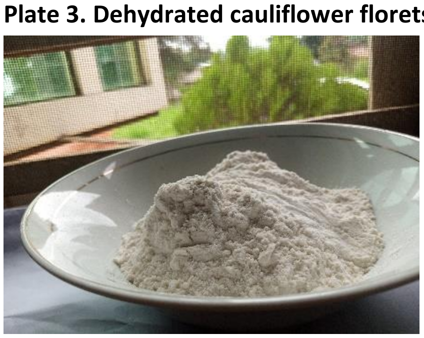

Plate 5. Refined wheat flour

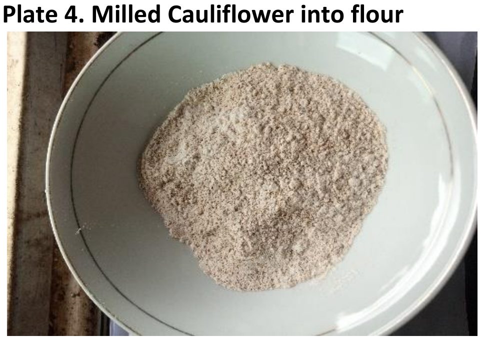

Plate 6. Formulated wheat-cauliflower flour

Preparation of wheat-cauliflower flour blends

Beside control sample, (100% wheat flour, WF), the composite flours were prepared by substituting wheat flour with 10, 20, 30, 40, and 50% cauliflower flour then packaged in polyethylene bags and stored in a desiccator until required for further analysis and until processing into chin-chin.

Table 2. **Blending ratios of wheat and cauliflower flour**

Sample	Wheat flour (%)	Cauliflower powder (%)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50

Table 3. Chin-chin formulation

Ingredient	Quantity of ingredient					
Cauliflower flour (g)	0	50	100	150	200	250
wheat flour (g)	500	450	400	350	300	250
Granulated sugar (g)	100	100	100	100	100	100
Salt (g)	2.5	2.5	2.5	2.5	2.5	2.5
Medium sized egg	1	1	1	1	1	1
Baking powder (g)	15	15	15	15	15	15
Margarine (g)	70	70	70	70	70	70
Nutmeg (g)	10	10	10	10	10	10
Powdered milk (g)	75	75	75	75	75	75
Water (ml)	75	75	75	50	50	40
Vegetable oil (ml)	500	500	500	500	500	500

Source: Akindele *et al.* (2017)

Preparation of chin-chin

Wheat flour was mixed with cauliflower flour at 0, 10, 20, 30, 40, and 50%. The flour blend, sugar, margarine, egg, baking powder and powdered milk were measured into a large bowl and mixed thoroughly together before kneading with water into a dough. The dough formed was placed on a floured board surface and kneaded until smooth and elastic. The kneaded dough was rolled with a wooden roller to about 2cm thick and cut into small squares with stainless knives and Vernier caliper into 2 cm by 6 cm sizes. The slices were deep-fat-fried in hot vegetable oil (about 180°C) with open pan for about 8 minutes until golden colour is attained. The fried chin-chin was removed and allowed to drain off excess oil before cooling and packing in air tight polyethylene film for analysis (Adegunwa *et al.,* 2014). The recipe formulation for chin-chin is shown in Table 3.

Figure 2 shows the unit operation for the production of chin-chin from the flour sample.

From the plates below, the samples with higher levels of cauliflower flour (30 %, 40 %, and 50 %) had darker crust colors in contrast to samples with lower levels of cauliflower flour (0 % and 10 %).

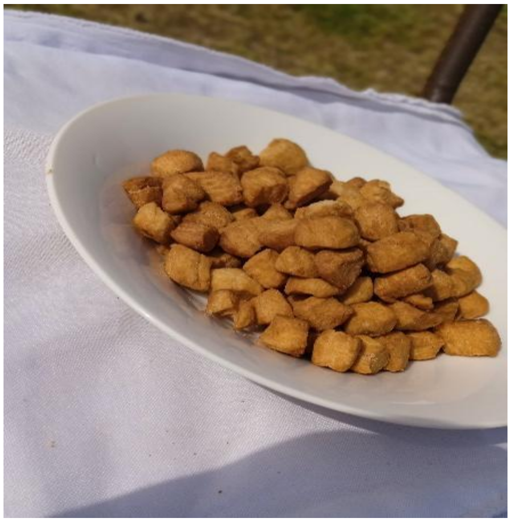

Plate 7. Fried chin-chin

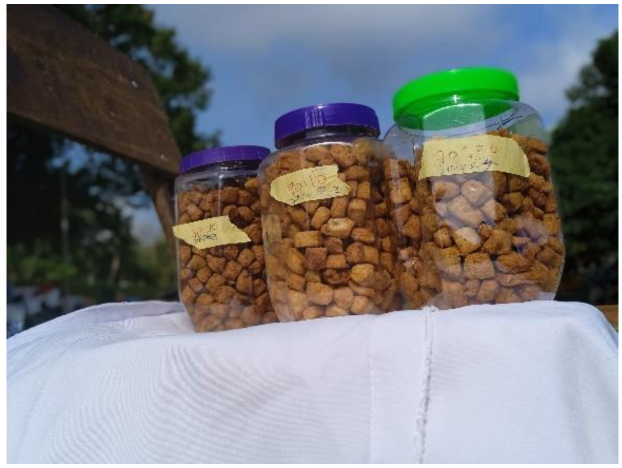

Plate 8. **Sample WCF2, WCF3 and WCF4**

Plate 9. Sample WCF1, WCF5 & WCF6

WCFs 1 = 100 % wheat flour: 0 % cauliflower flour. WCFs 2 = 90 % wheat flour: 10 % cauliflower flour. WCFs 3 = 80 % wheat flour: 20 % cauliflower flour. WCFs 4 = 70 % wheat flour: 30 % cauliflower flour. WCFs 5 = 60 % wheat flour: 40 % cauliflower flour. WCFs 6= 50 % wheat flour: 50 % cauliflower flour.

Flour blends

Weighing ingredients

↓

Mixing of ingredients

↓

Dough formation

↓

Kneading

↓

Rolling/cutting

↓

Deep frying

↓

Draining

↓

Cooling

↓

Chin-Chin

Packaging

Figure 2: Unit operation for chin-chin production

Source: Folorunso *et al.* (2018)

Sample Analysis

Functional properties of flour blends

The bulk density, water and oil absorption capacity were determined using different methods.

Bulk density

Bulk density was determined using standard methods (Ashraf *et al.,* 2012). Sample of 10g was measured into a 50 ml graduated measuring cylinder and gently tapped on the bench 10 times to attain a constant height. The volume of sample was recorded and expressed as grams per millilitre.

The bulk density (BD) of the sample was determined using the method described by Onwuka (2005). About 10 g of the sample (flour blends) were weighed into a 50ml graduated measuring cylinder. The sample was packed by gently the cylinder on the bench top 10 times from a height of 5 cm. The volume of the sample will be recorded.

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample}}{\text{weight of sample after tapping}}$$

(Equation 1)

Water absorption capacity (WAC)

The method described by Adebowale *et al.* (2012) was used for determining the water absorption capacity (WAC). Sample of 1g was weighed into clean pre-weighed dried centrifuge tube and mixed with 10 ml distilled water with occasional stirring for 1 h. The dispersion was centrifuged at 3000rpm for 15 min. After centrifuging, the supernatant was decanted and the tube with the sediment was weighed after removal of the adhering drops of water. The method described by Adebowale *et al.* (2012) was used for determining the water absorption capacity. Sample of 1g was weighed into a clean pre-weighed dried centrifuge tube and mixed with 10ml of distilled water with occasional stirring for 1 hour. The dispersion was centrifuged at 3000 rpm for 15 minutes. After centrifuging the supernatant was decanted and the tube with the sediment was weighed after removal of the adhering drops of water. The weight of water retained in the sample was calculated as:

$$\text{WAC} = \frac{\text{volume of water absorbed}}{\text{weight of sample used}} \times 100$$

(Equation 2)

Oil absorption capacity (OAC)

This is an index of the ability of food material to absorb oil which helps to improve the mouth feel and retains flavour. The method of Onwuka (2005) was used. One gram (1g) of the sample will be weighed in a 15ml centrifuge tube. The sample was mixed with 10 ml soybean oil and 10ml water respectively in a centrifuge tube and made to stand for at room temperature (30 ± 2°C) for 1 hour. It was centrifuged at 3000rpm for 30 minutes. The volume of free oil was then recorded and decanted. Fat absorption capacity was expressed as ml of oil bound by 100 g dried flour.

$$\text{OAC} = \frac{\text{Volume of oil absorbed}}{\text{weight of sample used}} \text{ X } 100$$

(Equation 3)

Proximate analysis

Proximate compositions of the freshly prepared enriched chin-chin samples were determined. The samples were analyzed for moisture, crude protein, ash content, crude fat, crude fibre, carbohydrate content based on the method of analysis of the Association of Official Analytical Chemists (AOAC 2010).

Moisture content determination

The moisture content of the samples was determined using hot air oven method of AOAC (2010). 5g of each of the sample was weighed into a previously washed, dried, cooled and weighed crucible. The dish with the sample was weighed and placed in a hot air oven at 105°C until constant weight was obtained. The samples were cooled in a desiccator and weighed. The moisture content was calculated using the formula:

$$\text{\% Moisture content} = \frac{W2-W3}{W2-W1} \text{ X } 100$$

(Equation 4)

Where:

W1 = Initial weight of empty crucible

W2 = Weight of crucible + sample before drying

W3 = Weight of crucible + sample after drying to a constant weight

Crude protein content determination

The crude protein content of the samples was determined according to the standard method of AOAC (2010), using Kjeldahl method.

Digestion: 2g of the sample was weighed into a Kjeldahl flask and four (4) Kjeldahl catalyst tablets was added to it. About 25ml concentrated sulphuric acid was added and the flask with its content was heated in a fume furnace cupboard until a clear solution was obtained. The solution was cooled to room temperature after which it was transferred into a 100ml volumetric flask and made up to mark with distilled water.

Distillation: The distillation unit was cleared and the apparatus set up. A 100ml conical flask (receiving flask) containing 5ml of 2% boric acid was placed under the condenser with the addition of a few drops of methyl red indicator. A digest of 5ml was pipetted into the apparatus through the small funnel, washed down with distilled water followed by the addition of 5ml of 60% sodium hydroxide (NaOH) solution. The digestion flask was heated until 100ml of distillate (ammonium sulphate) was collected in the receiving flask.

Titration: The solution in the receiving flask was titrated with 0.5M H_2SO_4 to a pink color end point. The titre value was noted down. A blank was also subjected to the same procedure.

Calculation:

$$\text{\% Nitrogen} = \frac{\text{T X N of acid (0.1) X 0.014007}}{\text{Weight of sample}} \text{ X } 100$$

(Equation 5)

Where:

T = titre value

% Protein = % Nitrogen ×6.25 (where 6.25 = protein conversion factor for milk and dairy product.

Crude Fat determination

The Soxhlet extraction method described by AOAC (2010) was used in determining fat content of the samples. The Soxhlet extractor with a reflux condenser and a 500ml round bottom flask was fixed. Two grams (2g) of the sample was accurately and placed inside an extraction thimble. The thimble was placed inside the Soxhlet extractor and the extraction flask was filled with 300ml of petroleum ether which was connected to the Soxhlet unit and then to the condenser. The assembled apparatus was allowed to reflux for about 6 hours, after which the thimble was dried at 105°C for 1 hour in an oven. The extracted oil was weighed and the percentage fat was calculated as:

$$\text{(\%) Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

(Equation 6)

Crude fibre determination

The crude fibre content of the samples was determined according to the standards of AOAC (2010). It was determined as the fraction remaining after digestion with standard sulphuric acid and sodium hydroxide. 2 g of the sample was hydrolyzed in a beaker containing 200ml of 1.25% of sulphuric acid and then boiled for 30 minutes. The mixture was filtered under vacuum and the residue was washed with hot distilled water for 3 times and then boiled again for 30 minutes with 200 ml of 1.25% of sodium hydroxide and filtered again. The digested sample was washed with hydrochloric acid to neutralize sodium hydroxide and then with hot distilled water for 3 times. The residue was taken into a crucible, dried at 100ºC for 2 hours in an oven, the sample was cooled in a desiccator and then weighed. The sample in the crucible was incinerated at 500ºC for 5 hours until all carbonaceous matter were burnt. Finally, the crucible containing the ash was cooled in the desiccator and weighed. The percentage crude fibre was calculated using the formula:

$$\% \text{ Crude fibre} = \frac{\text{Loss in weight after incineration}}{\text{Weight of sample}} \text{ X } 100$$

(Equation 7)

Ash content determination

A silica dish was heated at 600°C in a muffle furnace, cooled in a desiccator and weighed, using a digital balance. 2g of the sample was placed in a silica dish and then weighed. The dishes with the sample were transferred to the muffle furnace at 600°C and the samples was heated until a grey-white ash was obtained. The dish with the ash was cooled in the desiccator after ashing before weighing. Percentage ash was calculated using the expression:

$$\% \text{ Ash} = \frac{W3-W2}{W2-W1} \text{ X } 100$$

(Equation 8)

Where:

W1 = Weight of empty crucible

W2 = Weight of sample + crucible before ashing

W3 = Weight of sample + crucible after ashing

Carbohydrate determination

Carbohydrate content will be calculated by difference. It will be calculated using the equation below;

% Carbohydrate = 100 - % (moisture + protein + ash + fibre + fat) (Equation 9)

Mineral determination

The mineral composition of the samples was determined as described in the study of Ndife *et al.* (2014). A fraction of 0.5g of the sample was weighed into a digestion flask and 10 ml of nitric acid and 10 ml of HCl was added. The mixture was digested for 10 minutes in a micro kjeldahl flask. At the completion of digestion, the solution of each sample was transferred into a 50ml calibrated sample bottle and the solution was diluted to the mark with distilled water. Calcium (Ca), and Magnesium (Mg) in the samples were determined by flame atomic absorption spectrophotometer. Sodium (Na) and Potassium (K) in the samples were determined by flame photometer using a working standard of 10ppm for each of the samples.

Vitamin determination

Vitamin B_9 (Folate) content determination

Vitamin B_9 was determined according to the methods described by the Association of vitamin chemist. 2g of the sample was weighed into a 100 ml flask and 50 ml of 0.1N NaOH was added into the flask. The mixture was heated in a water bath at a temperature of 40ºc for 30 minutes. The solution was then filtered into a 100 ml flask and made up to the mark. 10 ml of the titrate was taken in a test tube. The reagent blank was prepared and folic acid standard was also prepared. The absorbance readings of both the standard and the sample were done at 265 nm wavelength and the concentration of the test sample calculated.

Microbial Analysis

The microbial analysis that was carried out was to determine the total viable count and mould count of the samples.

Determination of total viable count (TVC)

The total viable count test was carried out using the method of Prescott *et al.* (2005). One Ringer tablet was dissolved in distilled water (500ml). The clear solution formed was sterilized in the autoclave for 15 minutes at 121ºC. The Ringers solution was allowed and to cool completely to a temperature of about 28ºC. One gram (1g) of each sample was weighed and put in test tubes prepared for serial dilution. Ringer's solution (9ml) was added in all the test tubes having the samples and the mixtures was properly homogenized properly by shaking. Dilution of 10^{-2} was used for the total viable count determination. Then, 1ml of the diluents was transferred into sterile disposable petri dishes. Also, 20ml of the sterile nutrient agar was poured into each petri dish and swirled to mix properly. The mixtures were allowed to solidify and thereafter turned upside. They were cultured by incubating at the temperature of about 37ºC for 24 hours. At the end of the incubation period, the colonies were counted using the colony counter and was calculated using the colony counter. It was calculated as colony forming unit per gram (CFU/g of the samples). The average of the colonies from duplicates was determined.

CFU/100 g = average number of colonies x reciprocal of the dilution factor.

Determination of mould count

The mould count was determined using the method described by Prescott *et al.* (2005). The preparations of the reagents followed the same steps as stated in the determination of total viable count. The only difference is the agar that was used which is Sabourand Dextrose Agar used for media preparation for mould count determination. 1ml of each dilution (10^{-1}) was pipetted into duplicate petri dishes and then, 15 ml of SDA (Sabourand Dextrose Agar) was pipetted aseptically into the petri dishes. The petri dishes were swirled in order to mix the content thoroughly. It was allowed to solidify and turned upside down. The petri dishes were incubated for 48 hours at room temperature in the incubator. The mould count was expressed as Cfu/100 g (colony forming unit per gram) of the samples.

CFU/100 g = Average number of colonies x reciprocal of the dilution factor.

Sensory Evaluation

The chin-chin prepared from wheat flour and the cauliflower flour was subjected to sensory evaluation and this was done by coding all the samples and serving them to twenty (20) panelists that were familiar with the assessment of bakery products. The samples were evaluated for sensory parameters which are texture, taste, colour, flavour and general acceptability using the scoring text as described by Iwe (2002). The responses were scored on a nine-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely).

Data Analysis

All analysis was carried out in duplicates for all determinations and the results were expressed as mean of the duplicate determination. The SPSS 20.0 for windows computer software package was used for one way analysis of variance (ANOVA). The difference in means was compared by using the Duncan's multiple range tests at $p \leq 0.05$.

RESULTS AND DISCUSSION

Functional Properties of the Flour Blends

Table 4 presents the functional properties of Wheat-cauliflower composite flour. The functional properties are those parameters that determine the application and end use of food materials for various food products. It usually shows how the food materials under investigation will interact with other food components directly or indirectly affecting processing applications, food quality, and ultimate acceptance.

Bulk density

The result of bulk density (BD) is used to evaluate the flour heaviness, handling requirement, and the type of packaging materials suitable for the storage and transportation of food materials (Oppong *et al.,* 2015). The bulk density which varied from 0.63g/ml to 0.69g/ml decreased as the incorporation level of cauliflower flour increased. Bulk density of wheat flour (Sample WCF1) was higher (0.69g/ml) than that of composite flours (0.63g/ml-0.68g/ml). This parameter shows the heaviness of a particular flour sample. In food formulation, it is advisable to go for flour that has a low bulk density because the product derived from it has less retro gradation (Peter-Ikechukwu *et al.,* 2017). When formulating infant food, less bulk is preferable. On the contrary, higher bulk density is advantageous because it offers a greater packaging advantage making it possible for larger a quantity of flour to be packed within a constant volume. Bulk density is a function of particle size. There is an inverse relationship between particle size and bulk density (Adepeju *et al.,* 2015). There is no significant difference ($p > 0.05$) in the bulk density of the composite flours and the control sample.

Water absorption capacity (WAC)

The WAC of the chin-chin samples ranged from 90.46 %-329.13 % with sample WCF1 having the lowest WAC (90.46 %) and sample WCF6 having the highest WAC (326.13 %). This result is an indication that the increase in cauliflower flour contributed to the increase in water absorption capacity (WAC) of the composite samples. Apart from the control, there is no significant ($p>0.05$) difference between sample WCF2 to WCF4. WAC is important in foods where water will be absorbed without the dissolution of protein, thus increasing their viscosity and body thickening (Akinwale *et al.,* 2017), which in turn improves the reconstitution ability (Ajanaku *et al.,* 2012; Adebowale *et al.,* 2012). Though WAC is important, higher WAC will bind most of the free water and may take a longer time to achieve the desired crispness during chin-chin frying. Therefore, minimum WAC is required which is attainable with <10% inclusion levels of cauliflower flour.

Oil absorption capacity (OAC)

In food formulations, oil absorption indicates the rate at which protein binds to fat. This functional property refers to the physical entrapment of oils (Hanan, 2017). The result presented in Table 4 shows that the oil absorption capacity of the composite flours increased from 104 % (10 % cauliflower) to 151 % (50 % cauliflower) with an increase in the quantity of cauliflower flour in the composite flour. Sample WCF1 (100 % wheat flour) had the highest oil absorption capacity. The oil absorption capacity of Sample WCF3, WCF4 and WCF5 is not significantly different ($p > 0.05$). According to Peter-Ikechukwu *et al.* (2017), oil absorption capacity is a parameter to be considered in the preparation of baked foods, pancakes, ground analog, doughnuts, and soup. Retention of mouth-feels and flavor of food products is improved by the absorption of oil. The soft texture of chin-chin is a mark of quality usually improved by the oil retention capacity of flour used in preparing the product.

Table 4. Functional properties of wheat-cauliflower blends

SAMPLE	WAC (%)	OAC (%)	BD (g/ml)
WCF1	90.46^{a}±1.05	158.15^{b}±9.12	0.69^{a}±0.35
WCF2	137.38^{a}±14.46	104.57^{a}±26.35	0.68^{a}±0.03
WCF3	136.77^{a}±39.74	118.90^{ab}±14.00	0.63^{a}±0.01
WCF4	136.05^{a}±7.32	120.95^{ab}±9.26	0.65^{a}±0.04
WCF5	261.42^{b}±3.33	139.24^{ab}±27.21	0.68^{a}±0.05
WCF6	329.13^{c}±11.55	151.97^{b}±1.37	0.66^{a}±0.01

Values are means of duplicate determination ± standard deviation.

Means with different subscripts in the same column are significantly ($p<0.05$) different.

WCFs 1 = 100 % wheat flour: 0 % cauliflower flour (control). WCFs 2 = 90 % wheat flour: 10 % cauliflower flour. WCFs 3 = 80 % wheat flour: 20 % cauliflower flour. WCFs 4 = 70 % wheat flour: 30 % cauliflower. WCFs 5 = 60 % wheat flour: 40 % cauliflower flour. WCFs 6 = 50 % wheat flour: 50 % cauliflower flour.

Proximate Composition of Chin-Chin Made from Blends of Wheat and Cauliflower Flour

Table 5 shows the proximate composition of chin-chin samples made from wheat and cauliflower flour blends.

Moisture content

The values obtained for moisture content of the chin-chin samples ranged from 4.40 % to 11.54 % with sample WCF1 having the lowest moisture content and sample WCF6 have the highest moisture content. The moisture content of the chin-chin samples (5.69-11.54 %) increased significantly ($p < 0.05$) more than the control (4.40 %) with increase in cauliflower flour inclusion. This may be due to significant ($p < 0.05$) higher water absorption capacity of cauliflower flour than wheat flour which can be seen in Table 5. An increase in moisture content in crackers with an increase in cauliflower flour was also reported by El Sheikh *et al.* 2021). High moisture content has been associated with shorter shelf life and this implies that chin-chin samples with higher proportion of cauliflower flour will have a short shelf life relative to the control sample.

Protein

The values obtained for the protein content of the chin-chin samples were in the range of 8.59 % to 9.99 % for samples WCF2 with a low proportion of cauliflower flour (10 %) to sample WCF6 with a high proportion of cauliflower flour (50 %). Significant ($p < 0.05$) protein increase with the increase in cauliflower flour inclusion in the blend could be attributed to the high protein content of the cauliflower flour which tends to increase the protein content of the chin-chin. This is attested by higher protein content of sample WCF6 (50 % cauliflower) than WCF1 (100 % wheat flour). The protein increase could also be attributed to the inclusion of egg and milk into the chin-chin. Protein increase with increased cauliflower flour was also reported by El Sheikh *et al.,* (2021) with the -−incorporation of cauliflower in crackers. Chin-chin from 50 % cauliflower flour with high protein content could be of nutritional importance in most developing countries like Nigeria where many people can hardly afford high proteinous foods because of their high cost.

Fat

The fat content of the chin-chin samples ranged from 14.93 to 19.34 %. The lowest value was recorded by sample WCF1 (control), while the highest value was recorded by sample WCF6 (50 % cauliflower). There was an observed increase in the fat content of the chin-chin samples, this could be as a result of frying and also the inclusion of cauliflower flour at different levels. El Sheikh *et al.* (2021) reported an increase in the fat content of crackers as cauliflower flour increased. The varietal difference in the fat content of wheat and cauliflower may be another source of variation between the fat content of the chin-chin samples. Low-fat content in a dry product will help in increasing the shelf life of the sample by decreasing the chances of rancidity and also contribute to the low energy value of the food product while high-fat content product will have a high energy value and promote lipid oxidation. This implies a utilization of cauliflower at low levels and also the baking method in the production of chin-chin with low calories.

Fibre

The values obtained for the fiber content of the different chin-chin samples ranged from 0.50 % to 0.57 % with sample WCF6 having the highest value and sample WCF1 having the lowest value. There was no significant difference (p>0.05) between samples WCF1 to WCF5. The fibre content of the chin-chin samples increased with an increase in cauliflower. Hegazy and Ammar (2019) reported an increase in the fibre content of balady bread as the cauliflower stem flour increased. The increase in fiber content of the chin-chin samples could be improved with a higher level (<50 %) of cauliflower substitution. Consumption of high fiber food products has been linked to a reduction in hemorrhoids, diabetes, high blood pressure, and obesity (Chukwu *et al.,* 2013; Jaja & Yarhere, 2015).

Ash

The ash content indicates a rough estimation of the mineral content of the product. The ash content ranged from 0.80 % to 2.00 % in samples WCF1 and WCF6, respectively. Sample WCF1 and WCF2 had the lowest ash content while sample WCF6 had the highest ash content. The ash content of the blends increased as the inclusion level of cauliflower flour increased. There was a significant difference (p < 0.05) in the ash content of the chin-chin samples. The combined effect of the various flour blends produced chin-chin with higher ash content compared with the control sample WCF1 (100 % wheat flour). The ash content results of this study are at a variant with that of El Sheikh *et al.* (2021), who reported an increase with the increase in cauliflower flour inclusion in crackers.

Carbohydrate

The carbohydrate content (70.67–56.57 %) of the cauliflower-fortified chin-chin samples decreased as the substitution of cauliflower flour increased in the blend. Sample WCF1 (100 % wheat) had the highest carbohydrate content (70.67 %) while 50 % cauliflower-fortified chin-chin had the least carbohydrate content (56.57 %). This observation was in line with the study that also reported low levels of carbohydrate content in crackers from wheat and cauliflower flour blends. El Sheikh *et al.* (2021) reported a decrease of 69.98 – 61.80 % in the carbohydrate content of crackers produced from wheat and cauliflower flour blends. The low carbohydrate values showed that all samples cannot serve as energy sources.

Table 5. Proximate composition of chin-chin samples (%)

SAMPLE	MOISTURE	PROTEIN	FAT	FIBRE	ASH	CARBOHYDRATE
WCF1	4.40^{a}±0.14	8.71^{a}±0.10	14.93^{a}±0.40	0.50^{a}±0.00	0.80^{a}±0.00	70.67^{c}±0.45
WCF2	5.69^{b}±0.42	8.59^{a}±0.10	16.07^{ab}±1.41	0.51^{a}±0.01	0.80^{a}±0.00	68.34^{c}±1.08
WCF3	7.38^{c}±0.29	8.72^{a}±0.09	18.28^{bc}±1.20	0.52^{a}±0.01	0.89^{b}±0.00	64.23^{b}±1.58
WCF4	7.72^{c}±0.77	9.18^{b}±0.00	18.63^{c}±1.04	0.53^{a}±0.02	0.90^{b}±0.01	63.06^{b}±1.78
WCF5	10.72^{d}±0.40	9.40^{b}±0.30	19.22^{c} ±0.40	0.54^{ab}±0.05	1.59^{c}±0.00	58.55^{a}±0.28
WCF6	11.54^{d}±0.58	9.99^{c}±0.10	19.34^{c} ±1.10	0.57^{b}±0.01	2.00^{d}±0.01	56.57^{a}±0.42

Values are means of duplicate determination ± standard deviation.

Means with different subscripts in the same column are significantly (p<0.05) different.

WCFs 1 = 100 % wheat flour: 0 % cauliflower flour (control). WCFs 2 = 90 % wheat flour: 10 % cauliflower flour. WCFs 3 = 80 % wheat flour: 20 % cauliflower flour. WCFs 4 = 70 % wheat flour: 30 % cauliflower. WCFs 5 = 60 % wheat flour: 40 % cauliflower flour. WCFs 6 = 50 % wheat flour: 50 % cauliflower flour.

Micronutrient Content of Chin-Chin Samples from Wheat-Cauliflower Blends

Vitamin

The samples were not deficient in vitamins. However, there were significant differences in the ($p > 0.05$) in the vitamin values of the samples. Vitamin B9 and Vitamin K content of the chin-chin samples ranged from 0.00 – 0.05 µg/g and 0.15 –0.35mg/100g respectively. Sample WCF1 (100% wheat flour) had the lowest vitamin content while sample WCF6 had the highest value in vitamin B_9 and K (0.05 and 0.35µg/g). Chin-chin snacks containing higher quantity of cauliflower flour had higher values in vitamin B_9 and vitamin K. This was so because as cauliflower flour increased, the vitamin content increased. Vitamins are required for the proper functioning of the body systems to avoid disease conditions (Tadesse *et al.,* 2015).

Mineral

The mineral content of cauliflower flour has been reported by El Sheikh *et al.,* (2021). The mineral composition of chin-chin snacks is presented in Table 6.

The potassium and sodium content of the chin-chin samples ranged from 61.92 to 208.52 mg/100g) and 48.84 to 111.85mg/100g) respectively. The control sample had lower values compared to composite flour samples. Sample WCF6 had the highest potassium and sodium content (111.85mg/100g and 208.52mg/100g) while sample WCF1 had the lowest potassium and sodium content (61.92mg/100g) and (63.01mg/100g). The potassium and sodium content of the chin-chin samples with an increase in cauliflower flour levels. Higher potassium content (261.30 – 425.89 mg/100g) was reported by Olubukola *et al.* (2017) for chin-chin made from wheat flour enriched with pumpkin and spinach vegetables. This could be due to the fact that vegetable is known to have high potassium content (Hossain *et al.,* 2014). Chin-chin rich in these nutrients would enhance the health of both children and adults when consumed (Igbabul *et al.,* 2014). The magnesium content of the chin-chin samples was significantly different ($p<0.05$) and ranged from 14.35mg/100g (WCF2) – 18.42mg/100g (WCF5) with sample WCF2 being the lowest and sample WCF5 being the highest. The higher values obtained for composite flour chin-chin samples compared with the control (WCF1) showed that combining cauliflower flour with wheat flour enhanced the magnesium content of the snacks. Olubukola *et al.* (2017) reported an increase in magnesium with a range of 92.32 – 176.23 mg/100g for chin-chin made from wheat flour enriched with pumpkin and spinach vegetables. Magnesium is essential to good health because it helps to maintain normal muscle and nerve function, keeps heart rhythm steady, supports a healthy immune system and keeps bones strong. The result shows that the calcium content of the chin-chin ranged from 44.68mg/100 g to 64.28mg/100g. There was a significant difference ($p < 0.05$) in the calcium content of the chin-chin samples. Higher calcium was observed in chin-chin containing higher levels of cauliflower flour. Fasogbon *et al.* (2017) reported that the calcium content of 738.60-1262.60 mg/kg for chin-chin produced with wheat enriched with underutilized vegetables increased as the underutilized vegetables increased. El Sheikh *et al.* (2021) reported a high calcium content in cauliflower flour (136.42 %) compared to wheat flour (54.00 %). Calcium is necessary for supporting bone formation and growth.

Microbiological Status of Chin-Chin Produced from Wheat and Cauliflower Flour Blends

Results of the total viable counts (TBCs) of chin-chin samples are shown in Table 7. TVCs were

observed to range from 1.3x 10 – 2.7×10cfu/g. Samples substituted with cauliflower flour were observed to have lower TVCs than the control sample. This could be a result of how the cauliflower was handled during processing and its antimicrobial properties.

Table 6: Micronutrient composition of cauliflower

SAMPLE	VITB9 (µg/g)	VITK (mg/100g)	POTASSIUM (mg/100g)	SODIUM (mg/100g)	MAGNESIUM (mg/100g)	CALCIUM (mg/100g)
WCF1	$0.00^{a}\pm0.00$	$0.15^{a}\pm0.07$	$61.92^{a}\pm0.00$	$63.01^{a}\pm0.00$	$14.84^{b}\pm0.03$	$44.68^{a}\pm0.01$
WCF2	$0.02^{b}\pm0.01$	$0.27^{b}\pm0.00$	$101.77^{b}\pm1.00$	$63.84^{a}\pm4.84$	$14.35^{a}\pm0.06$	$46.31^{b}\pm0.01$
WCF3	$0.02^{b}\pm0.00$	$0.29^{bc}\pm0.01$	$148.74^{c}\pm2.01$	$64.59^{a}\pm2.23$	$15.94^{c}\pm0.04$	$49.60^{c}\pm0.59$
WCF4	$0.03^{bc}\pm0.01$	$0.33^{bc}\pm0.01$	$153.01^{c}\pm2.01$	$92.95^{b}\pm2.23$	$16.16^{d}\pm0.09$	$57.67^{d}\pm0.05$
WCF5	$0.04^{cd}\pm0.01$	$0.35^{bc}\pm0.01$	$157.60^{d}\pm3.02$	$102.40^{c}\pm2.23$	$17.22^{e}\pm0.04$	$61.36^{e}\pm0.11$
WCF6	$0.05^{d}\pm0.01$	$0.35^{c}\pm0.01$	$208.52^{e}\pm1.00$	$111.85^{d}\pm2.23$	$18.42^{f}\pm0.03$	$64.28^{f}\pm0.03$

Values are means of duplicate determination ± standard deviation.

Means with different subscripts in the same column are significantly ($p<0.05$) different.

WCFs 1 = 100 % wheat flour: 0% cauliflower flour (control). WCFs 2 = 90 % wheat flour: 10 % cauliflower flour. WCFs 3 = 80 % wheat flour: 20 % cauliflower flour. WCFs 4 = 70 % wheat flour: 30 % cauliflower. WCFs 5 = 60 % wheat flour: 40 % cauliflower flour. WCFs 6 = 50 % wheat flour: 50 % cauliflower flour.

Table 7: Microbial counts of chin-chin samples

SAMPLE	TVC (CFU/g)	MOULD (CFU/g)
WCF1	2.7 x 10	ND
WCF2	1.3 x 10	ND
WCF3	1.5 x 10	ND
WCF4	2.2 x 10	ND
WCF5	1.9 x 10	ND
WCF6	1.4 x 10	ND

WCFs 1 = 100 % wheat flour: 0 % cauliflower flour (control). WCFs 2 = 90 % wheat flour: 10 % cauliflower flour. WCFs 3= 80 % wheat flour: 20 % cauliflower flour. WCFs 4= 70 % wheat flour: 30 % cauliflower. WCFs 5= 60 % wheat flour: 40 % cauliflower flour. WCFs 6= 50 % wheat flour: 50 % cauliflower flour.

Sensory Evaluation of the Chinchin

The sensory scores of the chin-chin samples produced from wheat and cauliflower flour blends are presented in Table 8. Appearance is an important sensory attribute of any food because the eyes eat first before rejecting or accepting. For products like chin-chin, brown colour resulting from caramelized sugar during frying is desired. The values of appearance and colour ranged from 4.10-8.35 and 4.75-8.20 respectively with control sample (WCF1) as most preferred followed by sample WCF2 (10 % cauliflower), with 50 % cauliflower flour substitution as the least. Chin-chin substituted with cauliflower flour at different levels were significantly ($p < 0.05$) different. The scores for appearance and colour suggest that the higher the percentage of cauliflower flour, the lower the mean appearance and colour score of the chin-chin. Therefore, in both cases apart from the control sample, sample WCF2 (10 % cauliflower) had the highest value of 7.45 while sample WCF6 (50 % cauliflower) had the lowest values of 4.10 and 4.75 respectively. This might be attributed to the addition of cauliflower flour which resulted in colour darkening of the chin-chin. The low mean scores for appearance and colour of chin-chin substituted with cauliflower flour could also be due to the known popularity of the panelists with chin-chin prepared from wheat flour. Similar findings were also reported by Wordu and Akusu (2018) for wheat and fluted pumpkin flour blend chin-chin. The scores suggest that chin-chin substituted with up to 10 % cauliflower though, no significant difference ($p > 0.05$) between the two parameters for this sample, have some level of acceptable appearance and colour as the scores are above 6.00.

Texture is a major desirable quality of chin-chin as nobody desires soggy chin-chin which is regarded as spoilt. The texture of the chin-chin from the composite flour blends decreased (6.45-5.15) compared to sample WCF1 (8.55) with 100 % wheat flour. The low preference for texture (crispness) in chin-chin substituted with cauliflower flour as compared to 100 % wheat flour chin-chin may be due to moisture uptake by cauliflower flour. It has been reported that moisture uptake leads to loss of crispness of food products (Sengav *et al.,* 2015). This was evident in the least acceptability score of chin-chin from 40% cauliflower flour (5.00). A similar finding was also reported by Adebayo-Oyetoro, *et al.* (2017) for chin-chin made from wheat and tiger nut flour. The mean scores of texture of samples substituted with 10-20% cauliflower flour were above 6 suggesting that these samples may be acceptable.

Flavour and taste are the main criteria that decides product rejection or acceptability. In the flavor and taste sensory parameter, scores for flavor and taste of the chin-chin samples ranged from 3.90 to 8.00 and 3.70 to 7.95 respectively. There were significant differences (p<0.05) in both the flavor and taste attributes of the chin-chin. Apart from the control sample (WCF1), sample WCF2 (10 % cauliflower) had a high value for both flavor and taste (6.15 and 5.85) while sample WCF6 (50 % cauliflower) had the least value. The decrease in mean scores of flavor and taste observed as cauliflower flour substitution increased may be a result of the nutty flavor of cauliflower which may have altered the original taste of the chin-chin.

The aftertaste of the chin-chin samples ranged from 3.20 to 7.70 with the control sample (WCF1) as most preferred and the sample with 50 % cauliflower substitution (WCF6) as the least. Substitution of wheat flour with cauliflower flour significantly (p < 0.05) decreased the aftertaste of the chin-chin samples as the cauliflower increased.

Overall acceptability of chin-chin ranged from 3.55-8.50 with 100 % wheat flour chin-chin as the most preferred. This was followed closely by chin-chin substituted with 10 % cauliflower flour chin-chin. Sample substituted with 50 % cauliflower flour was least preferred. The control sample was significantly (p < 0.05) different from other samples. This study is in line with the findings of Deedam *et al.* (2020) who reported that control snack (chin-chin) made from 100 % wheat flour was most preferred followed by chin-chin made from 90 % wheat flour and 10 % cauliflower. The overall acceptability of the chin-chin was observed to decrease with an increase in the level of soursop flour substitution. This result agrees with the findings of Ajani, *et al.* (2012) who reported that increased levels of breadfruit flour in chin-chin resulted in a significant decrease in overall acceptability. On the basis of this observation, the substitution of cauliflower flour with wheat flour at the level of 10 % could be considered the best from sensory a point of view.

Table 8: Sensory evaluation of chin-chin samples

Sample parameters	A	B	C	D	E	F
Appearance	$8.35^{c} \pm 0.75$	$7.45^{c} \pm 0.89$	$5.15^{b} \pm 1.76$	$4.95^{ab} \pm 1.50$	$5.10^{b} \pm 1.77$	$4.10^{a} \pm 1.86$
Colour	$8.20^{c} \pm 0.89$	$7.45^{c} \pm 1.43$	$6.10^{b} \pm 1.94$	$5.95^{b} \pm 1.82$	$5.60^{ab} \pm 1.98$	$4.75^{a} \pm 2.29$
Texture	$8.55^{c} \pm 0.61$	$6.45^{b} \pm 1.85$	$6.60^{b} \pm 1.76$	$5.80^{ab} \pm 1.51$	$5.00^{a} \pm 2.08$	$5.15^{a} \pm 1.90$
Flavour	$8.00^{d} \pm 1.34$	$6.15^{c} \pm 1.76$	$5.60^{bc} \pm 2.04$	$4.70^{ab} \pm 1.84$	$4.45^{ab} \pm 1.79$	$3.90^{a} \pm 1.97$
Taste	$7.95^{c} \pm 1.19$	$5.85^{b} \pm 1.98$	$5.75^{b} \pm 1.74$	$5.20^{b} \pm 1.70$	$4.75^{ab} \pm 1.45$	$3.70^{a} \pm 1.98$
Aftertaste	$7.70^{d} \pm 1.30$	$6.40^{c} \pm 1.96$	$5.35^{bc} \pm 1.60$	$5.05^{b} \pm 1.60$	$4.80^{b} \pm 1.54$	$3.20^{a} \pm 2.02$
Mouthfeel	$7.65^{d} \pm 1.04$	$6.30^{c} \pm 2.08$	$5.95^{bc} \pm 1.64$	$5.35^{bc} \pm 1.87$	$4.80^{ab} \pm 1.77$	$4.10^{a} \pm 2.29$
Overall acceptability	$8.50^{d} \pm 0.61$	$6.55^{c} \pm 1.54$	$5.95^{bc} \pm 1.61$	$5.50^{b} \pm 1.73$	$5.00^{b} \pm 1.56$	$3.55^{a} \pm 1.93$

Values represent mean score ± SD of 20 panelist. Means with different subscripts in the same column are significantly (p<0.05) different.

WCFs 1 = 100 % wheat flour: 0 % cauliflower flour (control). WCFs 2 = 90 % wheat flour: 10 % cauliflower flour. WCFs 3 = 80 % wheat flour: 20 % cauliflower flour. WCFs 4 = 70 % wheat flour: 30 % cauliflower. WCFs 5 = 60 % wheat flour: 40 % cauliflower flour. WCFs 6 = 50 % wheat flour: 50 % cauliflower flour.

CONCLUSION

This study showed the potentials of utilizing cauliflower flour for the production of highly nutritious chin-chin. The substitution of wheat flour with cauliflower flour for the production of chin-chin significantly improved the nutritional composition in terms of proximate, mineral and vitamin compositions while carbohydrate content was observed to decrease. The chin-chin made from wheat and cauliflower flour blends has nutritional advantages over 100% wheat flour chin-chin because of its high ash, protein, crude fibre content yet low carbohydrate content. Sensory results showed that sensory attributes of chin-chin sample substituted with 10% cauliflower flour was preferred. Substitution of cauliflower flour with wheat flour at the level of 10% compared favourably with the control sample. Therefore, it could be suggested that acceptable chin-chin could be produced at 10% cauliflower substitution. This result therefore indicates that the use of cauliflower flour for the production of chin-chin would greatly enhance the utilization of this vegetable in Nigeria, and other developed countries where the vegetable has not been optimally utilized thereby creating awareness for the vegetable.

Authors' contribution

Amonyeze Ahunna Onyinyechi (AAO) designed the study; Aremu Kehinde Oludayo (AKO) performed the statistical analyses; Eze Chinazom Matilda (ECM) and Ocholi Simon Sani (OSS) wrote the protocol; AAO wrote the first draft of the manuscript; AKO managed the analyses of the study; AKO, OSS, ECM, AAO managed the literature researches; OSS edited the manuscript for final submission; All authors read and approved the final manuscript.

Conflict of interest

The authors declare that no conflict of interest exist

Authors' Declaration

The authors hereby declare that the work presented in this article is original and has neither been published nor under consideration for publication elsewhere.

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