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Proximate Composition, Sensory Properties and Microbial Quality of Chin-chin Developed from Wheat and African Walnut Flour Blends for Household Food Security

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Authors' contributions

The study was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objective: The objective of this study was to investigate the proximate composition, sensory properties and microbial quality of chin-chin developed from wheat and African walnut flour blends as a means of achieving household food security.
Methodology: African walnut was processed into flour. Chin-chin was prepared from blends of wheat and African walnut flours using 90:10, 80:20, 70:30, 60:40, 50:50 of wheat flour to African walnut flour (AWF), and 100% wheat flour as control. Samples were subjected to sensory evaluation within 30 min of production. Proximate analysis was carried out using standard methods. The samples were also stored for 3 weeks and evaluated at weekly intervals for total bacterial and fungal counts.
Results: Proximate composition of the chin-chin revealed a significant ($p<0.05$) increase in ash (0.42-1.38%), fat (34.39-40.03%), crude protein (5.53-7.95% protein), crude fibre (0.98-1.86%), and energy contents (402.65-414.08kcal) with a decrease in moisture (3.31-4.85%) and carbohydrate (45.59-53.84%). Sensory analysis of the chin-chin showed that the control chin-chin was more preferred than all other samples. This was followed closely by chin-chin substituted with

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10% African walnut flour having mean scores above 6 for all sensory attributes. Total bacterial counts (TBCs) and fungal counts (TFCs) of the chin-chin samples were observed to increase during storage. TBCs and TFCs of chin-chin samples after 3 weeks of storage ranged from 6.00×10^3-8.50×10^3cfu/g and 6.80×10^3-8.00×10^3cfu/g, respectively. The samples presented adequate microbiological conditions and were within recommended safe limit of microbial guidelines.

Conclusion: The findings of the study showed that chin-chin of acceptable sensory attributes and improved nutritional content could be produced with up to 10% African walnut flour (AWF) level. In effect, chin-chin substituted with African walnut flour can be consumed by households thereby improving their nutritional status and eradicating food insecurity and malnutrition which is common among households.

Keywords: Chin-chin; African walnut; proximate; sensory; microbial; household; food security.

1. INTRODUCTION

Food security and malnutrition are of critical concern in Nigeria and other developing countries especially among the poor and vulnerable rural farming households. According to China *et al*. [1], households are group of people living together in a common residence as consuming units in a physical environment. Most households in Nigeria are food insecure with prevalence of stunting, wasting and underweight at 42%, 9% and 25%, respectively [2]. The issue of food insecurity is a major developmental problem across the globe despite efforts made by government on ensuring that every household are provided with at least three square meal [3]. Household food security according to Abdulla [4] is defined as the capacity of households to have access to adequate food supply, on stable and in sustainable way. Household food security is one of the factors that predispose an individual to malnutrition and it is essential for adequate nutrition [5]. It is also the leading risk factor of malnutrition claiming approximately 300, 000 deaths each year due to inadequate food consumption and poor diet quality [6].

In Nigeria, there are some crops which are presently cultivated but are underexploited and underutilized due to lower production. Many of these crops are used for food and medicinal purposes, however, their uses are confined into the local production system although these crops are widely distributed around the globe. These plants are also known to contain various valuable nutritional components which can contribute to household food security [7]. At such, these underutilized crops can be incorporated into local food systems and bakery products which can ease malnutrition at the household level [8]. One of such underutilized crop is the African walnut.

African walnut (*Tetracapidium conorphorum*) is one of the underexploited and underutilized crops grown and consumed in the forest zones of Nigeria [9]. It is a woody perennial climber belonging to the family Euphobiacea with its common name as African walnut. The fruit is a capsule 6-10 cm long by 3-11 cm wide containing sub-globular seeds of 1-2.5 cm long with a thin brown shell [10]. The plant is cultivated mainly for their nuts which are cooked and consumed as snacks; however the successful utilization of African walnut for the production of bread, cookies and biscuits has been reported [11,12,13]. The nut is reported to contain 41.5% moisture, 4.28%fat, 21.65% protein, 7.34% crude fibre, 5.27% ash and 19.96% carbohydrate [14]. They have also been reported to be a rich source of mineral element such as calcium, magnesium, sodium, potassium and phosphorus [15]. Previous studies have also shown that the consumption of African walnut seeds increases protection against proliferous diseases, oxidative stress and endothelial dysfunction [16]. Olusanya [17] also reported African nut to contain significantly higher amounts of omega-3-fatty acids that may help in reducing the risk of cardiovascular diseases as compared to other nuts. However, despite the high nutritional value of African walnut, it is still included in the list of lesser known food crops [10].

Chin-chin is a traditional Nigerian snack which is consumed by children and adolescents and prepared primarily from wheat flour, butter, eggs and milk. The mixture is made into a stiff paste which is then deep fried until golden brown and crispy [18]. Wheat is the main raw material for the production of chin-chin, which is relatively of high cost due to the fact that wheat is not grown in Nigeria. There is therefore need to search for locally available raw materials which can be used in partial substitution with wheat for the production of chin-chin. In an attempt to achieve this and to improve the nutritional content of chin-chin, several researches have been carried out. Anozie *et al*. [19] produced chin-chin from *T. occidentalis* and *D. alata* while Akindele *et al*. [20] developed chin-chin enriched with ugu and Indian spinach vegetables. Partial replacement of wheat with millet flour for the development of chin-chin was also studied by Adegunwa *et al*. [21]. Results obtained from these studies showed an improvement in the nutrient content of chin-chin.To the authors' best knowledge, there is no work found on the use of African walnut for the development of chin-chin. Thus, utilization of African walnut for the production of chin-chin is feasible. This study is therefore aimed at producing chin-chin from wheat supplemented with African walnut flour blends as a means of achieving household food security and also evaluating its proximate composition, sensory and microbial properties.

2. MATERIALS AND METHODS

2.1 Materials

Fresh African walnuts were purchased from Fruit Garden Market at D-Line area Port Harcourt City, Rivers State, Nigeria. Refined wheat flour, whole wheat flour and other ingredients (i.e. margarine, eggs, roll oats, peanuts, brown sugar, wheat flour, olive oil and vanilla, milk, and vegetable oil) used in the granola and chin-chin production were purchased from Mile 3 Market Diobu, Port Harcourt. All reagents used for all analysis were of analytical grade.

2.2 Processing of African Walnut Flour

The flow chart for the processing of African walnut into flour is shown in Fig 1. African walnuts (*T. conophorum*) was washed thoroughly to remove any adhering contaminants, shells were removed by hand. The shelled walnuts were reduced into smaller sizes with the aid of stainless steel knives and then blanched at 100°C for 5 mins to maintain its colour and to prevent enzymatic reaction. The blanched walnuts were dried in a hot air oven at 60°C for 24 hrs to remove moisture, thereafter sliced and milled into flour using Nutri-Blender (BL487Q model). The milled nuts were passed through a US70 180µm diameter sieve and the flour obtained was stored in an airtight plastic polyethylene bag at of 37°C for further use.

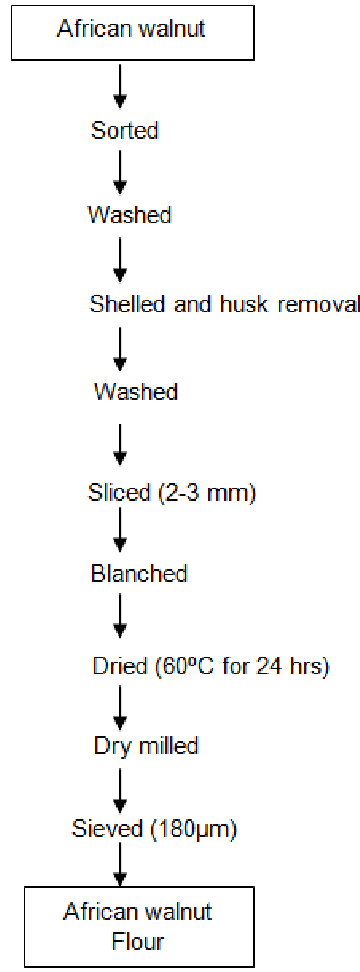

Fig. 1. Flow chart for the production of walnut flour

Source: [11]

2.3 Preparation of Chin-chin

The recipe used for the preparation of chin-chin is shown in Table 1 while the method described by Akindele *et al*. [20] was used. The ingredients except vegetable oil were mixed and rubbed together in a large bowl. The dough was placed on a flour surface and kneaded until smooth and elastic. The kneaded dough was then rolled out to appropriately 2 cm thickness and then cut into ¼ (2 cm by 2 cm) in size. Vegetable oil (500 ml) was poured into a deep fryer MC 1800 model and allowed to be hot enough. Thereafter, the cubes were poured into the hot oil and the chin-chin deep fried for 8 min until golden brown. The fried chin-chin was removed, drained off excess oil by placing a filter with serviette to absorb the oil, allowed to cool and then packaged for analysis.

Table 1. Ingredient formulation recipe for the preparation of wheat/African walnut flour blend chin-chin

Ingredients	Chin-chin samples					
	WCA	WCB	WCC	WCD	WCE	WCF
Refined Wheat flour (g)	100	90	80	70	60	50
Walnut flour (g)	-	10	20	30	40	50
Sugar (g)	40.00	40.00	40.00	40.00	40.00	40.00
Margarine (g)	25.00	25.00	25.00	25.00	25.00	25.00
Baking powder (g)	2.00	2.00	2.00	2.00	2.00	2.00
Nutmeg (g)	1.00	1.00	1.00	1.00	1.00	1.00
Eggs (Whole)	1	1	1	1	1	1
Milk (g)	15.00	15.00	15.00	15.00	15.00	15.00
Water (ml)	15.00	15.00	15.00	15.00	15.00	15.00
Salt (g)	0.5	0.5	0.5	0.5	0.5	0.5
Vegetable oil (L)	2.00	2.00	2.00	2.00	2.00	2.00

Source: [20]

2.4 Proximate Analysis and Energy Content of Chin-chin

Proximate analysis (moisture, ash, protein, fat and crude fibre) of the chin-chin samples was determined using the method of Association of Official Analytical Chemist [22]. Carbohydrate was calculated by difference of moisture, protein, fat, ash and crude fibre from 100%.

The energy content (E) was calculated using Atwater factor method as described by Adegunwa *et al.* [21].

E = (9 x Protein) + (4 x Fat) + (4 x Carbohydrate)

2.5 Sensory Analysis

The chin-chin samples were subjected to sensory evaluation 30 mins after preparation using a trained panel consisting of twenty members who are familiar with chin-chin. The panelists were asked to assess the chin-chin samples based on attributes of colour, crispness, texture, flavor, taste and overall acceptability. Sensory evaluation was conducted according to the ethical guidelines of the International Organization for Standardization [23]. The criteria for selection were also based on the panelists' knowledge of the products to be evaluated. Panelists ratings were based on a 9-point hedonic scale from 9 (like extremely) to 1 (dislike extremely) as described by Iwe [24].

2.6 Microbial Analysis

Microbiological examinations (bacterial and fungal counts) of the chin-chin samples were carried out using the method of Prescott *et al.* [25]. Chin-chin was crushed with the aid of a sterile ceramic mortar and pestle. The crushed sample was packaged in an airtight container, stored at room temperature (37°C) and analyzed for microbial analysis at weekly intervals for 3 weeks.

One (1.0 g) gram of the crushed sample was transferred into a 10 ml sterile normal saline, separately. The mixtures were shaken vigorously, and then 0.1 ml each mixture was inoculated on nutrient agar (Himedia Laboratories, India) plate and sabouraud dextrose agar (Himedia Laboratories, India) plate in duplicates using the spread plate method [25]. The inoculated nutrient agar plates were incubated 37°C for 24 h while the inoculated sabouraud dextrose agar plates were incubated at ambient temperature for 5 d. After incubation, counts of the ensuring colonies (expressed as cfu/g) on the NA and SDA plates were used to calculate the bacterial and fungal population respectively.

$$\text{Population (cfu/g)} = \frac{\text{Colonyx 10ml}}{\text{0.1ml x 1g}}$$

2.7 Statistical Analysis

All data obtained were analyzed in duplicate and subjected to the analysis of variance (ANOVA) using Statistical Package for Social Science (SPSS) version 23.0. Significant difference was defined at level of p<0.05 while sample means were separated using the Duncan multiple range test (DMRT).

3. RESUTS AND DISCUSSION

3.1 Proximate Composition and Energy Content of Chin-chin Produced from Wheat/African Walnut Flour Blends

The proximate composition and energy content of chin-chin produced from wheat and African walnut flour (AWF) blends is presented in Table 2. Moisture content for the chin-chin samples ranged between 3.14-4.85% with 100% wheat flour chin-chin having significantly ($p<0.05$) higher moisture content while chin-chin supplemented with 30% wheat flour was lowest. A decrease in the moisture content of the chin-chin as African wheat flour (AWF) was supplemented with walnut flour was observed. However, moisture content of chin-chin from wheat/African walnut flour blends were significantly ($p<0.05$) similar. As wheat flour was partially substituted with African walnut flour (AWF), it tended to bind moisture thereby decreasing the moisture content. This trend was also observed by Olanipekun *et al*. [12] for wheat/African walnut biscuits. Moisture content from the present study was within the range of 3.41-4.82% reported by Folola *et al*. [26] for wheat/cocoyam flour blend chin-chin. Moisture content below 10% is less likely to cause any adverse effect on the product. Moisture content of the chin-chin samples were below this range indicating that the products will be more shelf stable as products with lower moisture will store better [27].

The ash content of the chin-chin samples ranged between 0.42-1.29% with 100% wheat flour chin-chin having significantly ($p<0.05$) lower value while chin-chin supplemented with 50% AWF was highest but did not differ significantly ($p>0.05$) from chin-chin supplemented with 40% AWF. An increase in the ash content of the chin-chin samples as AWF substitution increase was observed and this is due to the substitution with walnut flour, implying increase in the quantity of minerals in the chin-chin samples. This trend was also observed by Almoraie [13] for wheat bread supplemented with walnut flour. Ash content of the composite flour chin-chin samples were higher than the range of 0.67-0.73% for chin-chin produced from broken rice flour [28].

Fat content of the chin-chin samples increased as substitution with African walnut flour increased from 34.39% in 100% wheat flour chin-chin to 40.03% in chin-chin supplemented with 50% AWF. Fat content of chin-chin supplemented with 40% AWF was significantly ($p<0.05$) different from all others while those supplemented with 10 and 20% AWF as well as the control sample were significantly ($p>0.05$) similar. Similar increase in the fat content was reported by Barber and Obinna-Echem [11] for cookies produced from wheat/African walnut flour (14.40-21.30%). This increase is in agreement with the reports of Edem *et al*. [14] that African walnut has high fat content. Kanu *et al*. [10] also added that African walnut seed are rich in fat, nearly 80% of polyunsaturated fats and omega 3 essential fatty acids implying that chin-chin substituted with walnut flour could be of vital importance in supplying the body with this essential fatty acids.

Protein content of the chin-chin samples also increased significantly ($p<0.05$) as substitution with AWF increased from 5.53% in 100% wheat flour chin-chin to 7.95% in chin-chin substituted with 50% AWF. Similar increase was also reported by Olanipekun *et al*. [12] for wheat/African walnut flour blends (10.34-18.44%). This increase could be due to high protein content of walnut flour (35.22%) as reported by Edem *et al*. [14]. The observed increase in the protein content of the chin-chin samples is an indication that African walnut is a good source of protein. Protein content from this study is comparable with the range of 5.10-6.82% for cuts and strips of chin-chin produced from *T. occidentalis* and *D. alata* as reported by Anozie *et al*. [19].

Crude fibre content ranged from 0.98-1.86% with 100% wheat flour chin-chin as lowest and chin-chin substituted with 50% AWF as highest but not significantly ($p>0.05$) different from chin-chin with 40% AWF substitution. An increase in the crude fibre content was observed as substitution with AWF increased. This increase is due to the substitution with African walnut flour. This trend was also observed by Almoraie [13] for wheat/African walnut flour blend bread (1.27-9.13%). This suggested that African walnut contributed more fibre to the chin-chin samples which will further help to prevent constipation and bowel problems.

Carbohydrate content of the chin-chin samples decreased from 53.84-45.59% as the substitution of AWF increased. The 100% wheat based chin-chin had the highest but not significantly ($p>0.05$) different from chin-chin supplemented with 10 and 20% AWF while chin-chin with 50% AWF was lowest. The decrease may be attributed to the low carbohydrate content of African walnut (19.96%) as reported by Edem *et al*. [14]. Similar decrease was also reported by Barber and Obinna-Echem [11] for wheat/African walnut flour blend cookies (60.9-53.6%) as African walnut flour substitution increased.

Table 2. Proximate composition and energy content of chin-chin produced from wheat/African walnut flour blends

Samples	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Crude fibre (%)	CHO (%)	Energy (kcal)
WCA	4.85±0.01^{a}	0.42±0.03^{c}	34.39±1.55^{c}	5.53±0.35^{c}	0.98±0.00^{c}	53.84±1.92^{a}	402.65±1.71^{c}
WCB	3.33±0.32^{b}	0.87±0.01^{b}	35.25±0.22^{c}	6.58±0.00^{b}	1.23±0.02^{bc}	52.76±0.06^{a}	411.22±1.13^{ab}
WCC	3.50±0.04^{b}	0.83±0.18^{b}	35.05±0.07^{c}	6.15±0.00^{bc}	1.41±0.22b	53.07±0.01^{a}	407.81±0.31^{b}
WCD	3.14±0.01^{b}	0.93±0.06^{b}	38.30±0.16^{b}	7.08±0.61^{b}	1.27±0.02^{bc}	49.29±0.40^{b}	414.08±3.27^{a}
WCE	3.34±0.01^{b}	1.38±0.00^{a}	38.08±0.00^{b}	7.25±0.00^{ab}	1.80±0.23^{a}	48.16±0.24^{b}	410.21±0.96^{ab}
WCF	3.31±0.36^{b}	1.29±0.12^{a}	40.03±0.23^{a}	7.95±0.00^{a}	1.86±0.01^{a}	45.59±0.02^{c}	414.01±0.99^{a}

Values are represented as mean ± standard deviation of duplicate samples. Mean values bearing different superscript in the same column differ significantly (p<0.05).

Key: WCA= wheat flour (100%), WCB=wheat/walnut flour (90:10), WCC=wheat/walnut flour (80:20), WCD=wheat/walnut flour (70:30), WCE=wheat/walnut flour (60:40), WCF=wheat/walnut (50:50)

Energy content of the chin-chin samples increased upon substitution with AWF with values ranging from 402.65kcal in 100% wheat flour chin-chin to 414.08kcal in chin-chin substituted with 30% AWF. The increase in energy values as AWF substitution increased is due to increase in fat content on substitution with African walnut flour. Samples substituted with 50% and 30% AWF were significantly (p<0.05) similar.

3.2 Sensory Evaluation of Chin-chin Produced from Wheat/African Walnut Flour Blends

The mean sensory scores of chin-chin produced from wheat/African walnut flour blends is shown in Table 3. From the table, it could be observed that increase in the substitution of wheat with African walnut flour (AWF) resulted to a decrease in the sensory scores for colour, crispness, texture, flavor, texture and overall acceptability. The 100% wheat flour chin-chin was more preferred than all other samples. This was followed closely by chin-chin substituted with 10% African walnut flour (Sample WCB). The decrease in taste and flavour of the chin-chin samples on substitution with AWF could be attributed to the bitter taste of some inherent compounds in African walnut. Similar decrease was also reported by Almoraie [13] for wheat bread substituted with walnut flour. Barber and Obinna-Echem [11] also reported a decrease in the likeness of cookies prepared from wheat and African walnut as substitution with walnut flour increased. Despite the decrease in sensory acceptability of the chin-chin from this study, the mean scores of all sensory attributes of sample substituted with 10% African walnut flour was above 6 suggesting that the sample may be acceptable. This also suggests that the panelists still preferred AWF substitution of up to 10% level for all sensory attributes.

3.3 Microbial Evaluation of Chin-chin Produced from Wheat/African Walnut Flour Blends

3.3.1 Total bacterial counts of chin-chin

The total bacterial counts (TBCs) of chin-chin produced from wheat/African walnut flour blends are presented in Table 4. TBCs of the chin-chin samples at week 0 recorded no growth while at week 1, all the samples had counts of 1.0×10^2 cfu/g. At week 2 and 3, there was an increase in mould count of the chin-chin samples with values ranging from 4.5×10^2-9.00×10^2 cfu/g

Table 3. Mean sensory scores of chin-chin produced from wheat/African walnut flour blends

Samples	Colour	Crispness	Texture	Flavour	Taste	Overall Acceptability
WCA	7.45^{a}	7.20^{a}	7.50^{a}	7.25^{a}	7.50^{a}	7.42^{a}
WCB	6.50^{ab}	7.15^{ab}	7.15^{ab}	7.15^{ab}	6.80^{ab}	6.95^{ab}
WCC	5.95^{bc}	6.65^{bc}	6.45^{bc}	5.70^{bc}	5.90^{b}	6.13^{bc}
WCD	5.30^{bcd}	5.70^{c}	6.05^{bc}	5.50^{bc}	6.50^{b}	5.93^{bc}
WCE	4.45^{cd}	5.80^{c}	5.80^{bc}	6.00^{b}	6.00^{b}	5.65^{cd}
WCF	3.80^{d}	5.50^{c}	5.25^{c}	4.70^{c}	4.25^{c}	4.61^{d}

Means with different superscript in the same columns differ significantly (p<0.05)

Key: WCA = wheat flour 100%, WCB = wheat/ walnut flour (90:10%), WCC = wheat/ walnut flour (80:20%) WCD =wheat flour/ walnut (70:30%), WCE = wheat flour/walnut flour (60:40%), WCF = wheat flour/walnut flour (50:50%)

and 6.00×10^3-8.50×10^3 cfu/g, respectively. Samples substituted with African walnut flour had higher TBCs than the control sample. This is due to the incorporation of African walnut flour which may have encouraged the microbial action. The high TBCs in samples substituted with African walnut flour is also due to the fact that increases in protein content of the samples incorporated with African walnut flour encourages the microbial action. This finding was supported by Omachi and Yusufu [29] who reported increased in the level of microbial contamination to be due to increased level of proteins and fats. According to Adams and Moss [30], spoilage organisms grow faster in medium that is highly nutritious. Despite the increase in total bacterial counts, these counts were within the microbial limit of 10^4-10^6 cfu/g for ready to eat food product [31].

Table 4. Total bacterial counts (cfu/g)of chin-chin Produced from wheat/African walnut flour blends

Samples	Storage period (Weeks)			
	1	2	3	4
WCA	NG	1.00×10^2	4.50×10^2	6.00×10^3
WCB	NG	1.00×10^2	4.38×10^2	8.50×10^3
WCC	NG	1.00×10^2	5.00×10^2	7.15×10^3
WCD	NG	1.00×10^2	6.00×10^2	7.30×10^3
WCE	NG	1.00×10^2	6.50×10^2	7.38×10^3
WCF	NG	1.00×10^2	9.00×10^2	8.50×10^3

Key: Cfu/g = colony forming units per gram, NG= No growth detected, WCA= Wheat flour 100%, WCB= Wheat/walnut flour (90:10%), WCC=Wheat/walnut (80:20%), WCD=Wheat/walnut flour (70:30%), WCE=Wheat/walnut flour (60:40%), WCF=Wheat/walnut flour (50:50%)

3.3.2 Total fungal counts of chin-chin

Total fungal counts (TFCs) of the chin-chin samples at week 0 recorded no growth. At week 1, all the samples had TFCs ranging from no growth in control sample to 4.0×10^2 cfu/g in chin-chin substituted with 50% AWF. At week 2 and 3, there was an increase in the TFCs with values ranging from 4.8×10^2-6.50×10^2 cfu/g and 6.0×10^3-8.00×10^3 cfu/g, respectively. Similarly, TFCs of the chin-chin samples were also observed to increase as substitution levels with African walnut flour increased. This increase is also due to an increase in protein content as result of incorporation of African walnut flour. Similar increase was also reported by Noah [32] for biscuits produced from wheat-coconut-almond flour blends. TFCs of the chin-chin samples after 3 weeks of storage were within acceptable statutory limits of $<10^4$cfu/g of ready to eat food products [31], suggesting that the chin-chin samples prepared at all levels of African walnut flour substitution has a good shelf-life up to 3 weeks of storage.

Table 5. Total fungal counts (cfu/g) of chin-chin produced from wheat/African walnut flour blends

Samples	Storage period (Weeks)			
	1	2	3	4
WCA	NG	NG	4.80×10^2	6.80×10^3
WCB	NG	3.00×10	6.80×10^2	7.00×10^3
WCC	NG	3.00×10	5.00×10^2	6.00×10^3
WCD	NG	4.00×10	5.00×10^2	8.00×10^3
WCE	NG	4.00×10^2	6.50×10^2	7.00×10^3
WCF	NG	4.00×10^2	6.00×10^2	7.00×10^3

Key: Cfu/g = colony forming units per gram, NG= No growth detected, WCA= Wheat flour 100%, WCB= Wheat/walnut flour (90:10%), WCC=Wheat/walnut (80:20%), WCD=Wheat/walnut flour (70:30%), WCE=Wheat/walnut flour (60:40%), WCF=Wheat/walnut flour (50:50%)

4. CONCLUSION

This study has revealed that the substitution of African walnut flour to wheat flour up to 50% for the production of chin-chin significantly improves the protein, fat, crude fibre and ash content. Hence, African walnut flour can be used in improving the nutritional status of households who are regular consumers of chin-chin. Microbial analyses of chin-chin throughout the storage period are within the acceptable microbial limit for ready to eat food product according to the International Commission for Microbiological Specification for foods. Chin-chin of acceptable sensory attributes could be produced with up to 10% African walnut flour (AWF) level. This would promote utilization of under-utilized crop such as African walnut and contribute to eradicating household food insecurity and malnutrition which are a critical concern in Nigeria and other developing countries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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