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Research article

Evaluation of nutritional properties of cassava-legumes snacks for domestic consumption—Consumer acceptance and willingness to pay in Zambia

Emmanuel Oladeji Alamu[1,*], Busie Maziya-Dixon[2], Bukola Olaniyan[2], Ntawuruhunga Pheneas[1] and David Chikoye[1]

[1] International Institute of Tropical Agriculture, Southern Africa, Research and Administration Hub (SARAH) Campus PO Box 310142, Chelstone, Lusaka 10101, Zambia
[2] International Institute of Tropical Agriculture, PMB 5230, Ibadan, Oyo State, Nigeria

* **Correspondence:** Email: o.alamu@cgiar.org; Tel: +260976338710.

Abstract: High-quality cassava flour (HQCF) is a cheaper alternative to wheat in the production of snacks. This study assessed the nutritional properties and consumer acceptability of cassava-legume snacks in Zambia. Cassava snacks were made from 100% HQCF, 50:50 cassava-soybean flour blend, 50:50 cassava-cowpea flour blend and 100% wheat flour as the control. The samples were analyzed for nutritional, functional and anti-nutritional properties using standard laboratory methods. Also, a well-outlined questionnaire was used to collect data on consumer preferences. The results showed a significant ($P < 0.05$) effect of product type on all the proximate components except starch that had no significant effect ($P < 0.05$). There was a significant ($P < 0.05$) increase in ash, protein and fat contents but a decrease in total sugars, amylose and starch contents of the legume-fortified snacks when compared with 100% cassava snacks. Cassava-legume snacks had a high acceptance in Kasama, Kaoma and Mansa districts, with a better preference for the cowpea variant of tidbit. There was a positive linear relationship between snack sensory characteristics (aroma, taste and texture) and consumer willingness-to-pay (WTP). The results show that snacks that are acceptable, affordable, nutritious and of excellent preference characteristics can be produced from cassava and legumes for households in Zambia.

Keywords: cassava flour; snacks; proximate composition; consumer preference; willingness-to-pay

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a widely grown drought-tolerant crop that can be cultivated on marginal soils and produce high yields in unfavourable growing conditions [1]. It is the most essential vegetatively propagated food staple in Africa and a prominent industrial crop in Latin America and Asia [2]. It is cultivated as a subsistence crop in developing countries across the world estimated to feed between 500 and 1,000 million people [3]. Its popularity is second to none in sub-Saharan Africa and the South-West Indian Ocean islands (SWIO) [4], where it has become the major staple food crop constituting the central part of the diet of traditional households. The world cassava production was estimated to be 277 million tonnes (fresh root equivalent); this has been projected to rise by half a per cent in 2018 [5]. So far, cassava has held the status of one of the fastest expanding staple crops at the global level that has recorded two decades of uninterrupted growth of more than 3% per annum.

In Zambia, cassava is the second most-consumed staple food crop after maize [6]. Before now, it was considered a backward crop, traditional foodstuff grown by women for subsistence [7]. The importance of cassava has become more prominent in recent years due to the increase in population and the drought susceptibility of maize brought about by climate change [8]. It accounts for roughly 15% of national calorie consumption and is mostly grown in the five provinces—Luapula, Northern, North-Western, Copperbelt and Western—where it is regarded as a staple [9]. In recent years, cassava production has expanded to the southern and eastern parts of the country [10] because cassava cuttings were being distributed to households as part of efforts to actualize food security in the southern part of Zambia. To combat the vulnerability of maize to adverse climatic conditions, Zambia introduced new and improved cassava varieties. It was reported that these varieties are often consumed as '*nshima*' (cassava flour alone or a mixture of cassava and maize meal, called *maize-cassava nshima*), or dried and roasted as snacks [11]. In the nineties, cassava was not a popular food crop because of its poisoning effect observed after consumption. Hence, different processing methods were adopted to reduce the toxic substance—cyanide. The most common processing methods in Zambia are "bwabi", "kasabe" and "kapesula". The kapesula method involves the peeling, drying, soaking and re-drying of the roots, which ensures a longer shelf life for chips/flour [11]. In addition to cassava "*nshima*", the cassava is also processed into dried chips or flour to reduce prevailing postharvest losses [12]. Again, the flour is used in the production of confectioneries, a step in the direction to increase cassava consumption [11,12]. Varieties usually used for flour include Nakamoya, Nalumino and Mupulanga, the latter being preferred for its plain white flour [13].

Cassava flour has been successfully used as a substitute for wheat (*Triticum aestivum* L.) all over the world in the production of biscuits and confectioneries. In Indonesia, a survey conducted in West and East Java in 2001 showed that 84% of respondents accepted cassava flour in the production of traditional dishes, cookies, cakes and noodles with substitution ranging from 20 to 100% [14]. In Egypt, partial substitution of wheat flour by cassava flour at 20 and 30% levels resulted in good quality bread like that obtained from wheat flour, although with the addition of 1% malt [15]. Sanful & Darko [16] reported the substitution of wheat flour with cassava and cocoyam flour up to 30% to produce rock cake as acceptable in Ghana. In West Africa generally, especially in Nigeria, bread made with 10 to 20% substitution levels of wheat flour with cassava flour has overall acceptability like 100% wheat bread [17]. Furthermore, bread made with the composite of cassava, wheat and maize flour has been reported with the cassava flour as high as 20 to 40% [18]. Also, in the production of cookies or biscuits, 100% cassava flour, composite with wheat or the incorporation of legumes such as cowpea or soybean as improvers have been reported to enjoy high acceptability and can favourably compete with wheat cookies/biscuits [19].

Over the years, leguminous grains like cowpea [*Vigna unguiculata* (L.) Walp.] and soybean [*Glycine max* (L.) Merr.], which contain a considerable amount of proteins and minerals, have been in use as fortificants or improvers in cassava-based products [19,20]. Research has shown that cassava flour alone does not contain the protein, fat, and essential amino acids the body needs for healthy growth and stay [21]. Hence, cassava flour products are usually fortified with legumes to increase their nutrient load. Cowpea and soybean are cultivated as an integral part of the traditional cropping system in Zambia [22]. As such, they are in abundance and increase food availability and food access, which results in increased income [23]. These legumes are grown across the country, with cowpea production concentrated in Northern and Southern provinces and soybeans in the Central province [24]. They are known to be productive and yet inexpensive sources of protein and have been found to offer several health benefits due to their dietary fibre and isoflavonoid content [25].

Chin-chin and tidbits are snacks popular in West Africa. While chin-chin is originally made with wheat flour, tidbits is a relatively new recipe developed from cassava flour and cowpea or soy paste mixed in equal proportions [20]. Bread, cookies and confectioneries have been successfully produced using 100% cassava flour with good acceptability [20]. The increasing rate of urbanization has given rise to the consumption of convenient foods known as "snacks" [26,27]. Snacks are a small portion of food consumed in between traditional meals such as breakfast, lunch and dinner [28]. Snacking could be a habit of both the young and old because it supplies the quick calories needed at some point during an active day, or it is just eaten for pleasure [27,29]. In a view to enforcing consumption standards, some countries have policy interventions to promote the consumption of healthy snack and guide against what could be detrimental to people's health [30].

A similar study to the current study was conducted by Maziya-Dixon et al. [31] in DR Congo, in which legumes and cassava showed the potential to alleviate protein malnutrition. Cassava and legumes are also considered as significant ingredients in the snack food sector both as partial substitutes for wheat flour and as a basis for new product development in the snack food industry. Alamu et al. [11] reported a low consumption of cassava-based snacks in Zambia in comparison with other staples and their derivatives. According to the Zambia Agriculture Status Report 2018 [32], low dietary diversity is a significant drive-in food and nutrition challenge in the country, giving rise to a gap which cassava production, promotion and product diversification can bridge. Thus, this research work aimed to evaluate the level of acceptance of cassava-based snacks (chin-chin and tidbits) by Zambians and their preference for legumes used for fortification in snacks.

2. Materials and methods

2.1. Materials

Fresh cassava roots were obtained from the IITA office in Lusaka, Zambia while the soybean and cowpea grains were purchased from a local market in Lusaka, Zambia.

2.2. Processing of fresh cassava roots, soybean and cowpea into flours

The cassava roots were processed immediately on arrival at the laboratory, according to the method described by Alamu et al. [11]. The cassava roots were washed, peeled, grated or chopped into slices or chips then sun-dried in a screen house to avoid contamination from the dust. The processes were completed within 24 hrs after harvesting to obtain high-quality cassava flour (HQCF). The soybean and cowpea flours were prepared using the methods described by Alamu et al. [33]. The legume grains were cleaned and sorted to remove stones and other impurities. The cowpea seeds were soaked in water and dehulled before drying. However, the cleaned soybean seeds were roasted slightly under low heat until the seed coat could be removed by hand. The roasted seeds were then coarse-milled and winnowed to remove the seed coat. The dried cassava chips, the dried and dehulled cowpea, and the decorticated soybean were finely milled to 0.5 mm particle size using a laboratory mill (Perten, Hägersten, Sweden) to obtain fine flour. The flours were packaged and appropriately stored before using to make the products. The 20% level of substitution was chosen because past studies have shown that legumes can be used to supplement cereals at this level without off-flavour [33].

2.3. Preparation of wheat and cassava chin-chin

Table 1. Ingredients and quantities for chin-chin.

Ingredients	Product type and quantity	
	Chin-chin (100% wheat) 201	Chin-chin (100% HQCF) 202
Wheat flour	599.18 g	0
HQCF	0	503.03 g
Sugar	124.60 g	124.60 g
Baking powder	11.40 g	11.40 g
Butter	60.0 g	60.0 g
Eggs	158 g	158 g
Nutmeg	7.5 g	7.5 g
Water	153.53 g	407.98 g

Table 1 contains the recipes of the products. Wheat flour, eggs, margarine, sugar, baking powder and nutmeg were mixed in a bowl before the gradual addition of water at room temperature to form a dough. About 125.7 g (1/4) of cassava flour was added to 210 g of water heated at 95 ℃ and mixed vigorously to form a viscous and smooth paste. The pre-cooked cassava flour was mixed with the remaining flour (377.3 g, the remaining 3/4) containing all other ingredients to form a dough. After proper kneading, the dough was rolled and cut into small rectangular shapes using a stainless-steel knife, then deep-fried in 1 litre of vegetable oil at a temperature between 170 ℃ and 175 ℃ until golden brown.

The colour of the fried product changed from cream to a golden brown, which depicts the completion of Maillard's reaction, which takes an average time of 7 mins and 5.5 mins for cassava chin-chin and wheat chin-chin, respectively. There was also a noticeable texture change from soft (compressible) to hard (crunchy) when cold.

2.4. Preparation of tid-bits

The formulations for tidbits are shown in Table 2. To begin with, 200 g cowpea and 200 g of soybean seeds were soaked for 10 minutes in 800 g of water to make the seed coat easy to remove. The dehulled portion was blended with one fresh medium-sized onion (approximately 50 g) using a warring blender. The blended cowpea and soy pastes were mixed thoroughly with cassava flour to form a soft, non-sticky dough with minimal salt added to obtain a savoury taste. The dough was scooped into an extruder and extruded into a deep fryer containing 4 litres of vegetable oil at a temperature of 170 ℃–175 ℃. The average frying time was 3.75 minutes for cowpea tidbits and 3.25 minutes for soy tidbits; the golden-brown colour depicts the completion of Maillard's reaction. The weight of the extrudates varied from 2.80 g and 4.20 g before frying to a range of 1.70 g to 2.70 g after frying for the cowpea variant. The soy extrudate weighed between 2.90 g to 4.90 g before frying and 1.60 g to 3.40 g after frying. The reduction in weight was due to moisture loss during frying.

Table 2. Ingredients and quantities for tidbits.

Ingredients	Product and quantity	
	Tidbit (cowpea)	Tidbit (soybean)
	301	302
Bean paste	627 g	0
Soybean paste	0	613.5 g
HQCF	355 g	400 g
Salt	2.9 g	4.6 g
Onion-bulb	50.5 g	50.5 g
Baking powder	0.9 g	0.9 g

2.5. Physicochemical and anti-nutritional components

The chin-chin and tidbits were analyzed for moisture, protein, fat, ash, total reducing sugars, digestible starch, amylose, phytate, tannins, pH, and bulk density.

Moisture content determination: The milled samples (5 g) in duplicate were used for the determination of moisture content by weighing in crucibles and drying in an oven at 105 ℃ for 24 hrs in a draft air Fisher Scientific Isotemp® Oven model 655F [32]. Ash content was determined by burning off moisture and all organic constituents in a furnace at 600 ℃ for 6hrs in a VULCAN™ furnace model 3-1750. The weight of the residue after incineration was recorded as the ash content [32].

Protein content determination: The Kjeldahl method [32] was used to determine the protein content by the multiplication of the nitrogen value with a conversion factor of 6.25 as described by Alamu et al. [33].

Crude fat content determination: This was determined using the Soxhlet extraction method [32]. Crude fat was extracted from the sample with hexane, and the solvent evaporated off to get the fat. The difference between the initial and final weights of the extraction cup was recorded as the crude fat content [32].

Digestible starch and total reducing sugar content determination: Digestible starch and total reducing sugar were determined using the method of Dubois et al. [34] as reported by Alamu et al. [33]. This involved the extraction of starch and free sugar from the samples with 95% ethanol, and the hydrolysis of the starch residue to sugars with perchloric acid. The sugar obtained after hydrolysis was converted to starch by multiplying by 0.9. The absorbance of both starch and sugar was read at 490 nm.

Amylose content determination: Amylose content was determined using the method reported by Alamu et al. [33] as described by Williams et al. [35]. This is a spectrophotometric method based on the formation of a deep blue - colored complex with iodine; the absorbance was read at 620 nm.

Determination of phytic acid content: Phytate was determined by the extraction and precipitation of phytic acid according to the method of Wheeler and Ferrel [36] as described by Okukpe & Adeloye [37].

Tannin content determination: Tannins were determined by the method described by da Silva Lins et al. [38]. The reaction is based on phosphotungstomolybdic acid reduced by tannin-like compounds in an alkaline solution producing a highly coloured blue solution which is measured at 760 nm.

pH determination: This was done using 10 g of pulverized chin-chin and tidbits dispersed in 20 ml of deionized water to detect the pH of the suspension using a table-top pH meter.

Bulk density determination: Bulk density was determined using the method recommended by AOAC [39]. The sample (7 g) was placed into a 50 ml graduated measuring cylinder and then tapped gently against the palm until a constant volume was obtained.

2.6. Consumer preferences

The survey was conducted in three camps per district in each of the four major cassava-growing districts (Kaoma, Kasama, Mansa and Serenje). The areas were selected based on consumption levels and accessibility. Thirty-five respondents per camp were randomly selected to give a total of 105 respondents and 430 respondents for the whole survey. The data was collected using a well-structured questionnaire which was administered to each respondent with the help of well-trained enumerators. They were well informed about the study, and each respondent consented. The cassava-based products were well coded to avoid positional error and presented to the participants randomly according to the method described by Alamu et al. [33]. The sensory attributes chosen are aroma, appearance, taste, texture, and overall acceptability. The attributes of each product were rated by participants on a 5-point hedonic scale to measure the degree of likeness using qualitative judgements that correspond to 1 = dislike very much, 2 = dislike a little, 3 = neither like nor dislike, 4 = like a little, 5 = like very much. The order of sensorial testing was such that product appearance was rated first, then aroma, and finally taste and texture. According to Altamore et al. [40], clean potable water was supplied to respondents for necessary rinsing of the mouth between one type of product and the other. Simultaneously, intention for consumption was measured on a 6-point scale corresponding to 1 = I would eat often, 2 = I would eat if available, 3 = I do not like but eat on occasion, 4 = I would hardly ever eat, 5 = I would eat if no other choice, 6 = I would eat only if forced. Furthermore, respondents were asked to indicate the most preferred snacks and how much they could pay for a specified quantity.

2.7. Data analysis

The data generated on the proximate, functional and anti-nutritional properties were statistically analyzed using IBM SPSS statistical software (Version 21). The data on preference and willingness to consume were subjected to analysis of variance (ANOVA) at a 95% level of significance. The differences between means were tested using the Duncan multiple range test ($P < 0.05$).

3. Results and discussion

3.1. Proximate composition

The results of the analysis for proximate parameters from 100% wheat chin-chin and 100% cassava chin-chin showed significant ($P < 0.01$) differences in moisture, ash, fat, amylose, sugars and digestible starch contents (Table 3). The moisture content of the products ranged from 2.40 to 4.20%, with 100% cassava chin-chin having a higher value. The moisture content values for the chin-chin were within the range reported having no adverse effect on the quality attributes of the product [41]. Moreover, the wheat chin-chin dough was more viscous because of its gluten, and the presence of multiple hydrophobic binding sites will not encourage moisture absorption [42].

Furthermore, HQCF-based products usually contain very high moisture content because of the high water absorption capacity of HQCF [43]. The moisture content of all the products falls within the range where the optimum textural property is achieved [38]. However, the low moisture content could be an added advantage for a longer shelf life of finished products stored at ambient temperature [11]. The ash content for the wheat chin-chin was higher than that of the cassava chin-chin; this indicates that wheat chin-chin had higher mineral content than cassava chin-chin [43,44]. The fat content for wheat chin-chin was also higher compared to that of cassava chin-chin. This can be attributed to wheat starch affinity to lipid because on the macromolecular level, soft wheat starch contains on its surface polar lipids such as digalactosyldiglyceride, monogalactosyldiglyceride, phosphatidylcholine and other phospholipids [45]. Hence, there are enough hydrophobic sites to attract the oil to settle within the products during frying. Another possibility could also be the lower water absorption capacity of wheat flour in comparison to cassava flour which produced a soft dough and as such absorbed more frying oil [46]. High-fat food is subject to oil deterioration, thereby reducing its shelf life [47]. Wheat chin-chin had a higher protein content (11.2%) than cassava chin-chin (2.6%). This agrees with the findings of Adebayo-Oyetoro et al. [40] who reported the protein content for 100% wheat chin-chin as 11.1%. The gluten in wheat is responsible for its high protein content. Cassava flour has a very low protein content ranging between 1 and 2% [19]. The higher amylose content for wheat chin-chin confirms the report that amylose is more in wheat than cassava [48]. However, some cassava varieties have been bred for high amylose content and exhibit healthy resistant starch which has been reported to be beneficial for the treatment of hyperglycaemia [49]. From the results, it is evident that the starch and total reducing sugars in the chin-chin variants had an inverse relationship, and wheat chin-chin contains higher starch and lower total reducing sugar.

In comparison, cassava chin-chin had lower starch with higher sugar content. Wheat flour usually consists of about 70–85% starch [50], while cassava flour has about 70–82% depending on the variety [51]. The results show that both chin-chin variants fell below their starch ranges which could be attributed mainly to varietal differences or environmental influence on the genetics of their raw materials. Higher total sugars in cassava chin-chin could make it a better snack because Alamu et al. [11] report that sugar impacts taste and flavour in foods. Furthermore, it may be available for rapid breakdown to release energy to the body in the form of glucose.

The analysis of variance showed that there was a significant ($P < 0.05$) effect of product type on all the proximate components except starch which had no significant effect ($P > 0.05$). The mean values of tidbit variants also exhibit significant ($P < 0.05$) differences across all proximate compositions except for ash content. This may be attributed to the presence of legumes (cassava + soybean or cassava + cowpea) in their formulations. Cowpea seeds have been reported to be generally high in ash [52,53]. Oluwamukomi et al. [19], reported an increase in ash content with 10% soy flour substitution of wheat-cassava biscuit. Protein- and carbohydrate-rich foods are characterized by higher water absorption than fatty foods [51,52]; this could be the reason why the cowpea tidbits had higher moisture content. This agrees with the findings of Brou et al. [52] that water and oil absorption capacities of soyflour/cassava flour blends increased with increasing levels of soy flour. The fortified soy tidbits exhibited higher values for fat, amylose, sugar and starch contents. The higher fat content is the contribution of oil from soy [19,52]. Furthermore, the particle size of the soy paste may have contributed to the uptake of excess frying oil. This may, however, be a disadvantage as the shelf life of the product cannot be guaranteed due to the oxidative deterioration of fatty acids. The cowpea tidbits had a protein content of 5.1% while the protein content of the soy variant was 7.6%. These results agree with that of Maziya-Dixon et al. [20] who reported protein contents for strip snacks from 50:50 cowpea:HQCF, boiled soy:HQCF and unboiled soy:HQCF as 5.58%, 9.89%, and 9.74%, respectively. The legumes as fortificant have successfully made up for the protein deficiency in HQCF. The higher amylose content may be advantageous for people suffering from insulin deficiency or hypoglycemia. The more elevated sugar and digestible starch contents are indicators that calories will be released faster and will be suitable for physically active people.

Table 3. Nutritional properties of cassava-based snacks.

Product type	% MC	% Ash	% Fat	%Protein	%Amylose	%Amylopectin	% Sugar	%Starch	TDCHO
Chin-chin (100% wheat)	2.4[c]	1.1[b]	17.4[b]	11.2[a]	13.3[a]	86.7[c]	21.2[b]	67.3[b]	88.5[a]
Chin-chin (100% HQCF)	4.2[ab]	0.8[c]	5.4[d]	2.6[d]	10.6[c]	89.4[a]	23.4[a]	63.0[b]	86.3[a]
Tidbit (50:50 HQCF: cowpea)	5.1[a]	2.9[a]	8.2[c]	5.1[c]	10.9[c]	89.1[a]	6.4[d]	54.6[c]	60.9[b]
Tidbit (50:50 HQCF: soybean)	3.1[bc]	2.9[a]	38.0[a]	7.6[b]	12.2[b]	87.8[b]	8.9[c]	77.5[a]	86.5[a]
Mean	3.7	1.9	17.2	6.6	11.7	88.3	15	65.6	80.6
Maximum	5.3	2.9	38.3	11.3	13.4	89.5	23.5	84.8	93.8
Std. deviation	1.1	1	13.7	3.4	1.2	1.2	7.9	9.9	12.9
Pr > F	**	***	***	***	***	***	***	ns	**

Notes: Parameters were analyzed in duplicate. Mean values in the same column with different letters are significantly different at $P < 0.05$. ns: not significant at $P > 0.05$; *: significant at $P < 0.05$; **: significant at $P < 0.01$; ***: significant at $P < 0.001$.

3.2. Anti-nutritional and functional properties of the snacks

Table 4 shows that the anti-nutritional and functional properties of wheat chin-chin were higher than those of cassava chin-chin, while the soy-tidbit had the highest anti-nutrient properties. Phytic acid is a significant anti-nutrient found in cereals and legumes, which is significantly reduced once subjected to processing such as dehulling, oven-drying, cooking, steeping, frying, fermentation and malting, among others. Phytic acid/phytate is considered an anti-nutrient mainly due to its ability to bind to essential dietary minerals as well as proteins and starch, and to consequently reduce their bioavailability in humans, especially children. In contrast, it is considered an antioxidant in adults. It works in a broad pH-region as a highly negatively charged ion. Therefore, its presence in the diet adversely affects the bioavailability of divalent and trivalent mineral ions such as Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+} and Cu^{2+}. It is found in fresh cassava roots but can be removed by processing such as fermentation, boiling, and oven-drying. For tidbits, cowpea and soybean variants have tannin and phytate contents of 0.36/0.77% and 0.33/0.87 mg/g, respectively, with higher values recorded for the soybean variant.

Table 4. Anti-nutritional and functional properties of cassava-based snacks.

Product types	Tannin (mg/g)	Phytate (%)	pH value	Bulk density (g/ml)
Chin-chin (100% wheat)	0.6^{ab}	1.6^{a}	6.2^{a}	0.8^{a}
Chin-chin (100% HQCF)	0.3^{b}	1.4^{a}	4.3^{b}	0.7^{b}
Tidbit (50:50 HQCF: cowpea)	0.4^{b}	0.3^{b}	4.3^{b}	0.7^{b}
Tidbit (50:50 HQCF:soybean)	0.8^{a}	0.9^{ab}	6.0^{a}	0.6^{b}
Mean	0.5	1.1	5.2	0.7
Minimum	0.2	0.3	4.3	0.6
Maximum	0.8	1.8	6.2	0.8
Std. deviation	0.2	0.6	1.0	0.1
Pr > F	**	**	***	**

Notes: Parameters were analyzed in duplicate. Mean values in the same column with different letters are significantly different at $P < 0.05$. ns: not significant at $P > 0.05$; *: significant at $P < 0.05$; **: significant at $P < 0.01$; ***: significant at $P < 0.001$.

The values of the anti-nutrients recorded for all the products are below the safe limit recommended by the World Health Organization (WHO) and the permissible range in the United Kingdom [52]. Thus, they are safe for human consumption. The low values are because of processing which resulted in the drastic reduction in their anti-nutrients. However, the tannins (polyphenols) and phytate are currently classified as bioactive components due to their antioxidant properties. Tannins have been reported to inhibit the digestive enzymes and lower digestibility of most nutrients, especially protein and carbohydrates, thereby increasing faecal nitrogen [53,54]. They are predominantly found in seed hull, and dehulling takes care of most, if not all. However, these anti-nutrients can also be useful to humans at low concentrations as anthelminthic antioxidants which protect against degenerative diseases [55,56], and they have also been shown to reduce blood glucose and insulin responses to starchy foods and plasma cholesterol and triglycerides [57,58]. Bulk density across all products was not significant except for wheat chin-chin. Bulk density is significant in the package design, storage and transport of foodstuff [53,59]. Wheat chin-chin and soy tidbits had a higher pH value, which was lower than the value reported by McGlynn [60], who gave the pH of raw soybean as 6.8. Cassava chin-chin and cowpea tidbit have low pH values. Cassava flour processed for confectionary purposes usually does not have a low pH as reported by the Standards Organisation of Nigeria; thus, the low pH observed could be due to fermentation during processing [61].

On the other hand, cowpea has been reported to be a low pH food [62]. A low pH could improve protein digestibility [63] and may also be an indicator of a reduced rate of spoilage [64]. Considering the pH of foods from another perspective, it does not matter whether a food is acidic or basic, it can still be a medium for mould growth even at very low moisture content [64].

3.3. Characteristics of survey respondents and consumption frequency

Table 5 presents some selected characteristics of participants in the consumer survey across four locations. Over 50% of the participants were males with a higher consumption frequency/week (2.40) than females (1.89).

Table 5. Characteristics of survey respondents and consumption frequency.

		Kaoma	Kasama	Mansa	Serenje
Variable		N (%)	N (%)	N (%)	N (%)
Gender	Female	110 (51.4)	112 (54.9)	102 (47.22)	68 (32.69)
	Male	104 (48.6)	92 (45.1)	114 (52.78)	140 (67.31)
Age (year)	Mean ± SD	49 ± 14.4	40 ± 13.2	42 ± 12.1	41 ± 14.1
	Minimum	19	18	18	21
	Maximun	89	72	70	84
Frequency of consumption/week					
Products		Mean ± SD	CV		
Chin chin (100% wheat)		1.89 ± 0.93	49.13		
		2.4 ± 1.15	48.11		
Chin chin (100% HQCF)		1.89 ± 0.93	49.13		
		2.4 ± 1.15	48.11		
Tidbit (50: 50 HQCF:cowpea)		1.55 ± 1.02	39.93		
		1.61 ± 1.03	39.36		
Tidbit (50:50 HQCF: soybean)		1.55 ± 1.02	39.93		
		1.61 ± 1.03	39.36		

3.4. Preference for sensory attributes across locations

Table 6a shows the mean preference ratings for sensory characteristics of chin-chin variants across locations. The general trend across sites showed that there were no significant differences ($P \leq 0.05$) observed for the overall mean values of appearance and aroma ratings for the chin-chin variants except in Serenje district. In Kaoma and Mansa, cassava chin-chin was preferred over wheat chin-chin for appearance and aroma. In Kasama, as much as appearance and aroma for wheat chin-chin were preferred to those for cassava chin-chin, the statistical difference in their ratings was not significant ($P \leq 0.05$). Alamu et al. [59] reported that fritters from HQCF were most preferred in Kasama. Also, Paloma et al. [65] reported that better acceptability was recorded for 50% cassava snack over 100% wheat bites with no significant differences in their appearance. Serenje district had the lowest ratings of sensory attributes for both chin-chin variants; this also agrees with the findings of Alamu et al. [59]. The taste of cassava chin-chin across all locations was preferred to that of wheat chin-chin, and differences were significant except in Kaoma and Kasama.

In contrast, the preference for cassava chin-chin texture superseded that of wheat chin-chin except in Kasama District. Nevertheless, statistically, there was no significant difference in the texture rating across all locations except in Serenje district, which could be because the sensory attribute ratings were at the lowest. An important factor that could be responsible for the varied preference in taste and texture could be the high fibre content in HQCF [65], which, in turn, affects the taste of the product.

Dischsen et al. [66] reported a formulated breakfast cereal with cassava residue and increased fibre content, showed a significant difference ($P \geq 0.05$) in texture and overall sensory attributes. Paloma et al., [65] established that root crop flour has a coarse texture, giving a sandy taste sensation which makes it unacceptable to consumers.

Thus, the overall acceptability for the chin-chin variants indicates that wheat chin-chin was the preferred product with the following percentages: Kasama (66.7%), Kaoma (57.9%), Mansa (53.7%) and Serenje (70.2%). However, the difference margin between the chin-chin variants across the locations was not so wide except in Serenje, where it had been reported that consumption of cassava-based secondary products is low [11].

Table 6b shows the mean preference ratings for sensory attributes of the tidbit variant across locations, and the two types of tidbits produced for the study were cowpea tidbit (301) and soy tidbit (302). Appearance as a sensory attribute across all locations had significant differences with a preference for cowpea tidbits.

Statistically, there was no significant difference in the taste and aroma of products across all sites, but the hedonic ratings showed that cowpea tidbit was preferred. This preference could stem out of the characteristic beany flavour of soybean which, when perceived in the product, can be a put off [67]. Also, at some elevated levels of soy, product acceptability may be affected as reported by Chanadang et al. [68]. Balogun et al. [67] reported that the organoleptic qualities of tapioca meal fortified with defatted soy flour were rated the most acceptable; the same trend observed with the high acceptability of products from the fortification of cassava flour with cowpea flour.

Table 6a. Preference for sensory characteristics of chin-chin variants across locations.

District	Product	Appearance Mean ± Std	CV	Aroma Mean ± Std	CV	Taste Mean ± Std	CV	Texture Mean ± Std	CV
Kaoma									
(N = 107)	201	4.7 ± 0.52	11.02	4.68 ± 0.51	10.82	4.58 ± 0.53	11.63	4.28 ± 0.86	19.99
	202	4.84 ± 0.37	7.59	4.77 ± 0.45	9.37	4.73 ± 0.49	10.3	4.64 ± 0.62	13.31
	Mean	**4.77 ± 0.45[a]**	**9.5**	**4.72 ± 0.48[a]**	**10.12**	**4.65 ± 0.51[ab]**	**11.06**	**4.46 ± 0.77[a]**	**17.18**
Kasama									
(N = 102)	201	4.8 ± 0.51	10.58	4.84 ± 0.52	10.77	4.61 ± 0.8	17.32	4.64 ± 0.67	14.49
	202	4.76 ± 0.53	11.12	4.81 ± 0.54	11.22	4.75 ± 0.59	12.47	4.37 ± 0.9	20.59
	Mean	**4.78 ± 0.52[a]**	**10.83**	**4.83 ± 0.53[a]**	**10.97**	**4.68 ± 0.7[ab]**	**15.06**	**4.5 ± 0.8[a]**	**17.83**
Mansa									
(N = 108)	201	4.71 ± 0.61	12.99	4.73 ± 0.62	13.12	4.71 ± 0.64	13.62	4.39 ± 0.94	21.32
	202	4.81 ± 0.44	9.05	4.74 ± 0.65	13.64	4.73 ± 0.61	12.79	4.65 ± 0.77	16.46
	Mean	**4.76 ± 0.53[a]**	**11.18**	**4.74 ± 0.63[a]**	**13.35**	**4.72 ± 0.62[a]**	**13.18**	**4.52 ± 0.86[a]**	**19.09**
Serenje									
(N = 104)	201	4.57 ± 0.55	12.11	4.47 ± 0.67	14.93	4.54±0.57	12.63	4.15 ± 0.79	18.91
	202	4.55 ± 0.59	12.96	4.43 ± 0.68	15.32	4.57 ± 0.62	13.56	4.34 ± 0.77	17.78
	Mean	**4.56 ± 0.57[b]**	**12.51**	**4.45 ± 0.67[b]**	**15.1**	**4.55 ± 0.6[b]**	**13.08**	**4.25 ± 0.78[b]**	**18.41**

Notes: Values in the columns with the same letters are not significantly different at $P > 0.05$. Sample codes: 201 = 100% wheat chin-chin; 202 = 100% cassava chin-chin.

Table 6b. Preference for sensory attributes of tidbit variant across locations.

		Appearance		Aroma		Taste		Texture	
District	Product	Mean ± Std	CV	Mean ± Std	CV	Mean ± Std	CV	Mean ± Std	CV
Kaoma									
(N = 112)	301	4.8 ± 0.4	8.31	4.71 ± 0.56	11.98	4.6 ± 0.58	12.54	4.67 ± 0.47	10.12
	302	4.7 ± 0.66	13.96	4.61 ± 0.65	14.08	4.5 ± 0.66	14.61	4.5 ± 0.66	14.61
	Mean	**4.75 ± 0.54[ab]**	**11.45**	**4.66 ± 0.61[a]**	**13.07**	**4.55 ± 0.62[a]**	**13.61**	**4.58 ± 0.58[a]**	**12.6**
Kasama									
(N = 106)	301	4.85 ± 0.47	9.77	4.93 ± 0.25	5.06	4.63 ± 0.68	14.7	4.35 ± 0.89	20.58
	302	4.37 ± 0.81	18.51	4.59±0.75	16.39	4.41±0.79	17.94	4.33±0.81	18.78
	Mean	**4.61 ± 0.7[c]**	**15.27**	**4.76 ± 0.58[a]**	**12.28**	**4.52 ± 0.74[a]**	**16.47**	**4.34 ± 0.85[b]**	**19.66**
Mansa									
(N = 107)	301	4.79 ± 0.51	10.62	4.28 ± 0.7	16.3	4.38 ± 0.56	12.79	4.26 ± 0.6	14.17
	302	4.5 ± 0.65	14.45	4.71 ± 0.51	10.92	4.64 ±0.52	11.24	4.61 ± 0.56	12.2
	Mean	**4.64 ± 0.6[bc]**	**12.95**	**4.5 ± 0.65[b]**	**14.42**	**4.51 ± 0.55[a]**	**12.3**	**4.43 ± 0.61[b]**	**13.7**
Serenje									
(N = 107)	301	4.92 ± 0.39	7.96	4.87 ± 0.44	8.96	4.84 ± 0.44	9.04	4.78 ± 0.57	11.97
	302	4.64 ± 0.54	11.55	4.48 ± 0.6	13.5	4.37 ± 0.76	17.35	4.38 ± 0.71	16.18
	Mean	**4.78 ± 0.49[c]**	**10.2**	**4.67 ± 0.56[a]**	**12.01**	**4.61 ± 0.66[a]**	**14.34**	**4.58 ± 0.67[a]**	**14.67**

Notes: Values in the columns with the same letters are not significantly different at $P \leq 0.05$. Sample codes: 301 = Cowpea tidbit (50:50 HQCF:cowpea); 302 = Soybean tidbit (50:50 HQCF:soybean).

3.4.1. Overall preference for chin-chin and tidbit variants by gender

Researchers have found that humans have an unlearned preference for sweet taste and learn a choice for salty taste very early in life. It was reported by Lombardo et al. [69] that women consume more sugar-sweetened products and prefer salty taste to sweet taste. Another research established the general belief that men eat more salty foods compared to women [70]. Casperson & Roemmich [71] found out that food reinforcement was higher for sweet than savoury snacks in men. In place of these, we discover that wheat chin-chin is the preferred variant by both genders with a higher proportion of female preference. While for tidbits, cowpea tidbit is preferred by both genders with a higher percentage of male preference. It can then be inferred that the preference for snack foods depends mostly on biological factors (genetic) influenced by social factors (environmental). Figures 1 and 2 explain the overall preference.

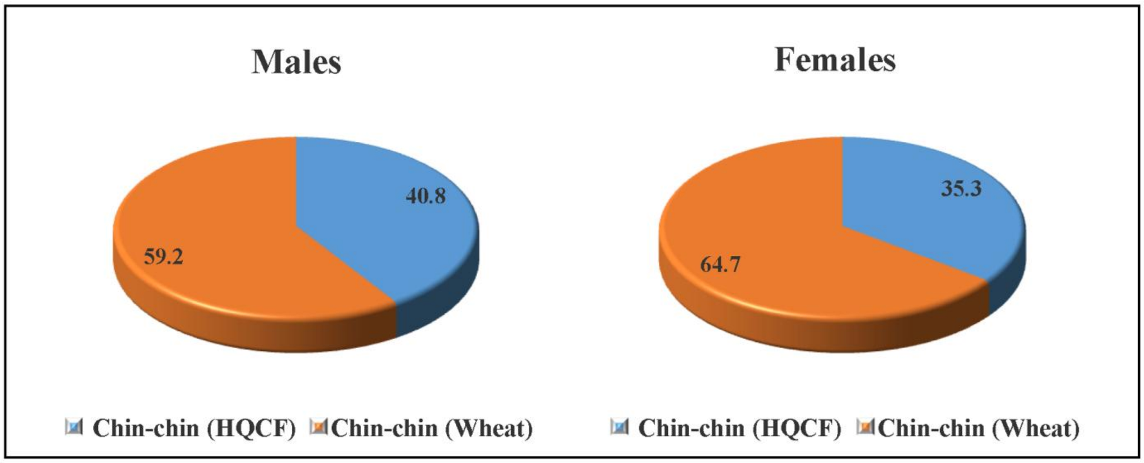

Figure 1. Most preferred chin-chin sample by gender.

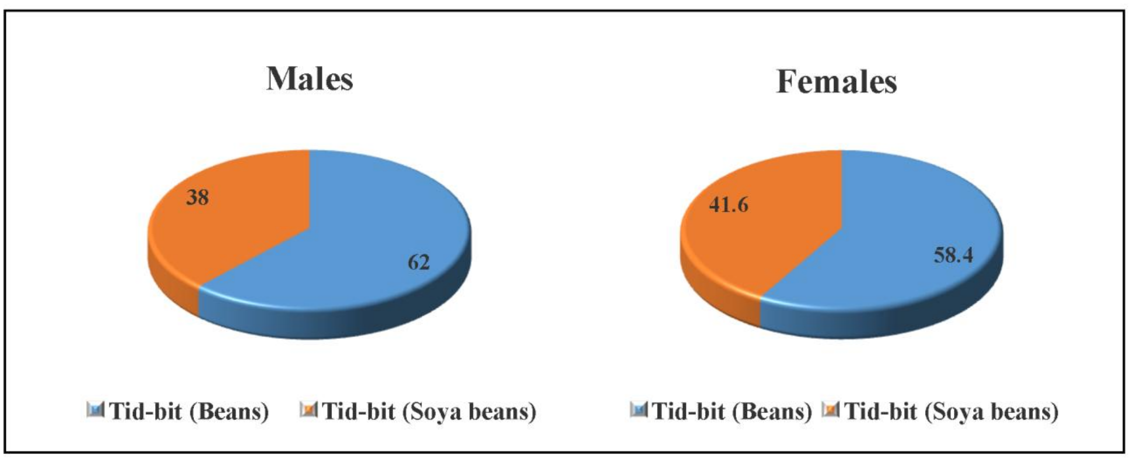

Figure 2. Most preferred tid-bit sample (%) by gender.

3.5. Analysis of variance for chin-chin

The results of the ANOVA for chin-chin (Table 7) show that district had a strong significant effect (P < 0.001) on the aroma and appearance, a significant effect (P < 0.01) on texture and a weak significant effect on taste **(**P < 0.05). The variety of the chin-chin showed a significant effect (P < 0.01) on aroma, taste and texture; this could be due to the difference in the base material (wheat and HQCF) used for the products.

In the case of the tidbits, the results (Table 7) show that district and variety had an exceptionally high significant effect (P < 0.001) on aroma and appearance respectively. These could lead to a strong inference that aroma and appearance of the products were district dependent, that is, a group of people within a locality may have a common sensory attribute but different from one region to another.

Table 7. Mean squares from the analysis of variance for the sensory characteristics of chin-chin and tidbits across all locations.

Source	DF	Product	Appearance	Aroma	Taste	Texture
District	3	Chin-chin	2.3575***	5.3856***	1.05875*	3.1952**
	3	Tidbits	1.4636*	2.6521***	0.407	3.0051**
Variety	1	Chin-chin	0.4751	0.0107*	1.45487*	4.1342*
	1	Tidbits	17.7963***	2.1400*	3.8935**	0.7824
Gender	1	Chin-chin	0.0012	0.0253	0	0.1229
	1	Tidbits	0.0338	0.0365	0.0369	0.101
Error	836	Chin-chin	0.2704	0.3411	0.3736	0.644
	858	Tidbits	0.3268	0.3603	0.416	0.4683

Notes: ns: not significant at P >0.05; *: significant at P < 0.05; **: significant at P < 0.01; ***: significant at P < 0.001.

3.6. Correlation between attributes and willingness-to-pay (WTP)

Table 8 shows the correlation between sensory characteristics and WTP for chin-chin and tidbits. There was a robust positive linear relationship between sensory attributes and consumer WTP for tidbit snacks based on aroma, taste and texture. By implication, WTP is directly proportional to sensory properties. This agrees with Maziya-Dixon et al. [20] who observed a correlation between WTP and the sensory evaluation of the cassava-based products evaluated among Nigeria and DR Congo respondents. Thus, it could be concluded that cassava-based snacks are acceptable, and respondents are willing to pay irrespective of the social culture. WTP was higher for wheat chin-chin (K2.66) compared to cassava chin-chin (K2.28) while Kasama had the highest mean WTP for both wheat chin-chin and cassava chin-chin (K3.88 and K3.55, respectively) and Mansa had the lowest for both samples.

Table 8. Correlation between attributes and willingness-to-pay(WTP).

	Chin-chin	Tidbits
Attribute	WTP	WTP
Appearance	0.0804*	0.0889**
Aroma	0.1117**	0.1493***
Taste	0.1103**	0.2320***
Texture	0.08838*	0.2097***

Notes: *: significant at $P < 0.05$; **: significant at $P < 0.01$; ***: significant at $P < 0.001$.

4. Conclusions

We conclude that the snacks fortified with legumes contained healthy nutrients that can contribute significantly to the protein-energy intake of poor households. The cassava chin-chin competes favourably with wheat chin-chin in terms of acceptability and other sensory attributes. It implies that cassava flour has the potential to be a partial substitute for wheat flour in the confectionery industries and thus making cassava to be an economic crop in Zambia. This is a pathway to an increase in its cultivation and utilization, which could lead to a significant reduction in the wheat importation.

Also, the legume-enriched cassava snacks have an impressive acceptance in Kasama, Kaoma and Mansa districts, with a higher preference for the cowpea variant of tidbit. Thus, cowpea cultivation is likely to increase among household farmers, thereby increasing food availability for improved household nutrition. Aroma, taste and texture are sensory properties that drive the acceptance and WTP for the snacks. There is a need for nutrition training and promotion of the product recipes among households and processors who are willing to adopt the technologies for commercialization, thereby creating employment, especially for the youths. However, further studies on the bioavailability of the nutrients and the shelf-life of these products are necessary to be carried out; the approach of this study could be extended to other available legumes.

Author contributions

EOA and BM designed the research; EOA, BM, OB and PN performed the research; BM, DC and PN supervised the study; EOA analyzed the data; EOA and OB prepared the manuscript, BM, PN DC reviewed the manuscript. EOA and BM were responsible for the contents of the paper.

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Conflict of interest

The authors declare no conflict of interest.

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