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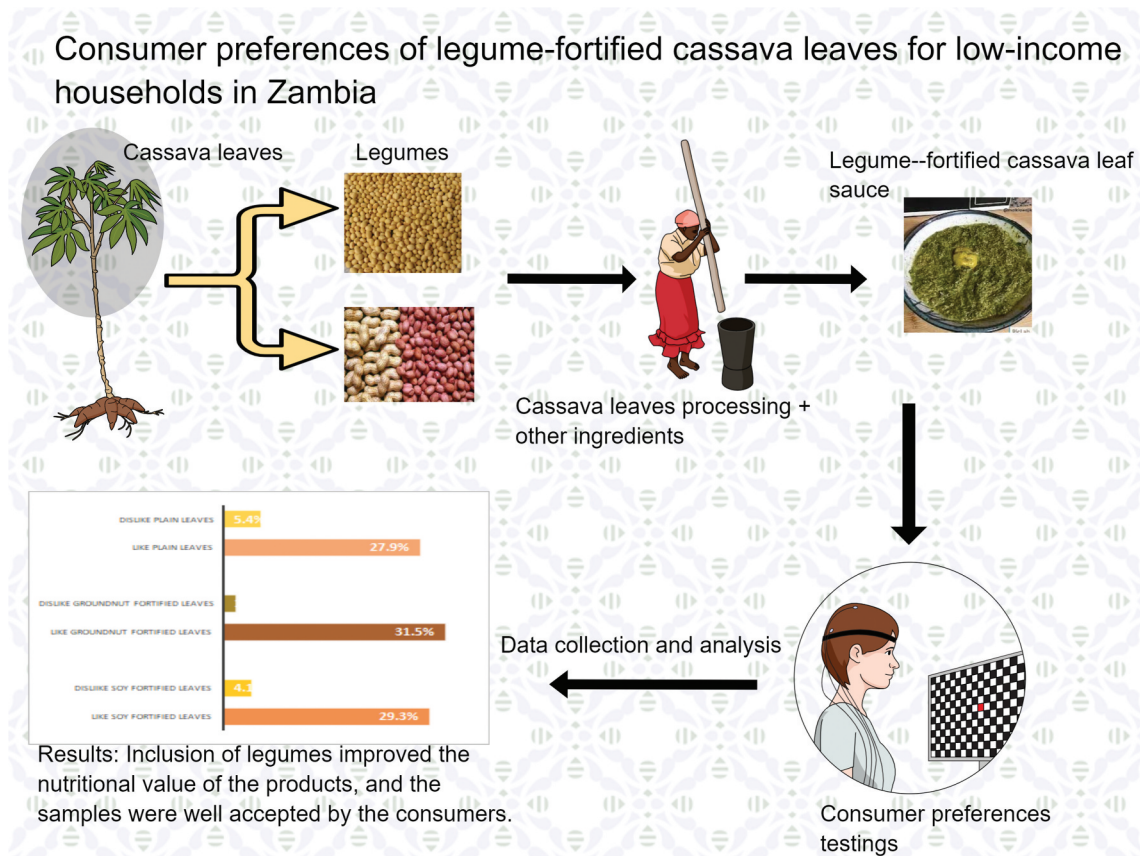
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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Evaluation of nutritional properties, and consumer preferences of legume-fortified cassava leaves for low-income households in Zambia

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Abstract: Cassava leaves have the potential to improve dietary diversity, the intake of protein and micronutrient of members of low-income households. The study aimed at evaluating nutritional properties, and consumer preferences of legume-fortified cassava leaves (soybean and groundnut fortified products) using plain leaves as control. The nutritional and anti-nutritional properties of the samples were determined using standard laboratory methods, and a structured questionnaire was used to assess consumer preferences. There were significant ($P < 0.05$) increase in the nutritional properties and the product type had a strong significant ($p < 0.05$) effect on the anti-nutritional properties (tannins, phytate, and cyanogenic potential (CNP)). Respondents from Kaoma and Serenje districts have a higher preference for soy-fortified over groundnut-fortified variant. In contrast, Kasama and Mansa

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PUBLIC INTEREST STATEMENT

Cassava leaves which are readily available in sub-Saharan Africa are of good nutritional value. There are areas in sub-Saharan Africa where cassava leaves are being consumed. However, its utilization as food is not as widespread as it is with the roots. Because of the relatively high nutritional value of cassava leaves, they have the potential to improve diet and health, particularly of people from low-income areas. In this study, the fortification of the cassava leaves with readily available legumes (groundnut and soybeans) was explored. The nutritional and anti-nutritional values of the formulated meals were assessed. Respondents from different areas of Zambia carried out the sensory evaluation of the products to determine the acceptability. Inclusion of the legumes improved the nutritional value of the products, and the samples were well accepted by the subjects of the sensory evaluation.

districts preferred both soybean and groundnut in the fortification of cassava leaves. The Willingness to pay (WTP) is significantly ($P < 0.05$) correlated with the taste and texture of the cassava leaf products.

Subjects: Agriculture & Environmental Sciences; Food Additives & Ingredients; Food Chemistry

Keywords: Cassava leaves; fortification; nutritional characteristics; consumer acceptability; willingness-to-pay (WTP)

1. Introduction

Cassava (*Manihot esculenta* Crantz) is an essential crop in sub-Saharan Africa occupying a double-edged position as food security and income generation crop (Forsythe et al., 2016; Devi & Singh, 2017; Suja & Nedunchezhiyan, 2008; Alamu et al., 2019a). It is seen as a dependable crop due to its ability to withstand harsh climatic conditions and the ability to grow in marginal environments (James & Sreekumar, 2015; Jiang et al., 2019; Oliveira et al., 2015; Shan et al., 2018; Utsumi et al., 2019). It is the second most crucial root crop next to potato and the fifth in terms of the overall human calorific intakes globally (Kebede, 2018). In Zambia, Cassava is the second most-consumed staple after maize (Kebede, 2018; Alamu et al., 2019a). It is mainly grown for its starchy roots.

Furthermore, cassava stem, leaves, and petioles are also edible and are widely used as food (Latif & Müller, 2015). Naturally present in Cassava are two cyanogenic glucosides, namely linamarin and lotaustralin (methyl linamarin) produced as a defence mechanism against predators that might try to feed on them as well as when the cassava tissue is crushed (Abraham et al., 2016; Pinto-Zevallos et al., 2016; Schmidt, 2018). These cyanogenic glucosides are distributed widely throughout the plant. The highest amounts are found in the young tender leaves and the root skin layer, with relatively lower amounts in the interior part of the root (Hidayat et al., 2016). Despite the high concentration of cyanogen in cassava leaves, they are a rich source of protein, minerals, and vitamins (Pizarro et al., 2018). Thus, its consumption has been recommended to people living in the tropics because of its availability coupled with nutritional value (Achidi et al., 2008). Pounding, soaking and subsequent washing has been reported to be an effective method of processing cassava leaves to ensure drastic reduction in the cyanogen content while preserving essential nutrients like proteins, vitamins and Sulphur-containing amino acids that are vital to detoxify ingested cyanide (Bradbury and Denton 2011; Ojiambo et al., 2017). However, recent research has reported that drying and boiling reduce the total cyanide content while drying alone drastically reduces free cyanide in cassava leaves (Junior et al., 2019).

Salata et al. (2014) reported that cassava leaves are regularly picked and cooked for human consumption in several countries. Latif and Müller (2015) listed about 20 Sub Saharan African countries from Senegal to Madagascar, and four Asian countries (Indonesia, Malaysia, the Philippines and Sri-Lanka) where cassava leaves are consumed in various forms. One of the most common preparations is when the leaves are eaten in the form of a sauce or stew, prepared by boiling for several hours followed by pounding or chopping and seasoned with locally available spices and additional ingredients.

In North-eastern Brazil, cassava leaves are sun-dried, ground into flour and blended with cereals such as wheat and maize, to combat child malnutrition in the national food supplement program for low-income households (Câmara & Madruga, 2001). Also, in the state of Para, cassava leaves are ground and utilized in the preparation of a dish referred to as manicoba (Katz et al., 2012).

It has been reported that more than 60 percent of the population in the Central African Republic, the Democratic Republic of the Congo, Angola, Liberia and Sierra Leone consume cassava leaves. Whereas, in countries like Tanzania, Mozambique, Malawi and Zambia, a major part of the

population consume cassava leaves (Achidi et al., 2005). Congo has been named one of the largest consumers of cassava leaves. In 2013, cassava leaves constituted about 60% (85,000 tons) of the whole (140,000 tons) vegetable consumption (FAO, 2014).

Regardless of the growing global attention towards Cassava in the scientific communities, and more recently in policy circles, it is mainly the roots that have been researched and promoted through various breeding and value chain interventions and hardly ever the leaves. In some countries, cassava leaves are considered as a poor man's food and only eaten when other vegetable leaves are unavailable, or during food shortage and in several countries, they are not consumed at all (Latif & Müller, 2015). In Brazil, for instance, a large amount of cassava leaves is wasted during root harvest, and it has been estimated that for an area of 158 million hectares, more than 178,000 tons of leaves are wasted each year (Ferrari et al., 2014). It is possible to obtain approximately 2,250 kg of cassava leaf flour per hectare, depending on the quantity of leaves produced per plant per hectare (Sagrilo et al., 2001). The waste could be utilized in the production of flour, which in turn can be used as a raw material for extrudates (Salata et al., 2014). Nevertheless, cassava leaves have for centuries been widely consumed in some parts of Africa due to its higher protein content than the roots. Although the leaves contain far less methionine than the roots, the levels of all other essential amino acids exceed the FAO's recommended reference for protein intake.

Leafy vegetables have been reported to be significant sources of antioxidants, dietary fibres, vitamins and essential amino acids (Nkongho et al., 2014). Cassava leaves are rich in protein, vitamins (B1, B2, C and carotenoids) and minerals (Calcium, magnesium and potassium) (Dada & Oworu, 2010). They are available throughout the year, making them a vegetable that can sustain a family even during the lean months. Cassava foliage meal has a relatively high vitamin A content (up to 56000 IU). Nevertheless, they contain large amounts of the cyanogenic glucosides, linamarin and a small quantity of lotaustralin (methyl linamarin), which are broken down by the enzyme linamarase present in the leaves to produce cyanohydrins, which then produces hydrogen cyanide which is a toxin hence the need to detoxify the leaves so that they are suitable for human consumption. Moreover, research has shown that traditional methods for preparing cassava leaves for use, which include grinding, cooking and heat-treating them before consumption sufficiently detoxify the cyanide (Achidi et al., 2008).

As a result of the rich nutrient content of cassava leaves, they have the potential to improve dietary diversity, the intake of protein and micronutrient and overall health of members of low-income households because they are sometimes the only available vegetable during the lean and hungry seasons (Chiwona-Karlton et al., 2016). Also, the market value of cassava leaves is often higher than that of the roots in areas where they are consumed, and the sale of cassava leaves thus contributes significantly to the income of farmers' households (FAOSTAT, 2013). The information from this study will be of interest to the Food scientists, Nutritionists, Food processors and breeders that are promoting the usage of local materials to alleviate protein-energy malnutrition (PEM), especially in cassava-growing areas of most developing countries.

2. Materials and methods

2.1. Study site

The collection of the survey data was carried out in three (3) camps of each of Kaoma, Kasama, Mansa and Serenje districts in Zambia. The four regions are cassava growing and consuming areas and were selected based on consumption levels and accessibility. Thirty-five respondents per camp were randomly chosen to give a total of 105 respondents giving 420 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.

Table 1. Ingredients and quantities for cassava leaves-based products

Ingredients	Product and quantity		
	Plain leaves	Soy Fortified	Groundnut fortified
Cassava leaves (bundles-100-150 g/bundle)	6-8	6-8	6-8
Soy flour-(250 ml cup)	0	2-3	0
Groundnut flour-(250 ml cup)	0	0	2-3
Tomatoes (medium size-120 g)	3	3	3
Onion (medium size)	1	1	1
Salt- (Teaspoon)	1	1	1
Cooking oil (62 ml)	1	0	0

2.2. Sample preparation

The fresh Cassava leaves used were obtained from the cassava field in Kaoma and Mansa districts, while in Kasama and Serenje districts they were obtained from the market. The young/mature leaves were first pounded using a mortar and pestle then boiled for about 30 minutes. After that, the leaves were rinsed with cold water and put back on fire to cook for about 30 minutes before the addition of different ingredients like cooking oil, groundnuts and soya bean flour. The formulation of the samples is presented in [Table 1](#).

2.3. Physico-chemical analysis

The three products were examined for proximate composition (moisture content, ash content, fat content, protein content, total dietary carbohydrate, amylose, amylopectin, sugar and starch contents), anti-nutritional and functional properties respectively using standard methods (Alamu et al., 2019a; AOAC, 2019b).

2.4. Sensory evaluation

The cassava leaves were coded with three-digit numbers and participants were presented with the samples at random to minimize positional error (Alamu et al., 2019b). The participants rated the appearance, aroma, texture and taste of each of the samples on a 5-point hedonic scale ranging from dislike very much to like very much. The consumption intent was measured on a 6-point scale ranging from 1 = "I would often eat" to 6 = "I would eat if forced". The respondents were asked to indicate the sample they preferred, if they were willing to buy any of the samples and how much they were willing to pay in Zambia Kwacha.

2.5. Data analysis

The data generated on the nutritional, functional, and anti-nutritional properties were statistically analyzed using SAS version 9.3. Analysis of Variance (ANOVA) at a 95% level of significance was carried out on the data about preference and Willingness to buy and pay (WTB and WTP). Also, the means were separated using the Duncan multiple range test.

3. Results and discussion

3.1. Nutritional properties of fortified and non-fortified cassava leaves sauce

[Table 2](#) shows the nutritional properties of the cassava leaf samples. There were significant differences ($P < 0.05$) across all parameters except starch content for the three samples. The moisture content ranged from 3.56 to 5.43% with the highest value for product 503 (groundnut fortified product), while product 502 (soy-fortified product) has the lowest value.

Table 2. Proximate composition of cassava leaves-based products

Products	% MC	% Ash	% Fat	% Protein	% Amylose	% Amylopectin	% Sugar	% Starch	TDCHO
Plain leaves (501)	4.3 ^b	7.8 ^b	16.0 ^c	34.3 ^a	1.7 ^c	98.3 ^a	14.5 ^c	67.4 ^a	81.9 ^b
Soy fortified (502)	3.6 ^c	6.5 ^c	33.7 ^a	24.7 ^b	2.6 ^a	97.4 ^c	20.7 ^a	73.2 ^a	93.9 ^a
Groundnut fortified (503)	5.4 ^a	8.4 ^a	24.2 ^b	19.5 ^c	1.9 ^b	98.1 ^b	14.8 ^b	71.6 ^a	86.5 ^{ab}
Minimum	3.4	6.5	15.8	19.3	1.7	97.3	14.5	64.7	79.2
Maximum	5.4	8.5	33.7	34.5	2.7	98.3	20.8	74.4	95.1
Mean	4.4	7.6	24.6	26.1	2.1	97.9	16.7	70.7	87.4
Std. deviation	0.9	0.9	7.9	6.7	0.4	0.4	3.1	3.4	5.8
Pr > F(Model)	**	**	***	***	**	**	***	ns	**
Pr > F(Products)	**	**	***	***	**	**	***	ns	**

Parameters were analyzed in duplicate

Mean Values in the same column with the different letters are significantly different at $P < 0.05$ ns, not significant at $P > 0.05$; **, significant at $P < 0.01$; ***, significant at $P < 0.001$.

MC: Moisture Content, TDCHO: Total Dietary Carbohydrate

There is a general increase in all the proximate compositions for the legume-fortified products (502, 503) in comparison with the plain (non-fortified) Cassava leaves product (501). The product with the highest moisture content is product 503, and this can be attributed to the groundnut; a legume used in the fortification. Shukla and Gautam (2016), reported a similar trend in the moisture contents of biscuits fortified with green gram flour. However, the low moisture content in product 502 could be an indicator for longer shelf life (Alamu et al., 2019b). The ash content ranges from 6.53 to 8.44%, with the highest value recorded for sample 503. This is an indication that the sample has the highest mineral content, a contribution by the cassava leaves and the groundnut used as fortificant. It has been established that cassava leaves have a higher ash content than cassava roots and other leafy vegetables (Ferrari et al., 2014; Karri & Nalluri, 2016). Some cassava leaves varieties have been found to have as high as 4.5% ash content (Montagnac et al., 2009). Cassava leaves have been reported to contain between 3.8% and 10.50% crude fat (Ravindran, 2017). The addition of the oil-rich legumes; soybeans and groundnuts to the products increased the fat content by 100% and 50% respectively. Legume oils increase the energy concentration in diets (Stein et al., 2008). The protein content of the plain Cassava leaves sample (501) recorded the highest value in comparison to the legume fortified variants. This affirms several reports of the relatively high protein content of cassava leaves (Hidayat et al., 2016; Lancaster & Brooks, 1983; Phuc et al., 2000). However, the protein digestibility is low due to high fibre content and complex formation with tannins through hydrogen bonding and covalent linkages (Natesh et al., 2017), thereby lowering its bioavailability (Boundy-Mills et al., 2019; Morales et al., 2018). Thus, an important reason why cassava leaves should be fortified with legumes rich in bioavailable protein before consumption.

Starch is the major component of the carbohydrate in cassava leaves (Gil & Buitrago, 2002; Montagnac et al., 2009), and the high values of the starch contents of the samples observed in this study agree with their findings. The soy fortified variant (502) recorded the highest starch content (73.2%) while the total sugars ranged from 14.54% to 20.69%, with product 502 having the highest sugar content. The plain cassava product (501) had the lowest carbohydrate content because there was no contribution from any other component. This follows the same trend as reported by Uzor-Peters et al. (2008) while studying the effect of partially defatted soybean or groundnut cake flours on proximate and sensory characteristics of Kokoro. The product with the highest sugar content (502) can be a speedy meal given to boost the blood glucose level for an active individual and to combat hypoglycemia. The amylose content of the samples ranged from 1.67% to 2.62% and was generally significantly lower than the amylopectin content. It seemed low, compared to what was reported by Montagnac et al. (2009) for unprocessed cassava leaves with amylose content varying from 19% to 24%, and this could be as a result of the variety, maturity and environmental factors. It is expected that the starch present in the cassava leaf samples will be rapidly digested because of the high amylopectin values (Horstmann et al., 2017)

3.2. Anti-nutritional and functional properties of cassava leaves-based products

As presented in Table 3, the product type had a significant ($p < 0.05$) effect on all the nutritional properties (tannins, phytate, and cyanogenic potential (CNP) but there were no significant differences on the pH and Bulk density. The tannin content ranged from 14.30–19.06 mg/g and no significant ($P > 0.05$) difference between the tannin content of the products 501 (plain cassava leaves) and 502 (soy-fortified product). Higher tannin content values were recorded for 503 (groundnut fortified product). Phytate content for the products ranged from 0.70–3.07%. There was no significant ($P > 0.05$) difference in the pH of the three samples assessed in this study. However, a significant ($P < 0.05$) difference among the bulk densities of the samples was recorded.

Cassava leaves contain some anti-nutritional factors which lower bioavailability of nutrients and digestibility, hence the need to assess their occurrence in their products (Omosebi et al., 2018; Oresegun et al., 2016). The tannin, phytate and CNP contents ranged between 1.4 to 1.9 g/100 g; 0.6 to 3.1% and 22.2 to 28.7 mg/100 g respectively. However, the lowest tannin, phytate and CNP contents were observed in soy-fortified (1.4 g/100 g), groundnut fortified (0.6%) and Soy-fortified

Table 3. Anti-nutritional and functional properties of cassava leaves products

Products	Tannin (g/100 g)	% Phytate	Cyanogenic potential(CNP) (mg/1000 g)	pH value	Bulk Density (g/ml)
Plain leaves (501)	1.4 b	3.1 a	28.1 a	5.5 a	0.7 a
Soy fortified (502)	1.4 b	1.6 b	22.6 b	5.6 a	0.8 a
Groundnut fortified(503)	1.9 a	0.7 c	24.1 b	5.6 a	0.8 a
Minimum	1.4	0.6	22.2	5.5	0.6
Maximum	1.9	3.1	28.7	5.7	0.8
Mean	1.6	1.8	24.9	5.6	0.7
Std. deviation	0.2	1.1	2.6	0.1	0.1
Pr > F(Model)	**	**	**	ns	ns
Pr > F(Products)	**	**	**	ns	ns

Parameters were analyzed in duplicate

Mean Values in the same column with the different letters are significantly different at $P < 0.05$
 ns, not significant at $P > 0.05$; **, significant at $P < 0.01$; ***, significant at $P < 0.001$.

(22.2 mg/kg) respectively. Thus, Soy fortified cassava -leaf product had the lowest tannin and CNP. The higher tannin content recorded for the groundnut fortified product is justified by Okonwu and Ugiomoh (2015). They reported the tannin content of groundnut to be relatively higher than that of some economic crops, including Cassava. In human diets, tannins have been reported to be the most abundant antioxidant (Han et al., 2007). They have been found to reduce protein digestibility by complex formation (Latif & Müller, 2015). The highest phytate content was found in 501 (plain cassava leaves). Phytic acid chelates essential minerals like magnesium, calcium, zinc and iron, thus making them unavailable to the body. Phytates also decrease the activities of digestive enzymes (Banaszkiewicz, 2011). Nevertheless, they have also been reported to be useful to the human body as antioxidants that helps in slowing down ageing and promotes endurance of the body against diseases (Poonsri et al., 2019) such as cancer, diabetes, hypertension, obesity and heart diseases (Ogbuji & David-Chukwu, 2016). Nevertheless, when permissible ranges are exceeded in the human diet, they could pose danger which is most of the time taken care of during processing.

The cyanide content ranged from 22.6 to 28.1 mg/1000 g with the Soy- fortified variant having the lowest. These values are lower than those reported by Ogbuji and David-Chukwu (2016) for three varieties of cassava leaves whose values ranged from 32.32 to 35.77 mg/1000 g. The difference observed could be due to the processing, genetic and environmental factors. The values of cyanide in the Cassava leaves products obtained in this study are lower than the safe limit of 50 ppm (fresh weight basis) recommended by the Codex Standard for “sweet cassava” varieties (FAO/WHO, 2005). The acute lethal dose of hydrogen cyanide for humans is reported to be 0.5 to 3.5 mg per kilogram of body weight. Therefore, the need to promote cassava varieties that are low in cyanide to be cultivated coupled with appropriate processing method(s) which will be adequate to reduce the cyanide to safe levels. This is of importance because research has established that cyanide consumption between 50–100 mg can lead to acute poisoning which has been reported to be lethal in adults and low cyanide consumption for a long time could cause severe health complications such as tropical neuropathy and glucose intolerance (Adugna, 2019). The samples fortified with groundnut and soybeans had significantly lower cyanide values in comparison to the sample prepared with plain cassava leaves. Fortifying the cassava leaves will lead to a reduction of the amount of

Table 4. Characteristics of survey respondents and consumption frequency

		Location				
		Kaoma	Kasama	Mansa	Serenje	Total
Variable	Gender	N (%)	N (%)	N (%)	N (%)	N (%)
Gender	Females	159(50.96)	141(51.65)	120(41.67)	90(29.41)	510(43.26)
	Males	153(49.04)	132(48.35)	168(58.33)	216(70.59)	669(56.74)
Age (year)	Mean ± SD	49 ± 14.4	40 ± 13.2	42 ± 12.1	41 ± 14.1	
Frequency of consumption(times/week)						
Product type		Mean±Std	CV			
Plain leaves (501)	F	2.75 ± 0.9	32.78			
	M	2.65 ± 0.83	31.42			
Soy fortified (502)	F	2.75 ± 0.9	32.78			
	M	2.65 ± 0.83	31.42			
Groundnut fortified (503)	F	2.75 ± 0.9	32.78			
	M	2.65 ± 0.83	31.42			

cyanide consumed by the weight of food consumed when compared with the plain cassava leaves and thus presenting a safer option.

Bulk density is an essential parameter; as reported by Senadeera (2009) that the density of foods could influence the texture or mouthfeel and the knowledge of the density of foods can be applied in processes involving heat transfer. This could be affected by the processing method employed for each Cassava leaves food formulation. The bulk density could also assist in the ease of packaging and transportation of particulate food products (Alamu et al., 2019b).

3.3. The characteristics of the respondents and their consumption frequency

The data on the sensory attributes rating evaluation of the Cassava leaves-based products are presented in Table 4. The assessment was carried out in four locations, with a higher percentage of participants being males. Females had a higher consumption frequency (2.75) than males (2.65).

3.4. The consumer preference for sensory attributes by location

The respondents' preferences for the sensory qualities across all locations are presented in Table 5. There is no significant difference ($P > 0.05$) in all the sensory attributes of products evaluated in Kasama and Mansa. Kasama and Mansa districts recorded the lowest percentage for soy-fortified cassava leaf sauce. At the same time, there were slight significant differences ($P < 0.05$) in the results of the sensory evaluation carried out in Kaoma and Serenje districts.

Across all the districts, most households indicated having consumed cassava leaves at least once a week, followed by twice in a week and more than three times a week. Few respondents indicated consuming cassava leaves every day. The patterns of cassava leaf consumption are generally similar for males and females. Miyagi (2017) and Alamu et al. (2019b) observed a similar trend where there was no significant difference between the consumer preference results of males and females.

3.5. Most preferred cassava leaves-based products by district

Across all the districts, the most preferred sample was groundnuts fortified cassava leaves, preferred by 58% of households, while the least preferred was plain cassava leaves with 18% of the respondents. The highest preference for groundnuts fortified cassava leaves came from

Table 5. Consumer preference for sensory attributes by location

District	Products	Appearance		Aroma		Taste		Texture	
		Mean±Std	CV	Mean±Std	CV	Mean±Std	CV	Mean±Std	CV
Kaoma (N = 104)	501	4.38 ± 0.73	16.61	4.26 ± 0.82	19.35	4.18 ± 0.83	19.92	4.24 ± 0.81	19.02
	502	4.63 ± 0.71	15.35	4.60 ± 0.74	16.19	4.64 ± 0.65	14.05	4.65 ± 0.68	14.60
	503	4.17 ± 0.84	20.16	4.12 ± 0.8	19.54	4.13 ± 0.81	19.61	4.13 ± 0.79	19.08
	Total	4.39 ± 0.78 ^a	17.81	4.32 ± 0.81 ^{ab}	18.84	4.32 ± 0.8 ^a	18.56	4.34 ± 0.79 ^a	18.20
Kasama (N = 91)	501	4.26 ± 1.04	24.43	4.44 ± 0.91	20.48	4.04 ± 1.13	28.05	4.09 ± 1.09	26.71
	502	4.29 ± 1.10	25.63	4.45 ± 0.9	20.17	4.49 ± 0.85	18.87	4.56 ± 0.69	15.05
	503	4.29 ± 1.06	24.67	4.45 ± 0.89	19.89	4.33 ± 0.94	21.79	4.30 ± 0.88	20.38
	Total	4.28 ± 1.06 ^a	24.83	4.45 ± 0.89 ^a	20.11	4.29 ± 1 ^a	23.23	4.32 ± 0.92 ^a	21.26
Mansa (N = 96)	501	4.06 ± 1.03	25.46	4.22 ± 1	23.63	4.07 ± 1.08	26.48	4.03 ± 1.07	26.56
	502	4.69 ± 0.62	13.25	4.80 ± 0.57	11.94	4.90 ± 0.34	6.94	4.78 ± 0.51	10.60
	503	3.94 ± 1.11	28.26	4.24 ± 1.02	24.14	4.06 ± 1.05	25.96	3.90 ± 1.11	28.48
	Total	4.23 ± 1 ^a	23.64	4.42 ± 0.93 ^a	20.95	4.34 ± 0.97 ^a	22.37	4.24 ± 1.01 ^a	23.89
Serenje (N = 102)	501	4.28 ± 0.98	22.85	4.25 ± 0.89	20.83	4.05 ± 1	24.67	4.01 ± 0.98	24.44
	502	4.69 ± 0.64	13.75	4.7 ± 0.52	11.13	4.77 ± 0.46	9.73	4.76 ± 0.53	11.12
	503	3.67 ± 1.21	32.86	3.77 ± 1.15	30.50	3.51 ± 1.15	32.76	3.48 ± 1.1	31.51
	Total	4.21 ± 1.05 ^a	25.03	4.24 ± 0.97 ^b	22.75	4.11 ± 1.05 ^b	25.61	4.08 ± 1.04 ^b	25.53

Values in the columns with the same letters are not significantly different at P ≤ 0.05

Products codes: 501 = Plain leaves, 502 = Soy fortified, 503 = Groundnut fortified

Serenje, while the highest preference for Soy fortified cassava leaves was from Kaoma. The highest preference for plain cassava leaves was from Kasama.

Figure 1 shows the preference for samples by gender. Both males and females preferred groundnut fortified cassava leaves. However, more females preferred plain cassava leaves than males. Also, the consumption intent for the different samples of cassava leaves was determined, and it was found across the districts that 23% of respondents indicated that they would consume soy-fortified Cassava at every opportunity. About 47% of the respondents indicated that they would consume groundnuts fortified cassava leaves at every opportunity, and only 17% of the respondents said so for plain cassava leaves.

The consumer preference for food usually depends on different factors; the characteristics of the product, the consumer or the environment of the consumer (Geel et al., 2005; Murray & Delahunty, 2000). Its

sensory appeal and visual appearance mainly influence the consumer acceptability of food. However, it is not easy to generalize as to whether appearance or texture attributes are the most important (Geel et al., 2005; Risvik, 1994). Their responses across all products strongly suggest that they are most likely to embrace cassava leaves fortification with legumes particularly those fortified with soybeans which are not as popular as those prepared with groundnut powder (Alamu et al., 2019). Respondents from Kaoma had a better preference for soy fortified cassava leaf meal product over groundnut-fortified product while Serenje was the exact opposite. This might be as a result of the fact that the consumption of Soy-enriched cassava leaves is already a norm in Kaoma based on a study by Alamu et al., (2019b). They evaluated cassava processing and utilization at the household level in Zambia. Consumer characteristics in terms of knowledge, beliefs and innovativeness have been shown to have a significant effect on the results of the sensory evaluation of foods (Phang et al., 2010).

The findings from this research imply that groundnut enriched cassava leaves sauce was the most preferred, followed by soy-fortified sauce across the districts. However, more males indicated that they would consume soy and groundnut fortified cassava leaves at every opportunity than their female counterpart. The finding provides valuable information on the preference for fortified Cassava leaves-based sauce that could be used to address protein malnutrition deficiency in Cassava growing area of Zambia.

From the results of the assessment of the effect of locations, processing and gender on the sensory attributes of Cassava leaves-based products, it could be inferred that the preference for cassava leaf meal has a lot to do with the type of legume used in the fortification. The legumes used in this study; soybean and groundnut are prominent for their characteristic taste and aroma (Cheng and Bhat2015; Al-Hafud et al., 2018). They also possess distinctive appearance and texture

Figure 1. Most preferred cassava leaves sample by gender.

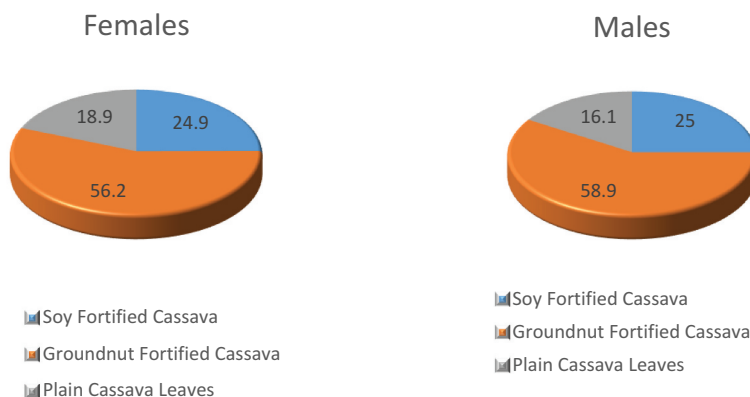


Table 6a. Willingness to buy (WTB) for Cassava Leaves by district

Products	Response	Kasama (N = 91)		Kaoma (N = 104)		Mansa (N = 96)		Serenje (N = 102)		Total (N = 393)	
		N	%	N	%	N	%	N	%	N	%
Soy fortified	yes	68	74.7%	101	97.1%	96	100.0%	80	78.4%	345	87.8%
	no	23	25.3%	3	2.9%	0	0.0%	22	21.6%	48	12.2%
Groundnut fortified	yes	74	81.3%	102	98.1%	96	100.0%	99	97.1%	371	94.4%
	no	17	18.7%	2	1.9%	0	0.0%	3	2.9%	22	5.6%
Plain Cassava Leaves	yes	71	78.0%	101	97.1%	95	99.0%	62	60.8%	329	83.7%
	no	20	22.0%	3	2.9%	1	1.0%	40	39.2%	64	16.3%

Table 6b. Willingness to Pay (WTP) (amount in Zambia Kwacha) for Cassava Leaves products by district

District		Soy fortified cassava leaves	Groundnut fortified cassava leaves	Plain Cassava leaves
Kasama (N = 91)	Mean	3.36	3.47	3.25
	Max	10	12	20
	Min	0.5	0.5	0.5
Kaoma (104)	Mean	2.16	2.79	2.15
	Max	5	12	10
	Min	0.5	0.3	0.3
Mansa(N = 96)	Mean	2.42	3.15	2.14
	Max	20	25	15
	Min	0.25	0.5	0.2
Serenje(N = 102)	Mean	3.15	3.69	2.65
	Max	15	12	10
	Min	1	1	0.5
Total(N = 393)	Mean	2.7	3.26	2.48
	Max	20	25	20
	Min	0.25	0.3	0.2

N = Total number of respondents

when added to foods (Malav et al., 2016; Meghwal et al., 2017; Pandey & Sangwan, 2019). They are added to foods/dishes/snacks as improvers due to their high protein content (Bird et al., 2017; Rizk et al., 2015; Yaver & Bilgiçli, 2019). Cassava leaf, though a highly nutritious vegetable, contains a considerable amount of antinutrients and toxic substances which makes it undergo rigorous processing methods in order to bring it to a permissible range that is safe for human consumption (Latif and Müller, 2015). Legumes are added to cassava leaf meal to make up for the assumed nutrient loss during detoxification as it has been mentioned earlier that protein in cassava leaf is not bioavailable (Boundy-Mills et al., 2019). Thus, cassava leaf meal fortified with legumes is a positive way to diet diversification and promotion of a highly nutritious relish in Zambia.

3.6. Willingness to buy (WTB) and Willingness to pay (WTP) for Cassava Leaves-based products

Tables 6a and 6b show the WTB and WTP (Zambia Kwacha) for cassava leaves by the district. In total, 88% of the respondents indicated WTB for Cassava with Mansa as the highest recording 100% of households. In comparison, 94% of the households expressed WTB for groundnut fortified cassava leaves with Mansa again recording 100% of the households. For plain cassava leaves, 84% of the respondents indicated WTB with Mansa again being the highest with 99% of households reporting WTB. More males expressed WTB for Soy fortified cassava leaves and groundnut fortified cassava leaves. However, more females indicated more WTB for plain cassava leaves compared to males.

Across the districts, the respondents stated that they were willing to pay an average of K2.7 for Soy-fortified Cassava leaves with Kasama indicating the highest at K3.36 and Kaoma the least at K2.16. The average WTP for groundnut fortified cassava leaves was K3.26, with the highest being from Serenje at K3.69 and again the least in Kaoma at K2.79. The average WTP for plain cassava leaves was K2.48, the highest from Kasama at 3.25 and the lowest from Mansa at K2.14 (Table 6b). This shows that the respondents were willing to pay more for groundnut fortified cassava leaves than the Soy fortified cassava leaves. It could be inferred that both legume- fortified cassava leaves sauce was acceptable, and respondents were willing to buy and pay for the products. The production of these

Table 7. Analysis of variance (ANOVA) of Cassava leaves-based products sensory attributes

Source	DF	Appearance MS	Aroma MS	Taste MS	Texture MS
District	3	1.7640	2.3967*	3.3592**	4.1538**
Products	2	32.1934***	26.1637***	58.1612***	61.5530***
Gender	1	1.6447	0.4595	0.0725	0.2849
Error	1172	0.9022	0.7690	0.8213	0.7897

*** means significant at $P < 0.001$, ** means significant at $P < 0.01$ and * means significant at $P < 0.05$

products could be commercialized and serves as a source of income for the household farmers and youths. Also, the products could be used to improve the nutrition of low-income household farmers.

3.7. Effects of locations, processing and gender on the sensory attributes of Cassava leaves-based products

The Mean Squares (MS) of the Analysis of variance (ANOVA) of sensory characteristics of Cassava leaves-based products are presented in Table 7. The processing methods had a highly significant effect ($P < 0.001$) on all the sensory attributes studied. In contrast, the district had a moderately significant impact ($P < 0.01$) on taste and texture and a lowly significant effect ($P < 0.05$) on the aroma, and no significant ($P > 0.05$) effect on appearance. Alamu et al. (2019b) reported that the district had a strong significant effect on the aroma, appearance, texture and taste for chinchin and tid-bit products. Also, gender had no significant ($P > 0.05$) effect on all the sensory attributes. It implies that the fortificant (soybean and groundnut) and the locations (districts) had effects on the sensory characteristics, especially the aroma, taste and texture. The sensory attributes of products are district dependent. This showed that cultural background influenced the preferences for cassava leaves products. Still, gender showed no significant effect ($P > 0.05$) in the preference ratings of the attributes of the cassava-leaves based products.

3.8. Pearson correlation coefficients between product attributes and WTP

Table 8 shows the Pearson correlation coefficients of willingness-to-pay and the sensory attributes. There was highly significant ($P < 0.001$) but a weak and positive linear relationship between sensory characteristics and consumers' Willingness to pay (WTP). However, Taste ($r = 0.19706$) and texture ($r = 0.20783$) showed higher coefficients among the attributes. It implies that the WTP and the consumption of products are driven by taste and texture attributes.

Based on the recorded Pearson correlation coefficients between product attributes and WTP, it can be inferred that WTP is hinged on sensory attributes where taste and texture take the lead among all other attributes in this study. The observation agrees with the findings of Bi et al. (2011) for fruits like tangerines for which taste is a significant factor, Beriain et al. (2009) for which taste and colour were important factors and that of Alamu et al. (2019b) that reported that taste and texture sensory attributes drive the acceptability of fritters in Zambia. Thus, it could be concluded that cassava-based snacks are acceptable, and respondents are willing to pay irrespective of the social culture

Table 8. Correlation between product attribute and willingness to pay (WTP)

Attribute	WTP
Appearance	0.17817***
aroma	0.16213***
Taste	0.19706***
Texture	0.20783***

*** means significant at $P < 0.001$, ** means significant at $P < 0.01$ and * means significant at $P < 0.05$

4. Conclusions

There was a noticeable increase in the values of proximate properties and a decrease in the values of anti-nutritional properties of legume-fortified products compared with the plain cassava leaf product. Also, both fortified cassava leaves products were preferred, and respondents were willing to buy and pay for them. However, male respondents preferred the legume-fortified products, while female preferred the non-fortified product. At the district level, Kaoma and Serenje districts showed a little preference for soy-fortified cassava leaf meal over groundnut fortified cassava leaf meal.

In contrast, Kasama and Mansa districts look promising in embracing both the soybean and groundnut fortified cassava leaf meal. The preference for Cassava leaves-based products is district dependent. Utilization of cassava leaves from sweet varieties for food purposes should be further encouraged based on its nutritional benefits. However, most importantly, its fortification with legumes should be emphasized to further improve the cassava leaves-based meal, in terms of nutrition and sensory attributes.

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