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Full Length Research Paper

Development and characterization of cake made with a mixture of cowpea and rice flours

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This study developed a cake recipe based on a flour mixture of cowpea and rice. Four formulations with different percentages of cowpea flour (CF) and rice flour (RF) (0% CF + 100% RF, 10% CF + 90% RF, 20% CF + 80% RF, 30% CF + 70% RF) were developed. Microbiological, physicochemical and sensory evaluations were performed. Tasters preferred the mix formulation containing 10% of cowpea and 90% of rice ($p < 0.05$), that revealed adequate physicochemical and microbiological characteristics. It is worth noticing the low lipid, high fiber, iron and zinc content, and gluten free characteristic of the developed product. The study also showed 91% of acceptance and 66% of purchase intention by the tasters. We conclude that the use of the flour mixture of cowpea and rice produced an innovative, nutritious product with good acceptance and technological potential that stimulates the production of family farming and, at the same time, increases consumption of rice and beans by the Brazilian population.

Key words: Legumes, family farming, *Vigna unguiculata*, sensory evaluation.

INTRODUCTION

Legumes are highly regarded both in the international and national scenario due to their nutritional value and socioeconomic importance (IQBAL et al., 2006). Brazil is the third producer of beans, accounting for 12% of the global production, making them an important crop in the country (Brasil CONAB, 2015).

Family farming is the main supplier of foodstuffs for the Brazilian domestic market. Thus, it helps to control the inflation rates by controlling the price of food (Brazil, 2017). According to the agricultural census, family farming is responsible for 83% of the bean consumed in the homes of the state of Bahia (Brasil, 2014).

Cowpea (*Vigna unguiculata* (L.) Walp.), also known as string beans or macassar beans, is one of the main agricultural crops in the Brazilian North and Northeast regions, widely cultivated by family farmers. This legume stood out as an important ingredient of the diet of the population in this region and represents one of the main

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Table 1. Formulations of the cakes containing 0, 10, 20 and 30% of cowpea flour (CF) and different percentages of rice flour.

Ingredient	CF (%)			
	0	10	20	30
Cowpea flour(g)	-	29.65	58.48	87.73
Rice flour (g)	292.44	262.80	237.95	204.71
Margarine (g)	87.87	87.87	87.87	87.87
Sugar(g)	150.00	150.00	150.00	150.00
Eggs(g)	110.12	110.12	110.12	110.12
Wholemilk (g)	189.52	189.52	189.52	189.52
Baking powder (g)	5.00	5.00	5.00	5.00
Salt (g)	0.40	0.40	0.40	0.40

sources of employment and income (Freire Filho et al., 2011).

From the nutritional point of view, cowpea is considered a staple food source for carbohydrates (mainly the complexes ones), considerable amounts of fibers, vitamins and minerals (phosphorus, iron, potassium, magnesium, zinc and manganese), bioactive compounds, and essential amino acid, especially lysine (Freire Filho et al., 2011; TACO, 2011). On the other hand, rice (*Oryza sativa L*.) is a very common component of the Brazilian diet, being a source of vitamins, mainly of the B complex, minerals and fibers. The typical Brazilian combination of rice and beans is recommended by health agencies for providing the complementarity of essential amino acids (Brazil, 2014; Mesquita et al., 2007; Monks et al., 2013).

The dietary guidelines for the Brazilian population recommend daily consumption of rice and beans in the proportion of 2: 1 (Brazil, 2014). However, due to changes in the eating habits of Brazilians between 2002 and 2009 there was a reduction of 40.5% in the participation of rice in the household dietary index and 26.4% of beans, while the participation of industrialized ultra-processed food products increased (IBGE, 2011).

The use of a flour mixture of beans and rice in food formulations has been studied as a strategy to add a higher nutritional value and functional properties to gluten-free products without raising their final cost (Chávez-Santoscoy et al., 2016).

In this context, the objective of this study is to develop a cake made with a flour mixture containing cowpea and rice, rescuing the consumption habits of rice and beans and eventually valuing the traditional Brazilian diet.

MATERIALS AND METHODS

Sampling and production of cowpea flour

The grains of the cowpea beans (immature seed) were obtained from family farmers in the city of Santo Antônio de Jesus - Bahia. Average temperature variation between seasons is small in the region. The grains were selected, washed and bleached in the Food Technology Laboratory at UFRB.

To obtain the flour, the cowpea grains were dried in an oven (Biopar, Porto Alegre, Brazil) at 50°C for 30 h and then ground in a food processor (Philips, São Paulo, Brazil). The flour was sieved with a 21 mm mesh, packed in plastic containers and stored at 25°C.

Technological functional properties of cowpea flour (CF)

To determine the gelling capacity of cowpea flour (CF), we used the modified method of Coffmann and Garciaj (1977). The water absorption index (WAI) was determined according to Beuchat's methodology (1977) and the water solubility index (WSI), according to the modified method of Okezie and Bello (1988).

Preparation of cake formulations

Following the results of previous laboratory tests, we developed four formulations with different percentages of cowpea flour (CF) and rice flour (RF) (0% CF+ 100% RF, 10% CF + 90% RF, 20% CF + 80% RF, 30% CF + 70% RF) based on a traditional recipe (Table 1).

All the ingredients were weighed in a semi-analytical balance (Marte, São Paulo, Brazil). Eggs, margarine and sugar were added to the mixer (Arno, São Paulo, Brazil) to prepare the dough. RF and CF were added to the mixture and homogenized for 15 min. Milk, salt and baking powder were added gradually. The prepared dough was placed in an aluminium tray, greased with margarine and sprinkled with RF, and baked in an oven (Metalmaq, Duque de Caxias, Brazil) preheated at 180°C for 1 h.

Sensory evaluation

This study was approved by the Federal University of Reconcavo da Bahia (UFRB) Ethics Committee (Process n. 31797114 00000056). All subjects signed the Informed Consent Form (ICF). Sensory evaluation was conducted at UFRB.

Ranked -preference test

The test was carried out inside individual booths with 40 untrained tasters. They were offered four cake samples in disposable dishes coded with a three-digit code in random order. The tasters were asked to taste the four samples from left to right and rate them

Table 2. Functional properties of cowpea flour

Parameter	CF
Gelification capacity (%)	10
Water Absorption Index (gel/g)	3.53 ±0.174
Water Solubility Index (%)	13.66 ±0.577

according to their preference.

Results were analyzed with the Friedman's non-parametric test at 5% of significance (Meilgaard et al., 2007).

Acceptance test and purchase intent

The acceptance test and purchase intent were carried out with potential consumers of the product based on the most preferred sample, according to the previous test. The test was conducted with 100 untrained tasters (employees, teachers and students at UFRB).

The 9-points hedonic scale was used in the acceptance test, ranging from 1 (dislike extremely) to 9 (like extremely). The same scale was used to evaluate the flavor, color, texture and overall consumer acceptance of the product. For the purchase intention assessment, we adopted a structured 5-points scale, ranging from 1 (certainly would not buy) to 5 (certainly would buy) (MEILGAARD et al., 2007).

Physicochemical evaluation

The cake selected into the ranked-preference test was characterized in relation to moisture (AOAC, 1997), water activity (DecágonoLab Master, Novasina®), pH, total titratable acidity, proteins, iron, zinc (IAL 2008), lipids (Bligh and Dyer, 1959), fibers (Goering and Van Soest, 1970; Van Soest et al., 1991). Carbohydrates were determined by difference and total caloric value by the Atwater System (Watt and Merril, 1963). The color parameters (a *, b, L *, C * and h) were determined by the CIELAB System. All evaluations were performed in triplicates.

Microbiological evaluation

The microbiological evaluations were made for total and thermotolerant coliforms at 45°C, and the detection of *Salmonella* species and yeasts and molds with the methodology described by the American Public Health Association-APHA (2001).

The physicochemical and microbiological evaluations were carried out at the Applied Research Laboratory of Biotechnology and Food at SENAI-CIMATEC in the city of Salvador –Bahia.

RESULTS AND DISCUSSION

Average WAI of cowpea flour was 3.53 ±0.174 g of water g^{-1} (Table 2). This result was higher than the one found by Gomes et al. (2012), who found 2.63 $g.g^{-1}$ in cowpea tegument-free flour. In the food industry it is known that higher WAI values yields better bakery products. This is due to water retention by the starch granules that confer moisture and softness to the final product (Wang et al., 2006). The WSI was 13.66%, a result lower than the one found by Rios et al. (2016). The authors found values between 17 and 23% in flours of five commercial cowpea cultivars. Solubility is closely related to proteins type, structural conformation and presence of polar amino acids. Globulins are abundant in beans, especially in the cotyledon. Although they are only partially soluble in water, they are easily denatured, which can influence the solubility index. In addition to that, the higher proportion of amylose in the starch granules of mature beans also contributes to an increase in hydrophilicity (Salgado et al., 2005; Lourenço, 2000). It is worth noticing, however, that our study was based on flours obtained from immature grains with tegument, which may explain our result. It is worth mentioning that the immature form of the grain is massively consumed by the population.

Gel formation was observed at the concentration of 10% of CF. Medeiros (2013) found similar results (8 - 10% of CF), while Pereira (2013) found gelling ability at 14% of CF. Gel formation is associated with starch gelatinization, dependent mainly on the amylose content, and on the ability of proteins to form three-dimensional networks capable of holding water (Singh et al., 2003).

Table 3 shows that sample CF10 is similar to the standard sample and differs from CF20 and CF30 ($p < 0.05$). Based on these results, we chose sample CF10 (the most preferred sample) to proceed with the acceptance test, and physicochemical and microbiological assessments.

Participants of the acceptance test were mostly females (74%), and their age range was distributed as: 51% (21-29 years); 16% (30-39 years); 7% (40-49 years); 2% (50-59 years). Regarding their cake consumption habits, most participants consume the product monthly (32%), followed by fortnightly (27%), 2 to 3 times a week (11%), once a week (28%), and daily (1%). This shows that the consumption of cakes by this population is not usual. However, cake consumption is high among children and adolescents. Bezerra et al. (2013) observed that adolescents are the main consumers of cakes, among the studied age groups. Corroborating this result, Souza et al. (2017) reported frequent cake consumption by elementary school children.

According to the acceptance test, the CF10 cake recipe was approved by tasters with 91% of positive acceptance (ratings 6 to 9 in the acceptance scale) (Figure 1A). Similarly, Frota et al. (2010) obtained 84.4% of acceptance for sweet biscuits with 10% of CF. This recipe also obtained 66% of positive purchase intent (probably would buy or certainly would buy). The negative purchase intention

Table 3. Statistical analysis of the cake formulations based on cowpea flour in the ranked –preference test.

Sample	Scores*
RF	92[ab]
CF10	78[a]
CF20	115[b]
CF30	115[b]

RF=Rice flour cake used as control; CF10=cake recipe with 10% of cowpea flour; CF 20=cake recipe with 20% of cowpea flour; CF30=Cake recipe with 30% of cowpea flour. Scores followed by the same letter did not differ from each other at the 5% of significance. *Total taste score attributed by tasters.

(certainly or probably would not buy) reached 4%, while 30% of tasters were not sure (Figure 1B).

The sensorial attributes of flavor, color, texture and overall acceptance obtained averages of 6.73, 7.52, 6.07 and 7.08, respectively, ranging from "like slightly" to "like moderately". Lower values were found by Farias et al. (2016) when evaluating cookies made with CF, obtaining averages of 5.46, 6.49, 5.65, and 5.93 for the attributes of color, flavor, texture and general evaluation, respectively.

The product's sensorial aspects were acceptable, demonstrating the viability of the use of RF and CF in cake recipes. The product incorporates ingredients cropped by family farmers, meets the demand for gluten-free foods and can be included in school meals, as recommended by the Brazilian School Feeding Program (PNAE) (Brasil, 2009).

The developed recipe can also help to rescue the habit of consumption of rice and bean recommended by the food guide (Brazil, 2014). The annual consumption of beans per capita in Brazil dropped from 12.4 kg/inhabitant/year in 2002-2003 to 9.1 kg/inhabitant/year in 2008-2009. In the same period, the annual consumption of rice per capita decreased 16.1%, from 24.5 to 14.6 kg/inhabitant/year (IBGE, 2011).

The results of the centesimal analysis of the CF10 formulation are shown in Table 4. pH found for the product was 7.53 and acidity 0.27%. Guimaraes et al. (2010) found post-cooking pH between 7.45 and 6.66, and acidity of 1.0 and 4.56% in cakes produced with 7 and 10% of watermelon rind, respectively.

The moisture content of the product was 34.20%, which is higher than that found by Carvalho et al. (2011) in a cake containing 50% of white bean flour in combination with wheat flour (32.83%). Water activity was 0.950, higher than that found by Gutkoski et al. (2009) in samples of English-type cakes (0.850 to 0.890).

Ash content was 5.62%. Carvalho et al. (2011) found 2.97% of ashes. Frota et al. (2010) found 2.83% of ashes in Brazilian rolls and 2.98% in biscuits with partial substitution of wheat flour for 10% of cowpea flour.

The lipid content (6.0%) was lower than the one reported by Carvalho et al. (2011) who identified 10.0% of lipids in cake formulation containing 50% of white bean flour. Frota et al. (2010) also identified higher lipid content (11.96 and 11.98%) in biscuits and Brazilian rolls with 10% CF, respectively. The reduced lipids content found in our recipe follows the global demand for healthy diets.

Protein content reached 8.17%, higher than the one found by Guimaraes et al. (2010), who reported 6.47% of protein in a cake recipe with wheat flour. The partial substitution of rice flour for beans flour not only increases the protein content of the recipe but also improves its amino acid profile (Brasil, 2014).

Carbohydrate content of the product was 36.62%. Cavalcante et al. (2016) and Carvalho et al. (2011) found between 51.5 and 74.91% in cassava cheese bread enriched with 5.6% of CF and cake containing 50% of white bean flour, respectively.

In the present study, we quantified two important micronutrients, iron and zinc, and compared them with a few existing studies. We found 2.04 mg of iron/100 g of product, which is higher than the results found by Awasthi (2014) in cake made with refined wheat flour (0.14 mg/100 g). The content of zinc was 2.48 mg/100 g. Frota et al. (2010) found 0.70 mg and 0.42 mg/100 g in biscuits and Brazilian rolls with 10% of CF, respectively.

Addition of CF can, thus, improve iron and zinc intake. This makes it especially suited for school meals, since children are the most affected by micronutrient deficiency (Pedraza and Rocha, 2016). The amount of iron and zinc found are within the recommended Dietary Reference Intakes (DRI) for children between 4 and 8 years old (20.4 and 40.8% of the DRI, respectively). For children between 9 and 13 years old, the product meets 25.5% of the DRI for iron and 22.54% for zinc (IOM, 2002).

The product contains 9.388% of fibers. Carvalho et al. (2011) found 5.18% of fibers in a cake containing 50% of white bean flour. Awasthi (2014) reported 1.12% of fibers in a cake is made with refined wheat flour.

The energy content of the cake was 233.16 Kcal/100 g. In cakes made with rice flour and cassava peel in different percentages, energy content varied from 184.76 to 281.7 Kcal.g^{-1} for recipes with 100% cassava peel flour and 100% rice flour, respectively (Souza et al., 2013).

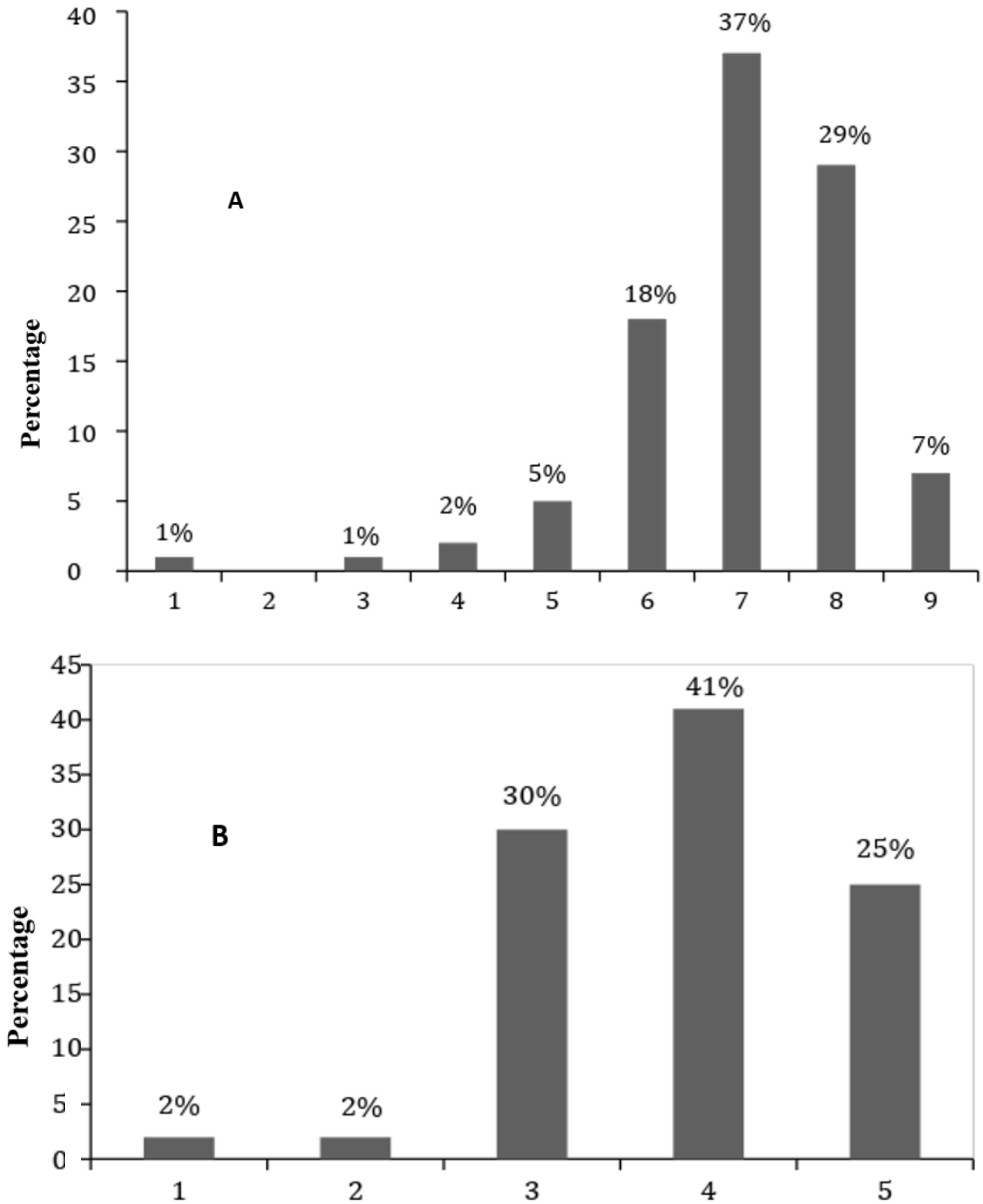

Figure 1. Distribution of acceptance rates of the cake recipe with 10% of cowpea flour. (A) Frequency distribution of acceptability scores: 1= Dislike Extremely; 2= Dislike a Lot; 3= Dislike Moderately; 4= Dislike Slightly; 5= Neither Like/Nor Dislike; 6= Like Slightly; 7= Like Moderately; 8= Like a Lot; 9 = Like Extremely; (B) purchase intention: 1= Certainly Would Not Buy; 2= Probably Would Not Buy; 3= Maybe Would Buy / Maybe Would Not Buy; 4= Probably Would buy; 5=Certainly Would Buy.

The parameters of chromaticity were a* = 2.77 ± 0.170 and b* =18.65 ± 0.421. The parameter of luminosity was L* = 53.223±0.456. C* and h indicated that the product showed low saturation and yellowish hue with values of 18.860 ± 0.407 and 51.547 ± 0.633, respectively. These results indicate that the addition of CF reduced L* and increased b*, moving towards a yellow core. Similar results were found by La Hera et al. (2012) for cakes made with lentil flours. Camili et al. (2016) found L* = 29.06, C* = 17.10 and h = 42.74 for the kernel of cakes made with wheat flour.

The microbiological evaluation showed that the product met the microbiological standards required by the Brazilian legislation (Brasil, 2001): negative for *Salmonella* species, contamination by molds and yeasts <1 log CFU/cm^2, total coliforms <3 NMP/g, and coliforms

Table 4. Mean and standard deviation of the centesimal composition of the recipe with 10% of cowpea flour.

Parameter	Average±SD
pH	7.53±0.081
Acidity	0.27±0.050
Water activity	0.950±0.008
Moisture (%)	34.20±1.191
Ashes (%)	5.62±1.31
Lipids (%)	6.0±0.339
Proteins (%)	8.17±0.053
Carbohydrates (%)	36.62±0.246
Energy value (Kcal/100 g)	233.16±4.300
Fibers (%)	9.38±1.585
Iron (mg/100 g)	2.04±0.003
Zinc (mg/100 g)	2.48±0.068

at 45°C <3 NMP/g.

Conclusions

It can be concluded that the incorporation of CF in RF resulted in a product with adequate sensorial, microbiological and physicochemical characteristics. The product use rice and cowpea in optimized gluten-free food formulations with low lipid, high fiber, iron and zinc content. Additionally, it stimulates the production of family farming and values the traditional Brazilian diet.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Physicochemical and sensory properties of bread with sweet potato flour (*Ipomea batatas* L.) as partial replacer of wheat flour supplemented with okra hydrocolloids

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The effects of partial substitution for wheat flour with sweet potato flour and the incorporation of aqueous okra hydrocolloid extract on the physicochemical and sensory characteristics of wheat bread processing was evaluated. Six breading formulations were prepared with substitution of 10, 20 and 30% wheat flour by sweet potato flour with or without incorporation of aqueous okra hydrocolloid extract of 0.5, 1.0 and 1.5%, respectively. Physicochemical, proximate and minerals composition of the dough and bread were evaluated. Higher addition of sweet potato flour (SPF) and okra hydrocolloid significantly affected dough and bread CIE color. Increasing SPF content decreased baking yield of the dough, whereas the incorporation of okra hydrocolloid improved yield. In general, wheat flour substitute by SPF and the incorporation or not of okra hydrocolloid did not change the chemical composition, pH and titratable acidity of the bread. Sensory acceptance showed that wheat-sweet potato composite flour for bread production is still not usual for local consumers who assigned grades 6 and 7 with comments like "I liked it slightly" and "I liked it moderately". Results of the study indicate that SPF is a feasible alternative as primary source material for bread production.

Key words: Sweet potato flour, wheat flour, okra hydrocolloid, color of bread, chemical composition, sensory evaluation.

INTRODUCTION

Bread is universally accepted as a very convenient form of food that is important to all populations, and is still one of the most consumed and acceptable staple food products in all parts of the world (Ijah et al., 2014) and can be used as a carrier for healthy ingredients (Akhtar et al., 2005). It is also an excellent source of complex

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carbohydrates which provides energy from starch and nutrients, such as protein and fiber (Eduardo et al., 2013). Wheat flour is one of the major conventional ingredients in bread making, due to its gluten fraction (Anwar et al., 2017).

The gluten-forming proteins (gliadin and glutenin), when combined with water, are hydrated, creating connection bridges between them and by mixing, form the viscoelastic structure of the gluten network (Ortolan and Steel, 2017), which is responsible for the retention of gases formed in the mass fermentation process and in the release of water vapor during the cooking process (Araújo et al., 2010). In addition to wheat, water, yeast, sugar, milk, improver, fat and salt are other ingredients commonly used in baking process (Mitiku et al., 2018).

Nowadays, globalization in food service industry has led to producers and retailers responding to consumer's demands by modifying healthy and attractive varieties. Bakeries are also challenged to produce either gluten-free bread or bread with reduced gluten content which have quality features comparable to wheat flour bread. Consequently, replacement of wheat flour in order to obtain healthier and less expensive products has been the subject of numerous researches, which is mainly focusing of sweet potato-wheat flour blends (Adeleke and Odedeji, 2010; Ijah et al., 2014; Nunes et al., 2016; Pérez et al., 2017; Yuliana et al., 2018; Mitiku et al., 2018; Nogueira et al., 2018). For the low income countries, like Mozambique, where sweet potato is largely produced in the whole country, its utilization for flour processing to bread making would be welcomed to reduce costs of importation of wheat flour and by offering nutritious bread products to consumers. However, sweet potatoes processed into flour has been reported with some drawback properties such as slightly dark color and low loaf volume when applied on bread products (Trejo-González et al., 2014; Amal, 2015; Yuliana et al., 2018). These noted technological difficulties that partial replacement of wheat flour with other types of flour presents its attributed to its proteins which do not have the capacity to form that network of gluten to retain the gas produced during fermentation (Gallagher et al., 2004; Eduardo et al., 2013). Therefore, more attention has been proposed in the use of hydrocolloids due to their accessibility, safety and also low cost (Gałkowska et al., 2013; Shahzad et al., 2019).

Okra (*Hibiscus esculentus*), found inside of dika nut (*Irvingia gabonensis*) and khan (*Belschmiedia* sp.), is the popular hydrocolloids African food with emulsion potential. Kinetic studies have indicated that the mechanism involved formation of thick and strong interfacial gum films around the oil globules, in addition to a high water absorption capacity (Ndjouenkeu et al., 1997). Okra is the most abundant and economically important vegetable in Mozambique. It offers a consistent hydrocolloid when cooked; and it is usually added to other foods that need improvement in consistency (Noorlaila et al., 2015). When okra hydrocolloid is extracted in water, it results in a highly viscose solution with slimy texture and has proven to strengthen soft wheat dough (Ramadas and Tharanathan, 1987). Therefore, a proper inclusion of okra hydrocolloids can alter the enthalpy of starch gelatinization, reducing the firmness of the dough and delaying the retrogradation which reduces syneresis (Li et al., 2017; Shahzad et al., 2019). Acquistucci and Francisci (2002) also studied the effects of the addition of okra (*H. esculentus* L.) pods to wheat flour devoted to bread preparation and showed effectiveness of this crop as food additive to produce bread of adequate technological and sensory characteristics.

Considering that sweet potato flour gets a low quality pastries due to the baking process and taking into account the fact that the okra mucilage can have a good stabilizing effect of sweet potato-wheat flour composite, the present study was carried out to evaluate the effects of partial replacement of wheat flour with flour from sweet potato (*Ipomoea potatoes*) flour; and, the respective supplementation with okra hydrocolloid in the preparation of wheat bread production.

MATERIALS AND METHODS

Sweet potato flour processing

Sweet potato cv. Brazlandia Branca was obtained at harvest from the local growers in Mapinhane and City of Vilankulo, Inhambane, Mozambique. The potatoes, free of cracks or any other defects were immediately transported in plastic bags to the Laboratory of Food Processing at Higher School of Rural Development (ESUDER) where the roots were stored for 24 to 48 h prior processing. The unpeeled roots were washed, thinly sliced (1.5 mm × 5 mm thickness) and dipped in 0.5% acetic acid, for 20 min. Treated slices were drained and dried in aluminum single batches of 1.5 kg using the drying oven (Selecta, SA, Spain) at 65°C for 13 h in order to keep the slices with a moisture content of approximately 6.9% in average and held in containers with desiccant until milled. The dehydrated sweet potato was milled in a blender (Philips Blender, 400W, 1L) in small batches of 30 g for 5 min, using a sieve coupled to the blender, which allow obtaining flour with uniform granulometry. The flour was packaged in impermeable polyethylene containers and stored before the bread processing and analysis. Prior to packaging, the yield of the process was determined using the following formula: Yield (%) = (SPF weight/peeled raw sweet potato weight) × 100%. The pH of SPF was also measured by dissolution technique (AOAC, 2000).

Hydrocolloid preparation

Freshly harvested okra was purchased in the local market at Manhiça – Maputo Province and transported in plastic bags to the Laboratory of Food Processing at ESUSER 12 h prior processing. The okra was washed and dipped in 0.5% acetic acid solution for 5 min, towed with towel paper, and then sliced to 5-10 mm using a stainless steel knife. Hydrocolloid was obtained by water extraction in proportion of okra slices and water in a ratio of 1:2 (w/v) in a polyethylene container. The hydration was performed under the refrigerator condition at ±5°C for 24 h to improve hydrocolloid extraction yield. A white cotton sieve was used to separate the hydrocolloid from the solid content. The extraction process was

Table 1. Formulation of wheat bread partially substituted with sweet potato flour.

Ingredient	F1	F2	F3	F4	F5	F6
Wheat flour (g)	90	80	70	90	80	70
Sweet potato flour (%)	10	20	30	10	20	30
Hydrocolloid (%)	-	-	-	0.5	1.0	1.5
Water (mL)	90	90	90	90	90	90
Yeast (g)	4	4	4	4	4	4
Sugar (g)	4	4	4	4	4	4
Salt (g)	1.5	1.5	1.5	1.5	1.5	1.5

F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet flour potato, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% hydrocolloid (in dry matter), respectively.

repeated five times in order to extract as much hydrocolloid as possible. In all stages of the experiment, the hydrocolloid was obtained by dehydration process and it was stored for less than 12 h before the bread production. In each stage, the yield of the extraction was determined using the following formula:

Yield (%) = (hydrocolloid weight/okra weight) × 100%. The pH of hydrocolloid was also measured by the dissolution technique (AOAC, 2000).

Bread evaluation

Six different bread formulations were prepared in each batch with a replacement of wheat flour by 10, 20 and 30% of SPF, with and without the addition of 0.5, 1.0 and 1.5% hydrocolloid (Table 1). The ingredients and additives were well homogenized manually in polyethylene containers for 5 min and the dough of each bread formulation formed. The sugar (sucrose), salt (sodium chloride) and water were mixed and stirred using a stainless spoon until a solution was obtained. Where necessary, the proportion of okra hydrocolloid was also added. Then, dry biological yeast was added under constant stirring until dissolved. The final solution was left to stand at room temperature for 5 min to activate the yeasts prior to the flour mixture. The pH and color characteristics of potato slices were measured, before the dough for each formulation was placed on a rectangular tray and shaped manually according to a conventional loaf shape.

The molded dough was allowed to ferment for 45 min and placed on a tray and introduced into a preheated oven at 30°C. The dough was baked at 180°C for 30min in an electric oven. Baking temperature was monitored by a simple thermometer to provide constant temperature during the process. After baking, the loaves were cooled at room temperature for 15 min. Each loaf was middle cut into two pieces as shown in Figure 1. One piece of loaf was packaged in waterproof polyethylene plastics and stored in freezing conditions until the analysis of chemical composition was carried out. The other piece of each loaf formulation was submitted to yield, pH, titratable acidity and instrumental color analysis. A single batch of bread for sensory evaluation was baked, packaged in water-proof polyethylene plastics and stored under refrigeration for 24 h. Prior to sensory tests all samples were sliced and oven heated at 30°C for 5 min.

Chemical composition and physicochemical characterization

Dough and bread were simultaneously evaluated for pH and color parameters. Bread were also assessed for titratable acidity, moisture, protein, fat, ash and carbohydrates, minerals iron, selenium, zinc, manganese and potassium. The pH of dough and loaves were measured using a digital pH meter (Butech PCD-650 potentiometer, Singapore) calibrated with pH 4 and pH 7 standard solutions. In addition, 5 g sample was weighed in a backer and homogenized with 50 mL of distilled water using a mixer (Philips HR2103, China). Then, the electrodes were introduced to read the pH. Dough and bread were also tested by instrumental color, using a Minolta CR-400 (Konica Minolta Sensing Inc. Osaka, Japan) colorimeter with a 8-mm aperture size, illuminant A and a 10º angle of the observer. The device was calibrated to use the specular component included (SCI) and the specular component excluded (SCE) modes. The CIE lightness (*CIE L**), redness (CIE *a**) and yellowness (CIE *b**) components were obtained from the SCE mode readings. Whiteness as the overall appearance index of the samples was calculated by the formula (Park, 2013):

$$\text{Whiteness} = [100 - (100-L^{*2}) + a^{*2} + b^{*2}]^{1/2}$$

The titratable acidity of loaves was determined by acid-basic titratable procedures, and expressed as the volume (mL) of 0.1 N NaOH consumed in 10g of bread dissolved in 90mL of distilled water, until pH 8.5 (Lima et al., 2009). The chemical composition of dough and bread was determined according to the official methods of the AOAC (2012). For proximate composition (%), samples were analyzed for the total moisture (AOAC 950.46B), fat (AOAC 960.39), protein (AOAC 981.10, using 5.7 as conversion factor), and ash (AOAC 950.46) contents. Carbohydrates content was calculated by different. Minerals iron, zinc, and potassium were determined by Inductively Coupled Plasma for Atomic Emission Spectrometer (SHIMADZU ICPE-9820, Japan). All measurements were made in triplicate.

Sensory evaluation

The sensory evaluation was carried out 24 h after preparation of the bread samples. The sensory panel consisted of 50 untrained students of ESUDER. In the first stage, the panelists were asked to answer how they liked the samples using the check-all-that-apply (CATA) questions. The CATA questions were defined by 9 untrained participants, consisted of students, with ages ranging from 18 to 25 years old, randomly recruited at ESUDER. Small slices approximately 25 mm edge of each sample were presented in a single testing session (Repertory Grid technique), and judges used an open-ended question to establish the appropriate terms for describing their appearance, flavor, aroma/odor and texture. The most mentioned terms for each attribute were chosen to compose the CATA questions (Table 2).

In the second stage, the sensory analysis was performed in a single testing session conducted individually in an open space.

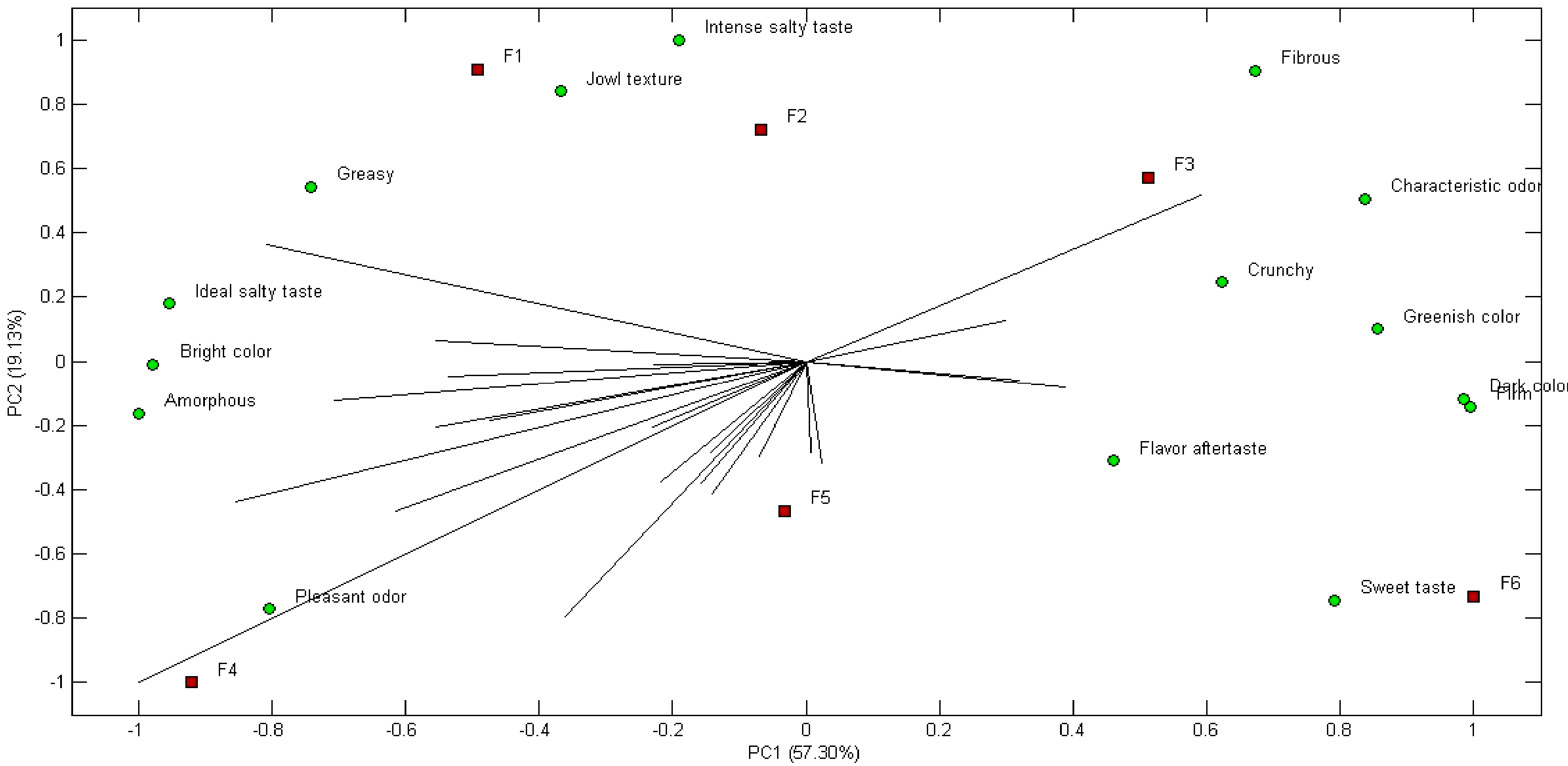

Figure 1. External preference map (EPM) of the sensory terms on the check-all-that-apply (CATA) questionnaire for the bread from wheat-sweet potato composite flour samples in the correlation matrix with overall consumer impression. F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet flour potato, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% okra hydrocolloid (in dry matter), respectively.

Heated sample slices of approximately 25 mm edge were labeled with a 3-digit code and were offered to the panelist randomly and balanced in a monadic sequence. Mineral water was offered to the panelists for mouth rinsing between sample trials. The panelists received the sensory evaluation form (acceptance test) and evaluated the samples using a hedonic scale of 1 (disliked very much) to 9 (liked very much) for each attribute (appearance, flavor, aroma, texture, and overall impression). In the same form, the panelists were asked to check all the terms of CATA questions (as previously defined, Table 2) considered appropriate to describe each attribute.

Statistical analysis

The experiment was conducted in a completely randomized design with three replicates. Data was tested by F-test (ANOVA) and the means were separated using Tukey's test ($P<0.05$) and using the Sisvar (DEX, UFLA, Lavras, Brazil) package, version 5.6. Multiple comparison method was performed to compare more than one pair of means or proportions at the same time.

To identify the relationship between the CATA terms selected for each sample, an external preference map (EPM) based in the regression of external descriptors against consumer data (overall impression acceptance in this case) was used. Only the slopes for

Table 2. Terms surveyed for check-all-that-apply (CATA) questions of each sensory attribute.

Appearance	Flavor	Odor/Aroma	Texture
Greenish color	Intense salty taste	Pleasant odor	Hard (firm)
Bright color	Ideal salty taste	Characteristic odor	Amorphous
Dark color	Sweet taste		Crunchy
Greasy	Flavor aftertaste		Jowl texture
			Fibrous

consumers that provided models with less than 30% of significance (Elmore et al., 1999) were plotted on the EPM, being performed in the Senso Maker statistical software (Lavras, Brazil), version 1.5.

RESULTS AND DISCUSSION

Processing yield and pH of raw materials

The drying process of sweet potato and okra hydrocolloid extract yielded 30.52 and 28.49%, respectively. There are few studies reporting potato flour yielding, with low yield of 17.4% observed by Almeida and Szlapak (2015) in sweet potatoes using an industrial oven at 80°C for 6 h; while Sousa (2015) obtained higher yield values of 33.51 to 39.89% when the SPF was subjected to 60°C for 8 h. According to Silva (2010), different yields could be found depending on the raw potato variety and its composition. Generally, tuber with a low percentage of dry matter has low yield. For the wheat flour pH was higher (6.76 ± 0.04), there was no significant difference observed between SPF and Okra hydrocolloid extraction (mean of 6.38±0.11). Previous studies regarding pH of SPF pointed closed values, as pH 6.38±0.05 obtained by Sousa (2015), and 5.4±0.1 observed by Silva (2010). Values of pH close to 6.38 have been bleached to prevent enzymatic browning reactions. Enzymatic reactions, like polyphenol activity, could be prevented by use 1% citric acid solution Franco (2015) or sodium bisulfite solution (Silva, 2010) which induces for pH decreasing. In our experiment the sweet potato was dipped in 0.5% acetic acid solution. Regarding the wheat flour, variations were observed by other researches as pH 6 to 6.1 (Macedo et al., 2017); whereas, Sharma et al. (2013) reported pH 5.99, similar value to that recorded in this study for okra hydrocolloid treatments.

Baking yield of bread

The baking yield of the bread is shown in Table 3. Bread made from the dough containing 10% with added SPF without okra hydrocolloid (F1) had the highest yield (90.18 ±1.24; P<0.05). Gradual yield decreasing (P<0.05) due to the heating treatment was observed in order F6, F5, F4 and F3, respectively. The reduction in baking yield of bread from wheat-sweet potato composite flour processing could be attributed to the low water holding capacity of SPF without the hydrocolloid (Franco, 2015). Miller and Hoseney (1993) stated that hydrocolloids in the food industry are associated with the food hydrophilic ability which improves water holding capacity. An increased yield of treatment for F4 (F4; yield ~79.89±0.42) was expected because it contains similar wheat-sweet potato composite flour as F1. However, the data for the baking yield of F1 and F4 were significantly different.

Physicochemical characteristics of the dough and bread

The pH, color indices and whiteness are given in Table 3. It was observed that there were no significant differences among treatments (P>0.05) in relation to pH values of the dough (6.38±0.41) and bread (6.12±0.02). Similar values were obtained by Pereira et al. (2005), whose results pointed pH values ranging from 5.88 to 6.06 for the dough as well as from 5.73 to 5.91 for the bread samples. However, during fermentation several compounds are produced, such as alcohols, proteolytic enzymes and various organic acids which can alter the pH of the dough (Pyler and Gorton, 2008).

No significant differences (P>0.05) was found among samples of bread in relation to the titratable acidity. A similar behavior was observed by stabilizing the pH (~8.5) at mean of 0.945±0.11 mL 0.1 N NaOH. These values were lower than that reported in the literature, as 1.53-3.17 mL (Quílez et al., 2006); however, values found in this study are similar to those reported by Silva et al. (2017). The great variations in acidity of cookies containing SPF can be attributed to the fact that wheat flour, ingredients and additives may have interfered on the fermentation process, and consequently the final pH of dough (Pereira et al., 2005).

Significant effects (P<0.05) of SPF and okra hydrocolloid incorporation were observed in the CIE $L^*a^*b^*$ parameters. The dough lightness (CIE L^*) decreased (P<0.05) when wheat flour was gradually replaced by SPF. Similar trend was observed with the increasing addition of hydrocolloid. This finding indicated that an increase of SPF content in the bread formulation made the dough increasingly dark (Low L^* and whiteness values). Similar behavior was observed

Table 3. Physicochemical characteristics (mean values ± standard deviations) of the dough and bread from wheat-sweet potato composite flour.

Characteristic	Treatments						Pr<F
	F1	F2	F3	F4	F5	F6	
Dough							
pH	6.62±0.51	6.76±0.62	6.87±0.79	6.15±0.24	5.78±0.02	6.21±0.29	0.133
CIE color							
Lightness (L*)	81.65±0.20[a]	79.50±0.35[b]	77.13±0.63[c]	80.81±1.70[ab]	76.77±0.22[c]	73.84±0.40[d]	<0.001
Redness (a*)	-3.07±0.03[b]	-2.89± 0.10[b]	-2.47±0.17[a]	-3.69±0.13[c]	-2.81±0.03[b]	-2.50±0.06[a]	<0.001
Yellowness (b*)	23.73±0.32[b]	23.75±0.37[b]	23.81±0.65[b]	23.61±1.15[b]	25.85±0.05[a]	25.93±0.23[a]	<0.001
Whiteness	69.85±0.37[a]	68.49±0.48[a]	66.89±0.85[b]	69.30±0.39[a]	65.13±0.12[c]	63.07±1.52[d]	<0.001
Bread							
Yield (%)	90.18±1.24[a]	81.30±2.65[bc]	75.62±1.38[d]	79.89±0.42[c]	82.18±0.59[bc]	85.12±1.24[b]	<0.001
pH	6,38±0,06	6,11±0,0	6,17±0,01	6,03±0,01	6,01±0,01	6.00±0,05	0.996
AT (mL NaOH)	0.75±0.07	0.97±0.17	1.05±0.21	0.80±0.00	1.05±0.14	1.05±0.07	0.993
CIE color (Crumb)							
Lightness (L*)	58.44±0.96[bc]	61.38±1.60[ab]	63.36±0.63[a]	52.84±1.33[d]	57.71±1.42[c]	57.67±1.5[c]	<0.001
Redness (a*)	-2.40±0.058[ab]	-2.93±0.10[bc]	-3.32±0.13[c]	-2.51±0.42[ab]	-2.52±0.21[ab]	-2.29±0.05[a]	0.003
Yellowness (b*)	21.09±0.75[a]	20.43±0.56[a]	20.33±0.53[a]	18.24±0.43[b]	19.83±0.44[a]	19.83±0.4[ab]	0.001
Whiteness	53.33±0.83[b]	56.20±1.18[ab]	57.96±0.42[a]	49.37±1.24[c]	53.22±1.32[b]	53.26±1.28[b]	<0.001

CIE, Commission Internationale de l'Eclairage; F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet potato flour, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% okra hydrocolloid (in dry matter), respectively.

by Singh et al. (2008). Additionally, Melini et al. (2017) also found that lightness values always decreases in combined wheat and legume flours, which can explain the lowest CIE *L** of the dough with 1.5% hydrocolloid (*L**=73.84±0.40) compared with all other treatments. Dough samples of F1 and F4 were mostly lighter with similar CIE *L** values (81.65±0.20 vs. 80.81±1.70), but this trend changed significantly during baking stage, where the treatment F3 became lighter (CIE *L**=63.36±0.63) as F2 (CIE *L**=61.38±1.60). The lightness (*L**) indices demonstrated a reduction after the dough baking (means from 58.44 to 63.36) compared to that of the raw dough (means from 73.84 to 81.65). In general, addition of okra hydrocolloid also significantly affected the lightness of the bread samples (Table 3). Moreover, the raw dough showed a tendency to increase of the CIE *L** values with SPF and okra hydrocolloid into the formation, however, in relation to the samples of the bread different behavior was observed ($P<0.05$). The gradual increase of lightness observed from F4 to F6 could be due to high oil absorption capacity of okra hydrocolloid (Bhat and Tharanathan, 1987; Ndjouenkeu et al., 1997). Although baking process was mainly correlated with decrease of the crumb's brightness of sweet potato-wheat bread (Purlis, 2010; Pérez et al., 2017), in contrast, Ngoma et al. (2019) stated that increasing of lightness might also be due to oven drying temperature, since higher temperature inactivates phenolase enzyme.

Beyond redness (CIE *a**) values of the dough and bread, negative indices suggest extremely absence of red characteristics. However, samples containing 30% SPF tend to have high values of CIE *a** when they are compared to that containing 10% (without okra hydrocolloid) or samples with 10 and 20% SPF with hydrocolloid. For the yellowness (CIE *b**), the samples of the dough or bread are significantly different due to the treatments (P<0.05). The dough produced with addition of 1.0 and 1.5% hydrocolloid (F5 and F6) appeared yellowish (High CIE *b**) and are similarly darker (mean of 25.89±0.14) than all others (mean of 23.73±0.62). This was confirmed by higher values of *b** and lower values of *L** in F5

Table 4. Proximate composition and mineral content of bread from wheat-sweet potato composite flour.

Characteristic	Treatments						Pr<F
	F1	F2	F3	F4	F5	F6	
			Proximate composition (%)				
Moisture	27.34±0.75	27.55±0.83	27.86±2.58	27.60±3.27	25.93±1.94	27.26±0.26	0.998
Protein	9,53±1,05	9,42±0,34	10,30±0,46	9,84±0,61	10,06±0,06	8,20±0,15	0.994
Fat	**0.50±0.10**	0.62±0.17	0.50±0.01	0.50±0.23	1.00±0.70	1.50±1.41	0.782
Ash	1.72±1.67	1.90±0.87	2.10±0.25	1.89±0.00	2.19±0.04	2.27±0.04	0.998
Carbohydrates	60.88±1.38	60.43±0.10	58.23±3.30	60.15±2.89	60.80±2.75	60.75±1.35	0.998
			Mineral content (mg/100 g sample)				
Potassium (K)	11.09±0.73^{b}	10.09±0.69^{bc}	8.85±0.59^{c}	**9.09±0.48^{c}**	10.46±0.69^{bc}	14.86±0.96^{a}	<0.001
Zinc (Zn)*	0.05^{c}	0.06^{b}	0.07^{a}	0.07^{a}	0.05^{c}	0.05^{c}	<0.001
Iron (Fe)*	0.004	0.004	0.005	0.003	0.005	0.004	0.979

*Standard deviation values are very lower. F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet potato flour, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% okra hydrocolloid (in dry matter), respectively.

and F6 dough. However, this effect appears to be favored by baking process in which bread exhibited small differences in CIE *b** (Table 3). According to Franco (2015), the use of SPF in the replacement of rice flour from 25 to 100% caused a significant variation on the color parameters, whereas the lightness (CIE *L**) decreased from 54.75±3.79 to 45.93±7.04, the redness (a*) increased from 3.14±2.84 to 11.84±4.25 and the yellowness (b*) from 12.90±3.23 to 18.40±3.66.

The proximate composition and mineral content of bread is given in Table 4. No significant differences were observed among treatments when wheat flour was replaced by SPF. The moisture content (mean of 27.26±1.61%) was closely similar to that observed by Bibiana et al. (2014) for wheat/maize/sweet potato bread samples, except to that 34.97±0.05 of control (100% wheat). However, it was higher than moisture found in other researches (Ijah et al., 2014; Mitiku et al., 2018) which incorporated different proportions of sweet potatoes flour in replacement of wheat in bread samples. According to Adeleke and Odedeji (2010), moisture up to 15% in the samples is out of the limit for the dry products. These authors reported low moisture content (2.60-3.68%) for different proportions of wheat flour and sweet potato flour blends. This finding reinforce that moisture could be higher due to the processing method, since sweet potato flour has more fiber and sugar content in the flour, more water absorption is expected (Singh et al., 2008). Saleh et al. (2018) stated that incorporating SPF increased water holding capacity on wheat pasta. Additionally, high moisture content may also be due to the processing methods that the samples were exposed to. In relation to protein (9.56±0.45%) and ash (2.01±0.48%) contents, they are similar to those found by Ijah et al. (2014), while the lowest carbohydrates content (60.21±1.96%) was not expected for the wheat-sweet potato flour bread, since increasing addition of SPF as wheat substitute has shown significant increase (up than 80.00%) of total sugar molecules (Ijah et al., 2014; Mitiku et al., 2018).

For the mineral content, potassium and zinc content were significantly different among treatments (P<0.05). In addition, potassium content decreased (from 11.09 to8.85 mg/100 g sample) with an increase of SPF added in samples without okra hydrocolloid, whereas zinc content increased (from 0.05 to 0.07 mg/100 g sample). However, samples with okra hydrocolloid, showed an increase in potassium content (9.09 to 14.86 mg/100 g sample) differently to zinc content. Iron (Fe) content was not significantly different among treatments (P>0.05) and its content was very low (mean of 0.004 mg/100 g sample). The lowest values were observed in the present study when

Table 5. Acceptance scores (means ± standard deviation) given for the sensory parameters of bread from wheat-sweet potato composite flour.

Attribute	Treatments						Pr<F
	F1	F2	F3	F4	F5	F6	
Appearance	6.52±1.63^{ab}	6.42±1.49^{bc}	5.62±2.17^{c}	7.28±1.60^{a}	6.76±1.33^{ab}	6.34±1.69^{bc}	**<0.001**
Flavor	6.32±2.06	6.56±1.77	6.54±1.79	7.00±1.49	7.04±1.43	6.30±1.81	0.136
Odor	6.22±1.93	6.18±2.08	6.18±1.91	7.04±1.64	6.42±2.07	6.28±1.60	0.183
Texture	6.22±1.73^{b}	6.22±1.96^{b}	5.84±1.91^{b}	7.12±1.41^{a}	6.44±1.92^{ab}	6.04±2.07^{b}	**0.017**
Overall Impression	7.08±1.45	6.76±1.48	6.34±1.68	7.28±1.46	7.02±1.61	6.72±1.64	0.056

F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet potato flour, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% okra hydrocolloid (in dry matter), respectively.

compared with that found by Mitiku et al. (2018) who reported values of zinc ranged from 1.39 to 3.05 mg/100 g sample and iron ranged from 3.74 to 14.93 mg/100 g sample of bread produced with SPF (up to 25%) as wheat substitute. Other researches (Melini et al., 2017) also cited that wheat bread provides several micronutrients, such as calcium, iron, zinc, magnesium, sodium, phosphorus and potassium. In this study, micronutrients content was very low. This behavior was reported by Triasih and Utami (2020) who found that nutrition content could vary as effect of processing technique.

Sensory analysis

The sensory panel comprised 52.0% male and 48.0% female judges. The majority of the judges (96.0%) were 18-30 years old and only 2.0% were 31-45 year old. Moreover, 40.0% of the judges reported that they rarely consume sweet potatoes, 34.0% consume twice a month, 16.0% consume once a month, 4.0% consume twice a week, and 6.0% consume twice a week.

Acceptance test

Overall, the inclusion of SPF in bread formulation as a substitute for wheat flour, as well as the addition of okra hydrocolloid, had little effect on the acceptance of the products (Table 5), scoring between 5 and 7 ("I either liked and neither disliked it" and "I slightly liked it"). Based on the acceptance scores given by the judges, some slight differences (P<0.05) in appearance (scores mean of 5.62 to 7.28) and texture (scores mean of 5.84 to 7.12) was observed, but there were unperceived differences between treatments. All samples had similar scores (P>0.05) for flavor (6.63±1.73), odor (6.40±1.87) and overall impression (6.87±1.55). Similar trend was observed by Franco (2015) who replaced rice flour with SPF and indicated that 25% substitution did not alter deeply the texture, and global acceptance when compared to the standard sample.

Check-all-that-apply (CATA)

The EPM was generated from the number of times that the consumers associated each of the 15 sensory terms of the CATA questions (Table 2) with the samples and overall impression scores from acceptance test. According to Elmore et al. (1999), models with less than 30% of significance could be considered valid to generate the EPM graphic. Therefore, only the slopes for 22 consumers (of the 50 participants) that provided valid models (P<0.20) were plotted on the map on two PCs (Figure 1). The PC plots show the relative positions of the samples and factor loading indicate the attributes that best describe the dimensions of the perceptive space. Combined, the PC1 and PC2 accounted for 76.43% of the total variance in the data after fitting by the vector model with a coefficient of determination (R2) of 0.8153. Thus, F1 and F4 were correlated to "ideal salty taste", "bright color" and "amorphous" texture. Whereas, F1 and F2 were grouped as "intense salty taste" and "jowl texture"; F1 was highly correlated with "greasy" texture and F4 with "pleasant odor". The treatment F3 appeared to be correlated with "fibrous", "crunchy" and "characteristic color". Judges also correlated F6 with "sweet taste", "firm" and perceived "dark color". The samples F3 and F6 were together grouped as having "greenish like color". However, the "aftertaste flavor" was described to F3, F5 and F6. To better understanding of the judges' responses, the Figure 2 showed clearly what the samples are. It could be observed that the incorporation of at least 1.5% okra hydrocolloid in the bread formulation of wheat-sweet potato compound flour contributed increasing darkness.

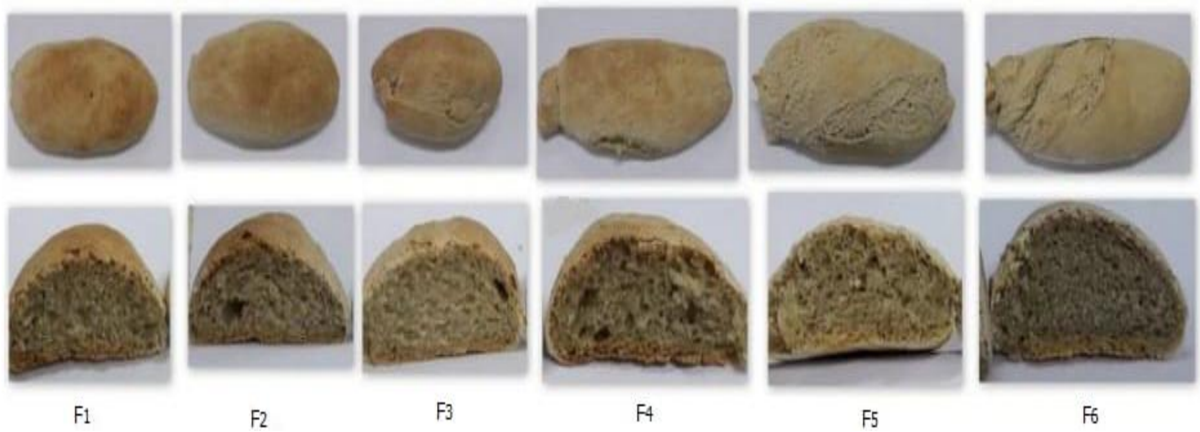

Figure 2. F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet flour potato, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% okra hydrocolloid (in dry matter), respectively.

Conclusions

The study revealed that replacing wheat flour with sweet potato flour in 10, 20 and 30% is a feasible alternative for bread production without remarkably changing its physical-chemical and sensory characteristics. However, replacement of 30% of wheat flour for an equal proportion of sweet potato flour and 1.5% okra hydrocolloid became the dough darker, and resulted in low acceptability of the bread samples. All findings indicated that replacement of wheat flour with sweet potato flour up to 30% in the production of bread can be an interesting alternative to produce low cost bread without significant changes in its sensory and technological properties.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Factors influencing consumption of street vended local foods (SVLFs) in Urban Ghana

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Street foods are important in meeting dietary and nutritional needs of growing urban populations, contributing to their food security needs. In spite of concerns of nutritional value, affordability and localness of street foods, street food vending enterprise is prolific in urban places with consumers of different socio-cultural and economic statuses. This is because several factors inform people on their food choices. These may include their socio-cultural and economic status and not just the food characteristics. This study was to examine the factors influencing consumption of *Hausa koko*, *Waakye* and *Ga kenkey* referred to as street vended local foods (SVLFs) associated with specific ethnic groups in Ghana. Data was collected from a cross section of 631 urban consumers of SVLFs in Accra, Kumasi and Tamale. Binary probit regression models were used to estimate factors influencing SVLFs consumption. Results showed that consumers were from different social, cultural and economic backgrounds. Food characteristics (such as safety, nutritional value, affordability, convenience and closeness to vendor), social status (including, age, educational level and work status), and cultural factors (like consumer coming from place of food origin and consumption of food from infancy) positively influenced consumption of SVLFs. Food vendors should be aware of these factors to promote consumers' continual patronage of healthy, nutritious and affordable SVLFs in urban Ghana.

Key words: Food choices, Hausa Koko, Waakye, Ga Kenkey.

INTRODUCTION

Food business entrepreneurs are mindful of consumers' food choices and preferences relating to taste, texture and cultural acceptability. Food has attached strong social meanings and functions. While some foods defined

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the status of their consumers, others are defined by the class of people who consistently consume them. The pleasure consumers derive from their choice of food is associated with their expectations and experience, and may be influenced by such things as trustworthiness, responsiveness, assurance, empathy, and the physical elements of any food service offering (Narine and Badrie, 2007). Streets foods play a very important role in the sociocultural settings of most urban dwellers due to its affordability and ensuring food and nutritional security (FAO, 2018). Thus, they tend to be abounding in several urban communities in Ghana and across Africa. However, one important issue raised about street foods is safety, regarding the environment within which they are prepared and sold (Hiamey and Hiamey, 2018). The studies on street foods in Ghana are limited to the microbial characteristics of foods (Annan-Prah et al., 2011; FAO, 2016a; Tugli et al., 2019), others focused on factors influencing street food choices (Asiegbu, et al., 2015; Hiamey and Hiamey, 2018). A few focused on social aspect of food quality (Rheinländer et al., 2008), and on the negotiation of street food regulations (Forkuor, 2014) with dearth knowledge on the sociological aspects of street foods. While some of the studies focused on the negative aspects of street foods such as being unsafe, non-nutritious, and not affordable, and not being authentically local, others highlight on the affordability of street foods and their ability to meet dietary requirements of consumers and the localness[1] of such dishes. Nevertheless, the consumption of street foods continued to increase in urban areas in many countries. This implied that consumption decisions are not only based on food characteristics but on several other factors. Factors such as consumers' social status and cultural background, the quality of foods and other external aspects may be included (Asiegbu et al., 2015). However, the available studies are limited on the factors that influenced street vended local foods (SVLFs) consumption in Ghana.

Given the strong ethnic linkage in food choices in Ghana, a better understanding of the underlying factors including sociocultural dimensions on consumption decisions of street vended foods would guide policy in strengthening street food vending enterprises for enhanced income and poverty reduction. This study was to examine the factors influencing the consumption of some specific ethnic related street foods such as "*Hausa koko*", "*Waakye*" and "*Ga kenkey*", hereafter referred to as SVLFs. While *Hausa koko* and *Waakye* are associated with Hausa speaking ethnic groups in Northern parts of Ghana (Photos 1 and 2), *Ga kenkey* is associated with Ga speaking ethnic groups in Accra, Southern Ghana (Photo 3).

[1] Localness refers to the food perceived as a local dish to the consumer. Consumers' perceptions of local may be diverse but for this paper local is referred to the dishes associated with some ethnic groups in Ghana.

Factors influencing food choices

Modern consumers are extremely diverse, so is their preference for street foods. Consumers, especially low-income earners are faced with diversity of factors in making food choices. Factors such as starvation, palatability, nutrition, family, environment and economics, low literacy on food standards, insufficient information on nutrition and psychological deprivation may be included. Others are emotion, cultural background, education, knowledge and skill, and also media and advertisement (Singh and Kathuria, 2016; Clark and Bagdan, 2019). While such decisions are largely positively influenced by perceived behavioural control, attitudes towards healthy eating, subjective norms, and level of knowledge regarding healthy food, other factors such as routine family habits, food affordability and availability are potential factors preventing access to healthy street foods (Samoggia et al., 2016; Clark and Bagdan, 2019).

Other studies have found attitude (Spence and Townsend, 2006; Prati et al., 2012; Singh and Kathuria, 2016), perceived usefulness (Nocella and Kennedy, 2012), subjective norms which included societal pressure for someone to perform an action and normative beliefs comprising information received through social networking, relatives and local traders (Chikweche and Fletcher, 2010; Chikweche et al., 2012) to influence food choice decisions of consumers positively or negatively, especially those with lower incomes. Empirically, perceived availability in terms of nearness of the food to homes or work places has been found to impact consumers' choice of foods especially of those economically disadvantaged (Mukherjee et al., 2012). In India, consumers were found to be attached to foods within 1 km radius of sale (Ali et al., 2010). Another important economic factor cited in previous studies that influence consumers' food choices is perceived affordability and availability (Asiegbu et al., 2015; Clark and Bagdan, 2019). Other socio-demographic characteristics such as age, gender, level of education and number of children in household, influences consumers' decisions on particular food choice (Asiegbu et al., 2015; Singh and Kathuria, 2016).

In addition to the factors discussed above, this study analysed the extent to which social status and quality characteristics of SVLFs influence consumption in urban Ghana. Thus, it examined how factors such as age, sex, education, worker, student, safe, convenience, closeness to vendor, nutrition, affordability, consumer coming from the place of origin of foods and consumed from infancy, influence the consumption of SVLFs.

MATERIALS AND METHODS

Study area

The study was conducted in three urban locations of regions in Ghana. They are Accra (which is also the national capital) in the

Photo 1. Hausa Koko Stand in Kumasi.

Photo 2. Waakye vendor in Accra.

Greater Accra Region; Kumasi in the Ashanti Region; and Tamale in the Northern Region. These cities were selected because of their metropolitan nature in providing people of different socio-cultural and economic backgrounds for this study.

Data sampling and data collection

Multi-stage sampling technique was used in the study. In the first stage, metropolitan cities and sub metros were purposively

Photo 3. Consumers eating Ga Kenkey and Beans sauce at the street food stand in Tamale.

selected. This was followed by a random sampling procedure from an infinite population of consumers (Louangrath, 2014). Every other consumer who was willing to participate in the survey was selected from the population of all who patronised the SVLFs at the studied foods vending sites, giving every consumer of SVLFs the opportunity to participate in the study. The formula proposed by Louangrath (2014) was:

$$n = \frac{z^2(p)(1-p)}{c^2}$$

Where;
n = minimum sample size needed for accuracy
z = standard normal deviation set at 95% confidence level (1.96)
p = percentage of selecting a response (50%=0.5)
c = confidence interval (0.05= ±5)

In all, a total sample of 631 consumers comprising 403 males and 228 females were selected. Semi-structured questionnaires were administered to consumers by trained enumerators through individual interviews. The questions included socio-demographics characteristics of consumers, the reasons for consuming SVLFs and how consumers define nutrition, safety, affordability and localness of SVLFs among others. The reasons were listed and whether they influenced their decision to consume SVLFs or not was obtained.

Data management and analyses

Primary data collected was entered, edited and analysed using Statistical Package for Social Sciences (SPSS) version 16 (SPSS Inc., USA) and STATA software version 15 (Stata Corp., USA) for some further analysis. The analysis included descriptive statistics such as frequencies and cross tabulations of the socio-demographic characteristics of consumers. The factors influencing the regular consumption of the SVLFs was examined using binary probit models. Major binary choice models that can be used in the analyses included the probit or logit models; however, this study used the probit model because it followed a standard normal distribution which is more adaptable in most statistical procedures unlike the logistic distribution which characterizes the logit model.

Empirical strategy of factors influencing consumption of SVLFs

Consumer behaviour relates with how people bought, what they bought, when they bought and why they bought (Srujana, 2012). This theory combined different disciplines; psychology, sociology, anthropology and economics. The process consumers go through while purchasing a product is complex, since many internal and external factors have effect on their buying decisions. The consumer behaviour theory studies how people decided to spend their money, given their preferences and budget constraints and provided better understanding of how individuals' tastes and incomes among other factors influence the demand curve. It has been classified into rational and moral based theories (Eide, 2013). The rational based theories assumed that consumers weigh the costs and benefits associated with the consumption of the product during the decision-making process. Hence, consumers evaluated several factors in order to achieve their utility maximizing objective. The moral based theories however posit that consumers considered moral implications in their decision-making processes. This study examines the factors influencing the consumption of specific SVLFs, "*Hausa koko*", "*Waakye*" and "*Ga Kenkey*", which are ethnic-based Ghanaian local dishes sold in the streets.

This study denoted decision to consume these SVLFs by "***strtvenfd***", which is modelled as consumer's choice and based on the utility maximization theory (Rahm and Huffman, 1984; Foxall and James, 2003). A consumer decided to consume a local dish if the utility derived is greater than not consuming ($U_{i1} > U_{i0}$). This decision is a binary one and outcomes are mutually exclusive. This

Table 1. Description of variables in model and a-priori expectations.

Variable	Definition	Unit
Strtvenfd	Consumption of SVLFs	1 if consumes SVLF; 0, otherwise
AGE	Age	Years
SEX	Sex	1 if consumer is male; 0, otherwise
EDUC3	Educational level	1 if consumer has attained secondary education; 0, otherwise
EDUC4	Educational level	1 if consumer has attained tertiary education; 0, otherwise
WORKER	Occupation; worker	1 if consumer is a worker; 0, otherwise
STUD	Occupation; student	1 if consumer is a student; 0, otherwise
SAFE	Safety of food	1 if food is safe; 0, otherwise
CONVEN	Consume based on its convenience	1 if food is convenient; 0, otherwise
CLOSVEND	Closeness to vendor	1 if consumer is close to vendor; 0, otherwise
NUTRI	Consume based on the nutrition	1 if food is nutritious; 0, otherwise
AFFORD	Affordability	1 if food is affordable; 0, otherwise
FROMLOC	Consumer from origin of food	1 if food is from the locality of consumer; 0, otherwise
CONINF	Consumes from infancy	1 if food is consumed from infancy; 0, otherwise

result in a binary dependent variable, C_i which assumed the value "1" if a consumer decided to consume "*strtvenfd*" and "0" if otherwise. The basic utility function depended on demographic characteristics, perceived risk and quality characteristics, social status and socio-cultural factors- X (such as age, sex, education, worker, student, safe, convenience, closeness to vendor or availability, nutritious, affordability, consumer coming from the place of origin of food and consumed from infancy) and an error term having mean to be zero specified as:

$$U_{i1}\left(X\right)=\alpha_1 X_i+\delta_{i1} \quad \text{for consumption} \tag{1}$$

$$U_{i0}\left(X\right)=\alpha_0 X_i+\delta_{i0} \quad \text{for no consumption} \tag{2}$$

Thus observing a value, 1 will yield a probability,

$$P_r=(C_i=1/x_i\alpha_i)=1-H(-x_i\alpha_i) \tag{3}$$

and for observing 0, could be given by,

$$P_r=(C_i=0/x_i\alpha_i)=H(-x_i\alpha_i) \tag{4}$$

Where H is a continuous and strictly increasing cumulative distribution function, which takes a real value and returns a value which ranges from 0 to 1.

Thus, the parameters in the model in Equations 3 and 4 are obtained using the maximum likelihood estimation procedure. The dependent variable is an unobserved latent variable which is related to

$$C_i \text{ as } C_i=\alpha_j X_{ji}+\delta_i \tag{5}$$

where δ_i is a random error term.

The observed dependent variable is determined by whether the predicted A_i* is greater than 1 or otherwise as specified in equation 6 as:

$$C_i=1 if C_i*>0 \text{ and } C_i=0 if C_i*\leq 0 \tag{6}$$

where C_i* is the threshold value for C_i and is assumed to be normally distributed.

Following Maddala (2005), the probit model adopted for the study is specified as:

$$P_i=P(C_i*<C_i)=P_i=P(C_i*<\alpha_0+\alpha_j X_{ji}) \tag{7}$$

where P_i is the probability that an individual will make an objective choice by consuming "*strtvenfd*" or not and C_i is the dependent variable.

The empirical model

The empirical model is simplified in the Table 1 and explicitly specified as:

$$\Pr(strtvendfd_i=1|x)=\alpha_0+\alpha_1 AGE+\alpha_2 SEX+\alpha_3 EDUC3+\alpha_4 EDUC4+\alpha_5 WORKER+\alpha_6 STUD+\alpha_7 SAFE+\alpha_8 CONVEN$$
$$+\alpha_9 CLOSVEND+\alpha_{10} NUTRI+\alpha_{11} AFFORD+\alpha_{12} FROMLOC+\alpha_{13} CONINF+\delta_i$$

Table 2. Sex, age, educational level and occupation of consumers.

Characteristic	Frequency	Percentage
Sex		
Male	403	63.9
Female	228	36.1
Age range		
5-20	159	25.2
21-40	427	67.7
41-60	42	6.7
61-80	3	0.5
Mean age 26.5, Minimum 10 and Maximum 64		
Educational Level		
No Education	61	9.7
Primary	62	9.8
Secondary	219	34.7
Tertiary	250	39.6
Vocational	39	6.2
Occupation		
Unemployed	73	11.6
Govt. worker/ paid salary	135	21.4
Trader	99	15.7
Artisan	47	7.4
Student	247	39.1
Other (driver, driver mate, farmers, NGO, private)	30	4.8
N=631		

RESULTS AND DISCUSSION

Consumer characteristics

Results from the consumer survey indicated that consumers were from different social, cultural and economic background and status (women and men, office workers, construction workers, students and non-school going children). Majority (63.9%) of respondents were males and 36.1% females with ages ranging between 10 and 64 years. Most (67.7%) of the respondents fell between the 21 and 40 age group and had an average age of 27 years (Table 2). Majority (74.3%) of the respondents had secondary or tertiary education and is consistent across different occupations including government, salaried workers, traders, artisans, students, farmers etc. with 12% of unemployed consumers patronising SVLFs. The findings suggested that SVLFs are patronised and consumed by people from all socio-economic backgrounds (Annan-Prah et al., 2011).

The three foods consumers' diverse ethnic backgrounds from the different locations of study are presented in Tables 3 and 4. Generally, people of the Akan tribes (Agona, Akuapem, Akwamu, Akyem, Asanti, Bono, Fante, Kwahu, Wassa and Sefwi people) of Ghana constituted 46% of consumers, followed by those of the Northern tribes (these included several tribes such as Dagomba, Nanumba, Maprusi, Moore, Frafra, Nankani, Bulsa, Kusaal, Grusi, Wali and Birifo etc) who formed about 36 % of respondents. Table 3 shows the ethnic background of *Hausa koko*, *Waakye* and *Ga kenkey* consumers. The results showed that the majority of consumers had Akan ethnic background. This was followed by those with Northern Ghanaian ethnic backgrounds. In Tamale, consumers of the Northern tribes dominated but in Accra and Kumasi, those of the Akan tribes dominated. There were also some respondents from the West African region, particularly Nigeria and Burkina Faso. This showed the diverse ethnic background of consumers of all three SVLFs and is in confirmation with findings of foreigners' patronage of street foods (Annan-Prah et al., 2011).

The distribution of location of respondents by ethnicity is presented in Table 4. The results showed that majority of respondents were from the Akan tribe for Accra (49%) and Kumasi (85%). However in Tamale, majority (75%) of respondents were of the Northern tribe with only 16%

Table 3. Ethnicity of Consumers by SVLFs.

Consumption of SVLFs	Akan	Ga/Adangbe	Ewe	Northern tribes	Mixed tribes	Total
Hausa koko						
No	52	18	13	34	3	120
Yes	238	28	47	194	4	511
Total	290	46	60	228	7	631
Waakye						
No	18	9	2	19	0	48
Yes	272	37	58	209	7	583
Total	290	46	60	228	7	631
Ga kenkey						
No	39	6	12	51	3	111
Yes	251	40	48	177	4	520
Total	290	46	60	228	7	631

Table 4. Location by consumers ethnicity.

Location	Ethnicity of consumers (%)					
	Akan	Ga/Adangbe	Ewe	Northern tribes	Mixed tribes	Total
Accra	49	16	16	17	1	100 (227)
Kumasi	85	4	4	5	1	100 (164)
Tamale	16	1	7	75	1	100 (240)
Total	48	7	10	36	1	100 (631)

from the Akan tribes (Table 4). The reason why people of the Akan tribe do not dominate in Tamale may be because, though Tamale is a Metropolis, people from the Northern tribe form majority of the population compared to Accra and Kumasi where the Akan tribes dominated the population.

Summary statistics of relevant variables

Table 5 presented the summary statistics of variables used in the probit regression models. The average age of respondent was 27, indicating that the consumers of SVLFs are generally young. The females constituted a lower percentage of the sample (36%) whereas the males constituted 64% of the sample. This low proportion involvement of women may be related to food association with women's self- image because of their traditional role as food providers and thus, may not be involved much in consuming street foods to protect this image. However, previous study has shown their involvement in SVLFs vending because of this role (Haleegoah et al., 2016). Thirty-five percent of consumers completed secondary education while 40% completed tertiary. Respondents constituted 55% workers and 40% students. Again, 67% of the respondent consumed *Hausa koko*, 72% consumed *Ga kenkey* whiles 78% consumed *Waakye*.

Furthermore, the proportion of respondents who consumed *Hausa koko* because of convenience constituted about 55% with only 0.7% of the respondents consuming because of closeness to the *Hausa koko* vendor. Also, 58% of the respondents attested to the nutritional value of the foods. Likewise, majority of the respondents (65%) perceive *Hausa koko* to be affordable and 42% also indicated they have been consuming the food since infancy. With regards to *Waakye*, 68% indicated they were closer to the vendor with 62% finding the food to be convenient, 77% attested to its nutritional value and 60% indicating that it was safe. With regards to affordability, the food originating from ones' locality and being consumed from infancy, accounted for 66, 36 and 43% of consumers respectively.

In the case of *Ga kenkey*, 54 and 58% of the respondents indicated that it was convenient and of nutritional value respectively. The Table 5 further showed that 65% of the sample indicated *Ga kenkey* was safe and 64% believed it was affordable. Again, results showed that, 52% of the respondents said consumers

Table 5. Variables summary statistics.

Variable	Mean	S.D.
Age	27	8.49
Secondary education	0.35	0.48
Tertiary education	0.40	0.49
Worker	0.55	0.50
Student	0.40	0.49
Consume *Hausa koko*	0.67	0.47
Consume *Waakye*	0.78	0.41
Consume *Ga kenkey*	0.72	0.45
Convenience of *Hausa koko*	0.55	0.50
Closeness to *Hausa koko* vendor	0.07	0.26
Hausa koko nutritious nature	0.58	0.50
Hausa koko affordability	0.65	0.48
Hausa koko is from ones locality	0.06	0.24
Hausa koko consumed from infancy	0.42	0.49
Convenience of *Waakye*	0.62	0.49
Closeness to *Waakye* vendor	0.68	0.47
Waakye nutritious nature	0.77	0.42
Waakye safety	0.60	0.49
Waakye affordability	0.66	0.47
Waakye is from ones locality	0.36	0.48
Waakye consumed from infancy	0.43	0.50
Convenience of *Ga kenkey*	0.54	0.50
Closeness to *Ga kenkey* vendor	0.50	0.50
Ga kenkey nutritious nature	0.58	0.50
Ga kenkey safety	0.65	0.48
Ga kenkey affordability	0.64	0.48
Ga kenkey is from ones locality	0.52	0.50
Ga kenkey consumed from infancy	0.35	0.48

came from the locality where the food originated, 35% also attested they had been consuming *Ga kenkey* since infancy, while 50% also found the vendors to be closer to them or food available to them.

Factors influencing the consumption of SVLFS

Hausa Koko

Table 6 presented the Probit regression estimated for the factors influencing respondents' decision to consume *Hausa koko* regularly. The results showed that the consumption of *Hausa koko* is significantly influenced by factors such as age, sex, being a student, convenience of the food, its nutritious value, affordability, consumer coming from the place of origin of food and its consumption from infancy. These results corroborated with the findings by Asiegbu et al. (2015) on street foods and Clark and Bagdan (2019) on several factors influencing food choices in general. These factors were positively related with *Hausa koko* consumption except for age and sex.

The age of the consumer negatively influenced decision to consume *Hausa koko*. Consequently, an increase in age decreased the probability of the consumption of *Hausa koko*. This implied that *Hausa koko* is more likely to be consumed by young consumers than older ones. This presented huge prospects for investors of the *Hausa koko* industry as the young generation constitutes a greater proportion (57%) of the population (Ghana Statistical Service, 2019); hence, investments into improving *Hausa koko* production and sale has the tendency of yielding the needed returns. Sex of respondent had a significant negative effect on the decision to consume *Hausa koko*. This implied that females are less likely to consume *Hausa koko* compared to males. This is because generally, women like to cook and hence were more involved in the preparation and consumption at home as compared to the men. The results further showed that students were more likely to consume *Hausa koko*, this was significant at the 1% level. Results showed that convenience of *Hausa koko* sold on the street was significant at 1% level; implying that the convenience of the food result in a 0.51%

Table 6. Probit Estimates of Factors Influencing Consumption of *Hausa koko*.

Variable	Coefficient	Robust S.E	M.E
Age	-0.01**	0.01	-0.01
Sex	-0.31***	0.12	-0.31
Secondary education	-0.07	0.18	-0.07
Tertiary education	-0.18	0.16	-0.18
Worker	0.56	0.18	0.56
Student	0.40***	0.19	0.40
Safe	0.38	0.61	0.14
Convenience	0.51***	0.13	0.51
Closeness to vendor	0.22	0.19	0.22
Nutritious	0.43***	0.13	0.43
Affordability	0.48***	0.13	0.48
Food from ones locality	0.62*	0.32	0.62
Consumed from infancy	0.88***	0.14	0.88
Constant	-0.68**	0.31	

Asterisks * = 10% significance level; **= 5% significance level; * **= 1% significance level, M.E. denote Marginal Effect.

Table 7. Probit estimates of factors influencing consumption of *Waakye*.

Variable	Coefficient	Robust S.E.	M.E
Age	-0.02***	0.01	-0.01
Sex	-0.13	0.13	-0.03
Secondary Education	0.14	0.18	0.04
Tertiary Education	0.37**	0.17	0.09
Worker	-0.18	0.18	-0.05
Student	-0.20	0.20	-0.05
Safe	0.28**	0.13	0.08
Convenience	0.34***	0.13	0.09
Closeness to vendor	-0.34	0.14	-0.03
Nutritious	0.33**	0.14	0.09
Affordability	0.30**	0.13	0.08
Food from ones locality	0.15**	0.14	0.04
Consumes from infancy	0.59***	0.14	0.15
Constant	0.46	0.34	

Asterisks **= 5% significance level; * **= 1% significance level, M.E. denote Marginal Effect.

increase in the probability of consumption of the food. Again, nutritional value of *Hausa koko* positively influenced its consumption. This attested that consumers perceive the *Hausa koko* to be quite nutritious hence, are more inclined to purchase and consume it. The result further showed that affordability positively and significantly influenced the consumption of *Hausa koko.* An increase in affordability by one Ghana Cedi would lead to a 0.48% increase in the probability of consumption. This finding confirmed studies, which indicated street foods affordability and thus a food security source for many urban dwellers (FAO, 2016b; Imathiu, 2017). Also, consumers who came from localities where *Hausa koko* originated influenced the consumption of *Hausa koko* positively. This is not surprising because of the social network implications of this variable, knowing the people who prepare the food boost the confidence in consumers to purchase *Hausa koko*. Furthermore, the results showed that the consumption of *Hausa koko* from infancy increases the tendency of consumption by 0.88%.

Waakye

Table 7 presented the probit regression estimated for the

Table 8. Probit estimates of factors influencing consumption of *Ga kenkey.*

Variable	Coefficient	Robust S.E.	M.E
Age	-0.03***	0.01	-0.01
Sex	0.14	0.13	0.04
Secondary education	-0.14	0.18	-0.04
Tertiary education	-0.01	0.16	-0.01
Worker	0.23	0.19	-0.07
Student	0.16	0.22	0.05
Convenience	0.24***	0.14	-0.01
Nutritious	0.69***	0.14	0.04
Safe	0.18	0.13	0.06
Affordability	0.64***	0.14	0.20
Food from ones locality	0.07	0.14	0.02
Consumed from infancy	0.54***	0.17	0.15
Closeness to vendor	0.49***	0.14	0.15
Constant	-0.27	0.34	

= 5% significance level; *= 1% significance level, M.E. denote marginal effect.

factors influencing respondents' decision to consume *Waakye*. The results showed that the age of consumer negatively and significantly influences the decision to consume *Waakye*. This implied that a unit increase in age would result in a 0.01% decrease in the probability of one to consume *Waakye*.

Similar to Hausa koko, this inferred that the young are more likely to consume *Waakye* as compared to the old. Attaining tertiary education positively influenced the decision to consume Waakye, denoting that the probability to consume *Waakye* is high among consumers who attained tertiary education. This is as expected because of the generally busy life style of tertiary students; they tend to have high affinity for SVLFs of which *Waakye* is a major delicacy because of its high nutritional value (Tugli, et al., 2019). Furthermore, the safeness of *Waakye* had a significant and positive effect on the decision to consume *Waakye*. The perception that *Waakye* is safe increased the probability of the respondent to consume the food by 0.08%. Food safety has serious implications on health (Annan-Prah et al., 2011; FAO, 2016a), hence any sign of safety of a particularly food will have positive effect on its consumption.

Again, the results indicated that convenience of *Waakye* positively influenced its probability of consumption by 0.09%. Similarly, the nutritional value of *Waakye* positively influenced consumption at 5% level. When *Waakye* sold on the street is affordable the more likely its consumption is expected to increase as affordability as a factor, positively and significantly influenced consumption. A Cedi increase in affordability will increase the probability to consume *Waakye* by 0.08%. *Waakye* coming from consumers' locality and its consumption from infancy had positive and significant effects on the decision to consume.

Ga Kenkey

Table 8 presented the probit regression estimated for the factors influencing respondents' decision to consume *Ga kenkey*. The results showed that the consumption of the food is significantly influenced by factors such as age, convenience of the food, nutritional value, and affordability, consumption from infancy as well as closeness to a vendor, which designated the availability of food, and were all positively related with *Ga kenkey* consumption except the age of the consumers.

The negative effect of age implied that older persons were less likely to consume *Ga kenkey* than younger ones and was significant at the 1% level. This may be due to many of the respondents being Akan's. The older Akan's perceive of *Ga kenkey* (kenkey in general) as a fasting food during funerals. Again, the convenience of *Ga kenkey* significantly and positively influenced the decision to consume it. With respect to nutritional value of *Ga kenkey*, the results depicted that consumption of *Ga kenkey* is positively influenced by consumers' perceived nutritional value of the food. This is because consumers perceived *Ga kenkey* as nutritious with the accompaniments noted in a previous study (Haleegoah et al., 2016). In addition, the affordability of *Ga kenkey* sold on the street showed positive significant effects on its consumption. This means that people are more likely to consume *Ga kenkey* because they find it to be more affordable.

Similar results were found with consumption of *Ga kenkey* from infancy as well as closeness to the vendor. This implied that an individual who had been consuming *Ga kenkey* since childhood was more likely to continue consuming it. This is because consumers generally develop a taste for certain food they have been exposed to culturally, which has the tendency of enhancing future consumption of the same food whenever the opportunity arises. The results showed that largely, food attributes (safeness, nutritional value, affordability, convenience and closeness to vendor or availability), social status (age, educational level and work status), and cultural factors (food coming from consumers' locality and consumption of food from infancy) influence the consumption of SVLFs. These results confirmed the finding of others that several factors influenced the choice of foods (Asiegbu et al., 2015; Clark and Bagdan, 2019). From the probit regression results, factors such as the convenience of *Hausa koko*, closeness to vendor, nutritional value, affordability, and food eaten from infancy have positive influence on the consumption of *Hausa koko*. The food from the consumers' ethnic origin also has a positive influence on the regular consumption of *Hausa koko*, whereas age and sex of consumer have negative influence. While age is significant at 5% significant level, sex is at 1% significant level. For *Ga kenkey* consumption, all the factors had positive influence except convenience and eaten from infancy. Factor such as age, convenience of the food, nutritional value, and affordability, consumption from infancy and closeness to a vendor significantly influenced the consumption of *Ga kenkey* positively. Therefore, for the consumption of SVLFs such as *Hausa koko*, *Waakye* and *Ga kenkey*, the demographic, social status and culture characteristics of the consumers, and the consumer perceived risk and quality characteristics such as convenience, closeness to vendor, the safety, nutritional value, affordability and cultural characteristics of the foods are the influencing factors considered by consumers in their decisions to consume street foods.

Conclusions

This study examined the factors influencing the consumption of SVLFs among consumers in three regional capital cities in Ghana. Using data from 631 consumers comprising 403 males and 228 females, the probit regression model was used to estimate the factors influencing consumption of major SVLFs such as *Hausa koko*, *Waakye* and *Ga kenkey*. The results showed that the consumption of SVLFs is positively influenced by a set of factors that describes quality characteristics of the food (such as safeness, nutritional value, affordability, convenience and closeness to vendor or food availability), social status (including age, educational level and work status), and cultural factors (such as the consumer coming from the place of origin of the food and consumption of food from infancy). Consumers as rational and moral beings would base their choices on all or several of these factors. It is imperative to consider these factors in designing strategies for promoting the consumption of SVLFs particularly so because of its importance in the society in the wake of the increasing urban population coupled with the changing dietary lifestyle of society. These influencing factors are the reasons for the continual patronage of SVLFs despite the negative attributions associated with them. The import of this result is that consumers make choice of food based on these factors and their experiences therefore policy to strengthen local food vending should consider these factors in order to ensure their continual patronage. Food vendors should consider these factors in their manoeuvring to ensure the persistence of SVLFs in urban areas.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Evaluation of proximate and functional properties of rubber (*Hevea brasiliensis*) seed meals

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With the ever-growing demand for food and food-feed competition because of population growth, the nutritional and functional properties of rubber seed meal were evaluated. Rubber seeds were processed as raw, cooked, and fermented seed meals and analysed for proximate, bulk density, water absorption capacity, oil absorption capacity, emulsion capacity, and least gelation concentration. Results showed significant differences (P< 0.05) in the proximate and functional properties of the seed meals. Fermented rubber seed meal (FRSM) had higher ash (4.04%), crude fat (54.17%), and crude protein (22.25%) but with the least content in carbohydrates (11.58%). Cooked rubber seed meal (CRSM) and FRSM had improved oil absorption capacity (OAC), bulk density (BD), and water absorption capacity (WAC). The seed meals showed good thickening and gelling properties with WAC of 138 to 174% and least gelation concentration (LGC) of 5 to 6%. Rubber seed has an appreciable amount of food nutrients and good functional properties and therefore has a great potential for use in food and food product formulations.

Key words: Rubber seed, functional properties, proximate, food formulation.

INTRODUCTION

In developing countries such as Nigeria, with impeding population growth and high level of inflation, there has been increased demand for food and food-feed competition on the available grain seeds accepted for consumption, which has led to shortage and high cost of protein rich sources. There is therefore need to exploit the less utilized seeds abundant in the region such as rubber seeds.

The rubber tree (*Hevea brasiliensis*) is of commercial value in Nigeria for its latex production but its seeds are not utilised as a food material (Iyayi et al., 2008). Rubber tree yields about 150 to 250 kg of seeds per hectare (Yusup and Khan, 2010). The yield depends on the soil nutrients, ecosystem of the located area, type of planting materials adopted and crop density (Lukman et al., 2018). The seeds are underutilized except when used as sources of seedlings (Lukman et al., 2018).

Some researchers have reported that rubber seed meal has considerable amounts of absorbable nutrients than many conventional seed meals and exhibits high essential nutritive value as a better alternative for protein supplements in livestock diets (Aguihe et al., 2017; Udo

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et al., 2018). The oil content in dried kernel varies from 35 to 45% (George et al., 2000). According to Aigbodion and Bakare (2005), rubber seed oil has good fatty acid constituents and a higher percentage of linolenic acid; an omega 3 fatty acid important in human diet. Rubber seed is processed and consumed in some regions of Indonesia as part of their staple diet (Lukman et al., 2018). In Jerantut, Pahang (Malaysia), rubber seed has been in use as one of their daily dishes known as '*asamrong*'; a native dish in which the seeds are served with sambal and curries (Siti et al., 2013). Notwithstanding, there has continued to be hindrances to the utilization of rubber seeds as food or feed product.

To eradicate hunger and minimize waste, there is need for continuous discovery, investigation and documentation of unharnessed potential food sources. This research is designed to access the proximate composition and functionality of rubber seed meal in a bid to increase its acceptability and awareness as a high nutrient dense seed and suggest possible methods of utilizations for human consumption or at least for livestock feed formulation.

MATERIALS AND METHODS

Source of material

Mature rubber seeds were collected from Nigerian Rubber Institute, Akwete, Abia State. The sample preparation was carried out in Food Science and Technology Laboratory, Federal University of Technology, Owerri, Imo State. All reagents used were of analytical grade.

Sample preparation

Dirt and foreign materials were sorted out from the seeds. The cleaned seeds were divided into three treatment groups.

Treatment group 1 was oven dried at 60°C and pulverised in a blender (KenWood BL330) into fine meal. Treatment group 2 was boiled in a stainless steel vessel for 2 h at 100°C after which it was oven dried at 60°C and then blended into fine meal. Treatment group 3 was boiled for 2 h; boiled seeds were wrapped in blanched plantain leaves and put in a basket to ferment for 3 days at room temperature, then oven dried at 60°C and ground into fine meal. The processing treatments are as presented in Figure 1. Multipurpose dryer operating at 60°C owned and fabricated at the Nigerian Stored Products Research Institute (NSPRI), Port Harcourt station was used and samples were dried for duration of 24 h. The meal samples were stored in properly labelled air tight glass containers.

Determination of proximate composition

Determination of moisture content

The moisture content of the rubber seed was analysed using the method of AOAC (2000). An evaporating dish was weighed in 5 g of the sample which was dried in an oven for 3 h at 105°C, after which, it was cooled in a dessicator and weighed. The process was repeated continuously every 30 min until constant weight.

The moisture content was then calculated as follows with Equation 1:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1 - W_0} X\,100 \qquad (1)$$

where W_0= weight of Petri dish in grams, W_1 = weight of Petri dish in grams and sample before drying, and W_2 = weight of Petri dish in grams and sample after drying.

Total ash determination

Ash content was analysed using the method of AOAC (2005). Weighed out 5 g of sample was incinerated in a muffle furnance at 550°C in duplicate crucibles till constant weight and light grey ash was obtained. Ash was then cooled in a dessicator and weighed.

Percentage ash was calculated using Equation 2:

$$Ash(\%) = \frac{W_3 - W_1}{W_2 - W_1} X\,100 \qquad (2)$$

where W_2= weight of food sample and dish; W_1= weight of crucible; W_3 = weight of crucible and ash.

Crude protein determination

The protein of the samples was analysed using Micro-Kjeldahl method as described by Chang (2003). Measured 0.5 g of the sample was digested till a clear solution was obtained; the sample was mixed with 10 ml of concentrated H_2SO_4 in a Kjeldahl apparatus and heated in a fume chamber. Then in a Kjeldahl distillation apparatus, 10 ml of the digest was mixed with 45% NaOH and distilled. A solution containing 10 ml of 4% boric acid solution with 3 drops of mixed methyl red and bromocresol green indicator was used to collect the distillate. 50 ml of the distillate was then titrated against 0.02N H_2SO_4. A reagent blank was also digested and titrated.

Percentage crude protein was calculated using Equation 3:

$$Crude\ protein\,(\%) = \left[\frac{100}{W} X\,\frac{NX14}{1000} X\,\frac{V_f}{V_a} X\,T\,\right] X\,6.25 \qquad (3)$$

where W=weight of sample analysed; N=concentration of H_2SO_4 titrant; V_f=total volume of digest; V_a=volume of digest distilled; T=titre value- blank.

Fat content determination

Fat content was determined using the method of AOAC (2005). Measured 5 g of the sample was wrapped in a filter paper which was then transferred to already cleaned, oven dried and cooled extraction thimble. Fat was extracted by addition of 25 ml petroleum ether solvent after which solvent was evaporated by oven drying. The flask was cooled in a desiccator and weighed. The percentage fat content was calculated using Equation 4:

$$Fat\,(\%) = \frac{Weight\ of\ the\ extracted}{Weight\ of\ sample} X\,100 \qquad (4)$$

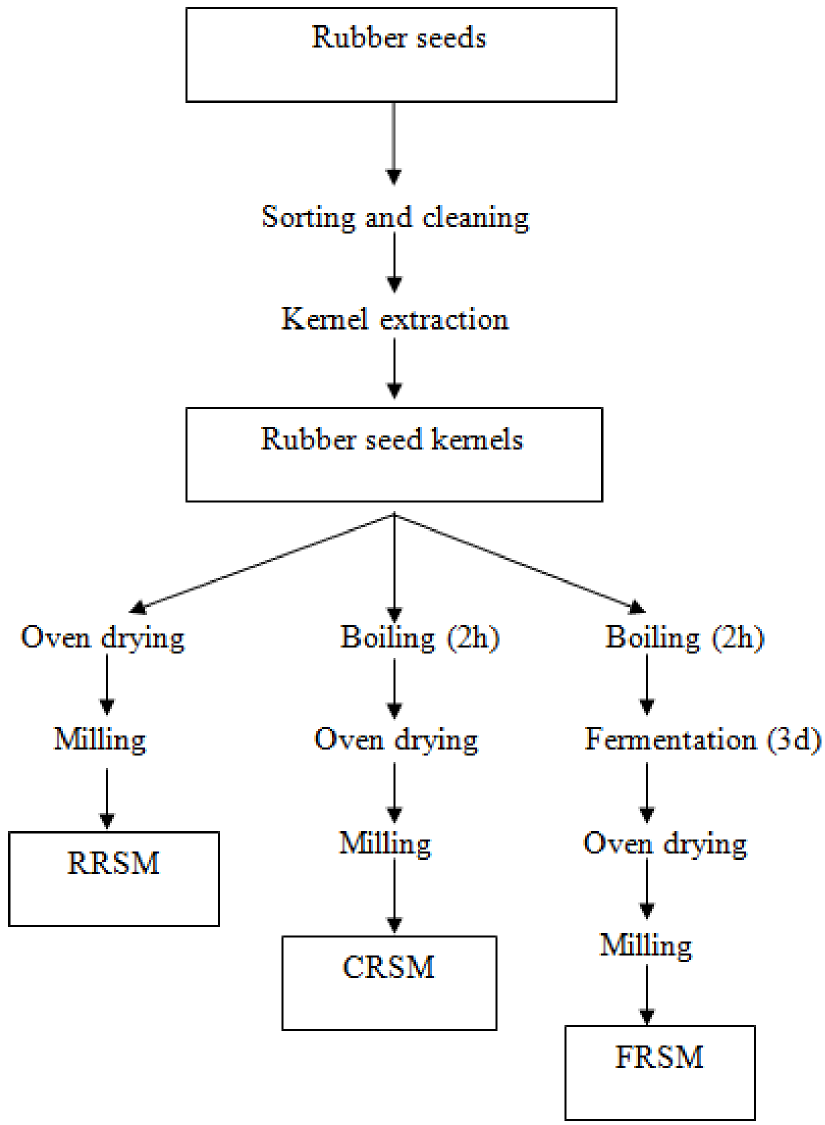

Figure 1. Flowchart for sample preparation. FRSM: Fermented rubber seed meal; CRSM: cooked rubber seed meal; RRSM: raw rubber seed meal.

Crude fibre determination

Fibre content was analysed using the method of AOAC (2005). Five grams of the defatted sample was boiled under reflux in 200 ml of 1.25% H_2SO_4 for 30 min and then washed with boiling water trapping the particles with a 2 fold muslin cloth. Collected particles were again boiled under reflux in 200 ml of 1.25% H_2SO_4 for 30 min and washed with hot water as earlier. Then, sample particles were collected in weighed porcelain crucibles and oven dried for 3 h at 105°C. It was then cooled in a dessicator and reweighed (W2) and then ashed in a muffle furnace at 550°C for 2 h. It was cooled and reweighed.

The crude fibre content of each sample was calculated gravimetrically using Equation 5:

$$\text{Crude fibre (\%)} = \frac{W_2 - W_3}{Weight\ of\ sample} X\,100 \qquad (5)$$

where W_2=weight of crucible + sample after washing and drying in oven; W_3=weight of crucible + sample ash.

Carbohydrate determination

The carbohydrate content was calculated by difference as the nitrogen free extract (NFE). The nitrogen free extractive will be calculated using Equation 6:

$$\text{NFE (\%)} = 100\text{-\% } (a+b+c+d+e) \qquad (6)$$

where a=protein; b=fat; c=fibre; d=ash; e=moisture.

Functional properties

These were carried out according to methods described by Onwuka (2018).

Bulk density (BD) (g/ml)

The sample was gently filled into 10 ml capacity calibrated measuring cylinder. Bulk density was calculated as weight of the sample (g) divided by the volume of sample (ml).

Water absorption capacity (WAC) and oil absorption capacity (OAC) (g/g)

One gram of sample was mixed with 10 ml distilled water (WAC) or oil (OAC) in a conical calibrated centrifuge tube for 30 s. The mixture was allowed to stand at room temperature for 30 min and then centrifuged for 30 min at 5000 rpm. The volume of the supernatant was read from the calibrated centrifuge tube. The absorption capacity was expressed as grams of water and oil absorbed per gram of sample for WAC and OAC, respectively.

Emulsification capacity (EC) (%)

Two grams sample was mixed with 25 ml distilled water in a blender for 30 s at 1600 rpm. 25 ml vegetable oil was added slowing into the mixture and blended for another 30 s. Mixture was then centrifuged at 1600 rpm for 5 min. The volume of oil separated from the mixture after centrifuging was read directly from the tube. Emulsification capacity was calculated as the amount of oil emulsified per gram of sample expressed in percentage.

Least gelation concentration (LGC) (%)

Sample suspension preparations of 2 to 20% (W/V) in 5 ml distilled water in test tubes were prepared and heated for 1 h in a boiling water bath followed by rapid cooling under running cold tap water. Then, further cooled at 4°C for 2 h. The least gelation concentration is determined as the concentration when the sample from the inverted test tube will not fall.

Statistical analysis

The data generated from the study was analyzed by one way analysis of variance (ANOVA) using statistical package of social sciences software (SPSS) version 20 for windows. The results were expressed as mean ± standard deviation. A level of P value less than 0.05 was considered to be significant.

RESULTS AND DISCUSSION

The results of the analysis carried out on the proximate and functional properties are presented in Tables 1 and 2, respectively.

Proximate composition

The proximate composition of the rubber seed meals is presented in Table 1. The cooked seed meal with moisture content of 9.92% had the highest moisture content and differed significantly from the other samples, which could be due to starch hydrolysis with consequent higher moisture retention. However, the moisture percentage is lower than 16% as reported by Sharma et al. (2014) and 14.30% as reported by Hossain et al. (2015). The moisture contents of the raw (4.05%) and fermented (3.75%) seed meal are generally low, in agreement with literature (Eka et al., 2010; Aguihe et al., 2017), and therefore will be more shelf stable. The fermented seed meal had the lowest moisture content, which is in line with increased shelf stability after fermentation as reported by Chaves et al. (2014).

Ash content gives an estimation of quantity of minerals in the sample (Oyekunle and Omode, 2008). The cooked meal had the lowest ash percentage, which could be because of some losses due to cooking. The fermented seed meal with ash percentage of 4.04% had the highest ash percentage, differed significantly from the raw (3.47%), and cooked (3.10%) seed meals. This could be attributed to the effect of the fermentation in reducing antinutrients thereby making more minerals available (Kumar et al., 2010). The results of the ash percentage in rubber seed meal agreed with values of 3.10 to 5.90% as reported in previous researches (Mmereole, 2008; Suprayudi et al., 2015; Udo et al., 2018). The values compare favourably with the ash contents of other oil seeds like melon seed (3.30%), groundnut seed (3.08%) as reported by Atasie et al. (2009) and soybean seed (5.1%) as reported by Oladimeji and Kolapo (2008).

The crude fat content of the seed meals are in the range of 43.52 to 54.17% and is in good comparism with earlier studies; 42.50% as reported by Onwurah et al. (2010), 45.50% as reported by Lalabe et al. (2017) and 49.30% as reported by Suprayudi et al. (2015). However, it is lower than 68.53% reported by Eka et al. (2010). This could be due to differences in varieties of the rubber tree as well as the method of seed meal preparations. The results obtained can also be compared to the crude fat content of well know oil seeds like soybean, 28.20% (Ogbemudia et al., 2018) and groundnut 46.10% (Ayoola et al., 2012). It could therefore be said that rubber seed with respect to oil yield is a good substitute for these seeds. The fermented seed meal had the highest value (54.17%) which could be as a result of reduced carbohydrates used up by the enzymes during fermentation as carbohydrates are the preferred nutrient choice of fermentation microorganisms (Nkhata et al., 2018).

The crude fibre ranged from 3.83 to 4.63% and is comparable to earlier reports; 3.19% reported by Suprayudi et al. (2015), 4.50% (Lalabe et al., 2017) and 5.61% (Aguihe et al., 2017). The cooked rubber seed meal sample had the highest value of 4.63% and is in unison with earlier studies. A study by Vasishtha and Srivastava (2013) reported an overall increase in dietary fibre of chickpeas when cooked; cellulose, lignin and pectin concentrations increased while hemicelluloses decreased. The study by Dhingra et al. (2012) also observed that domestic cooking causes a reduction in amount of *in-vitro* digestible starch and therefore, increases both the resistant starch and water-insoluble

Table 1. Mean values for the proximate composition (%) of *Hevea brasiliensis* seed meal sample.

Parameter	RRSM	CRSM	FRSM
Moisture	$4.05^{a} \pm 0.22$	$9.92^{b} \pm 0.40$	$3.75^{a} \pm 0.09$
Ash	$3.47^{a} \pm 0.13$	$3.10^{a} \pm 0.01$	$4.04^{b} \pm 0.24$
Crude fat	$43.52^{a} \pm 0.21$	$47.60^{b} \pm 0.29$	$54.17^{c} \pm 0.13$
Crude fibre	$3.83^{a} \pm 0.11$	$4.63^{b} \pm 0.13$	$4.20^{c} \pm 0.00$
Crude Protein	$19.95^{a} \pm 0.13$	$17.89^{b} \pm 0.01$	$22.25^{c} \pm 0.15$
Carbohydrate	$25.19^{a} \pm 0.04$	$16.86^{b} \pm 0.04$	$11.58^{c} \pm 0.07$

FRSM: Fermented rubber seed meal; CRSM: Cooked rubber seed meal; RRSM: Raw rubber seed meal. Means with similar superscripts in the same row are not significantly different (p>0.05).

Table 2. Mean values for the functional properties of *H. brasiliensis* seed meal sample.

Parameter	RRSM	CRSM	FRSM
BD (g/ml)	$0.45^{a} \pm 0.01$	$0.43^{a} \pm 0.01$	$0.39^{b} \pm 0.01$
WAC (%)	$138.00^{b} \pm 25.06$	$174.00^{a} \pm 5.29$	$168.67^{a} \pm 4.16$
OAC (%)	$135.00^{a} \pm 4.28$	$142.50^{a} \pm 6.36$	$130.50^{a} \pm 6.36$
EC (%)	$59.00^{a} \pm 1.41$	$57.00^{a} \pm 1.41$	$51.50^{b} \pm 2.12$
LGC (%)	$5.00^{a} \pm 0.00$	$6.00^{a} \pm 0.00$	$6.00^{a} \pm 0.00$

FRSM: Fermented rubber seed meal; CRSM: Cooked rubber seed meal; RRSM: Raw rubber seed meal; BD: Bulk density; WAC: Water absorption capacity; OAC: Oil absorption capacity; EC: Emulsification capacity; LGC: Least gelation concentration. Means with similar superscripts in the same row are not significantly different (p>0.05).

dietary fibre. The subsequent reduction in crude fibre with fermentation (4.20%) could be because of digestion by microbial activities.

The crude protein values ranged from 17.95 to 22.25%. The values compare favourably with earlier studies as reported; 17.41% (Eka et al., 2010), 19.40 (Lalabe et al., 2017), 21.87 (Suprayudi et al., 2015) and 22.30% (Onwurah et al., 2010). The protein content of groundnut is in the range of 22 to 30% (Mckevith, 2005), soybean ranges from 37 to 40% (Ogbemudia et al., 2018; Grieshop and Fahey, 2001), and castor bean (20.11%) and African oil bean (20.60%) (Enujiugha and Ayodele-Oni, 2008). Similar to these legumes, rubber seed can be said to be a good source of plant-based protein and can contribute to the daily protein need. The raw seed meal had a crude protein value of 19.95%, which was reduced to 17.89% in the cooked seed meal. Cooking is known for degradation and conversion of proteins in raw food samples into soluble forms but also is usually accompanied by some losses in quantity (Omenna et al., 2016). The fermented seed meal crude protein value of 22.25% could be explained by reduction of carbohydrate after fermentation (Pranoto et al., 2013).

The carbohydrate values ranged from 11.58 to 25.19%. The raw seed meal had the highest percentage of 25.19%, which was reduced to 16.86% by cooking. This was similar to the research done by Ikanone and Oyekan (2014) which recorded a considerable loss of low molecular weight carbohydrates into the processing water. The fermented seed meal had the least value of 11.58%. This is because, activities of microorganism lead to the breakdown of complex carbohydrates into simpler forms. Therefore, decrease could be because of breakdown and usage by microorganisms (Osman, 2011). The rubber seed meal carbohydrate values from the study compare favourably with 13.80% (Hossain et al., 2015) and 21% (Suprayudi et al., 2015) from earlier studies.

Functional properties

The bulk density of the seed meals was 0.45 g/ml (raw seed meal), 0.43 g/ml (cooked seed meal) and 0.39 g/ml (fermented seed meal). The fermented seed meal had a significant reduction in bulk density from the cooked and raw seed meal, which is in line with the reports of Ogodo et al. (2016) which reported decreasing bulk density of maize flours with increasing fermentation period. Fermentation has also been a traditional tool for reducing bulk density of foods especially those intended for infant weaning meals.

The water absorption capacity of the seed meals was 138% (raw seed meal), 174% (cooked seed meal) and 168.67% (fermented seed meal). The processed seeds had a significant increase in water absorption. Although, no significant difference between the CRSM and FRSM was recorded, the cooked seed meal had the highest

WAC percentage. This is in line with the report of Obatolu et al. (2001) on the water absorption of African yam bean flours; the processed flours had significantly higher water absorption than the raw African yam bean flour. Water absorption is a measure of the optimum amount of water than can be added to flour before it becomes too sticky to process. Heat processing known to cause starch gelatinisation and protein denaturation increases its water absorption capacity (Ha-jung et al., 2019; Obatolu et al., 2001). High water absorption capacity is required in baking applications (Iwe et al., 2016). WAC range from 149.1 to 471.5% is critical in viscous foods as gravies and soups (Akinyede and Amoo, 2009). The high WAC of the flours suggests that it may have application as a thickening agent in food formulations.

Oil absorption capacity of the seed meals was 135% (raw seed meal), 142.5% (cooked seed meal) and 130.5% (fermented seed meal). CRSM had the highest OAC although no significant difference exists amongst the samples. High oil absorption is required in food formulations because of its relationship with mouth feel and flavour retention (Iwe et al., 2016). The result obtained is closely related to 128.8% reported for white melon seed flour, a well-known thickening ingredient used in soups, gravies and in the formulation of meat analogs (Ogunbusola et al., 2012). The result suggests that the seed meals have a good oil absorption capacity and therefore can function optimally in food formulations.

The emulsion capacity of the seed meals was 59% (raw seed meal), 57% (cooked seed meal) and 51.5% (fermented seed meal). FRSM had emulsion capacity that was significantly lower than that of CRSM and RRSM. It was also noted that the emulsion capacity decreased with processing. The report of Obatolu et al. (2001) on the effect of processing on emulsion capacity of African yam beans reported similar trend. The emulsion capacities of the seeds were lower than 85% reported for white melon (egusi) seeds (Ogunbusola et al., 2012). Processing by cooking (which is necessary for detoxification of antinutrients) will be more appropriate for use for rubber seed meal intended for use in systems requiring high emulsifying properties.

The least gelation concentration of the seed meals was 5% (raw seed meal), 6% (cooked seed meal) and 6% (fermented seed meal). There were no recorded significant differences on LGC due to processing. The processed seed meals however had higher LGC percent. The values were generally lower than 16% reported for white melon seeds (Ogunbusola et al., 2012). The lower the LGC, the better the gelling ability of the protein material (Chandra et al., 2015). The low LGC of the seed meals suggest its usefulness in food formulations that require thickening and gelling.

Conclusion

Rubber seed has appreciable amount of food nutrients and showed high similarity with other oil seeds such as melon (*Egusi*) seed and groundnut seed. A protein content of up to 22% makes it a great potential raw material in the production of high protein food ingredients. The study on the functional properties showed that processing improved the bulk density, oil absorption and water absorption capacity of the seed meal. Rubber seed meal has great potentials for incorporation as a thickening agent in soups, gravies and food products. Further study is required on the behaviour of the seed meal in relation to other ingredients in a potential food product. The crude fat content of up to 54% also suggests a great potential in oil production, therefore, further study is required to ascertain its fatty acid profile and oil characteristics (Chaikil et al., 2017).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Traditional production and quality perception of grilled pork consumed in Benin

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Traditional grilled pork is a well appreciated ready-to-eat on the spot or takeaway food produced in Benin. This study, realized via field investigation, aimed to provide a better understanding of the traditional grilled pork production in Benin, for future improvement of the process and product quality for urban dwellers. The study showed most processors were men (85.6%), illustrating the particularity of this activity in the country where most street food vendors are women. They were also young (≤ 40 years - 63.9%), mainly from *Goun* and *Fon* sociocultural groups (59.5%), illiterate or primary school educated (72.3%). Indigenous pig breeds were preferred for processing (93.6%). Bristles elimination of the pig was carried out either by scalding or singeing. Among the eight grilling equipment recorded, vertical barrel grill was the most commonly used (46.8%) followed by locally made clay grills (28.7%). Wood (62.8%) and charcoal (37.2%) were the most used fuel for grilling. The diversity of equipment and methods used in traditional grilled pork production could be a source of quality variability of grilled pork in Benin. The texture was considered the suitable criteria to appreciate precooked (40.5%) and grilled pork (72.3%), while colour was used to appreciate fresh pork quality (53.2%).

Key words: Pig meat, traditional grill, fuel, singeing, quality.

INTRODUCTION

Pork is highly appreciated and consumed in West African countries due to its organoleptic characteristics and nutritional quality (Fuller et al., 2004). The number of domesticated pigs increased by 44% from 2004 to 2014

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in Benin, with 5172 tons of pork produced (DE, 2014; FAOSTAT, 2016). As the third most-consumed meat after beef and poultry, pork consumption has increased in Benin despite religious prohibition for about 20% of the Beninese population (Youssao et al., 2008a). Meat such as pork is heat processed using traditional methods of grilling and smoking during which meat is directly laid on grid above the embers made from different fuels (Lee et al., 2016; Park et al., 2017; Assogba et al., 2020). Grilling is one of the most common methods of pork processing in Benin (Ayssiwede et al., 2009), being used to improve the meat's sensory characteristics including taste, appearance, colour, and aroma (Stołyhwo and Sikorski, 2005; Ciecierska and Obiedzinski, 2007; Igwegbe et al., 2014; Yusuf et al., 2015). Anihouvi et al. (2020) reported spoilage and pathogenic bacteria such as Enterobacteriaceae, *Escherichia coli* and *Clostridium perfringens* in grilled pork and explained their presence by different factors including the method and environment of processing. Several authors also reported that heat treatment of meat including grilling of pork results in production of toxic compounds like heterocyclic amines (Buła et al., 2019; Polak et al., 2020), oxidation products of cholesterol (Min et al., 2016) and aldehydes (Munasinghe et al., 2003). Iko Afé et al. (2020) also reported polycyclic aromatic hydrocarbons (PAHs) including benzo(a)pyrene, the carcinogenic compound, in grilled pork produced in cottage industry of Benin and showed that this contamination was due to traditional grilling. Even though, grilled pork produced in Benin has good nutritional quality, its consumption may result in public health issue due to the presence of both microbial and chemical hazards.

To our knowledge, there is no scientific data giving a good insight about the methods used to produce grilled pork in cottage industry. In addition, to improve the overall quality of grilled pork, the inventory of grilling processing is needed. Thus, the present study aimed to provide a better understanding of these processing practices and the perception of quality according to the processors of grilled pork in Benin.

MATERIALS AND METHODS

Choice of the survey areas

The field investigation was carried out in five cities located in four districts of Benin (Figure 1): Adjarra and Porto-Novo (Ouémé), Cotonou (Littoral), Abomey-Calavi (Atlantic), and Bohicon (Zou). High pork production and consumption levels were the main criteria justifying the choice of these districts (Youssao et al., 2008a; Ayssiwede et al., 2009; ANAT, 2014; PAFILAV, 2014).

Sample population

The number of randomly selected grilled pork producers was obtained according to Dagnelie (1998), using the following equation:

$$N = \frac{4p(1-p)}{d^2}$$

where N is the total number of stakeholders (processors) to be interviewed, d is the expected margin of error (d = 0.05), and p is the proportion of pork processors living in the survey areas.

A total of 188 processors were randomly selected and investigated at the production sites located in the following five municipalities of Benin: Adjarra (n = 10), Porto-Novo (n =42), Cotonou (n = 80), Abomey-Calavi (n = 46) and Bohicon (n =10).

Field data collection

A preliminary survey was conducted in order to identify the processing sites and to test the questionnaire design. The investigation was then carried out using the validated questionnaire designed in two parts based on processing and marketing. Processors (also sellers) were surveyed in the field at the processing sites. Individual interviews were used to collect data during the survey, with focus group discussions and observations of processors at work employed to collect complementary information for flow diagram description. The survey was conducted in French and five Beninese languages (*Goun*, *Fon*, *Mina*, *Torri*, and *Kotafon*). Data collected included demographic information, socio-cultural status of the processors, raw material and other ingredients used, as well as processing and storage. During the survey, questions related to their perception of quality criteria of pork products were also asked to the processors.

Data analysis

Sphinx Survey Plus 2 (version 4.5) was used to record the collected data and Microsoft Excel 2010 for descriptive statistics. The Statistical Analysis System (SAS Institute, Cary, NC) was used for data treatment. The Logistic Regression Model (LRM) method was used to assess the effect of the selected independent variables (survey area; academic qualifications, religion and socio-cultural groups of processors; pig breed; grilled pork form; type of fuels) on the dependent variables (bristle removal practises and precooking). The Chi-squared ($\chi 2$) test and Fisher's Exact Test were employed to test the qualitative variables.

RESULTS

Socio-demographic characteristics of processors

The socio-demographic characteristics of processors are summarized in Table 1. The results revealed that pork processing in the study areas is mainly carried out by men (85.6%), with most female processors starting this activity via a relative or spouse. Processors interviewed belonged to various age ranges, with most (63.9%) aged less than 40 years old. Those questioned had an average length of grilling experience of twelve years, and belonged to various socio-cultural groups including *Goun* (30.8%), *Fon* (28.7%), and *Torri* (18.1%). The majority of the processors (58.5%) received explicit schooling (primary, secondary, university). Most were married (89.4%) and Christian (88.8%).

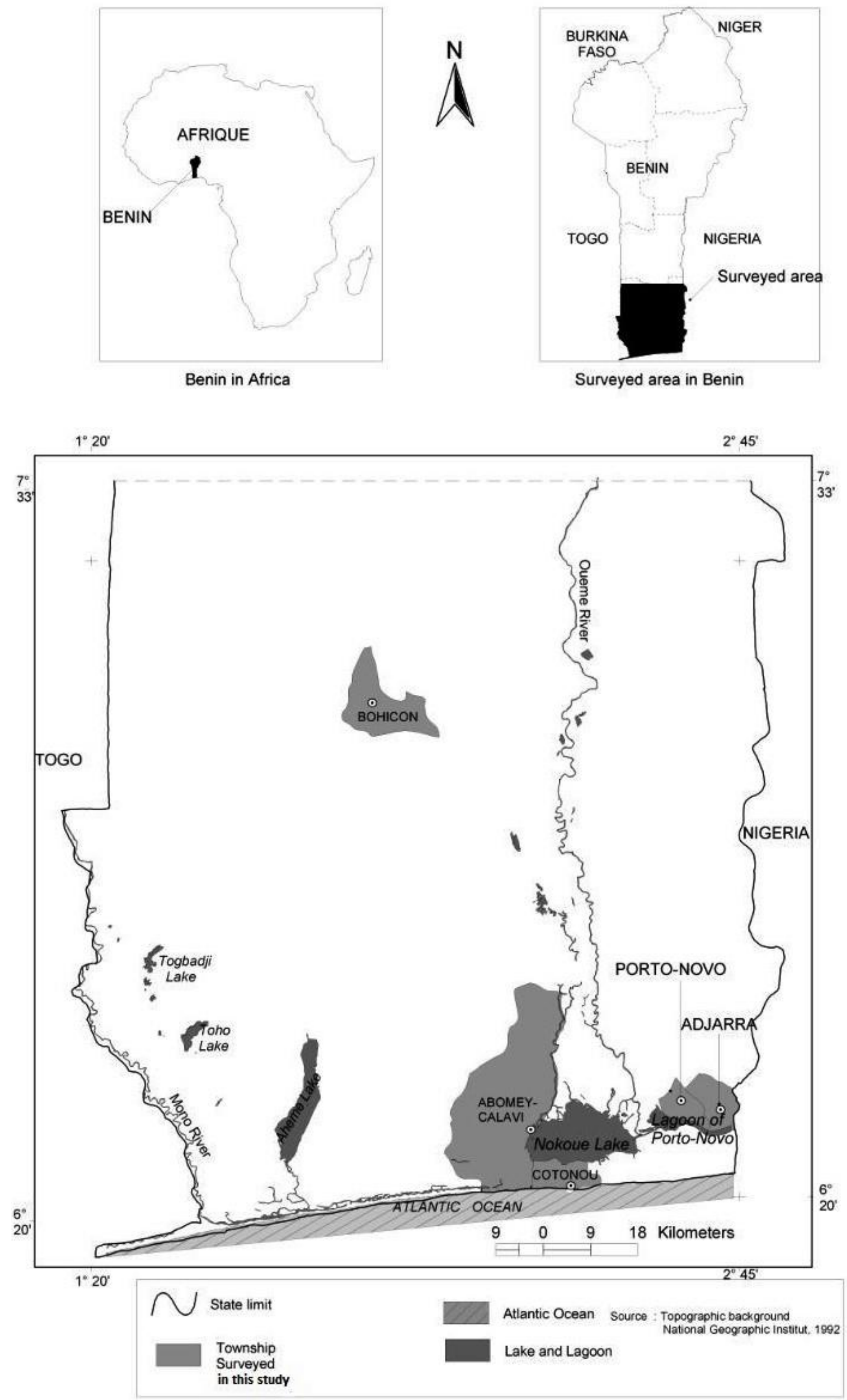

Figure 1. Map of Benin showing the surveyed areas.

Table 1. Socio-demographic characteristics of the surveyed Beninese grilled pork processors.

Characteristics	Processors (%) (n=188)
Age (years)	
<20	8.0
20-30	17.1
31-40	38.8
41-50	22.3
51-60	8.5
>60	5.3
Gender	
Male	85.6
Female	14.4
Sign. Test	***
Socio-cultural groups	
Goun	30.8
Fon	28.7
Torri	18.1
Aïzo	6.4
Mina	3.2
Xlwa	3.2
Sign. Test	***
Academic qualification	
Primary school	35.1
Secondary school	18.6
University	4.8
Illiterate (no schooling)	37.2
Local language education	4.3
Sign. Test	***
Marital status	
Unmarried	10.1
Married	89.4
Divorcee	0.5
Widowed	0.0
Sign. Test	***
Religion	
Animism	11.2
Christianity	88.8
Islam	0.0
Sign. Test	***

Sign. Test: Significance tests among proportions. ***: significant difference ($p < 0.001$).

Production of grilled pork

The various processing methods employed during the production of the three forms of grilled pork sold in Benin are summarized in the flow diagram in Figure 2. Raw pork is firstly boned, followed by optional fat removal, and then cut into sliver or skewer form using a knife and wooden cutting table. The pork is then seasoned in a

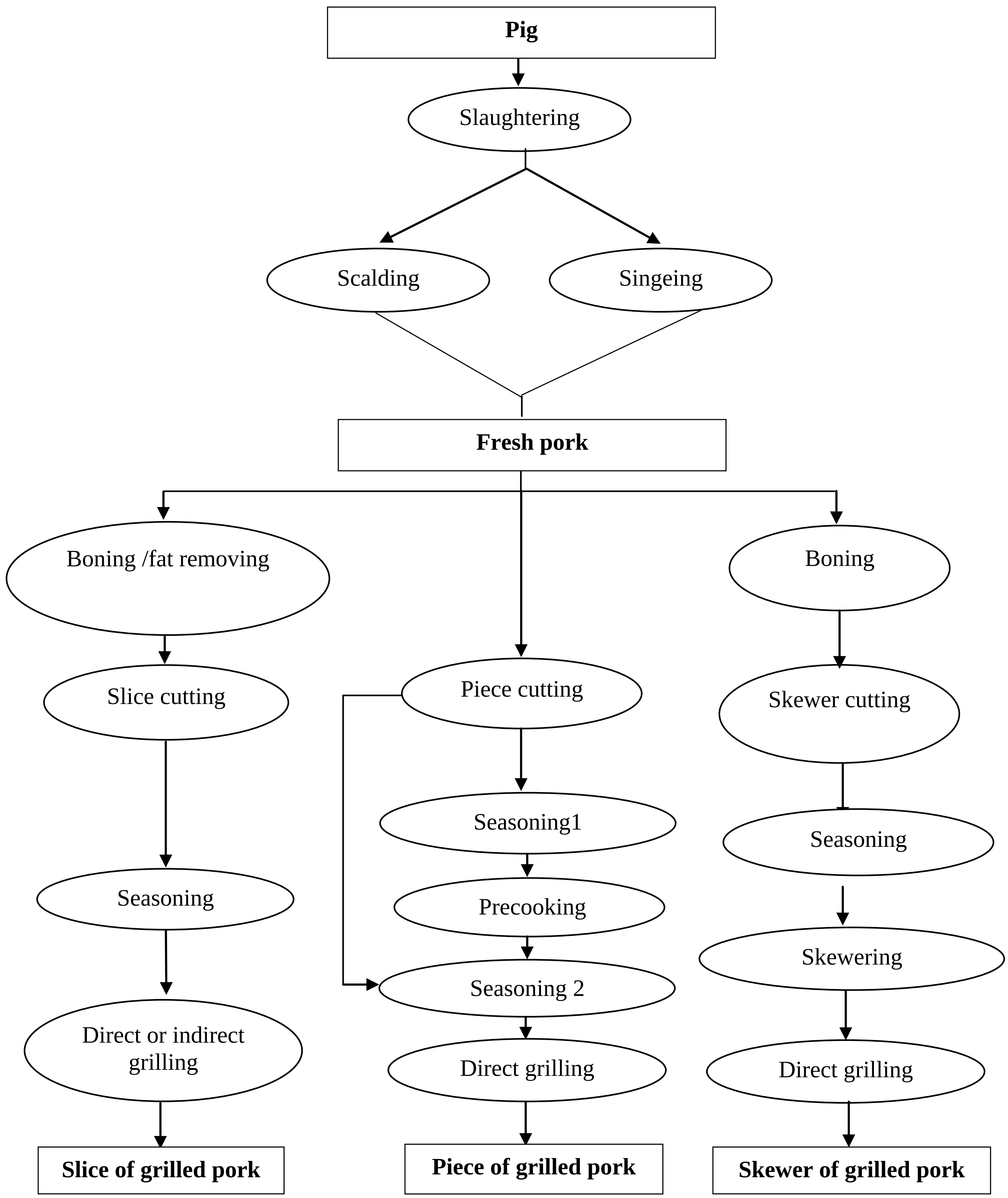

Figure 2. Flow diagram of fresh pork processing into grilled pork in Benin.

bowl and grilled. Precooking in boiling water and complementary seasoning are the main operations differentiating piece-form grilled pork from the other two options.

Three breeds of pig are non-exclusively used by the processors: indigenous (93.6%), crossbreed (Large White × Indigenous, 71.8%), and exotic (Large White, 38.3%). Pigs are purchased in national markets (90.4%) including Adjarra and Azovè, breeding farms and small cattle breeders (43.6%), or are imported from neighbouring

Table 2. Proportions of processors using different methods of processing and types of fuels.

Variable and modalities	Proportion (%)
Processing	
Processing including precooking	22.9
Processing excluding precooking	77.1
Significance test	***
Bristle removal by scalding	52.1
Bristle removal by singeing	47.9
Significance test	***
Types of fuels	
Charcoal	37.2
Wood	62.8
Significance test	***

***p<0.001

countries (36.7%), namely Burkina Faso, Nigeria and Togo. Most processors (88.8%) preferred castrated pigs. Pig choice is based mainly on health status and fat content, regardless of breed (Supplementary data 1).

Most processors claimed to check the pigs before purchasing, to ensure quality. About 64.3% of processors control pig health status by checking for the presence of tongue cysts, with 10.1% checking eye colour. About 46.8% of processors felt pig neck to state if the animal is fat or lean; if the neck is too developed, the pig is considered too fat and therefore inappropriate for processing due to lower profitability. Pigs are also inspected by a veterinary officer both prior to slaughter (ante-mortem inspection, 47.9% of processors) and more often after slaughter (post-mortem inspection, 98.9% of processors). The surveyed processors slaughter the pigs in their residence (42.6%), on the processing site (42%), in a slaughterhouse (20.2%) or in slaughtering areas (6.4%). Pig bristles are eliminated either by scalding (52.1%) or singeing (47.9%) (Table 2). The scalding is carried out by immersion of the slaughtered pig in hot water for a few seconds and then removing the bristles from the skin using a knife. In the second case named singeing, pig is firstly exposed to flames and then bristles are eliminated with a knife. The pig is then gutted, cleaned and the carcass packed and transported to the processing site, mainly in bowls (45.7%), polyester bags (26.1%), burlap (12.8%), baskets (3.7%) or iceboxes (0.5%). Transportation is carried out mostly via motorbikes (55.9%), although some interviewees reported transport on foot (20.2%) or car (3.7%).

The cleaned pork is deboned and sometimes defatted before being cut into either small pieces for skewers or thin slices, which are seasoned and grilled (Figure 2). Ingredients such as garlic (*Allium sativum*), pepper (*Piper nigrum* and *Capsicum* species), onion (*Allium cepa*), ginger (*Zingiber officinalis*), laurel leaves (*Laurus nobilis*) and glutamate concentrate may be mixed and used for seasoning of the pork before grilling. The grilling of the pork in piece form is carried out either by precooking in hot water (22.9%) or without precooking (77.1%) before grilling (Table 2). Significant difference (p <0.001) was found among processors in terms of the three main variables (processing, main fuel, and bristle removal). Whereas those located in Cotonou and Abomey-Calavi tend to precook pork, grilling of pork without precooking is exclusively undertaken by processors in Adjarra and Bohicon, and by almost all the processors in Porto-Novo. Bristle removal via singeing is carried out by almost all processors in Adjarra, Bohicon and Porto-Novo.

Types of grills and fuels used for processing

Eight different types of grills were recorded during the field investigation (Table 3), the most common being vertical barrel grills (46.8%) and locally made clay grills (28.7%). Two variants of locally made clay grill have been identified: the first comprises two chambers, one for combustion and one for grilling, which communicate through an opening (indirect grilling technique used by 21.8% of processors), while the second variant comprises only one chamber for both combustion and grilling (direct grilling technique used by 6.9% of processors).

The fuels used for the grilling of pork were wood (62.8%) and charcoal (37.2%). Processors recognized about fifteen tree species as sources of fuel wood (Table 4), predominantly *Acacia auriculiformis* (38.3%), *Tectona grandis* (36.2%), *Manguifera indica* (17.6%), and *Anogeissus leiocarpa* (13.3%). To light their charcoal or wood fires, processors use secondary fuels such as petroleum (6.4%), cake of palm nuts (5.3%), coconut husks (4.3%), palm nut shells (3.2%), and plastic bags (0.5%). A variety of factors were provided with respect to the choice of a fuel source, as illustrated in Figure 3.

Among these, 'it burns well' was the main reason

Table 3. Frequency of use of different types of grills for pork grilling in Benin.

Types of grill	Fuel	Features	Frequency of use (%)	Total (%)
Locally made clay grill	Wood	With two chambers	21.8	28.7
		With one chamber	6.9	
Metallic and parallelepiped	Wood	Without chimney	8.5	10.6
		With chimney	2.1	
Brick and parallelepiped	Wood	NA	5.9	5.9
Vertical barrel	Wood	NA	37.8	46.8
	Charcoal	NA	9.0	
Horizontal barrel	Charcoal	Without cover and chimney	10.6	12.8
		With cover and chimney	1.1	
		With moving grid	1.1	
Gas grill	Gas	NA	0.5	0.5
Metallic with wheel rim	Charcoal	NA	3.7	3.7
Metallic and rectangular	Charcoal	NA	3.7	3.7

NA: Not applicable.

Table 4. Proportions of processors using different tree species as wood fuel for grilled pork production in Benin.

Scientific name	Local name of tree species	Processors (%)
Acacia auriculiformis	Cassia	38.3
Tectona grandis	Tekitin	36.2
Mangifera indica	Amanaguatin	17.6
Anogeissus leiocarpa	Agni/Kétoutin	13.3
Azadirachta indica	Kininoutin	4.8
Anacardium occidentalis	Acajoutin	4.8
Garcinia kola	Ahowétin	4.2
Casuarina equisetifolia	Filaotin	8.5
Psidium guajava	Kinkountin	0.5
Zanthoxylum zanthoxyloides	Hêtin	1.1
Khaya senegalensis	Caïlcédratin	3.2
Pterocarpus erinaceus	Kossoétin	3.7
Eucalyptus camaldulensis	Eucalyptustin	4.3
Citrus sp.	Yovozintin	0.5
Elaeis guineensis	Dékpa	1.1

provided by 21.8, 20.7, 9 and 10.1% of processors using *A. auriculiformis*, *T. grandis*, *M. indica* and *A. leiocarpa*, respectively (Figure 3).

Effect of socio-demographic characteristics, technological parameters and survey area on precooking and bristle removal practices

The results (Table 5) showed that both bristle removal and pork precooking significantly ($p < 0.001$) varied with the production areas. Moreover, bristle removal ($p<0.05$) and precooking ($p<0.01$) also significantly varied with the type of fuel while only bristle removal significantly($p<0.05$) varied with the socio-cultural groups. Regarding the other independent variables, no significant change was recorded.

Quality criteria for fresh pork, intermediary products, and end product

The quality criteria used by processors to judge fresh

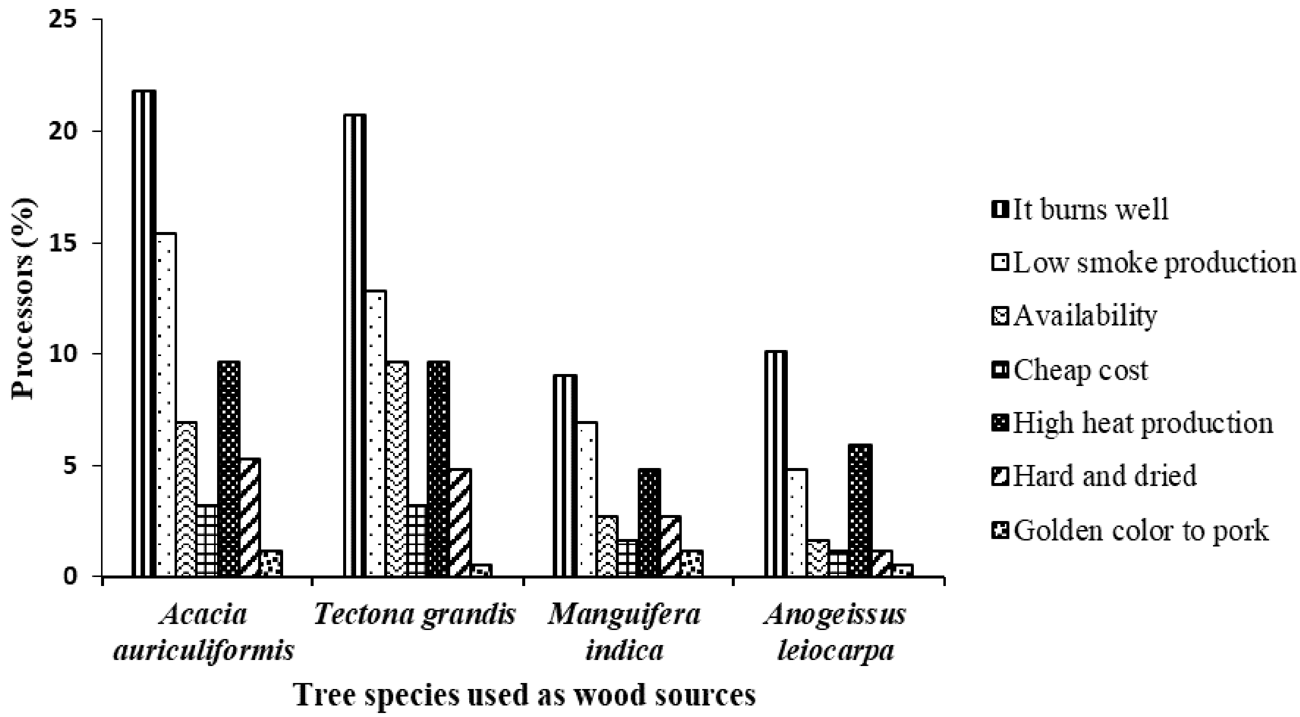

Figure 3. Proportions of processors giving the reasons regarding the choice of the four main tree species used for fuel in pork grilling in Benin.

Table 5. Effect of survey areas, socio-demographic characteristics and technological parameters on precooking and bristle removal practices.

Variable	Survey areas	Socio-cultural groups	Religion	Academic qualification	Pig breed	Grilled pork form	Type of fuels
Bristle removal (scalding or singeing)	***	*	NS	NS	NS	NS	*
Precooking (yes or no)	***	NS	NS	NS	NS	NS	**

NS: Non-significant; *p<0.05; ***p<0.001.

pork, the intermediary product and end product (grilled pork) included texture, colour, aroma, taste and low fat content. However, texture was considered the most suitable to appreciate precooked (40.5%) and grilled pork (72.3%), while colour was used to appreciate fresh pork quality (53.2%) (Supplementary Data 2).

Quality issues for fresh pork and processed products

Several quality issues were listed by processors during the investigation (Supplementary Data 3). Quality issues related to fresh pork included malodour emission (claimed by 23.7% of processors), presence of cysts (21%), and the presence of blood (13.2%). For precooked pork, a less soft texture and malodour emission were listed as main quality issues by 31.2 and 25% of processors, respectively. Carbonization of pork during grilling and malodour emission was the two main quality issues selected by 30.5 and 21.8% of processors interviewed, respectively, with respect to grilled pork. Surprisingly, 36.8, 37.5 and 17.4% of processors were not aware of any quality issues regarding fresh, precooked and grilled pork, respectively.

Preservation of grilled pork and treatment of unsold grilled pork

The survey showed that not all grilled pork may be sold during the day of processing, with the remaining products kept at ambient temperature (41%), in the fridge (45.2%) or under ice (13.8%) for selling the next day. Various techniques for selling unsold products were described by the processors (Supplementary Data 4), including grilling again the next day (46.3%), flavouring and grilling (23.9%), frying (9.6%) or cooking in a sauce commonly known as *kpètè* (2.1%) in *Goun* language.

Factors influencing the selling price of grilled pork

Processors sell grilled pork directly at processing sites. Selling price was found to depend on three main factors: production cost, influenced by the purchase price of the pig (77% of processors); quality of grilled pork (5.7% of processors); and yield of grilled pork (17.4% of processors).

DISCUSSION

Socio-demographic characteristics of processors

The socio-cultural groups of processors recorded in this study are in agreement with those reported by Ayssiwede et al. (2009), who found a preponderance of the *Goun* and *Fon* sociocultural groups among pork butchers in Benin. The high proportion of these sociocultural groups is due to the fact that most of them are originally from these municipalities and the production of grilled pork is family activity transmitted from father to son or relatives. The high proportion of men undertaking pork grilling illustrates the particularity of this activity, as in Benin, most street food stalls and traditional restaurants are run by women (Nago et al., 1994; FAO, 1997). Moreover, the fact that processors averaged around twelve years of experience and most of them were aged less than 40 years old demonstrates that many processors likely started at a young age in recent decades, illustrating the vitality of this activity among the younger generation.

Production of grilled pork

The three pig breeds used for processing are derived from both national markets and neighbouring countries (Burkina Faso, Nigeria, and Togo), all of which have a land border with Benin, facilitating the pig trade. These results are in agreement with observations made by several authors (Ayssiwede et al., 2009; Goussanou et al., 2013) listing the same countries as the main exporters of pigs to Beninese butchers. The use of castrated pigs by processors for pork grilling might be due to the fact that castration improves pig zootechnical performance, as well as the sensorial and technological properties of pig meat (Youssao et al., 2008b). The use of singeing and scalding as bristle removal methods may affect the carcass and raw pork quality. Indeed, Monin et al. (1995) recorded higher carcass yield when singeing was used rather than scalding. Moreover, the fact that singeing is carried out using organic matter including wood could be a potential pathway for the contamination of raw pork with PAHs.

Grilled pork is sold in three different forms (skewer, slice and piece) whose production differs based on specific unit operations. Whereas grilled pork slices are made via both indirect and direct grilling operations, grilled pork pieces differ from the other two forms due to the practice of precooking. Precooking before grilling was found to be widespread in the Cotonou and Abomey-Calavi municipalities and was not a common practice in the other production zones under study.

Types of grills and fuels used for processing

During direct grilling, the pork is simply laid above the combustion/grilling chamber and is exposed to smoke and heat, enabling pork fat to drop through the grill into the embers below. This is significant, as Viegas et al. (2012) reported the contribution of fat combustion during meat grilling to PAH production. Iko Afé et al. (2020) reported contamination with PAHs of traditional grilled pork produced with barrel grill using *A. auriculiformis*. Kpoclou et al. (2014) reported that the use of *A. auriculiformis* as fuel resulted in a higher PAH concentration compared to *M. indica*, with both tree species recorded during the present investigation. We also recorded the use of coconut husks as a secondary fuel. The Codex Alimentarius Commission reported that the use of coconut husks in food grilling/smoking can lead to high PAH contamination due to its high lignin content (CAC, 2009). Moreover, because of the temperatures of cooking applied to pork during traditional grilling, the digestibility of grilled pork proteins could be affected. According to Bax (2012) and Djekic et al. (2020), the impact of meat cooking on proteins results in a progressive combination of denaturation, oxidation and aggregation of proteins, what can improve or slow down the digestibility of proteins according to the temperatures of cooking. A heat treatment led to a denaturation of protein, which results in an externalization of the hydrophobic amino acids, thus offering hydrophobic sites attainable to the proteases (Bax, 2012; Santé-Lhoutellier et al., 2017).

The traditional grilling could also affect the quality of fatty acids (Janiszewski et al., 2016) and contribute to the formation of oxidation products like aldehydes (Munasinghe et al., 2003). These traditional practices of grilling showed that improvement of the grilling process and product quality for urban dwellers are needed to reduce consumer's exposure to toxic compounds.

Effect of socio-demographic characteristics, technological parameters and survey area on precooking and bristle removal practices

The significant variation recorded among these parameters showed that for future improvement, particular attention should be paid to bristle removal practices and precooking to reduce their effect on grilled pork production.

Quality criteria for fresh pork, intermediary products and end product

The quality criteria mentioned by processors will be useful in future studies to assess the change in sensory characteristics of grilled pork after traditional process improvement.

Quality issues for fresh pork and processed products

The malodour emission described by processors for fresh pork, precooked pork and grilled pork is a consequence of poor preservation practices (at ambient tropical temperature), which lead to produce spoilage. In addition to malodour, the presence of cysts in fresh pork reported as a quality issue by processors indicates that pig from which the pork derived was ill and probably unsafe for consumption. The presence of cysts in pork has previously been reported as responsible for several seizures in veterinary inspectors during inspection (Goussanou et al., 2013). The carbonization of grilled pork described by 30.5% of processors involves the blackening of grilled pork and/or the emission of a strong smoked odour.

Preservation of grilled pork and treatment of unsold grilled pork

The heat treatments applied to unsold grilled pork as preservation practices could result in modification of nutritional (protein and lipid oxidation) and sensory quality of pork.

Factors influencing the selling price of grilled pork

The purchase price of the pig is the biggest factor influencing the selling price of grilled pork since it affects greatly the production cost. In that condition, the only factor under the control of the processors is the quality of pigs in term of healthiness, low fatness and ability to provide high yield of grilled pork.

Conclusion

This investigation contributes to improving the understanding of grilled pork production and marketing in the South Benin. Processors of grilled pork in the region are mainly men from different socio-cultural groups, the most important of which are *Goun* and *Fon*. Three forms of grilled pork are produced (slice, skewer, and pieces), made from three pig breeds including indigenous, exotic and cross-breed. Precooking is a key unit operation differentiating the production processes of these forms. Among the various grill types recorded for pork grilling, locally made clay grills and vertical barrel grills are the most common, with wood and charcoal as the main fuels. In terms of quality perception, processors predominantly use texture and colour as main quality criteria to appreciate grilled pork. The malodour emission is the main quality issue raised by grilled pork processors. However, further investigation is required to better characterize the chemical and microbial hazards associated with grilled pork.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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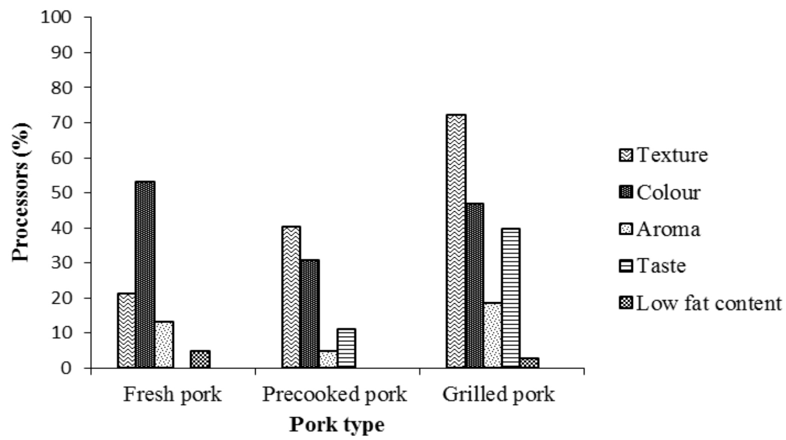
Supplementary Data

Supplementary data 1. Criteria used by grilled pork processors in choosing pig breeds

Pig breed	Processor percentage (%) (n = 188)			
	Age (year)	Health status	Fat content	Weight
Indigenous	0.5	80.9	36.7	18.1
Crossbreed	1.1	59.2	31.9	11.7
Exotic breed (Large White)	1.1	25.5	19.7	11.2

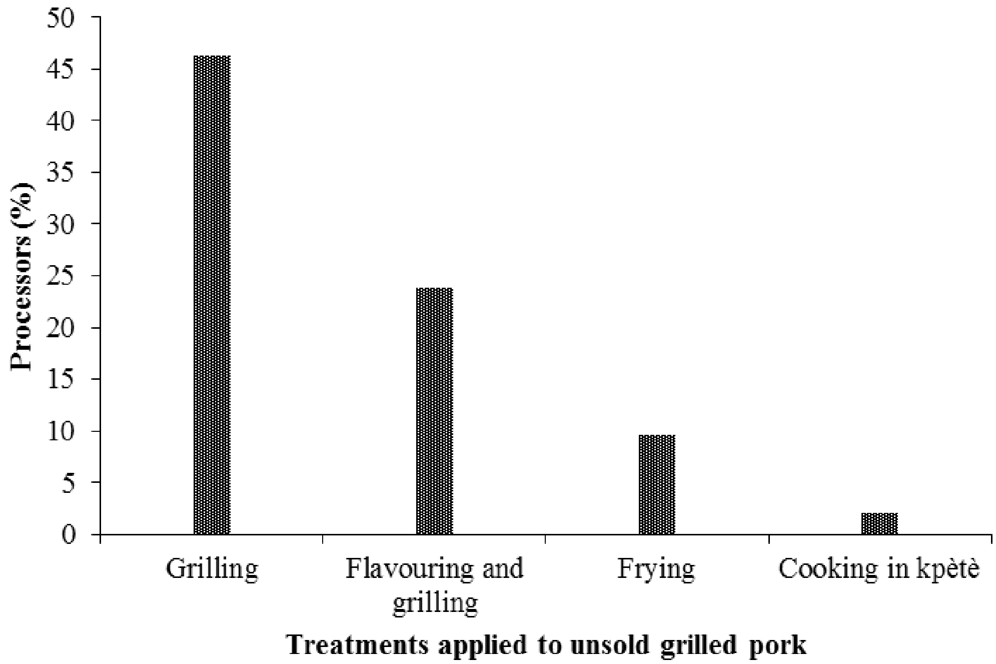


Supplementary data 2. Quality criteria used for fresh pork, precooked pork and grilled pork as selected by the sampled grilled pork processors

Supplementary data 3. Quality issues for fresh, precooked and grilled pork, and proportion of processors

Quality issues	Proportion of processors (%)
Fresh pork	
Malodour emission	23.7
Presence of cysts	21
Presence of blood	13.2
Pork fat status	2.6
Greenish colouring	2.6
Others	36.8
Precooked pork	
Less soft texture	31.2
Malodour emission	25
Bad precooking of pork	6.3
Others	37.5
Grilled pork	
Carbonization of pork	30.5
Malodour emission	21.8
Less soft texture	17.4
Presence of blood	4.3
Bad flavour	4.3
Bad cooking of pork during grilling	4.3
Others*	17.4

*Others: processors with no opinion about the quality



Supplementary data 4. Proportion of processors employing each treatment applied to grilled pork before selling to consumers

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