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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.

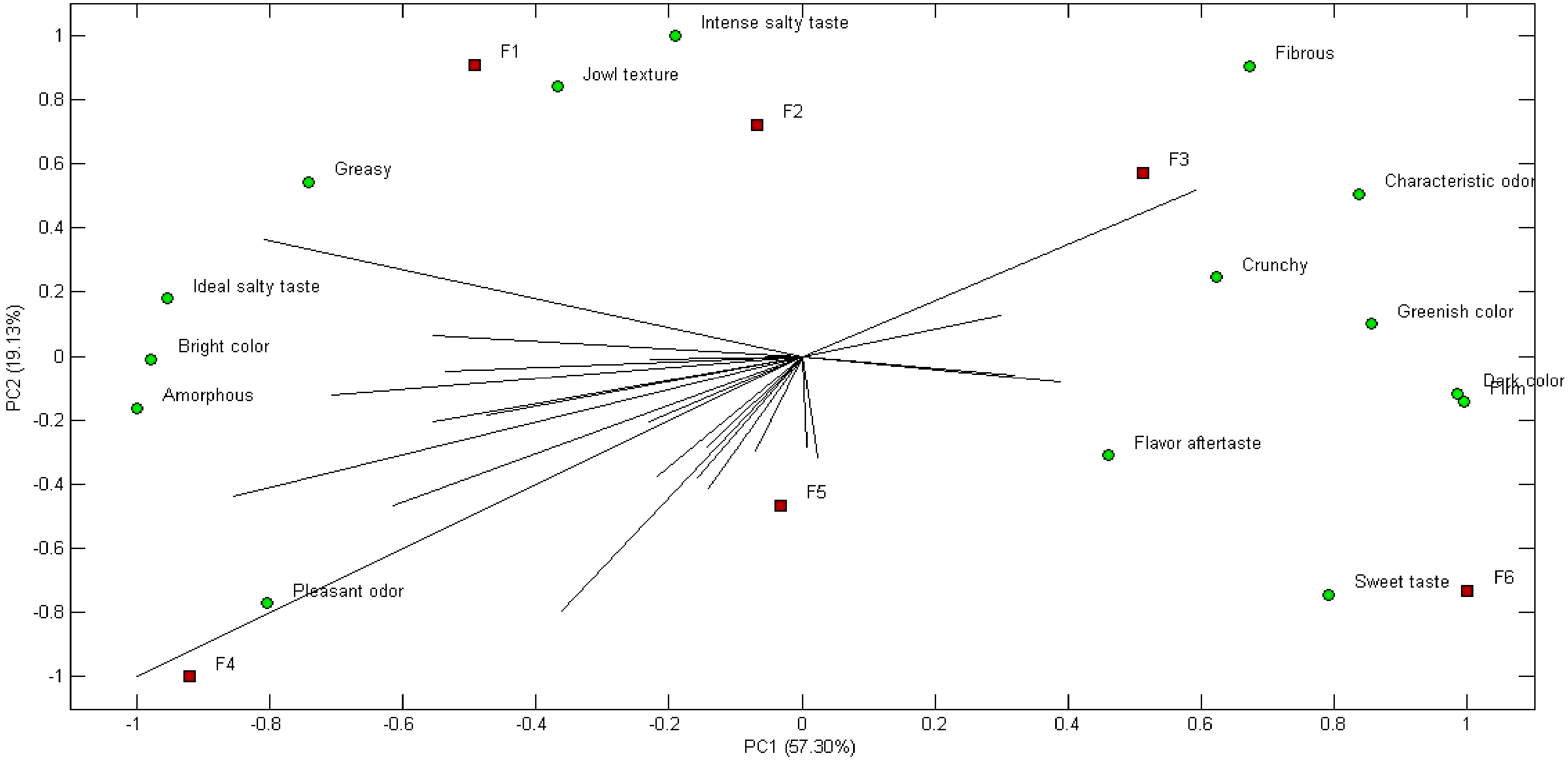

Figure 1. External preference map (EPM) of the sensory terms on the check-all-that-apply (CATA) questionnaire for the bread from wheat-sweet potato composite flour samples in the correlation matrix with overall consumer impression. F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat 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.

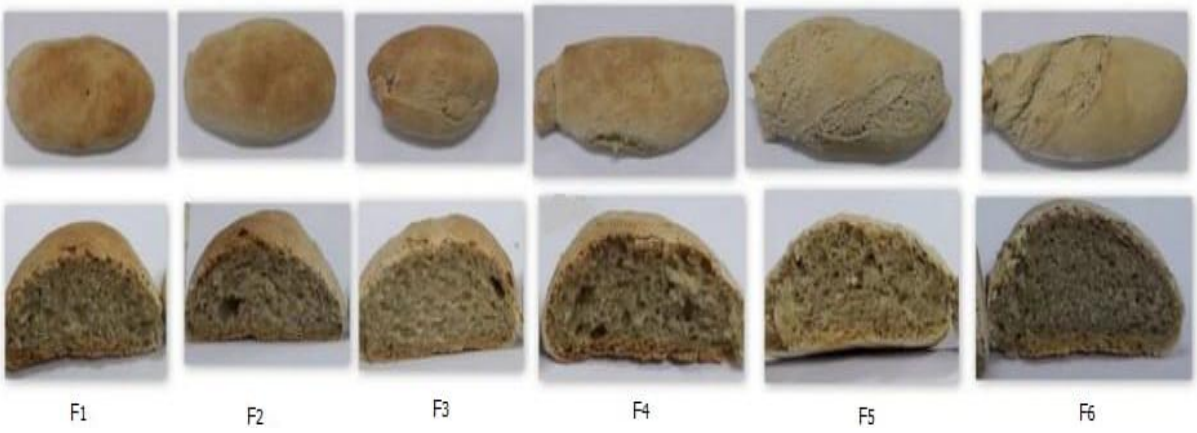

Figure 2. F1 and F3, F2 and F4; and, F3 and F6 are formulations in which wheat flour was replaced by 10, 20 and 30% sweet flour potato, respectively; and, F4, F5 and F6 contain 0.5, 1.0 and 1.5% okra hydrocolloid (in dry matter), respectively.

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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