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Effect of roasted rice bran on the quality characteristics of biscuits developed with cassava starch

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Abstract

This study aimed to evaluate the effect of roasted rice bran on the quality of cassava starch biscuits. The rice bran was submitted to heat treatment at 102.5 ± 2.5°C, with a roasting time that varied between 3 and 7 min. The optimal time for roasting was 5 min, with the bran having the characteristics of moisture (wet basis): 1.52% ± 0.20%, acidity: 0.24% ± 0.01% and lipids: 20.39% ± 0.18%. Four biscuit formulations were produced with 5, 10, 15, and 20% of roasted rice bran and a standard formulation (100% wheat flour). The nutritional value and sensory analysis of the biscuits were analyzed. The shelf life was tested for 60 days, at 30 ± 2°C, spaced 20 days apart for each measurement. The biscuit with rice bran roasted up to 15% proved to be acceptable from a nutritional value (ash: 2.54% ± 0.09%, proteins: 9.28% ± 0.19%, lipids: 20.78% ± 0.15%, fibers: 2.94% ± 0.03% and caloric value: 468.183 ± 0.57 kcal), water activity: 0.357% ± 0.028% and obtained an acceptance rate above 80%. The new biscuits produced were within acceptable quality standards for human consumption and it was concluded that roasted rice bran can be used as an ingredient in the production of biscuits with high nutritional and sensory quality.

Keywords: rice bran; by-product; roasting; cassava starch; biscuits; nutritional value.

Practical Application: Boosts biscuit nutrition with rice bran for a healthier, sustainable snack choice.

1 INTRODUCTION

Rice (*Oryza sativa* L.) is the second most consumed cereal worldwide and the most important in most developing countries because it is an excellent source of energy due to the high concentration of starch. The production of this cereal is more concentrated in Asian countries, especially China, with an average annual production estimated at 200 million tons (Mishra, 2017; Oliveira et al., 2017). Cassava is produced throughout the country and is the food base of the Mozambican population.

In Mozambique, rice is one of the cereals that is part of the population's diet, and its annual consumption is estimated at 36 kg per capita (Abbas, 2017). Rice bran is one of the rice by-products in addition to husk and broken rice, and its production is estimated to be around 8.0% of the total weight of rice with husk (for a production of 154,000 tons of rice with bark, 12,320 tons correspond to bran) (Bodie et al., 2019). Rice bran contains significant amounts of lipids, proteins, raw fiber, B vitamins, and minerals (iron, potassium, calcium, chlorine, magnesium, and manganese) (Sapwarobol et al., 2021), which may be responsible for the improvement of human health in general.

Due to its high lipid content (21% on average), rice bran is prone to rapid rancidity, which limits its use in human food. The rancidity of this raw material is attributed to lipolytic enzymes which, in turn, release the free fatty acids responsible for bad odors in food (Champagne et al., 1992; Mishra, 2017; Soares et al., 2009). For this reason, the literature reports the treatment of rice bran by dry/moist heat, by acid, or even by oil extraction (defatted bran) to achieve several objectives: enrichment of wheat flour as a source of dietary fiber in pizza preparation (Delahaye et al., 2005), bread (Soares et al., 2009), biscuits (Feddern et al., 2011; Xhabiri et al., 2014), improvement of nutritive quality (protein, ash, and fiber) in biscuits with the application of up to 25% of defatted rice bran (Elgammal et al., 2018). Elgammal et al. (2018) and Younas et al. (2011) report that rice bran has been used to supplement biscuits in a proportion that varies between 5 and 10%, with technological characteristics similar to wheat flour biscuits.

Rice bran is a nutrient-rich raw material whose use as an ingredient in the formulation of food products is almost non-existent. For this reason, the production of flour from food waste wasted by the food industry proves to be a good alternative to human food, helping combat hunger, misery, and waste, promoting food security and the integral consumption of food (Sapwarobol et al., 2021) as a source of high protein-fiber (Bunde et al., 2010). However, the application of rice bran in non-wheat flour in the formulation of various food products may constitute a major technological challenge, and, consequently, negatively influence the organoleptic and texture characteristics of the final product. For this reason, the present study was carried out

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with the aim of exploring the physicochemical characteristics of roasted rice bran and its technological potential in the production of biscuits. The study aimed to characterize the biscuits produced in terms of nutritional content, assess shelf life, and assess the acceptability of the biscuits. Biscuits are usually made with wheat flour. Due to the fact that there are people who are intolerant to gluten, that is, wheat protein, cassava starch was used in this study.

2 MATERIAL AND METHODS

The experiments were carried out at the Laboratory of the Department of Chemical Engineering (DEQUI), Faculty of Engineering, University Eduardo Mondlane (UEM).

2.1 Material

Rice bran [moisture: 8.945% (wb, wet base), acidity: 0.451%, lipid: 20.004%, water activity: 0.552, fiber: 7.113%, protein (N x 6.25): 15.113% and ash: 12.764%)] was kindly provided by Wanbao SA company (Gaza Province, Mozambique). Cassava starch was supplied by the Department of Chemical Engineering (DEQUI) as part of the Cassava Flour-based Bread Project. The other ingredients such as sugar, margarine, eggs, powdered milk (Promex brand), dry yeast, high Methoxyl pectin (HM-pectin) (DANISCO), and lemon were purchased from the local market (Maputo City, Mozambique) or directly obtained from the suppliers. Lemon peels (0.3 kg) were ground to a granulometry of 0.35 mm, corresponding to a 45-mesh sieve (ASTM, series nº 614276).

2.2 Rice bran preparation

Notably, 800 g of rice bran was divided into four equal portions, each weighing 200 g. The first portion did not undergo heat treatment and was coded as a FAT 0 sample. This sample was used as a standard for comparison with the heat-treated samples. The other three were roasted in a gas oven at 102.5 ± 2.5ºC for different times of 3, 5, and 7 min. The roasting process was carried out in a pan placed on a low flame on a domestic stove, where the temperature varied between 100–105°C, stirring continuously and manually with a wooden spoon to avoid burning. The product was removed at 3 min and cooled to room temperature (~25 ± 2°C), over 30 min. The same procedure was repeated for 5 and 7 min. After the operation, the following treated brans were obtained: FAT 3 (bran treated for 3 min), FAT 5 (bran treated for 5 min) and FAT 7 (bran treated for 7 min). Treated and untreated brans were analyzed in relation to the physicochemical properties of color and lipids, and these parameters were used to choose the optimal roasting time. The rice bran roasted at that time was used to make the biscuits.

2.3 Processing of biscuits containing roasted rice bran based on cassava starch

Biscuits containing roasted rice bran based on cassava starch were prepared according to the methodology described by (Soares et al., 2009), with some modifications. Roasted rice bran (FAT) was added to the formulation of gluten-free biscuits at four levels (5, 10, 15, and 20% w/w) (Table 1) by replacing an equal amount of cassava starch in the mixture of the dough. The basic ingredients used were 300 g of mixed flour (manioc starch + roasted rice bran), 6 g of chemical baking powder, 45 g of Promex brand milk, 99 g of sugar, 120 g of margarine, 9 g of lemon peel, 0.6 g of HM-pectin, and 2 eggs. Lemon peel flour was added to the mixture at a constant level of 3% w/w. Table 1 indicates the proportions, expressed in % w/w, of the ingredients in the formulation.

Figure 1 shows the flowchart of the gluten-free cookie processing sequence. Initially, the sugar and margarine were mixed in a mixer (Kenwood Chef, USA) for 5 min, and then other ingredients such as powdered milk, baking powder, eggs, HM-pectin, and lemon peel flour were added and mixed again until a homogeneous cream is obtained. Lemon peel flour was added to the formulation of the biscuits with roasted rice bran to add flavor. To the cream obtained, cassava starch (AM) and roasted rice bran (FAT) were added and mixed until a homogeneous and smooth mass was obtained. The obtained mass (510.5 g) was divided into 14 g portions, and molded, according to the circular shape, which is the shape commonly found on the market for this type of product. After molding, the biscuits were placed in metal trays properly separated, and taken to the electric oven with forced air circulation (Model: Macadams convecta, manufacturer: Macadams) at a temperature of 160°C, for approximately 15 min. After that, the biscuits were cooled to room temperature (25 ± 1°C). The cooled biscuits were packed in polypropylene plastic bags for subsequent analyses. The biscuit produced with 100% wheat flour was used as a standard.

2.4 Evaluation of physicochemical properties

2.4.1 Diameter and thickness

The diameter (D) and thickness (δ) of the biscuits were determined using a caliper. The values obtained were recorded and expressed in mm. The result was taken as the mean value of three determinations. The expansion factor (EF) was calculated as the ratio of the diameter to the thickness of the biscuits.

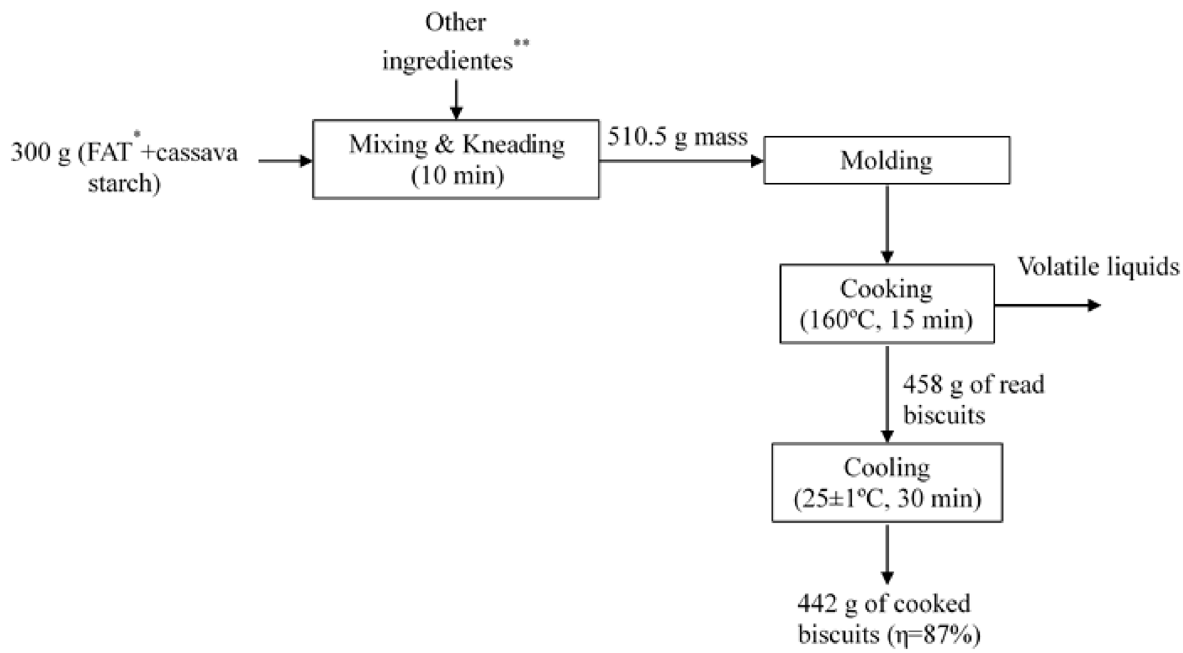
2.4.2 Color analysis

The Color Reader CR-10 (Minolta, Japan) was used to analyze the color parameters (L^*, a^*, and b^*). The lightness component L ranges from 0 (black) to 100 (white); the a^* component extends from a negative value (green hue) to a positive value

Table 1. Formulation of biscuits containing roasted rice bran.

Formulations*	Wheat flour (%)	Roasted rice bran (%)	Cassava starch (%)
Standard	100	0	0
BFAT 5	0	5	95
BFAT 10	0	10	90
BFAT 15	0	15	85
BFAT 20	0	20	80

BFAT 5: 5% roasted rice bran; BFAT 10: 10% Roasted rice bran; BFAT 15: 15% roasted rice bran; BFAT 20: 20% roasted rice bran; *calculated in relation to the total amount of 300 g (cassava starch + rice bran).



*Rice bran roasted for 5 min; **see quantities in Table 1.

Figure 1. Flowchart for the preparation of biscuits containing toasted rice bran based on cassava starch.

(red hue); and the b^* component ranges from negative blue to positive yellow. The color of the biscuits was reported as the browning index (BI) (Equation 1):

$$BI = 100 \times (x - 0.31)/0.17 \quad (1)$$

Where: $\mathbf{x} = \dfrac{\boldsymbol{a^*} + \mathbf{1.75} \times \mathbf{L}}{(\mathbf{5.645L} + \boldsymbol{a^*} - \mathbf{3.01} \times \boldsymbol{b^*})}$

2.4.3 Hardness

The hardness of the biscuits was determined by the texture analyzer (Model Instron 5542, USA). The analysis was done using a 2-mm diameter probe compressing the biscuits at a cross-head speed of 0.1–2 mm/s for 5 s. The hardness of the biscuits was measured based on force, expressed in Newton (N).

2.4.4 Acidity value

The acidity value was determined according to the methodology described by (Instituto Adolfo Lutz [IAL], 2008). About 3 g of the dry sample was mixed with 50 ml of distilled water in an Erlenmeyer flask. Then, the titration was carried out using a 0.1 M NaOH solution with the addition of three drops of 1% phenolphthalein solution. The titration continued until a pink color was observed.

2.4.5 Moisture content

The moisture content was determined by oven-drying (Dig-iTronic, Spain) at 105°C for 3 h and then cooling the sample in a desiccator. The process was repeated several times until the weight was constant.

2.4.6 Ash determination

Samples were oven-burned at 550°C to a constant weight and the ash content was determined by weighting.

2.4.7 Lipid content determination

The lipid content of samples was extracted using the Soxtherm extractor (Gerhardt, Germany) with petroleum ether as a solvent for approximately 6 h. About 2 g of the sample was weighed and placed in a filter paper cartridge, which was connected to the Soxtherm apparatus, whose flask, after washing, was heated for 1 h in the oven at 105°C, cooled in a desiccator to room temperature and weighed. The solvent was recovered and the flask with the fat was placed in an oven at 105°C for approximately 1 h.

2.4.8 Fiber content

The fiber content was determined according to the method described by (IAL, 2008). Notably, 2 g of the sample was homogenized and oven-dried to constant weight at 105°C for 2 h. Samples were removed the fat using petroleum ether in Soxtherm unit. The dried and defatted samples were heated to eliminate the rest of the solvent. The sample was transferred into a 750-mL Erlemneyer flask. A volume of 100 ml of H_2SO_4 (1.25%)/KOH (1.25%) solution was added to the sample and boiled for 30 min. After that, in a muffle furnace, the dried filtrate was heated at 550 °C for approximately 8 h.

The following formula was used to determine the percentage of fiber (Equation 2):

$$\%\ \text{Fiber} = 100 \times \frac{[(\text{Weight of crucuble with deffacted dried sample}) - (\text{Weight of crucible with ash})]}{\text{Weight of sample}} \quad (2)$$

2.4.9 Protein content

The protein content was determined by the Kjeldahl method by digesting the samples in H_2SO_4 in the presence of a catalyst resulting in the nitrogen conversion in ammonia. After distillation, ammonia was distilled in a trapping solution. Ammonia was quantified by titration with a standard solution. The percent of the protein content of the sample was calculated as the percent of nitrogen X 6.25 (FAO & WHO, 1973; Instituto Adolfo Lutz, 2008).

2.4.10 Carbohydrate content

Carbohydrates were calculated by the difference between 100 g of the sample and the contents of (moisture, ash, proteins, fiber, and lipids) (Equation 3).

$$\text{Carbohydrates (\%)} = 100 - (\text{moisture} + \text{ash} + \text{proteins} + \text{fiber} + \text{lipids}) \quad (3)$$

2.4.11 Caloric value

The caloric value was calculated by multiplying the values in grams of proteins by 4 kcal/g, lipids by 9 kcal/g, and carbohydrates by 4 kcal/g, respectively (FAO & WHO, 1973), where the results were expressed in kcal per 100 g of the sample, as follows (Equation 4):

$$\text{Caloric value} = 4 \times \%\text{carbohydrates} + 9 \times \%\text{lipids} + 4 \times \%\text{proteins} \quad (4)$$

2.5 Sensory evaluation

The organoleptic properties of the biscuits were investigated in the Faculty of Engineering, UEM. Fifty untrained panelists aged between 18 and 50 years, both sexes, all of whom are students and employees of the Faculty of Engineering, UEM. The samples were compared on the basis of the following organoleptic characteristics: color, taste, appearance, texture, aroma, and overall acceptability. An information sheet was given to them. Each attribute was scored based on its intensity scaled on a 9-point hedonic scale, with 1 representing the lowest score (disliked extremely) and 9 the highest score (liked very extremely). Biscuits were considered accepted with acceptability index (AI) values equal to or above 70% ($AI \geq 70\%$) (Doporto et al., 2017; Feddern et al., 2011).

2.6 Evaluation of the shelf life of biscuits

The shelf life of the biscuits was controlled, every 20 days, for 60 days, at a temperature of approximately 30 ± 2°C. The biscuits were packed in plastic bags with a capacity of 10 units each. A total of 20 packages were prepared, each containing 10 samples of the biscuits produced.

Hardness, moisture, and acidity were controlled as shelf-life parameters.

2.7 Statistical analysis

The results obtained were statistically analyzed using analysis of variance (ANOVA) at a significance level of 5% error probability, followed by the Tukey test used for comparisons. The results obtained are presented in terms of mean values ± standard deviation and are illustrated graphically or tabulated.

3 RESULTS AND DISCUSSION

3.1 Effect of roasting time on rice bran characteristics

Table 2 presents the results of lipid, acidity, and moisture content of rice bran. These results were obtained under temperature conditions of 102.5 ± 2.5°C and roasting times of 3, 5, and 7 min (FAT 3, FAT 5, and FAT 7), and were compared to those of untreated rice bran (FAT0).

The increase in roasting time (3, 5, and 7 min) caused a significant decrease ($p < 0.05$) in rice bran moisture and acidity. Regarding the increase in lipid content, it was not significant ($p > 0.05$) between the bran samples submitted at different times. As for the browning index, there was a significant increase ($p < 0.05$) in this parameter. Maillard reactions explain the behavior in the color parameter, which results from the heat treatment to which the brans were submitted. Heat treatment was used in this work to inhibit the activity of the lipase enzyme present in the bran, which is responsible for the development of free fatty acids, and consequently improving the conservation characteristics of this raw material (Ramezanzadeh et al., 2000).

Younas et al. (2011) stabilized rice bran with dry heat (120°C and 10–15 s) and found a moisture content of 18.17% and a lipids content of 16.93%. Sharma et al. (2004) evaluated the physicochemical characteristics of rice bran stabilized with dry heat (120°C for 30 min) and observed, among others, a brown color when compared with the color of the untreated bran, which had a light brown color, a slight increase in the lipid content from 14.72 to 15.06%.

The values reported in the literature are higher (moisture) or lower (lipids) than those observed in this work, which are probably justified by the differences in the roasting/processing conditions used in the present study (102.5 ± 2.5°C and variable times: 3, 5, and 7 min).

Based on the results of Table 2, it was concluded that the time of 5 min (FAT 5) is the optimal time for roasting rice bran compared with the times of 3 and 7 min analyzed, due to the fact that the product presents greater uniformity in color, lower moisture, and acidity contents. Rice bran with these characteristics was used for the production of starch-based biscuits.

3.2 Effect of roasted rice bran on the physicochemical characteristics of cassava starch biscuits

Table 3 presents the values of the parameters of thickness, diameter, and factor elaborated based on the expansion of roasted rice at the levels of 5, 15, and 20% w/w.

The thickness and diameter of the biscuits decrease in a non-proportional way with the addition of roasted rice bran, with the biscuit containing 5% rice bran having the highest value and the biscuit with 20% roasted rice bran having the lowest value.

Table 2. Effect of roasting time on lipid content, acidity, moisture, and browning index of rice bran.

Constituents	Roasting time (min)			
	0 (FAT 0)	3 (FAT 3)	5 (FAT 5)	7 (FAT 7)
Moisture (%, w.b.)	8.95 ± 0.35[a]	4.40 ± 0.12[b]	1.52 ± 0.20[c]	0.35 ± 0.06[d]
Acidity (%)	0.45 ± 0.03[a]	0.31 ± 0.04[b]	0.24 ± 0.01[c]	0.17 ± 0.02[d]
Lipids (%)	20.00 ± 0.46[a]	20.17 ± 0.31[a]	20.39 ± 0.18[a]	20.42 ± 0.03[a]
Browning Index (-)	92.74 ± 0.12[a]	99.73 ± 2.27[b]	102.30 ± 3.97[b]	108.26 ± 1.08[c]

[a,b,c,d]Means followed by at least one letter in common on the same line do not differ from each other by Tukey's test, at a significance level of 5%. FAT 0: unroasted rice bran; FAT 3: rice bran roasted for 3 min; FAT 5: 5-min roasted rice bran; FAT 7: 7-min roasted rice bran. The temperature was maintained at approximately 102.5 ± 2.5°C, constant.

Table 3. Effect of the roasted rice tariff on the characteristics of the diameter, thickness, and expansion factor of biscuits.

Formulations	Physical Parameters		
	Diameter (mm) D	Thickness (mm) δ	Expansion factor (mm) EF
Standard (100% wheat)	50.47 ± 0.32[a]	11.31 ± 0.79[a]	4.48 ± 0.37[a]
BFAT 5%	50.96 ± 0.64[a]	10.27 ± 0.95[a]	5.01 ± 0.45[ab]
BFAT 10%	50.32 ± 0.71[a]	10.50 ± 0.80[a]	4.84 ± 0.37[a]
BFAT 15%	49.99 ± 0.18[a]	8.31 ± 0.37[b]	6.03 ± 0.28[b]
BFAT 20%	48.25 ± 0.39[b]	8.05 ± 0.70[b]	6.05 ± 0.56[b]

[a,b]Means followed by different letters in the same column differ from each other by Tukey's test ($p < 0.05$); Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

According to the results of Table 3, there was a decrease in the diameter after baking the biscuits. The BFAT 5% cookie sample had the largest diameter (50.96 mm). As the concentration of roasted rice bran increases in the crackers, the diameter decreases. This result may show that the addition of large amounts of roasted rice bran may have interfered with the formation of the biscuit, causing the dough to spread less during cooking, thus reducing the diameter of the biscuits.

The average thickness of the biscuits showed a significant difference between the formulations, verifying that BFAT 10% presented the highest average thickness value, significantly differing from the other formulations. Thus, it was possible to verify that the thickness of the biscuits tends to decrease as the diameter decreases, as the concentration of roasted rice bran in the cookie formulations increases.

These results are in agreement with those found by (Younas et al., 2011), evaluating the effect of adding heat-treated rice bran on the quality of biscuits, obtaining diameter values between (51.88–49.46 mm) and thickness between (9.91–10.45 mm) for 5 and 20% of rice bran, respectively. Mishra and Chandra (2012) developed gluten-free biscuits with 10–25% of a mixture of soy flour and rice bran and found that the diameter of the biscuits decreased from 44 to 36.2 mm as the substitution of flour composed of rice bran and soybean.

The different values of diameter and thickness demonstrate a difference between the biscuits produced, probably because of the method of elaboration used, since the biscuits were shaped manually according to the characteristics of the dough and not with the help of molds.

Figure 2 illustrates the external appearance of biscuits containing rice bran based on cassava starch.

The results of water activity and acidity index for the formulations of biscuits made from cassava starch containing roasted rice bran at levels of 5, 10, 15, and 20% w/w are found in Table 4.

Acording to Table 4, there are significant statistical differences ($p < 0.05$) between the formulations, with the law of BFAT 15% and BFAT 20% biscuits having a higher value of this parameter compared to standard wheat flour biscuits and BFAT 5% formulation and BFAT 10%. Regarding aw, biscuits made from roasted rice husk bran and cassava starch present lower values than standard wheat flour biscuits. It should be noted that all samples present aw values below 0.5, which is important for the conservation of biscuits, as it reduces the rate of microbial proliferation and possible oxidation of lipids present in this type of food.

According to Reid and Fennema (2008), the main feature of biscuits is their low water activity, which should be between 0.30 and 0.40, ensuring stability during storage. Water activity values above 0.8 favor the development of molds and above 0.88 provide the development of yeast in biscuits. The water activity of the biscuits under study ranged from 0.346 to 0.390, and these results demonstrate that they are a stable product from a microbiological point of view. Regarding the acidity content, there were also significant differences ($p < 0.05$) between the standard wheat flour biscuits and the biscuits made from roasted rice bran and cassava starch. It was also found that the formulation of BFAT 5% contains a lower percentage of acidity in relation to the other biscuits produced and the formulation BFAT 20% had a higher content of this index. Acidity is an important parameter of the conservation status of a product. For biscuits, the maximum acidity allowed corresponds to 2 g/100 g (Brasil, 1978), thus showing that, in relation to this parameter, the biscuits produced are in a good state of conservation, thus hindering the development of spoilage microorganisms.

Figure 3 illustrates the results of the browning index of the formulations of biscuits made from cassava starch containing roasted rice bran at levels of 5, 10, 15, and 20% w/w.

Regarding the browning index, it can be observed that the value of this index is different for the biscuit formulations made. It was verified that this value is lower for biscuits with a low percentage of roasted rice bran and as the roasted rice bran increases, the browning index also increases. This increase is smaller in relation to the browning index of standard biscuits.

Browning reactions induce changes in the color of food products. The dark color of the biscuits may be generated by the caramelization of the sugar added to the biscuit formulation or Maillard reactions during baking at high temperatures

Standard BFAT5% BFAT10% BFAT15% BFAT20%

Standard: biscuit produced with 100% wheat flour; BFAT 5%: biscuit produced with 5% roasted rice bran; BFAT 10%: biscuit made with 10% roasted rice bran BFAT 15%: biscuit made with 15% roasted rice bran BFAT 20%: biscuit made with 20% roasted rice bran.

Figure 2. External appearance of biscuits containing roasted rice bran based on cassava starch.

Table 4. Effect of roasted rice bran on the water activity and acidity parameters of cassava starch biscuits.

Physical parameters*	Treatments**				
	Standard (100% wheat)	BFAT 5%	BFAT 10%	BFAT 15%	BFAT 20%
Water activity (a_w)	0.409 ± 0.029^{a}	0.390 ± 0.016^{a}	0.388 ± 0.004^{a}	0.357 ± 0.028^{b}	0.346 ± 0.013^{b}
Acidity (%)	0.275 ± 0.674^{a}	0.260 ± 0.020^{a}	0.294 ± 0.045^{ab}	0.314 ± 0.016^{bc}	0.331 ± 0.028^{c}

*a,b,c Means followed by different letters in the same line differ from each other by Tukey's test ($p < 0.05$); **Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

(Sharma et al., 2004). These results are in agreement with the findings of (Xhabiri et al., 2014) who reported that more wheat bran (5 to 40%) incorporation resulted in a darker surface in biscuits.

Figure 4 shows the strength results of the formulations of biscuits made from cassava starch containing roasted rice bran at levels of 5, 10, 15, and 20% w/w.

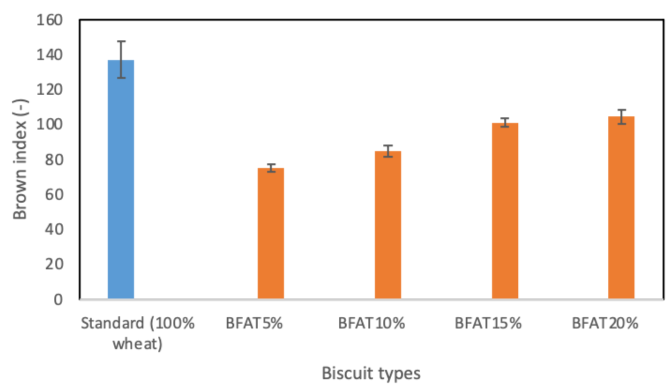
For breaking strength (breaking strength), the percentage of roasted rice bran flour had a significant effect ($p < 0.05$), indicating that for different percentages of roasted rice bran flour, there is a difference in the breaking strength of the biscuits. This difference increases as the amount of roasted rice bran flour is added to the starch. These results show that the biscuits that obtained the highest consistency in the dough are BFAT 20%, the ones that have the highest breaking strength.

3.3 Effect of roasted rice bran on the chemical characteristics of cassava starch-based biscuits

Table 5 presents the results of the chemical characteristics of biscuits containing roasted rice bran based on cassava starch, in the proportions of rice bran: cassava starch of 5:95% w/w, 10:90% w/w, 15:85% w/w, and 20:80% w/w, respectively, designated as BFAT 5%, BFAT 10%, BFAT 15%, and BFAT 20%.

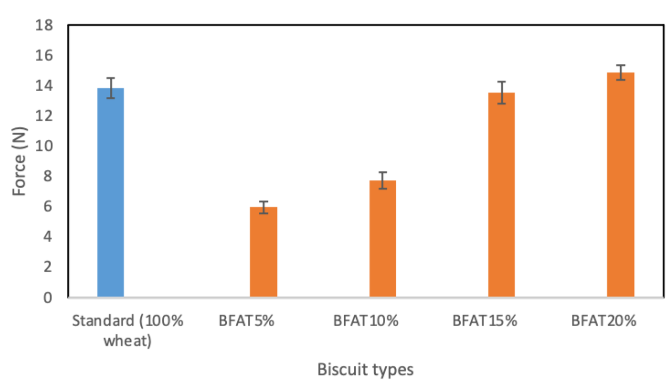
From Table 5, it can be seen that the addition of roasted rice bran translates, in relation to the standard (100% wheat flour), into an increase in ash, lipid, fiber, and protein contents and a decrease in moisture and carbohydrate contents. It is also observed that the gradual addition of rice bran in the formulation increases the caloric value of the biscuits. The lipid content increases with the addition of roasted rice bran, this increase being significant for the BFAT 20% sample (~ 20.0% w/w).

The moisture content of the biscuits produced varies from 3.404 to 4.182% and is in accordance with the standard established by (Brasil, 1978), which determines a maximum standard of 14% moisture for biscuits. It can be seen that when increasing the concentration of roasted rice bran in the formulations of the biscuits under study, the moisture content of the biscuits decreases. This decrease may be related to the fact that the roasted rice bran flour is possibly a residue with low water retention.



Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

Figure 3. Effect of roasted rice bran on the browning index of cassava starch-based biscuits.



Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

Figure 4. Effect of roasted rice bran on the breaking strength of cassava starch-based biscuits.

Table 5. Effect of rice bran on the chemical parameters of cassava starch-based biscuits.

Constituents	Treatments				
	Standard (100% wheat)	**BFAT 5%**	**BFAT 10%**	**BFAT 15%**	**BFAT 20%**
Moisture (%, w.b.)	4.182 ± 0.330^{a}	3.905 ± 0.308^{ab}	3.576 ± 0.371^{b}	3.453 ± 0.643^{b}	3.404 ± 0.627^{b}
Proteins (%, Nx6.25)	6.963 ± 0.351^{a}	7.558 ± 0.213^{b}	8.407 ± 0.209^{c}	9.282 ± 0.190^{d}	9.872 ± 0.212^{e}
Lipids (%)	16.671 ± 0.619^{a}	19.542 ± 0.197^{b}	20.344 ± 0.015^{c}	20.775 ± 0.151^{c}	21.613 ± 0.466^{d}
Fiber (%)	2.104 ± 0.076^{a}	2.473 ± 0.074^{b}	2.605 ± 0.072^{c}	2.937 ± 0.027^{d}	3.192 ± 0.041^{e}
Ash (%)	1.343 ± 0.116^{a}	1.645 ± 0.053^{b}	2.182 ± 0.079^{c}	2.536 ± 0.092^{d}	2.757 ± 0.071^{e}
Carbohydrates (%)	68.838 ± 0.324^{a}	64.877 ± 0.493^{b}	62.886 ± 0.385^{c}	61.020 ± 0.527^{d}	59.162 ± 0.532^{e}
Caloric value (kcal)	453.242 ± 2.909^{a}	465.618 ± 1.052^{b}	468.268 ± 0.848^{c}	468.183 ± 0.572^{c}	470.653 ± 2.839^{d}

[a,b,c,d,e]Means followed by at least one letter in common on the same line do not differ from each other by Tukey's test, at a significance level of 5%; Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

Lacerda et al., 2010, making partial substitution of wheat flour for extruded rice bran, obtained low moisture values compared to those found in the present research, which ranged from 1.46 to 5.58% moisture. These differences are due to the heat treatments to which the brans were submitted, in addition to differences in the technology of processing the biscuits.

There is a significant effect ($p < 0.05$) on the ash content found in the biscuits produced, indicating that for different percentages of roasted rice bran, there is a difference in this content. The ash content of the biscuits under study ranged from 1.343 to 2.757% and these values are within the standards established by (Brasil, 1978), which is 3.0% of fixed mineral residue. It is observed that the higher the concentration of roasted rice bran in the biscuits produced, the greater the amount of mineral residue, that is, the greater the amount of roasted rice bran, the greater the amount of minerals present in the biscuits produced. Tripathi and Tripathi (2018) added wheat bran to biscuits and obtained similar ash content values (2.73 to 3.91%) to those found in the present work. The consumption of foods rich in this nutrient (ash/minerals) can help supply the deficiency of this macronutrient in a population suffering from malnutrition.

In relation to lipids, it was found that this content ranged from 19.542 to 21.613%, and the greater the addition of roasted rice bran, the greater the concentration of lipids, which probably favored the profile of essential fatty acids of the biscuits produced. However, they had a significantly higher lipid content than the standard treatment (16.67%). The lipid content of foods may vary depending on the ingredients used. In their study of the quality of biscuits made with extruded rice bran in place of wheat flour and cassava starch, Soares et al. (2009) obtained an average value of lipids in the biscuits between 19.5 and 21.9%. In their study of elaboration and evaluation of gluten-free rice bran biscuits and rice and soy flours, Mariani et al. (2015) obtained lipid content of 20.29–22.13%, which are similar to those found in this work.

Analyzing the fiber content, it can be seen that the greater the amount of roasted rice bran added to the biscuits, the greater the amount of fiber, thus differentiating ($p < 0.05$) this parameter. According to the results obtained, the standard formulation and BFAT 5% have fiber content lower than 2.5%, thus classifying them as foods with low fiber content. Biscuits produced with the formulations of 10, 15, and 20% BFAT belong to the category of food sources of fiber. These fiber contents may be associated with the amount of fiber present in the roasted rice bran added in the biscuit formulation. Fibers have beneficial effects on human health and can significantly contribute to lowering cholesterol levels.

As for the protein content, there was a significant difference ($p < 0.05$) between the different cookie formulations. This content ranged from 6.963 to 9.872%, and the greater the addition of roasted rice bran, the greater the protein content present in the biscuits under study. Mishra and Chandra (2012) mixed rice bran (FA) and soy flour in cookie formulations and obtained a high protein content of (9.43–15.7%), which is due to the mixture of the FA protein source (13.5%) and soy flour (~40%).

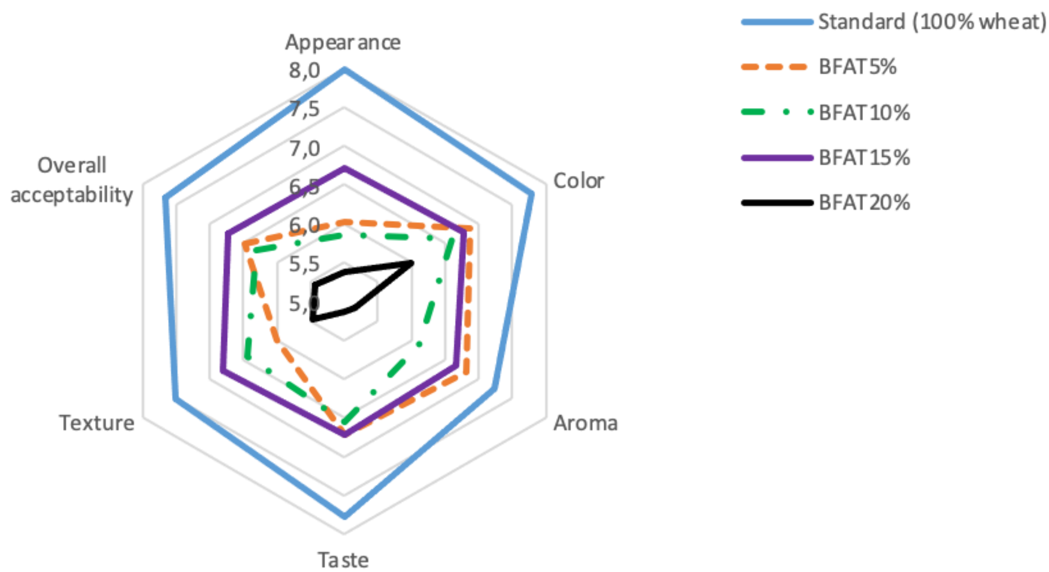
The carbohydrate content decreases with the increase in rice bran. The caloric value, (expressed in kcal), increases with the level of rice bran in the biscuits from 465.618 ± 1.052 (BFAT 5%: biscuits with 5% rice bran) to 470.653 ± 2.839 (BFAT 20%: biscuits with 20% rice bran) compared with standard biscuits (100% wheat). The results of the carbohydrates and caloric values of biscuits are in line with those reported by Mariani et al. (2015) and Xhabiri et al. (2014), respectively.

If one compares the increase obtained in ash, fiber, and protein contents by the addition of roasted rice bran in extreme cases (BFAT 5% and BFAT 20% samples), it is observed that, in relation to the standard (100% wheat flour), there is an increase in these contents in the final product of about 23 and 106% ash, 18 and 52% fiber, and 9 and 42% protein, respectively.

3.4 Effect of roasted rice bran on the sensory attributes of cassava starch-based biscuits

In Figure 5, it is possible to observe the averages of the results attributed to the samples regarding the sensory attributes evaluated in the treatments: appearance, color, aroma, flavor, texture, and global appreciation. The evaluation method was based on a 9-point hedonic scale. The classification of the parameters to be analyzed was performed according to this scale, which ranged from 1 to 9, with 5 being a neutral value (= indifferent) (Mishra, 2017).

According to Figure 5, the treatments differed significantly ($p < 0.05$) in relation to the attributes of the biscuits under study. It can be seen (Figure 5) that the standard formulation (100% wheat flour) presented a good average in relation to the other formulations, with high values for all evaluated attributes. As for



Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

Figure 5. Effect of roasted rice bran on the sensory attributes of cassava starch-based biscuits.

appearance, the standard formulation obtained the highest value of 7.77, and the lowest was verified for the BFAT 20% formulation, with 5.20. The behavior observed for attributes such as color, aroma, flavor, texture, and global appreciation is the same, that is, the standard formulation has high values in all attributes, and consequently the highest acceptance rate of 83.88%.

The formulations BFAT 15% and BFAT 5% had the best scores in all attributes, right after the standard formulation, with acceptance rates of (72.99 and 74.30%, respectively). However, the BFAT 10% and BFAT 20% formulations had the lowest acceptance scores of (67.1 and 55.99%), respectively. According to the above, it can be concluded that the formulations BFAT 15% and BFAT 5% are considered accepted by consumers, while BFAT 10% and BFAT 20% were not accepted, as they had acceptance rates below 70%. These results are in agreement with the findings of Younas et al. (2011) who reported the highest scores for the overall acceptability of biscuits with a low level of wheat bran substitution, that is, < 20%; but in contrast with Feddern et al. (2011) and Mariani et al. (2015).

3.5 Effect of roasted rice bran on the quality characteristics of cassava starch biscuits after storage

Figures 6A–6C show the results of the shelf life of the biscuits obtained from the formulation containing roasted rice bran based on cassava starch corresponding to samples BFAT 5%, BFAT 10%, BFAT 15%, and BFAT 20% and standard sample (100% wheat) stored for 60 days and 30 ± 2°C.

The results of the shelf life in relation to the moisture parameter in the wet base are shown in Figure 6A.

It can be seen that in relation to the period (0–60 days) under study, there was no significant change in moisture ($p < 0.05$) in the wet base. For day zero, it appears that the standard biscuit and BFAT 5% have the same content of this parameter, and in turn, the remaining formulations do not differ from each other ($p < 0.05$).

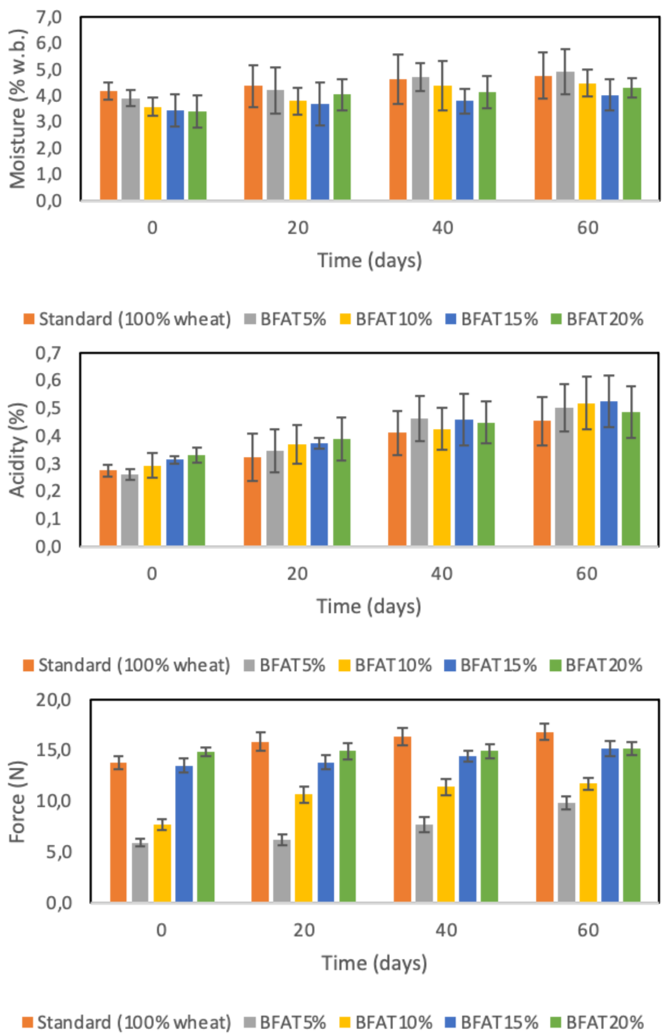
If, for example, the BFAT 5% formulation is observed, it is clear that, as the days go by, there is an increase in the moisture content. This observation is visible for all cookie formulations under study. The moisture content of the biscuits under study varies from 3.4 to 4.9 (%, w.b.) and is in accordance with the standard established by Brasil (1978), which sets a maximum standard of 14% moisture for biscuits.

The results of the shelf life in relation to the acidity of biscuits made from cassava starch and roasted rice bran are shown in Figure 6B.

For day 0, it can be seen that there was a significant change in moisture ($p < 0.05$) in the wet base for the biscuit formulations under study. It is verified that the standard biscuit has an acid index value close to the treatment BFAT 5%, BFAT 10%, and BFAT 15% and in turn for the treatments BFAT 15% and BFAT 20% this value did not differ significantly ($p < 0.05$). Regarding the results, it is observed that the acidity index increases as the percentage of roasted rice bran in the biscuits increases.

Regarding the treatments in the studies, there were also significant differences ($p < 0.05$) between the standard wheat flour biscuits and the biscuits made from roasted rice bran and cassava starch. This index ranged from 0.26 to 0.52 g/100 g. The determination of acidity in biscuits is important, taking into account that, through it, data are obtained regarding their processing and conservation status. According to Brasil (1978), since the acidity values found are less than 2 g/100 g, the biscuit treatments under study are in good condition.

The results of the shelf life in relation to the strength of biscuits made from cassava starch and roasted rice bran are shown in Figure 6C.



Standard: 100% wheat flour; BFAT 5%: biscuit with 5% of toasted rice bran; BFAT 10%: biscuit with 10% of toasted rice bran; BFAT 15%: biscuit with 15% of toasted rice bran; BFAT 20%: biscuit with 20% toasted rice bran.

Figure 6. (A) The effect of the addition of roasted rice bran on the moisture of the cassava starch biscuit during 60 days of storage at 30 ± 2°C. (B) Effect of the addition of roasted rice bran on the acidity of the cassava starch-based biscuit during 60 days of storage at 30 ± 2°C. (C) Effect of the addition of roasted rice bran on the strength of cassava starch biscuits during 60 days of storage at 30 ± 2°C.

It can be observed that there was a significant change in strength ($p < 0.05$) for the cookie formulations under study. It is verified that the standard biscuit has a higher strength value than the treatments BFAT 5%, BFAT 10%, and BFAT 15%, and close to the treatment BFAT 20%. The force value differs significantly ($p < 0.05$) in relation to the type of increase in roasted rice bran and in relation to the shelf-life periods. The longer the shelf life, the greater the cracking strength of the biscuits.

4 CONCLUSIONS

According to the study carried out, it was concluded that the optimal time for roasting rice bran was 5 min (FAT 5) since the rice bran showed greater uniformity in color, lower moisture, and acidity contents compared to 3 and 7 min of roasting and for the shelf-life of 60 days there was no significant change in the analyzed parameters, namely moisture, acidity, and breaking strength. It was also concluded that the rice bran can be used in the preparation of biscuits in partial replacement of cassava starch, improving the nutritional value of biscuits, dietary fiber, proteins, and lipids.

In all the physical-chemical analyses, the biscuits made from rice bran presented results within the requirements of the special technical standards for foods of ANVISA and can be used as an alternative for the bakery industry, especially with the purpose of expanding the supply of gluten-free foods and enhanced/enriched with functional substances. The results of the sensory evaluation indicate that, in general, consumers accepted the biscuits produced, and the formulations BFAT 15% and BFAT 5% had the best score in all attributes with an acceptance rate of 72.99 and 74.30%, respectively.

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