Brazilian cheese bread rolls from fermented and native waxy maize starch

Pão de queijo a partir de amido de milho ceroso nativo e fermentado

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ABSTRACT

Brazilian cheese bread (CB) rolls are gluten-free bread made from sour cassava starch. They are soft in the center and have crispy crust, reminding of the extruded structure. Although native waxy maize starch (WMS) has higher technologic quality, it has not been used in CB rolls; therefore, this study aimed to investigate the use of WMS and the backslopping fermentation process plus sun drying in WMS to replace sour cassava starch (0, 25%, 75%, and 100%) and the effects on dough development, color, and textural properties. Data were analyzed using variance and Tukey test (p ≤ 0.05%), and the results were set against a commercial product from cassava starch. The better formulation was characterized by proximal composition, sensorial acceptance, and willingness to buy, and data were presented as means and standard deviation. The different statistic parameters included color to redness coordinate, baking expansion capacity, specific volume, hardness, fracturability, and chewiness. The best formulation had 100% of sundried WMS and was microbiologically safe. The proximal composition had lower values than that obtained from the Brazilian Food Database. The product was considered satisfactory as it had a score of more than 7.79 to texture, appearance, and flavor with higher willingness to buy (92.5%). The backslopping fermentation plus SWMS was considered a potential replacement for sour cassava starch.

Index terms: Gluten-free bread; backslopping fermentation; starch modification; bakery; celiac diet.

INTRODUCTION

Brazilian cheese bread (CB) rolls are a bakery product with a crispy crust and soft center. They taste savory and sweet (Chadbourn, 2016). As CB rolls are a higher source of energy and do not contain gluten, it is widely consumed in Brazil (INMETRO, 2017). This kind of bread has rarely been studied. It is a mixture of low moisture cheese, eggs, milk, fat, salt, and cassava starch, which can be native, sour, or a mixture of both (Anjos et al., 2014; Fernandes et al., 2015; Papalia et al., 2015).

The process of obtaining sour cassava starch turns the native starch into a product with a high expansion characteristic, and during baking, it behaves like extruded snacks (alveolar structure, high specific volume, and crispness). Fermentation and sun drying (SD) processes are used to obtain sour cassava starch. Because of
fermentation, starch has a low viscosity peak and higher paste clarity and solubility (Demiate; Kotovicz, 2011). Moreover, SD affects the pasting properties of starch through oxidation (ultraviolet [UV] radiation) (Santos; Sartori; Cabello, 2012).

Although changes are observed in maize starch after UV oxidation, they are not adequate to change maize starch to sour cassava (Bertolini et al., 2001). On the other hand, waxy starch retains more water, can be easily solubilized, has a compact physical structure, and changes its structure after swelling (Schirmer et al., 2013). Therefore, it can be easily modified as shown in our previous study (Teixeira et al., 2019); however, it has not been used in CB rolls. Cassava is not available in some temperate regions such as the USA and Europe, and its production is lower than maize (Faostat, 2017). Therefore, this study aimed to produce CB rolls using different proportions of native waxy maize starch (WMS) and sour waxy maize starch (SWMS) by SD after backslopping fermentation to replace sour cassava starch and compare characteristics from them to a commercial product from cassava starch.

MATERIAL AND METHODS

Raw materials

Raw eggs, meia cura cheese (São Francisco, Brazil), soy oil (Sinhá, Brazil), sodium chloride (Cisne, Brazil), and cassava sour starch (Kodilar, Brazil) were purchased from a local market in Goiania (city of State of Goiás, Brazil). WMS was obtained from Fecularia Bela Vista (Bela Vista de Goiás, Goiás, Brazil).

Sour waxy maize starch by backslopping fermentation and sun drying

In our previous study (Teixeira et al., 2019) the WMS (5 kg) was fermented using the commercial sour cassava starch (375 g) as inoculum at 25 °C in the plastic containers with 8 L of water for 11 days until 4% of total acidity was achieved. The water was drained and fermented WMS was poured in aluminum trays and sun dried until 18 g 100 g⁻¹ of moisture retains, as set forth by the Brazilian legislation in force (Brazil, 1978).

Brazilian cheese bread rolls processing

The main formulation of CB rolls used was 250 g of starch, 135.6 g of water, 41.1 g of oil, 5.5 g of salt, two eggs, and 62.5 g of grated cheese and was adapted from the Machado and Pereira’s study (2010). Other formulations were obtained from this study, and a completely randomized design was used (Table 1), with five treatments (replacement levels of SWMS by WMS: 0, 25%, 50%, 75%, and 100%) and four repetitions.

For dough development, the ingredients were manually mixed as follows: scalding SWMS, native WMS, or a mixture of both were taken with boiling water and oil and after cooling at 25 °C, raw eggs, salt, and cheese were added and mixed until a homogeneous dough was formed. Then, rolls of approximately 15 g were manually made. CB rolls were ready after 20 min of baking at 180 °C in a preheated electric oven (electric oven - FERI60, Venâncio Aires, Brazil); they were then cooled and packed in low-density polyethylene bags for physicochemical analyses.

Table 1: Replacement levels of WMS by SWMS in Brazilian cheese bread rolls (CB) formulations.

| Ingredient | 100 (CB1) | 75 (CB2) | 50 (CB3) | 25 (CB4) | 0 (CB5) |
|------------|-----------|----------|----------|----------|--------|
| SWMS       | 250       | 187.5    | 125      | 62.5     | 0      |
| WMS        | 0         | 62.5     | 125      | 187.5    | 250    |
| Soy oil    | 41.1      | 41.1     | 41.1     | 41.1     | 41.1   |
| Water      | 135.6     | 135.6    | 135.6    | 135.6    | 135.6  |
| Cheese     | 62.5      | 62.5     | 62.5     | 62.5     | 62.5   |
| Salt       | 5.5       | 5.5      | 5.5      | 5.5      | 5.5    |
| Raw eggs   | 112       | 112      | 112      | 112      | 112    |

¹ g: CB1: 100/0; CB2: 75/25; CB3: 50/50; CB4: 25/75; CB5: 0/100 percentage of replacement of SWMS (sour waxy maize starch) and WMS (native waxy maize starch).
Physical analyses

The expansion index was determined using the ratio of the unit diameter plus unit height divided by two before and after baking. A digital pachymeter (Digital Messen, Messen, Berlin, Germany) was used to measure the diameter and height (mm) of bread before and after baking. The bread volume was measured using the displacement of millet seeds method and weighed using a precision balance, accurate up to two decimal points. The specific volume was calculated using the volume/weight ratio (Machado; Pereira, 2010). The color parameters were measured using a colorimeter (CR-10, Konica Minolta, Ramsey, EUA) in the CIELab scale, from which the chroma (C*) and hue angle (H°) were calculated. Each CB roll was considered one repetition and was read as six-fold to each CB.

After baking for 30 min, 10 CB units per repetition were added for uniaxial compression on texturometer (TA, HD Plus Stable Micro Systems, Surrey, England), with a probe diameter of 100 mm (P100) and pretest, test, and posttest speed of 5.0 mm s⁻¹, 2.0 mm s⁻¹, 2.0 mm s⁻¹, respectively. Hardness, fracturability, elasticity, and chewiness were calculated (Pereira et al., 2010).

The results obtained from the physical analyses were compared with those of the frozen commercial CB made using sour cassava starch. The formulation that had similar results to the commercial product was used for the validation of the regression adjusted models and evaluation of the proximal composition, microbiologic risk, and sensorial acceptance.

Proximal composition, microbiological analysis, and sensorial acceptance

Moisture was determinate of the mass loss from the sample under oven heating at 105 °C until a constant weight was achieved (method nº 925.10). The protein content was estimated using the Kjeldahl method for determining total nitrogen, which was converted into crude protein using the factor of 6.25 (method nº 960.52). The Soxhlet method was used to extract fat with petroleum ether (method nº 945.16). The ash content was determined by carbonization, followed by complete incineration in a muffle furnace at 550 °C (method nº 923.03). The total dietary fiber was obtained using the enzymatic-gravimetric method (method nº 985.29). The total carbohydrates content was estimated from the difference. All methods were used according to AOAC methods (AOAC, 2012).

The presence of coliforms at 45 °C g⁻¹ and Salmonella spp. were studied as per the Brazilian legislation in force (Brazil, 2001), and to evaluate the hygienic conditions of handling and storage, presence of Bacillus cereus, coagulase-positive Staphylococci, molds, and yeasts were evaluated using the American Public Health Association (Apha, 2015) methods.

A total of 100 untrained adults (aged 18-65 years, without any obligation to eat the product) evaluated color, flavor, taste, and texture using a nine-point hedonic scale, ranging from 1 (dislike it very much) to 9 (liked it very much). Moreover, the willingness to buy the product was evaluated (Dutcosky, 2013). The global acceptance index was calculated by dividing the mean score by the maximal score obtained (Bastos; Paulo; Chiaradia, 2014). This study was approved by the Federal University of Goiás Ethics Committee (nº 1616234).

RESULTS AND DISCUSSION

Physical characteristics

Expansion capacity varies with dough aeration degree and size of cells inside bread (Itthivadhanapong; Sangnak, 2016; Zhou; Faubion; Walker, 2011). In this study, the expansion index increased with increasing SWMS replacement. Moreover, CB5 (1.55) and CB1 (1.45) differed statistically, suggesting that only total replacement changed this characteristic. All formulations showed higher values than the commercial product (1.31) (Table 2).

The specific volume also increased from 3.67 to 4.20 mL g⁻¹, whereas the commercial product had a lower value (1.88 mL g⁻¹). Fermentation followed by SD, greatly altered the expansion characteristics of WMS during baking similar to sour cassava starch. This expansion was because of the oxidation reaction induced by UV sunlight on the fermented starch (Santos; Sartori; Cabello, 2012; Konak; Certel; Karakaş, 2017; Teixeira et al., 2019).

The color of bakery products can be used as a quality parameter. As for other foods, it is the first qualitative parameter evaluated by consumers (Mesomo et al., 2010). In this study, lightness (L*), saturation (C*), and hue (H°) were not affected (p ≤ 0.05) by SWMS replacement (Table 2), suggesting that fermentation does not change WMS color in the CB formulations studied. The commercial product was dark red in color and the experimental CB was light yellow in color (Figure 1).
Table 2: Expansion Index (EI), Specific volume (SV), lightness (L*), redness (a*), yellowness (b*), Chroma (C), Hue (H°), and textural parameters (hardness, fracturability, elasticity and chewiness) for Brazilian cheese bread rolls (CB) with different replacement levels of sour waxy maize starch (SWMS) and waxy maize starch (WMS), and a commercial product.

| Parameter     | SWMS and WMS replacement levels (%) | Commercial product |
|---------------|-------------------------------------|--------------------|
|               | 100 (CB1)  | 75 (CB2)  | 50 (CB3)  | 25 (CB4)  | 0 (CB5)  |                      |
| EI            | 1.55±0.04 | 1.50±0.02 | 1.49±0.05 | 1.49±0.02 | 1.45±0.02 | 1.31±0.05 |
| SV            | 4.20±0.10 | 4.12±0.08 | 3.86±0.24 | 3.68±0.13 | 3.67±0.13 | 1.88±0.08 |
| L*            | 79.47±3.67| 79.78±0.91| 83.81±3.03| 84.67±1.46| 84.78±2.96| 71.70±1.04|
| a*            | 4.40±0.35 | 4.30±0.35 | 2.48±0.34 | 2.32±0.26 | 1.98±0.27 | 7.66±0.83 |
| b*            | 19.42±1.44| 18.42±1.61| 17.82±0.96| 18.03±1.05| 17.98±0.62| 24.86±0.80|
| C*            | 22.49±1.54| 22.20±1.46| 20.22±1.46| 19.90±0.03| 19.86±1.04| 30.06±1.53|
| Hue°          | 78.68±2.30| 77.51±2.52| 76.95±2.52| 76.91±2.29| 74.13±5.19| 72.9±1.19 |
| Hardness      | 1320.62±11.60| 1406.29±12.54| 1847.88±21.43| 1855.14±17.82| 2654.86±28.14| 991.99±6.44 |
| Fracturability| 1426.34±19.87| 1433.52±19.07| 1528.76±7.49| 1557.85±23.39| 1778.29±19.09| 0.00±0.00 |
| Elasticity    | 0.69±0.03 | 0.69±0.02 | 0.70±0.02 | 0.71±0.03 | 0.71±0.03 | 0.84±0.03 |
| Chewiness     | 381.39±10.51| 387.71±4.36| 456.14±34.09| 459.94±9.8 | 515.99±13.11| 416.11±1.95 |

1 Average values, followed by standard deviation, different superscripts in a row differed significantly (p≤0.05); 2 mL g⁻¹; 3 Newton.

Figure 1: Photographs of Brazilians cheese bread rolls produced using different percentages of native waxy maize starch (WMS)/sour WMS replacement: (A) CB1:100/0; (B) CB2:75/25; (C) CB3:50/50; (D) CB4:25/75; (E) CB5:0/100; (F) Commercial product.

This behavior could be explained by the differences in ingredients in the commercial formulations (Eduardo; Svanberg; Ahrné, 2016) and also because maize starch had more lightness than cassava starch when used in CB, according to our results (Table 2, commercial product versus CB). Chroma values are associated with food freshness that has the largest consumer preferences (Lee et al., 2013). For bakery foods, consumers associated...
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Pereira et al. (2010) found $L^*$, $a^*$, $b^*$, chroma, and hue values to be approximately 77.83, 2.24, 26.81, 34.83, and 50.32°, respectively, in CB with cassava starch. In this study, $L^*$ and $H^\circ$ were higher (more clarity and yellowness) and $C^*$ was lower (less intensity) than the referred studies. López-Tenorio, Rodríguez-Sandoval and Sepúlveda-Valencia (2015) studied the influence of emulsifier on pandebono, a cheese bread from Colombia made with 50% sour cassava starch and 20% maize flour. They observed lower values of $L^*$ (71.59); higher of $a^*$ (8.57), $b^*$ (33.58), and chroma (34.40); and similar $H^\circ$ values (77.51) than CB with SWMS and WMS; however, these values were near to that of the commercial product evaluated.

The increase in the expansion and specific volume of the Brazilians CB rolls produced with a larger proportion of SWMS led to a high percentage of alveolus during baking and lower values of hardness, fracturability, and chewiness. This is because of the action of acids and enzymes in microorganisms, which were catalyzed by UV light during SD, thus changing the starch structure (Putri; Marseno; Cahyanto, 2012; Marcon et al., 2009).

The ability to return to an initial state after deformation (elasticity) did not differ ($p \leq 0.05$) ranging from 0.71 to 0.69 for experimental CB and 0.84 for the commercial product, which could be associated with cassava starch and the cheese type used (Banslvile et al., 2015; Foegeding et al., 2015; Pereira et al., 2010). CB with 100% of SWMS showed better physical characteristics than the commercial product (Table 2). Therefore, it was chosen for microbiological, sensory, and physicochemical evaluations; all formulations were suitable.

Proximal composition, microbiological analyses, and sensory acceptance of CB with 100% of SWMS

Proximal composition

According to the Brazilian Food Database (TACO), the proximal composition of baked CB (g 100 g$^{-1}$) was as follows: moisture: 33.7, crude protein: 5.1, crude lipids: 24.6, total carbohydrates: 34.2, total ash: 2.3, and total energetic value: 363 Kcal (Unicamp, 2011). In this study, lower values of moisture and total energy and higher values of ash, protein, and carbohydrates were observed (Table 3). The difference in the proximal composition values could be associated with the use of SWMS and other ingredients used in formulations.

Table 3: Means and standard deviation to proximal composition and sensory responses of Brazilian cheese bread rolls (CB) with 100% sour waxy maize starch (SWMS).

| Parameter                  | Levels       |
|----------------------------|--------------|
| Moisture$^1$              | 31.27±0.87   |
| Crude protein$^1$         | 9.07±0.08    |
| Crude lipids$^1$          | 12.8±1.2     |
| Total Ash$^1$             | 2.86±0.04    |
| Total Fibre$^1$           | 0.27±0.01    |
| Carbohydrates$^1$         | 44           |
| Total energetic value$^2$ | 326.4        |
| Appearance$^3$            | 7.79±1.33    |
| Texture$^3$               | 8±1.47       |
| Flavour$^3$               | 7.95±1.21    |
| Odour$^3$                 | 7.8±1.1      |
| Williness to pay$^3$      | 92.5±13.4    |
| Global acceptance index$^3$| 98.56        |

$^1$ g 100 g$^{-1}$; $^2$ kcal 100 g$^{-1}$; $^3$ Accessors response (%). Hedonic scale: 1) Dislike extremely; 2) Dislike very much; 3) Dislike moderately; 4) Dislike slightly; 5) Neither like nor dislike; 6) Like slightly; 7) Like moderately; 8) Like very much; 9) Like extremely.

Lemos et al. (2012) studied CB from the amaranth flour and found moisture, crude protein, crude lipids, carbohydrates, and total energetic values to be 28.7(g 100 g$^{-1}$), 6.8(g 100 g$^{-1}$), 19.5(g 100 g$^{-1}$), 38.5 (g 100 g$^{-1}$), and 356 kcal, respectively. When these results were compared with our study results, only total energetic value and crude protein were higher, as amaranth flour was used in the CB formulation. Cavalcante et al. (2016) studied CB using cowpea flour and found similar values for moisture (26.9 g 100 g$^{-1}$), crude protein (10.6 g 100 g$^{-1}$), total ash (2.9 g 100 g$^{-1}$), and total energy (321.3 kcal).

The characteristics of the final products were compared after the use of a new ingredient (Pereira et al., 2004). However, it is crucial to emphasize that in our study, we did not find a CB protocol to compare formulations and all formulations used were as per empirical knowledge.
Microbiologic analyses and sensory acceptance

CB was considered safe as no microorganisms were found, and the standard Brazilian legislation in force proposes maximal values only to coliforms at 45 °C (10^2 Most Probable Number g^-1) and Salmonella sp. (absence in 25 g of sample) (Braz, 2001).

CB with 100% of SWMS had a score of 7.79 for appearance, 8 for texture, 7.8 for odor, and 7.95 for flavor (Table 3). Other studies on CB showed lower sensory acceptance and willingness to buy as sour cassava starch was increasingly replaced by green banana (Fernandes et al., 2015).

Cavalcante et al. (2016) investigated the replacement of sour cassava starch by cowpea flour and observed low values of willingness to buy (67%) and global acceptance (72.8%) when compared with this study. However, 98.56% of global acceptance index was observed in this study by the assessors, which certainly would buy the product.

CONCLUSIONS

CB1 formulation had better physical parameters, with 100% of SWMS and good sensory acceptance. SWMS used in CB rolls showed a higher baking expansion capacity and specific volume than sour cassava starch. The use of SWMS is technologically feasible.

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