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ORIGINAL ARTICLE

Effect of the storage period on physical-chemical characteristics, microbiological composition and sensory acceptance of two varieties of frozen sweet cassava

Efeito do período de armazenamento na composição físico-química, na qualidade microbiológica e na aceitação sensorial de duas variedades de mandioca de mesa congelada

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Abstract

Sweet cassava can be sold frozen, i.e., frozen food, to facilitate preparation and consumption. This study aimed to evaluate physical-chemical characteristics, cooking time, microbiological quality and sensory attributes regarding the varieties BRS Aipim Brasil and Eucalipto in frozen storage. The roots were washed in water, sanitized, cut into cylinders, peeled, sanitized, drained, packed in nylon/ low density polyethylene packages and stored at -18 °C, being evaluated every 30 days, approximately. The Eucalipto variety showed the lowest moisture (61.98%) and the highest pulp yield (71.41%) and starch content (33.45%). However, the BRS Aipim Brasil variety had lower color intensity (11.48) and greater color angle (97.45°) than Eucalipto. The two cassava genotypes showed no difference in terms of acidity, luminosity, soluble solids, total sugar content and pH. The Eucalipto variety showed the shortest cooking time (25 minutes) and moisture (62.92%) concerning the five storage times that were evaluated. This variety also had the highest starch content during storage, except at 31 days. The Eucalipto variety was more accepted for the color, aroma and overall impression attributes. Regarding flavor and texture, the two varieties were considered similar and were classified between the hedonic terms "like slightly" and "like moderately". The sensory acceptance of the roots was not altered during storage and the grades attributed were above 6.0, which represents the minimum acceptance limit, for all evaluated attributes. Cassava frozen at -18 °C can be marketed for 120 days without microbiological risk, and without significant changes in its physical-chemical and sensory characteristics.

Keywords: *Manihot esculenta* Crantz; Processing; Shelf life; Cooking; Sensory analysis; Chemical composition.

Resumo

A mandioca de mesa pode ser comercializada congelada para facilitar o preparo e o consumo. Este trabalho teve como objetivo avaliar as características físico-químicas, o tempo de cozimento, a qualidade microbiológica e os atributos sensoriais das variedades BRS Aipim Brasil e Eucalipto, durante o armazenamento sob congelamento. As raízes foram lavadas em água, sanitizadas, cortadas em cilindros, descascadas, sanitizadas, drenadas, acondicionadas em embalagens de nylon/ polietileno de baixa densidade e armazenadas a -18 °C, sendo avaliadas a cada 30 dias, aproximadamente. A variedade Eucalipto apresentou a menor umidade (61,98%) e os maiores rendimentos de polpa (71,41%) e teor de amido (33,45%). A variedade BRS Aipim Brasil apresentou menor intensidade de cor (11,48) e maior ângulo de cor (97,45°). Os dois genótipos de mandioca não apresentaram diferenças em termos de acidez, luminosidade, sólidos solúveis, teor de açúcar total e pH. A variedade Eucalipto apresentou o menor tempo de cozimento (25 minutos) e umidade (62,92%), para os cinco tempos de armazenamento avaliados. Essa variedade também apresentou o maior teor de amido durante o armazenamento, exceto aos 31 dias. A variedade Eucalipto foi mais aceita para os atributos cor, aroma e impressão global. Em relação ao sabor e à textura, as duas variedades foram consideradas semelhantes e foram classificadas entre os termos hedônicos "gostei ligeiramente" e "gostei moderadamente". A aceitação sensorial das raízes não foi alterada ao longo do armazenamento e as notas atribuídas foram acima de 6,0, o que representa o limite mínimo de aceitação, para todos os atributos avaliados. A mandioca congelada a -18 °C pode ser comercializada por 120 dias com segurança microbiológica, sem que ocorram alterações significativas das suas características físico-químicas e sensoriais.

Palavras-chave: *Manihot esculenta* Crantz; Processamento; Vida útil; Cocção; Análise sensorial; Composição química.

1 Introduction

Cassava (*Manihot esculenta* Crantz) is one of the main energy foods in developing countries. More than 100 countries produce cassava, and Brazil is the world's fifth largest producer (Food and Agriculture Organization of the United Nations, 2020). Culture is of fundamental importance for the country, because it is one of the most relevant products for family farming and food security, seeing that it is a plant adapted to low fertility soils and irregular rain conditions as well as important for its multiple uses (Oliveira et al., 2015).

Sweet cassava, also known as manioc, presents low content of cyanogenic compounds in its pulp. However, bitter varieties, also called poisonous, have higher concentrations of these compounds (Montagnac et al., 2009). Bitter cassava is used in the manufacture of flour and production of cassava starch, also known as starch, *goma* and *tapioca*.

Regarding the cyanogenic compounds, the pulp color of the sweet cassava roots can vary from white to yellow, i.e., an important characteristic that interferes with consumer acceptance, varying according to the region of the country (Carvalho et al., 2017). In the studies carried out to characterize the fresh sweet cassava roots, ashes, color, cooking time, fibers, lipids, minerals, moisture, pH, proteins, pulp yield, starch, titratable acidity and total carotenoids have been evaluated (Alves et al., 2008; Carvalho et al., 2017; Ceni et al., 2009; Mezette et al., 2009; Pedri et al., 2018). The chemical composition of cassava roots has an average value of 61.8% of moisture, 36.2% of carbohydrates, 1.9% of dietary fiber, 1.1% of protein, 0.6% of ash and 0.3% of lipids (Universidade Estadual de Campinas, 2011). Moisture is one of the most important aspects of root conservation due to the direct influence on its durability (Bezerra et al., 2002).

In addition to its high perishability, characterized by physiological and microbiological deteriorations that prevent the maintenance of fresh roots for several days after harvest, another obstacle to the commercialization of fresh sweet cassava roots is associated with peeling problems, which reflect the little practicality regarding the product characteristics (Rinaldi et al., 2015a). To minimize these problems, the roots can be commercialized minimally processed, frozen, pre-cooked and frozen, in addition to processed as dough, fries and snacks (Oliveira et al., 2017; Ramos et al., 2013).

Among these various conservation methods, freezing proves to be efficient and stands out for controlling both physiological and microbiological deterioration (Carvalho et al., 2011; Rinaldi et al., 2015a, 2015b). In addition, the production of frozen cassava is a viable alternative for rural producers in order to add value to their productions (Sanches et al., 2017). On the other hand, the expansion of the sweet cassava market depends on varieties that have good sensory characteristics such as flavor and texture and low cooking time, even after frozen storage time.

The Eucalipto cultivar is the most widely planted sweet variety in the Recôncavo Baiano region due to the short cooking time in different harvest periods and the low physiological deterioration, whereas the variety BRS Aipim Brasil was recommended by Embrapa Mandioca e Fruticultura in 2001, as an early sweet cassava variety for the Cruz das Almas and Conceição do Almeida – in the Bahia region (Araujo & Almeida, 2013). These varieties have not been studied with respect to frozen storage time. Thus, this study aimed to evaluate physical-chemical characteristics, cooking time, microbiological quality and sensory attributes of the varieties BRS Aipim Brasil and Eucalipto during frozen storage.

2 Material and methods

2.1 Evaluated genotypes and culture conditions

The Eucalipto and BRS Aipim Brasil varieties were cultivated in the experimental field of Embrapa Cassava & Fruit in Cruz das Almas, in the state of Bahia (BA), in Brazil, at an altitude of 199 m, 12° 67' S latitude and 39° 15' W longitude. The climate region is designated as hot and humid tropical, Aw to Am, according to the Köppen classification, with an average annual temperature of 24.5 °C, relative humidity of 80% and average rainfall of 1,249.7 mm annually (Agritempo, 2020). The soil of the experimental area is classified as Argisolic Cohesive Yellow Latosol, according to the classification of Empresa Brasileira de Pesquisa Agropecuária (1993) and updated by Santos et al. (2018).

2.2 Processing

The roots of the two varieties were harvested at the age of 12 months and the processing was carried out on the same harvest day, consisting of three experimental replications, with 25 kg of root being processed in each repetition. The roots were harvested in a single area, selected, washed in running water, sanitized in sodium hypochlorite solution (200 mg L^{-1} of active chlorine) for 15 minutes, cut in 6 cm long cylinders (after removing the tips), peeled and sanitized again in sodium hypochlorite solution (20 mg L^{-1} of active chlorine) for two minutes. Then, the roots were drained in sieves to remove excess water and packed in nylon/ low density polyethylene multilayer packages with a thickness of 150 µm, dimensions of 20 x 30 cm and thickness of 0.15 mm (500 g), sealed in an automatic sealer, without the use of vacuum, and stored in a freezer at -18 °C.

The experiment was carried out in a completely randomized design in the subdivided plot scheme, comprising the two varieties (BRS Aipim Brasil and Eucalipto) as the plots, whereas that the five storage times (0, 31, 60, 92 and 120 days) as the subplots. The frozen roots were evaluated for physical-chemical characteristics, cooking time and sensory acceptance in the five storage times.

2.3 Physicochemical analysis

The pulp yield was calculated as a percentage of weight, i.e., based on the weight of the roots with the skin and peel and after peeling. The other analysis was carried out after grinding the roots in a multiprocessor. The soluble solids content, total titratable acidity (% citric acid), pH and moisture (Instituto Adolfo Lutz, 2018) were determined.

The total sugar content was determined by spectrophotometry, according to the methodology of Somogyi (1945) and Nelson (1944), at the first stage of acid hydrolysis (Instituto Adolfo Lutz, 2018). The starch analysis was performed according to the methodology described by Holm et al. (1986) for the dry sample, and the starch being hydrolyzed by the enzyme activity of α-amylase and amyloglucosidase, and the glucose content quantified by spectrophotometry.

The pulp color of the crushed roots was evaluated with the aid of the Konica Minolta colorimeter, model CR400, CIELAB system (Konica-Minolta, 2013). The device was calibrated using a white ceramic plate, using the D65 illuminant (z = 93.6; x = 0.3133; y = 0.3195). The color attributes L* (luminosity) ranged from zero (black) to 100 (white), C* (chroma/color intensity) and h* (shade/color angle) ranged from 0° to 360°, where 0° corresponded to red, 90° to yellow; 180° represented green and 270° blue.

2.4 Cooking time

The roots were added frozen in boiling water, in the proportion of 2 liters of water for each kg of root, being counted the time after adding the roots in the boiling water until cooking. The cooking time was determined using a fork by a single analyst, whereas the roots were considered cooked when they could offer low resistance to penetration. The cooking of the frozen roots (zero time) was carried out on the same day of the harvest after freezing, in order to compare the cooking time with the frozen stored roots.

2.5 Microbiological analysis

To evaluate the hygienic-sanitary conditions of the processing, analysis of thermotolerant coliforms were performed using the Most Probable Number (MPN) and *Salmonella* method in the raw material and in the frozen product at 31, 60, 92 and 120 days of storage according to Silva et al. (2017).

2.6 Sensory analysis

The varieties were evaluated for sensory acceptance over the storage time under freezing (0, 31, 60, 92 and 120 days) by 50 judges who were regular consumers of cooked cassava. The test was performed in individual booths under white light. Each judge received about 25 g of cooked cassava, coded with random three-digit numbers. The order of presentation was randomized in the design of complete blocks, totaling two samples.

The sensory attributes of color, aroma, flavor, texture and overall impression were evaluated using a nine-point hedonic scale, from “dislike extremely” (1) to “like extremely” (9).

The project was approved by the Committee of Ethics in Research of the *Multidisciplinary Institute in Health*, of the Federal University of Bahia, presenting the emission issued by a Presentation Certificate for Ethical Appreciation (CAAE nº. 23109213.9.0000.5556).

2.7 Statistical analysis

All data were submitted to Analysis of Variance (ANOVA) in a split plot scheme. For significant “F” ($p \leq 0.05$), Tukey’s test at 5% significance was applied for qualitative variables and regression analysis for quantitative variables (linear and quadratic models). The analysis of variance was performed with the aid of the Sisvar statistical program (Ferreira, 2010).

3 Results and discussion

3.1 Characterization of varieties

The Eucalipto variety (71.41 ± 1.27%) showed significantly ($p \leq 0.05$) higher pulp yield than BRS Aipim Brasil (68.24 ± 0.56%) (Table 1), which was directly related to the processing yield. Oliveira et al. (2017) evaluated four sweet cassava cultivars at 12 months and observed similar values (68.9% to 72.8%), whereas Alves et al. (2008) evaluated two clones harvested at 13 months and obtained an average value of 83.2%.

Table 1. Pulp yield, physical and chemical composition, color parameters and cooking time of the roots of two cassava varieties harvested at the age of 12 months.

Evaluations	Varieties		F	CV
	BRS Aipim Brasil	Eucalipto		
Pulp yield (%)	68.24 ± 0.56[b]	71.41 ± 1.27[a]	15.70	1.40
Moisture (%)	68.92 ± 1.63[a]	61.98 ± 0.20[b]	53.57	1.78
Starch (%)	24.45 ± 1.57[b]	33.45 ± 0.52[a]	85.34	4.05
Total sugar (%)	1.27 ± 0.06[a]	1.32 ± 0.02[a]	2.14	3.23
Soluble solids (°Brix)	6.33 ± 0.44[a]	5.64 ± 0.66[a]	2.26	9.39
Total titratable acidity (%)	0.11 ± 0.00[a]	0.12 ± 0.01[a]	0.80	7.61
pH	6.23 ± 0.14[a]	6.37 ± 0.05[a]	2.27	1.72
L* (luminosity)	72.75 ± 0.19[a]	72.36 ± 0.93[a]	0.52	0.92
C* (color intensity)	11.48 ± 0.70[b]	19.43 ± 0.27[a]	335.11	3.44
h* (color angle)	97.45 ± 0.27[a]	94.65 ± 1.05[b]	20.23	0.79
Cooking time (minute)[1]	34.50 ± 2.18[a]	26.67 ± 3.33[b]	11.14	9.17

Means (±Standard Deviation) followed by the same letter on the line do not differ by the F test. CV = Coefficient of Variation. [1]Cassava previously frozen.

The Eucalipto variety had the lowest moisture and the highest starch content (Table 1). Oliveira et al. (2017) evaluated four sweet cassava cultivars at the age of 12 months with moisture, the BRS Jari showed the highest value (75.18%), followed by the hybrid 2003 14-11 (71.75%). On the other hand, Rinaldi et al. (2015a) studied three varieties of cassava harvested at the age of 12 months with different pulp colorations and reported moisture from 64.48% to 72.15%. These results were similar to the moisture values obtained in the present work. However, Oliveira et al. (2007) evaluated the Eucalipto variety in two different fertility soils and observed moisture of 56.7% and 61.0%, and these values were lower than the values of this study.

The two cassava genotypes showed no difference in terms of total sugar content, soluble solids, acidity, pH and luminosity (Table 1), with average values of 1.30% total sugar, 5.99 °Brix of soluble solids, 0.12% titratable acidity, expressed as citric acid, 6.30 (pH) and 72.56 (luminosity).

Carvalho et al. (2017) evaluated 22 genotypes of sweet cassava and obtained values similar to the present study for pH (6.33 to 7.50) and luminosity (67.14 to 73.90). Acidity and pH analysis are important characteristics in food quality control and for cassava roots indicate possible occurrence of early fermentation and consequently deterioration of fresh roots (Carvalho et al., 2017), which did not occur in this study.

The variety BRS Aipim Brasil had lower color intensity and greater color angle (Table 1) than Eucalipto. The color angle value of the Eucalipto variety was smaller, closer to 90º than BRS Aipim Brasil, which characterizes yellow color, i.e., being in accordance with the classification developed by the International Center for Tropical Agriculture, which indicates that BRS Aipim Brasil had a white flesh color and Eucalipto, light cream color,

according to the visual measurement of the root parenchyma (Sánchez et al., 2006). The observed luminosity could be characterized as light colors as they were close to pure white (Table 1).

The Eucalipto variety had the shortest cooking time (Table 1). The cooking of sweet cassava roots, as well as the physical and chemical characteristics are influenced by several factors, such as cultivar, age at harvest, cultivation practices and environmental conditions, which may lead to changes in the chemical composition of the cassava root (Lorenzi, 1994; Beléia et al., 2004; Oliveira & Moraes, 2009; Franck et al., 2011). The cooking time is related to the quality of the cooked mass, i.e., for a shorter time, the mass generated will be the most relevant (Lorenzi, 1994; Beléia et al., 2006; Pedri et al., 2018).

The starch content could also vary according to the cultivar, edaphoclimatic conditions and harvest time of the plant (Alves et al., 2008). Cassava roots with less moisture, consisting of more dry matter, had higher starch contents (Borges et al., 2002) than with more moisture. Franck et al. (2011) and Kawano et al. (1987) found that whether the dry matter content is high, the cooking capacity of cassava will be significant, consisting of similar values and being in accordance with the present study. However, Ngeve (2003) and Borges et al. (2002) did not observe this relationship.

Ceni et al. (2009) studied the composition of five varieties of sweet cassava and obtained starch contents between 24% and 39% and moisture between 64% and 70%. Borges et al. (2002) analyzed 26 varieties of cassava for human consumption and found starch content between 24.89% and 33.55%, moisture between 61.80% and 70.46% (dry matter 38.20% and 29.54%) and cooking time between 19.33 and 30.00 minutes. These values were similar to those found for the varieties evaluated in this study. Whereas Mezette et al. (2009) reported cooking times longer than this study (29.4 to 51.6 minutes) when evaluating sweet cassava clones in the selection process.

The observed variations in cooking time, moisture, starch content, color angle and color intensity (Table 1) are related to the differences between the two cultivars, since both were planted in the same place, on the same day, under the same cultivation conditions and were also harvested on the same date.

3.2 Physicochemical quality of frozen roots

The evaluated varieties BRS Aipim Brasil and Eucalipto had different cooking times, pulp color and moisture (Table 1), with these characteristics being important in the evaluation of roots in frozen storage.

During the storage time, there was no significant variation for the characteristics of moisture, color intensity (C*) and color angle (h*). There was a significant difference between the two varieties for these characteristics (Table 2). The levels of total sugars and soluble solids did not change during storage and there was no difference between the two varieties, ($p > 0.05$), which presented average values of 1.44% and 6.10 °Brix, respectively.

Table 2. Average values of moisture, color parameters and cooking time of two varieties of cassava frozen and stored for up to 120 days.

Evaluations	Varieties[1]		F	CV (%)
	BRS Aipim Brasil	Eucalipto		
Moisture (%)	67.39 ± 1.70[a]	62.92 ± 2.18[b]	39.08	3.01
C* (color intensity)	11.89 ± 0.67[b]	20.28 ± 0.57[a]	1365.55	3.87
h* (color angle)	97.15 ± 0.68[a]	95.80 ± 0.82[b]	24.24	0.78
Cooking time (minute)	30.78 ± 5.54[a]	25.32 ± 4.72[b]	8.46	18.35

Means followed by the same letter on the line do not differ by the F test at 5% probability. CV = Coefficient of Variation. [1]Values representing the averages of the five storage times (0, 31, 60, 92 and 120 days) evaluated for these variables.

According to Alves et al. (2005), the packaging material used to condition the roots was decisive in relation to the rate of moisture loss. The granulometry of the packaging and the permeability to water and gases interfere with moisture during storage under freezing. The nylon polyethylene package used in the present study was efficient to maintain moisture and assist in the conservation of the product.

The Eucalipto variety showed the highest C* value and the lowest h* value. The C* values define the color intensity, i.e., values close to zero are indicative of neutral colors, and values around 60 indicate intense colors (Rinaldi et al., 2015a). Regarding this parameter, the Eucalipto variety (20.28) had a much more intense color than BRS Aipim Brasil one (11.89). Color is an important quality attribute and is directly related to product acceptability (Doymaz et al., 2006). Thus, if the color is attractive, it is unlikely that the food will not be eaten or at least tasted by consumers (Silva et al., 2000).

The cooking time was different for the varieties and the Eucalipto had the shortest time (Table 2). The variety versus storage time interaction was not significant ($p > 0.05$) for cooking time and varied similarly for the two varieties during storage, so an average curve of the cooking times of the two varieties was presented (Figure 1). The adjusted quadratic model was significant ($p < 0.05$) and could explain 72% of the variation in the experimental data. There was a tendency to reduce cooking time until 60 days of storage, after which the values increased, however, with values close to those observed immediately after harvest (Figure 1). Cooking time is a fundamental property in the selection of a variety of sweet cassava, both by the consumer and the industry. The low cooking time saves time and energy, being a desired feature for the final consumer (Moreto & Neubert, 2014).

In the study conducted by Rinaldi et al. (2015a), the cooking time of the frozen cassava varieties BRS 399 and BRS 400, kept for 28 days of storage, ranged from 22.33 to 29.97 minutes and from 26.00 to 30.00 minutes, respectively. This result was similar to the present study, which ranged from 24.00 to 31.92 minutes, with 30.67 minutes at zero time and 31.92 minutes after 120 days of storage. The same effect was observed by Rinaldi et al. (2015b) for the roots of IAC 576-70 frozen at -18 °C (16.83 to 19.00 minutes), after 31 days of storage.

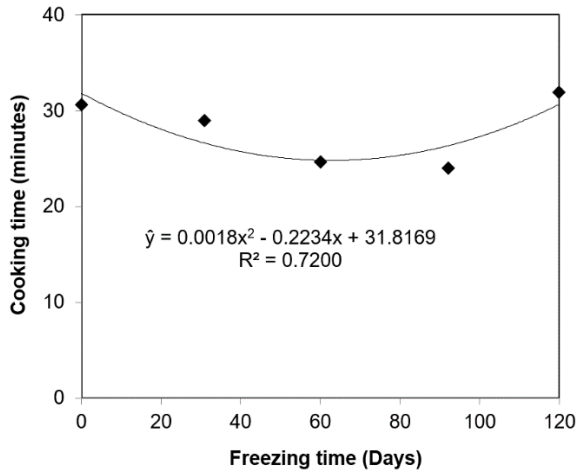

Figure 1. Average values for cooking time of the BRS Aipim Brasil and Eucalipto varieties frozen and stored for 0, 31, 60, 92 and 120 days.

There was no difference between the two varieties for L*, which had an average value of 73.11. However, this coordinate varied significantly during storage, but with a slight increase occurring after 120 days of freezing, from 72.56 to 73.24 (Figure 2), this color difference may not be visually perceived. The quadratic model was significant ($p < 0.05$), but could explain only 35% of the variation in the experimental data, whereas the linear model was not significant. The variation in the value of L * may be related to the intrinsic effects of the root, which consider the variations within and between the roots of the same plant and between plants of the same variety (Lorenzi, 1994).

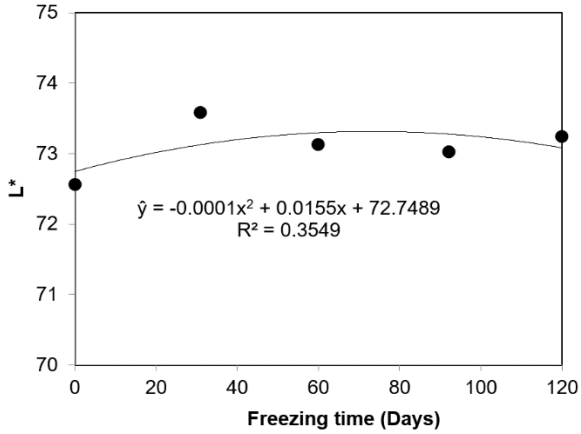

Figure 2. Average values for luminosity of the BRS Aipim Brasil and Eucalipto varieties frozen and stored for 31, 60, 92 and 120 days.

The variety versus storage time interaction was not significant ($p > 0.05$) for acidity and pH. There was no difference between the two varieties for acidity and pH, and the varieties had an average value of 0.15 and 6.32, respectively. However, it was found that these two variables changed slightly over the freezing time (Figure 3). The acidity increased from 0.12% (time zero) to 0.14% (time 120 days). The quadratic model was significant and explains only 98% of the variation of the experimental data. Similar results were found by Carvalho et al. (2011), who observed that the acidity increased with the storage time of the frozen root for 150 days, despite the small amplitude of the values, between 0.05% and 0.07% of citric acid.

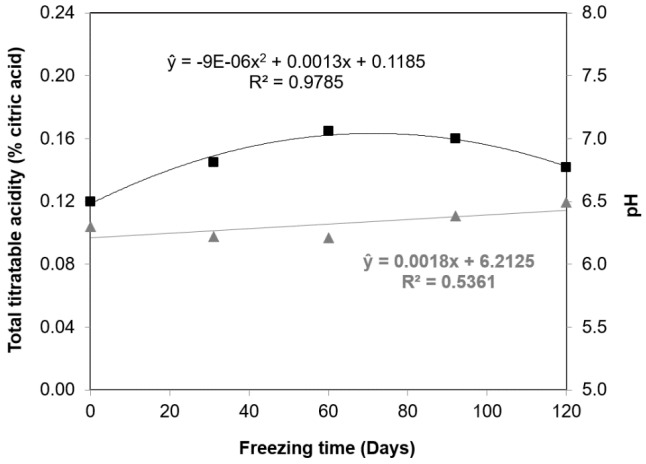

Figure 3. Average values for total titratable acidity (■) and pH (▲) of the BRS Aipim Brasil and Eucalipto varieties frozen and stored for 31, 60, 92 and 120 days.

The pH values obtained for the varieties evaluated in this study were similar to those observed for frozen cassava by Carvalho et al. (2011), from 6.59 to 6.73, as well as by Rinaldi et al. (2015a), from 5.96 to 6.55 and Rinaldi et al. (2015b), from 6.09 to 6.47. The linear model was significant, but it explains only 54% of the variation of the experimental data, whereas the quadratic model was not significant. As biochemical reactions occur very slowly under freezing, the changes observed over time for pH and titratable acidity may be intrinsic to the heterogeneity of the studied plant material.

As for the starch content, the interaction between varieties versus storage time was significant ($p < 0.05$) (Figure 4). The Eucalipto variety had the highest starch content during storage, except at 31 days, ranging from 33.45% (zero time) to 31.87% (120 days), whereas BRS Aipim Brasil presented values from 24.58%

(zero time) to 25.04% (120 days). For this variable, it was not possible to adjust regression models to explain the observed variations.

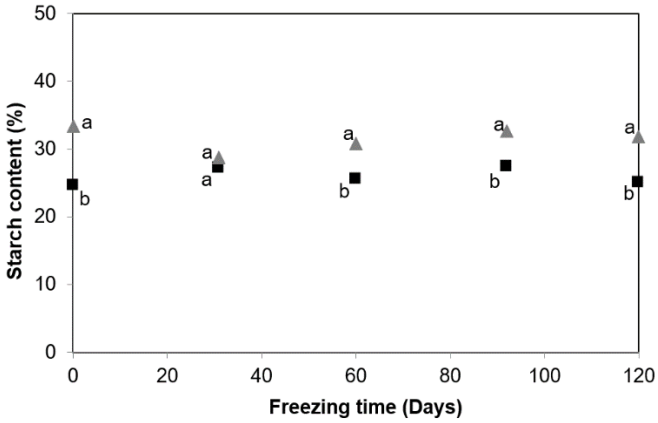

Figure 4. Starch content of frozen cassava varieties of BRS Aipim Brasil (■) and Eucalipto (▲) stored for 31, 60, 92 and 120 days.

3.3 Microbiological evaluation

The frozen roots of the two varieties evaluated were in accordance with the microbiological standards recommended by the RDC 12 January 2001 (Brasil, 2001) with regard to the MPN of thermotolerant coliforms (Table 3) and *Salmonella*, since the number of coliforms was lower than the established limits and the *Salmonella* bacterium was absent in all samples.

Table 3. Average values of microbiological analysis on frozen roots of two cassava varieties, stored for up to 120 days.

Varieties	Storage time (days)				Legal standards*
	0	60	92	120	
	Total coliforms (MPN g^{-1})				-
BRS Aipim Brasil	43	9.7	3.2	3.2	
Eucalipto	9.2	7.1	<3.0	<3.0	
	Thermotolerant coliforms (MPN g^{-1})				$1x10^3$
BRS Aipim Brasil	<3.0	9.7	3.2	3.2	
Eucalipto	<3.0	7.1	<3.0	<3.0	

*Legal standards established by the Brazilian National Health Surveillance Agency (ANVISA) for fresh roots and tubers in natura prepared (peeled or selected or fractionated), sanified, chilled or frozen, for direct consumption.

The MPN of total coliforms varied between <3.0 and 4.3×10^1 MPN g^{-1} (Table 3), demonstrating that the processing occurred in accordance with the good manufacturing practices recommended by the Brazilian National Health Surveillance Agency (*Agência Nacional de Vigilância Sanitária* (ANVISA)).

Indeed, it was also observed that the number of total coliforms decreased with the storage time up to 92 days (Table 3). This reduction can be explained by the effect of freezing on microbial cells, as the number of microorganisms in frozen vegetables tends to be lower, due to the death of some microorganisms during freezing (Jay et al., 2005). It should be noted that the main factors responsible for death or injury of microorganisms during freezing processes are related to mechanical damage to cell walls and membranes owing to the formation of intracellular crystals, loss of electrolyte balance resulting from dehydration and increased concentration of solutes due to ice formation, which can lead to denaturation of proteins, in addition to membrane rupture owing to maximum compression and decrease in cell volume (Colla & Prentice-Hernández, 2003).

A similar result for coliforms was obtained by Rinaldi et al. (2015a, 2015b) on frozen cassava roots stored at -18 °C for up to 31 days.

The product showed microbiological quality during the 120 days of storage. These results demonstrated that the processing took place in accordance with the good manufacturing practices recommended by the ANVISA and that freezing is an efficient food preservation method responsible for slowing the metabolic process of microorganisms and, consequently, increasing the shelf life of the food.

3.4 Sensory evaluation

There was a significant difference between the two varieties in terms of acceptance (Table 4). For color, BRS Aipim Brasil was classified between the hedonic terms "like slightly" and "like moderately" and Eucalipto was classified as "like very much". Cassava with white roots in the municipality of Cruz das Almas and neighborhood is generally associated with wild cassava, which may have negatively influenced the acceptance of the color of BRS Aipim Brasil by the tasters. Similarly, Rinaldi et al. (2015b) did not observe changes in the color of the frozen IAC 576-70 variety stored for 31 days, with the average grades ranging from 6.87 to 7.50.

Table 4. Acceptance of the attributes of two varieties of cooked cassava, previously frozen, stored for up to 120 days.

Varieties	Storage time (days)[ns]					Mean[1]
	0	31	60	92	120	
Color						
BRS Aipim Brasil	7.26 ± 1.32	6.68 ± 1.83	6.58 ± 1.74	6.78 ± 1.66	7.26 ± 1.29	6.91 ± 0.33[b]
Eucalipto	8.16 ± 1.08	8.04 ± 0.95	7.94 ± 1.32	8.16 ± 0.82	7.98 ± 1.04	8.06 ± 0.10[a]
Aroma						
BRS Aipim Brasil	7.16 ± 1.31	6.44 ± 1.85	7.04 ± 1.28	6.84 ± 1.31	7.18 ± 1.08	6.93 ± 0.31[b]
Eucalipto	7.16 ± 1.23	7.30 ± 1.20	7.18 ± 1.17	7.30 ± 1.26	7.22 ± 1.23	7.23 ± 0.06[a]
Flavor						
BRS Aipim Brasil	7.28 ± 1.71	6.24 ± 2.14	7.02 ± 1.79	7.14 ± 1.47	7.38 ± 1.28	7.01 ± 0.45[a]
Eucalipto	7.00 ± 1.51	6.90 ± 1.47	6.94 ± 1.46	7.18 ± 1.41	6.96 ± 1.43	7.00 ± 0.11[a]
Texture						
BRS Aipim Brasil	7.02 ± 2.08	6.50 ± 2.22	6.96 ± 2.10	7.12 ± 1.84	7.40 ± 1.68	7.00 ± 0.33[a]
Eucalipto	6.90 ± 1.79	6.80 ± 1.74	6.88 ± 1.76	7.06 ± 1.56	6.70 ± 1.90	6.87 ± 0.13[a]
Overall impression						
BRS Aipim Brasil	7.40 ± 1.31	6.60 ± 1.93	7.20 ± 1.58	7.26 ± 1.35	7.56 ± 1.26	7.20 ± 0.37[b]
Eucalipto	7.48 ± 1.42	7.50 ± 1.15	7.54 ± 1.28	7.72 ± 1.21	7.64 ± 1.08	7.58 ± 0.10[a]

[1]Means followed by the same letters do not differ by the F test at 5% probability.

The Eucalipto variety was also more accepted for the aroma and overall impression attributes (Table 4), and for these attributes this variety was classified between the terms "like moderately" and "like very much".

Flavor is the main factor in determining the acceptability of any product, so it has a major impact with respect to the successful product in the market (Mbassi et al., 2018). Regarding flavor, the two varieties were considered similar, and were classified between the hedonic terms "like slightly" and "like moderately" (Table 4). The same was observed for the texture attribute.

The sensory acceptance of roots by consumers did not change significantly ($p > 0.05$) during storage and the grades attributed were above 6.0, which represented the minimum acceptance limit, for all evaluated attributes and at all storage times (Table 4). This fact demonstrated that the processing followed by freezing was able to maintain the sensory characteristics of the roots.

A similar result was obtained by Carvalho et al. (2011), who found that cassava roots frozen for up to 150 days were sensorially accepted for the evaluated attributes (aroma, color, flavor and overall impression), throughout the period, with average grades ranging from 7.40 to 8.39. The same was observed by Sanches et al. (2017), in which the frozen cassava samples of the Cacau variety were accepted for all evaluated attributes, with average values ranging between 7.5 and 8.4.

In a study by Mbassi et al. (2018), the texture acceptance of the frozen "Makumba" cassava variety was the same after 30 days of storage, different from the result reported by Rinaldi et al. (2015b), who observed a significant reduction in the acceptance note of the texture concerning the frozen IAC 576-50 variety, varying from 7.80 (zero time) to 5.13 at 31 days of storage.

4 Conclusion

The Eucalipto variety showed the higher pulp yield, starch content and color intensity, however, less cooking time and being more accepted for overall impression than the BRS Aipim Brasil. Therefore, the Eucalipto may be more suitable for planting and marketing.

The BRS Aipim Brasil and Eucalipto frozen at -18 °C can be stored for at least four months without microbiological risk, as well as without significant changes in its physical-chemical and sensory characteristics, thus being suitable for the consumption.

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