

## Subtropical region cambuci accessions: characterization and jam processing potential<sup>1</sup>

Acessos de cambuci de regiões subtropicais: caracterização e potencial de processamento em geleia

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**ABSTRACT** - The consumption of the cambuci *in natura* is limited due to the strong acidity and astringency of its fruits, and in view of the various accessions that can currently be cultivated, it is of great importance to study the cambuci processing in the form of products such as jams, as well as to survey which accessions are more suitable for processing. Thus, the aim of this study was to characterize different cambuci accessions (7240, 7225, 7262, 7292 and 7278) and to evaluate their influence on the physicochemical characteristics, rheological properties and sensory acceptance of jam in order to identify the accession with the highest potential for industrial use. To characterize the different cambuci accessions, analyzes of length, diameter, unit mass, firmness, total soluble solids, titratable acidity, pH, SS/total acidity (ratio) and color (L\*, a\* and b\*) were performed on fresh fruit. The different accessions were also analyzed for the content of phenolic compounds, antioxidant activity (DPPH and  $\beta$ -carotene method) and vitamin C. In the jellies obtained from different accessions, analyzes of soluble solids, titratable acidity, pH, color (L\*, a\* and b\*), besides the sensorial analysis and texture profile were performed. Although the physicochemical characteristics of cambuci indicate that this fruit is not suitable for fresh consumption, due to the high acidity (0.64-1.41 g citric acid.100 g<sup>-1</sup>) and low sweetness (1.33-2.67 °Brix), it was verified that the cambuci processing is extremely feasible, in particular the accessions 7240, 7278 and 7225, since the resulting jam has shown good sensory acceptance. In addition, it was verified that cambuci is a very nutritional rich fruit, being considered an excellent source of phenolic compounds (331.74-1134.54 mg GAEs.100 g<sup>-1</sup>), presenting a high antioxidant activity (DPPH- 83.06 to 97.18% of sequestration and beta-carotene 87.02 to 94.56% of protection) and a high vitamin C content (98.67- 128.80 mg.100 g<sup>-1</sup>).

**Key words:** *Campomanesia phaea* (Berg) Landr. Sensory quality.

**RESUMO** - O consumo do cambuci *in natura* é limitado devido à forte acidez e adstringência de seus frutos e perante aos vários acessos que atualmente podem ser cultivados, torna-se de grande relevância o estudo do processamento do cambuci na forma de produtos como geleias, bem como o levantamento dos acessos que sejam mais adequados para o processamento. Desta forma, o objetivo deste estudo foi caracterizar diferentes acessos de cambuci (7240; 7225; 7262; 7292 e 7278) e avaliar a influência destes sobre as características físico-químicas, propriedades reológicas e aceitação sensorial da geleia visando identificar o acesso com o maior potencial de utilização industrial. Para caracterizar os diferentes acessos cambuci, análises de comprimento, diâmetro, massa unitária, firmeza, sólidos solúveis totais, acidez titulável, pH, SS/acidez total (ratio) e cor (L\*, a\* e b\*) foram realizadas sobre as frutas frescas. Os diferentes acessos foram também analisados quanto ao conteúdo de compostos fenólicos, atividade antioxidante (método de DPPH e  $\beta$ -caroteno) e teor de vitamina C. Nas geleias obtidas a partir de diferentes acessos, foram realizadas análises de sólidos solúveis, acidez titulável, pH, cor (L\*, a\* e b\*), além da análise sensorial e perfil de textura. Embora as características físico-químicas do cambuci indicaram que este fruto é impróprio para consumo fresco, devido à elevada acidez (0.64 a 1.41 g ácido cítrico.100 g<sup>-1</sup>) e baixa doçura (1.33-2.67° Brix), verificou-se que o processamento do cambuci é extremamente viável, em particular dos acessos 7240, 7278 e 7225, uma vez que a geleia resultante apresentou boa aceitação sensorial. Além disso, verificou-se que o cambuci é um fruto muito rico nutricionalmente, sendo considerado uma excelente fonte de compostos fenólicos (331.74-1134.54 mg GAEs 100 g<sup>-1</sup>), apresentando uma alta atividade antioxidante (DPPH- 83.06 a 97.18 % de sequestro e beta caroteno 87.02 a 94.56 % de proteção) e um elevado teor de vitamina C (98.67- 128.80 mg 100 g<sup>-1</sup>).

**Palavras-chave:** *Campomanesia phaea* (Berg) Landr. Qualidade sensorial.

DOI: 10.5935/1806-6690.20180035

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Received for publication on 24/08/2016; approved 16/08/2017

<sup>1</sup>Pesquisa realizada pelos próprios autores financiada pelo CNPq (Processo 405466/2016-1)

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## INTRODUCTION

The cambuci or cambucizeiro (*Campomanesia phaea* (Berg) Landr.) is a native Brazilian fruit tree that occurs in the states of São Paulo, Rio de Janeiro and Minas Gerais, on the slope of the Serra do Mar area called Atlantic Coastal Forest, one of the vegetation types at risk of extinction in Brazil (VALLILO *et al.*, 2005). In addition to deforestation of the Atlantic Forest, this fruit species is threatened with extinction due to predatory exploitation of its wood for tool manufacturing (KAWASAKI; LANDRUM, 1997).

The fruit characteristics include thin skin and green color (SILVA *et al.*, 2012). It presents a sweet aroma, but due to its astringency and high acidity the fruit has consumption limitations in fresh form. The high industrial and commercial potential of the cambucizeiro is due to the amount of pectin in the pulp. This polysaccharide has high gelling power, a very important property of some proteins used in many industrial foods, such as gelatin gels and jams (BIANCHINI *et al.*, 2016). Although not show uniformity in shape, cambuci also has potential for industrialization due to its quality attributes such as high pulp yield, high acidity and reasonable ascorbic acid concentrations (VALLILO *et al.*, 2005).

The high acidity can be extremely interesting for processing, because the low pH eliminates the acidification step during processing of products where gelification is needed. Moreover, the high acid content contributes to the sharp pulp taste, which promotes a high dilution factor in the formulation of juices and jams, hence higher manufacturing yield (VALLILO *et al.*, 2005). Thus, the cambuci processing, in the form of products such as jams, would be an excellent way to reduce waste/loss and increase the use of this fruit, considered unfit for fresh marketing (SILVA *et al.*, 2012).

There are several cambuci accessions, which can have a great physicochemical variability among them with a huge variation in the shape and size of the fruit, that according to their occurrence extends from mountain regions to nearby areas at sea level, which can cause not only a morphological change, but also a variation in the chemical composition of the fruits (BIANCHINI *et al.*, 2016). Studies have shown that the cultivar or the accession may influence the rheological and sensory characteristics of the products obtained after fruits processing (GUEDES *et al.*, 2013).

There are few studies in the literature on the characterization and processing of cambuci, and the studies that exist are often inconclusive or superficial. Silva *et al.* (2012), for example, performed a basic physical and physicochemical characterization of four varieties

of cambuci and verified sensory, for one of the varieties processed in the form of jam, the best proportion of sugar and fruit pulp. The acceptability of cambuci jelly has not been studied, much less a comparison of jelly obtained from different cultivars. In addition, no in-depth studies on physicochemical and nutritional characterization of different cambuci accessions were found in the literature. Due that, it is highly relevant to acquire greater knowledge of different cambuci accessions as well as verify which are the most suitable for processing, in order to identify the most interesting accession to be cultivated.

Thus, the aim of this study was to characterize different cambuci accessions grown in subtropical regions as to their physicochemical characteristics and bioactive compounds, and to evaluate the influence of these different accessions on the physicochemical characteristics, rheological properties and sensory acceptance of jam resulting in order to identify accessions with the highest potential for industrial use.

## MATERIAIS AND METHODS

The jams were prepared from five cambuci accessions (7240; 7262; 7292; 7278 and 7225). The fruits in their physiological maturity, were collected at a location in the Mantiqueira range, with an altitude of 874 meters, latitude 22°41' south and longitude 45°44' west (climate is the Cwb type, mesothermal or tropical altitude with dry winter and rainy summer). In addition to the fruit, sucrose and high methoxyl pectin (Danisco, SP, Brazil) were used for the jam preparations. Citric acid was not added because the fruits showed a pH suitable for processing (average of 3.0).

The jam processing, physical, physicochemical and sensory analysis were performed at the Plant Products Processing Laboratory, Post Harvest Laboratory and Sensory Analysis Laboratory of the Universidade Federal de Lavras (UFLA), Minas Gerais- Brazil.

After discarding the fruits with physical or microbiological damage, manual removal of the leaves and washing with chlorinated potable water, the fruits were homogenized for 5 minutes in an industrial Poly. For the jam preparations we used 58% clarified cambuci juice, 40% sucrose and 2% high methoxyl pectin. For the processing, sugar and pulp were first mixed and heated in an open pan with a gas flame (Macanuda SC, Brazil). After boiling, the pectin was added. At the end of the process, when the soluble solids reached 70°Brix, the heating was stopped. The total soluble solids were determined using a refractometer.

To characterize the different cambuci accessions, analyzes of length, diameter, unit weight, firmness, total

soluble solids, total titratable acidity, pH, SS/total acidity (ratio) and color ( $L^*$ ,  $a^*$  and  $b^*$ ) were performed in fresh fruit. The different accessions were also analyzed for the content of phenolic compounds, antioxidant activity (DPPH and  $\beta$ -carotene / linoleic acid) and vitamin C content.

In the jams obtained from different accessions, analysis of soluble solids, titratable acidity, pH, color ( $L^*$ ,  $a^*$  and  $b^*$ ), texture profile and sensory analysis were performed.

The length and diameter of fruit were measured with the aid of a 150 mm digital caliper (Kingtools, São Paulo, SP), and average fruit weight was determined by individual weighing of each fruit with the aid of a AUX220 semi - analytical scale.

For conducting fruit firmness, we measured the force required for a 3 mm probe coupled to a digital penetrometer, Instrutherm PTR-300, to overcome the resistance of the fruit pulp. The results expressed in Newtons (N).

The total acidity, soluble solids and pH values were determined according to the Curi *et al.* (2016). The color was determined according to the method described by Maro *et al.* (2014). The  $L^*$ ,  $a^*$  and  $b^*$  values were determined using a Minolta CR 400 colorimeter with standards and D65 CIELab.

The phenolic analysis was obtained according to Souza *et al.* (2014b). The absorbance at 750 nm was determined in a spectrophotometer (Pharmacia Ultrospec 2000 Bioteche, Cambridge, UK) and the content of total phenolics was calculated using the gallic acid standard curve. The results are expressed as gallic acid equivalents (GAE).100 g<sup>-1</sup>.

The antioxidant capacity was determined by the reduction of DPPH (2,2-diphenyl-1-picrylhydrazyl) by antioxidants present in the sample described in the Maro *et al.* (2013) method with a few modifications (DUARTE-ALMEIDA *et al.*, 2006). The results were expressed as percentage of sequestration.

The antioxidant activity was also determined by the  $\beta$ -carotene method. The antioxidant activity was calculated as the percent of inhibition relative to the control.

The texture profile analyses (TPA) of the jams were performed in penetration mode under the conditions described by Souza *et al.* (2014a, 2015) "a pre-test speed of 1.0 mm/s, a test speed of 1.0 mm/s, a post-test speed of 1.0 mm/s, a time interval between penetration cycles of 10 s, a distance of 40.0 mm and a compression with a 6.0 mm diameter cylindrical aluminum probe using a Stable Micro Systems TA-XT2i texturometer (Goldaming, England)". The jam samples were compressed by 30%.

The parameters analyzed were hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness (CURI *et al.*, 2016).

An acceptance test was conducted with 90 consumers (50 females and 40 males), where the evaluated attributes were color, taste, texture and overall impression, using a 9-point hedonic scale (1 = disliked extremely and 9 = like extremely) (CURI *et al.*, 2016). Each taster assessed, on average, 5 grams of each of the five cambuci jam formulations, which were served in plastic 50 ml cups (SOUZA *et al.*, 2014b). The test was obtained in individual booths under white light and proper ventilation. Tasters were instructed on the use of the hedonic scale and water consumption between samples. Sensory analysis was performed according to the local Ethics Committee approval number 1091594.

To compare the different accessions in relation to physical and physicochemical characteristics, bioactive compounds and antioxidant activity and the different cambuci jams obtained in relation to physicochemical, rheological and sensory characteristics, a univariate statistical analysis (ANOVA) and mean Tukey test to verify that there was a significant difference between samples at a 5% level of significance ( $p \leq 0.05$ ) were performed.

In order to visualize the consumer sensory acceptance and correlate it with the jam physicochemical parameters and rheological properties, a 3-way external preference map obtained by PARAFAC (NUNES; PINHEIRO; BASTOS, 2011) was obtained. The PARAFAC model was optimized using the value of Core Consistency Diagnostics (CORCONDIA) to choose the number of factors (NUNES; PINHEIRO; BASTOS, 2011). PARAFAC procedures and the construction of a 3-way preference map and 3-way external preference map have been previously reported in detail (NUNES; PINHEIRO; BASTOS, 2011).

Data analysis was performed with SensoMaker version 1.8 (PINHEIRO; NUNES; VIETORIS, 2013).

## RESULTS AND DISCUSSION

### Cambuci Fruits: Physical and physicochemical characteristics

The physicochemical characteristics evaluated for different cambuci accessions are shown in Table 1. The different cambuci accessions significantly differed for all analyzed parameters ( $p \leq 0.05$ ) except soluble solids, ratio and color parameter  $a^*$ .

As for the size and weight parameters of the different cambuci accessions, through Table 1, it can be

**Table 1** - Average length (AL), average diameter (AD), unit weight (UW), firmness, total soluble solids (SS), titratable acidity (TA), solids / acidity (ratio), pH and color (L\*, a\* and b\*) for the different cambuci accessions

Accessions	AL (mm)	AD (mm)	UW (g)	Firmness (N)	SS (°Brix)	TA (%)	pH	Ratio	L*	a*	b*
7240	38.41 b	52.57 a	42.14 b	8.43 b	1.50 a	1.00 ab	2.88 b	1.52 a	60.27 a	-4.10 a	10.91 ab
7262	28.02 e	43.33 d	28.68 c	8.56 b	1.67 a	0.64 b	3.04 a	2.69 a	56.30 b	-4.76 a	14.07 a
7292	35.35 c	51.50 a	42.26 b	9.33 a	1.33 a	1.52 a	2.73 c	0.89 a	58.63 ab	-3.12 a	8.20 ab
7278	33.30 d	48.27 c	41.05 c	6.41 c	2.67 a	0.73 ab	2.92 ab	3.73 a	58.00 ab	-4.39 a	12.52 a
7225	40.44 a	49.57 b	43.42 a	5.73 d	1.33a	1.41 ab	2.81 bc	0.93 a	56.64 b	-3.29 a	6.60 c
CV (%)	1.16	0.86	0.79	2.32	3.53	6.12	1.47	8.58	2.22	16.61	11.00

\*Mean values with common letters in the same column indicate that there is no significant difference among samples ( $p \leq 0.05$ ) from Tukey's mean test;

\*\* Total acidity: g citric acid.100 g<sup>-1</sup> f.w

seen that accession 7225 had the highest average length (40.44 mm) and the highest unit weight (43.42 g). The 7240 and 7292 accessions stood out due to the higher average diameter (52.57 mm and 51.50 mm, respectively). Generally larger and heavier fruit have greater market value for fresh consumption.

In relation to the firmness, it ranged from 5.73N (accession 7225) to 9.33N (accession 7292). Accession 7292 differed from the others, being considered that with the firmest fruit, accession 7225 had the lowest firmness which may reflect more juicy fruits, which can be more interesting for fresh consumption and industrial use possibly due the higher yield.

The soluble solids content ranged from 1.33 to 2.67 °Brix, the acidity ranged from 0.64 to 1.41g of citric acid.100 g<sup>-1</sup>, the pH ranged from 2.73 to 3.04 and the ratio ranged from 0.89 to 3.73. The different cambuci accessions did not show significant difference in relation to soluble solids, and although they showed significant differences for acidity and pH (accession 7292 stood out for being the most acidic), this did not result in significant difference in the ratio values. The values for soluble solids, acidity, pH and ratio for the different cambuci accessions studied corroborate those reported in other studies, performed by Bianchini *et al.* (2016). These parameters, in particular the ratio, are extremely important since they can indirectly estimate the taste of fruits indicating the best destination, that is, if they are more suitable for fresh consumption or if they are most suitable for processing in the form of products such as jams and juices (CAMPAGNOLO; PIO, 2012).

In general, it appears that all cambuci accessions showed high acidity and low soluble solids content, which reflected in a low ratio. This confirms that the cambuci is not a suitable fruit for fresh consumption, because this is an extremely acidic (SILVA *et al.*, 2002). Thus, this fruit is highly suitable for processing of products such as jams,

mainly due to the low pH, which is ideal for the occurrence of gelification (SOUZA *et al.*, 2014b).

In relation to the fruit color of the different cambuci accessions, the color parameter L\* ranged from 56.30 to 60.27, a\* ranged from -3.12 to -4.76 and the b\* ranged from 6.60 to 14.07 (Table 1). The different accessions showed no significant difference in the color parameter a\*, so all of them present the same intensity of yellow coloration. Accession 7240 stood out with higher values for the color parameter L\*, and as such, is the clearer accession. Accession 7225 was noteworthy due to the lower value for the color parameter b\*, being considered the accession with the most intense green color, typical of this fruit. The color of the fruit will probably influence the colors of the obtained jelly, which may influence the acceptability of the product.

### Bioactive compounds and antioxidant activity

The bioactive compounds and antioxidant activity of the different accessions evaluated are shown in Table 2. The accessions showed great variability and significantly differed ( $p \leq 0.05$ ) for the total phenolics content, antioxidant activity (DPPH) and vitamin C content.

Through the average table for bioactive compounds and antioxidant activity (Table 2), it can be seen that accession 7262 characterized by having the highest phenolic content (1134.54 mg GAEs.100 g<sup>-1</sup>). Following the classification described by Vasco, Ruales and Kamal-Eldin (2008), the fruits, according to the phenolic compounds content are divided into three groups: low phenol content (<100 mg 100 g<sup>-1</sup>), average phenol content (100 - 500 100 g<sup>-1</sup>) and high phenol content (> 500 mg GAE 100 g<sup>-1</sup>). According to this classification, all cambuci accessions (except the accession 7240) feature as having a high concentration of phenols, being considered an excellent source of phenolic compounds. In a study with several Brazilian exotic fruits, Genovese *et al.* (2008)

**Table 2** - Phenolics, antioxidant activity (DPPH and  $\beta$  carotene) and vitamin C in the different cambuci accessions

Accessions	Phenolics	Antioxidant- DPPH	Antioxidant- $\beta$ carotene	Vitamin C
7240	331.74 d	95.30 bc	89.61 a	111.17 c
7262	1134.54 a	93.96 b	94.56 a	98.67 d
7292	509.62 c	83.06 c	87.02 a	117.39 b
7278	596.03 c	96.14 ab	92.39 a	128.80 a
7225	905.82 b	97.18 a	89.52 a	121.19 b
CV (%)	5.35	0.70	1.33	1.59

Abbreviations: DPPH: 2-diphenyl-1-picrylhydrazyl radical scavenging activity; GAE: gallic acid equivalent. Total phenolics (mg GAEs/100 g f.w.); Antioxidant capacity - DPPH (% of sequestration); Antioxidant capacity -  $\beta$ -carotene (% of protection); Ascorbic acid (mg.100 g<sup>-1</sup> f.w.) \*Mean values with common letters in the same column indicate that there is no significant difference among samples ( $p \leq 0.05$ ) from Tukey's mean test

verified that the cambuci stood out among the fruits as one of the fruits richest in phenolic compounds.

Regarding the antioxidant activity, it was found that accession 7292 showed better ability to scavenge the DPPH radical, with the lowest sequestration percentage (83.06% sequestration) thus presenting the highest antioxidant activity. Regarding the antioxidant activity by the  $\beta$ -carotene method, no significance difference was verified. According to Hassimoto, Genovese and Lajolo (2005), an antioxidant potential above 70% is considered ideal for the inhibition of lipid oxidation, so all accessions that were investigated in the present study reached antioxidant activity above 70%, presenting a high potential for lipid oxidation inhibition.

The different methods used for the determination of antioxidants did not demonstrate which accession presented the highest activity since they did not corroborate between them. This was expected because each method is specific for only one property and they do not necessarily have to give the same result. According to Hassimoto, Genovese and Lajolo (2005) one of the major problems with the antioxidant activity of biological materials is the choice of the analysis method.

In relation to the vitamin C content, accession 7278 stood out by presenting the highest levels (128.80 mg.100 g<sup>-1</sup>). According to Ramful *et al.* (2011) fruits are divided into three categories in relation to their ascorbic acid content: low (<30 mg 100 g<sup>-1</sup>), average (30-50mg 100g<sup>-1</sup>) and high content (> 50 mg 100 g<sup>-1</sup>) of vitamin C. According to this classification, all cambuci accessions assessed are classified with a high concentration of vitamin C, proving that this fruit is an excellent source of this vitamin.

Although it is a fruit rich in phenolic compounds and vitamin C, with still high antioxidant activity, cambuci is not consumed in fresh form. This type of fruit is mainly indicated for processing in the form of products such as jams and jellies. Due to high temperature, much of the nutritional richness of the fruit ends up being lost. This is why a nutritional assessment of the resulting jelly has not been done.

### Cambuci jams: Physicochemical characteristics

The physicochemical characteristics evaluated for the jams obtained from different cambuci accessions are shown in Table 3. The jams differed significantly ( $p \leq 0.05$ ) for all analyzed parameters, except soluble solids. It was expected that the soluble solids content would not significantly differ,

**Table 3** - Soluble Solids (SS), pH, acidity and color parameters (L\*, a\* and b\*) for the jams obtained from different cambuci accessions

Samples	SS	pH	Acidity	L*	a*	b*
7240	71.33 a	2.76 b	1.49 a	35.90 ab	0.95 a	3.18 b
7262	71.00 a	2.84 a	1.33 ab	38.31 ab	1.38 a	6.71 a
7292	71.00 a	2.78 b	1.42 a	40.15 a	0.85 a	3.37 b
7278	71.00 a	2.80 ab	1.20 b	32.08 b	1.34 a	5.02 ab
7225	71.00 a	2.77 b	1.20 b	32.92 b	1.37 a	3.67 b
CV (%)	0.36	0.69	18.87	5.89	18.14	24.24

\*Mean values with common letters in the same column indicate that there is no significant difference among samples ( $p \leq 0.05$ ) from Tukey's mean test.

\*\* Total acidity: g citric acid/100 g f.w

because it was established that during the jam preparation the Brix would be fixed and standardized.

The jam pH ranged from 2.76 to 2.84 and the acidity ranged from 1.20 to 1.49 g citric acid.100 g<sup>-1</sup> (Table 3). It was verified that the jam made with accession 7262 stood out with higher pH (2.84) and the jam made with accession 7240 stood out with the highest acidity (1.49 g citric acid.100 g<sup>-1</sup>).

Regarding color, the color parameter L\* ranged from 32.08 to 40.15, the parameter a\* ranged 0.85 to 1.38 and the b\* ranged from 3.18 to 6.71 (Table 3). As in the fresh fruit, jams obtained from different cambuci accessions did not show significant difference for the color parameter a\*, and therefore presented the same intensity of yellow color. Accession 7292 stood out with highest values for the color parameter L\*, and as such, was the clearer jam. accessions 7240; 7292 and 7225 stood out for presenting the lowest values for the color parameter b\* and were considered the jams with the highest intensity of green color.

Comparing the jam colors with the fresh fruit colors it is noticed that in general with processing there was a darkening, greater intensification of red color and reduction of the yellow color intensity. These color changes may be explained due to reactions occurring during heating, such as the caramelization and Maillard reaction (AJANDOUZ *et al.*, 2001).

### Rheological characteristics

The rheological characteristics for the jams obtained from different cambuci accessions are shown in Table 4. The jams obtained from different cambuci accessions significantly differed ( $p \leq 0.05$ ) for all rheological parameters evaluated, except for springiness.

Regarding the texture, it can be verified from Table 4 that the jam obtained with accession 7262 different from the others by presenting the highest values for hardness

(3.03), adhesiveness (6.74), cohesiveness (12.48), gumminess (1.47) and chewiness (1.44) parameters. The hardness measures the force required to achieve a given deformation, the adhesiveness measures the amount of force to simulate the work necessary to overcome the attraction forces between the food surface and the surface in contact with it, the cohesiveness measuring the extent to which the material can be stretched before breaking irreversibly, the gumminess refers the energy required to disintegrate one semi-solid food to the point of being swallowed and chewiness measures energy required to chew solid food to the point of being swallowed (CURI *et al.*, 2016). Thus, accession 7262 gives rise to firmer, gummier, more rigid, adhesive and elastic jam.

There are several factors that can influence the final texture of the resulting jams, among them: the sugar quantity, pH, acidity and soluble pectin present in each accession (SOUZA *et al.*, 2014a). It was verified that accession 7262, which gave rise to jam with the highest texture parameters, stood out with the lowest acidity and highest pH (Table 1).

### Sensory Analysis

Through analysis of variance it was a significant difference for taste, consistency and overall liking attributes ( $p \leq 0.05$ ) (Table 5) was verified for jams obtained from different cambuci accessions. Figure 1 shows the 3-way external map that represents the distribution of consumers, samples, consumer sensory attributes related to acceptance and physicochemical and texture properties.

According to Table 4, in general all jams showed good sensory acceptance, with average scores situated between the hedonic terms "like slightly" and "liked very much". According to TWEPM (Figure 1) and Table 4, it appears that jams obtained from the accessions 7240; 7278 and 7225 stood out by being the most accepted. The jams obtained from accessions 7292 and 7262 were the least accepted formulations.

**Table 4** - Hardness (N), adhesiveness (N/s), springiness, cohesiveness, gumminess and chewiness for the jams obtained from different cambuci accessions

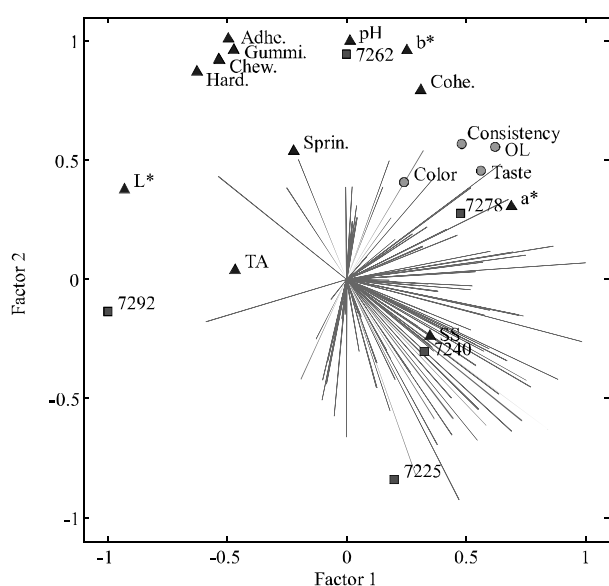
Samples	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness
7240	0.66 d	2.09 d	0.99 a	0.47 ab	0.31 d	0.31 d
7262	3.03 a	6.74 a	0.98 a	0.48 a	1.47 a	1.44 a
7292	2.36 b	4.54 b	0.99 a	0.42 bc	1.00 b	0.99 b
7278	1.35 c	3.13 c	0.99 a	0.44 abc	0.60 c	0.60 c
7225	0.68 d	1.45 d	0.95 a	0.40 c	0.28 d	0.27 d
CV (%)	20.11	14.12	11.09	12.20	11.20	21.14

\*Mean values with common letters in the same column indicate that there is no significant difference among samples ( $p \leq 0.05$ ) from Tukey's mean test

**Table 5** - Sensory characteristics of the jams obtained from different cambuci accessions

Samples	Color	Taste	Consistency	Overall Liking
7240	6.91 a	6.92 b	6.97 a	7.08 a
7262	6.79 a	6.62 bc	5.49 b	6.32 b
7292	6.70 a	6.27 c	5.21 b	6.01 b
7278	6.98 a	6.86 b	6.53 a	6.91 a
7225	6.92 a	7.03 a	7.15 a	7.22 a
CV (%)	5.21	8.34	6.67	7.78

\*Mean values with common letters in the same column indicate that there is no significant difference among samples ( $p \leq 0.05$ ) from Tukey's mean test

**Figure 1** - Three-way external preference map (TWEPM) for sensory attributes and physicochemical properties for the cambuci jams

\*\* OL, Overall Liking; SS, Soluble Solids; TA, Total acidity; Hard., Hardness; Adhe., Adhesiveness; Sprin., Springiness; Cohe., Cohesiveness; Gummi, Gumminess; Chew, Chewiness

Through TWEPM (Figure 1) and the average table for the jam physicochemical and rheological parameters (Tables 3 and 4), it can be seen that the jam obtained from accession 7262 was characterized by being a jam with the highest texture parameters, less intense green color and the highest pH value. The jam prepared from accession 7292 was noteworthy by being more acidic and lighter than the others formulations. Thus it is clear that the consumer has a preference for softer, less firm, darker and more intense green colored jams. Regarding the acidity, we cannot reach a reasonable conclusion since the two least accepted jams do not corroborate the fruit acidity (pH and total acidity).

From the sensory acceptance results it is verified that the cambuci processing is feasible due to high sensory acceptance of the jams obtained. Moreover, it appears that the processing of all cambuci accessions studied is feasible, since simple adjustments in the process can be made in order for the jams to meet consumer acceptance.

In similar studies with strawberry, loquat and physalis it was also verified that the cultivars present great physicochemical variability which directly influences the results of the sensory acceptance of the resulting jam (CURI *et al.*, 2016, 2017). As in this work, it was verified that some cultivars gave origin to jam with inferior sensorial acceptability, but this does not mean impossibility of use, because adjustments in the processing can change the undesirable characteristics.

As the production of jams with all the accessions is feasible, the adaptation, susceptibility to pests, production cost and yield of different cambuci accessions are the factors that should indicate which of them are the most indicated for industrialization.

In future studies it is advisable to also carry out a nutritional study of the product obtained from different cambuci accessions. This may be an alternative to choose the most suitable accession for processing. The accession which results in the most sensorial accepted jam and concomitantly the richest nutritionally, is of the most interest.

## CONCLUSIONS

The cambuci is a nutritionally very rich fruit been considered an excellent source of phenolics, has high antioxidant activity and high vitamin C content. Although the cambuci physicochemical characteristics indicate that this fruit is unsuitable for fresh consumption, due to high acidity and low sweetness,

it was found that the cambuci processing in the form of jam is extremely feasible, in particular jam from accessions 7240, 7278 and 7225.

## ACKNOWLEDGEMENTS

To FAPEMIG, CNPq and CAPES for the financial support.

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