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Caracterização nutricional e propriedades funcionais tecnológicas da farinha de polpa de marolo

Nutritional characterization and technological functional properties of marolo pulp flour

Caracterización nutricional y propiedades funcionales tecnológicas de la harina de pulpa marolo

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Jéssyca Santos Silva
ORCID: https://orcid.org/0000-0002-2414-3327
Universidade Federal de Lavras, Brasil
E-mail: jessycarv89@hotmail.com
Clarissa Damiani
ORCID: https://orcid.org/ 0000-0001-8507-0320
Universidade Federal de Goiás, Brasil
E-mail: damianiclarissa@hotmail.com
Thays Lorrayne Lavrinha e Silva
ORCID: https://orcid.org/0000-0001-5981-842X
Universidade Federal de Goiás, Brasil
E-mail: thays_lorrayne@hotmail.com
Edson Pablo da Silva
ORCID: https://orcid.org/0000-0003-4921-0677
Universidade Federal de Goiás, Brasil
E-mail: edsonpablos@hotmail.com
Mariana Crivelari da Cunha
ORCID: https://orcid.org/0000-0002-5441-2751
Universidade Federal de Lavras, Brasil
E-mail: mariana.crivelari@hotmail.com
Eduardo Ramirez Asquieri
ORCID: https://orcid.org/0000-0003-3312-8003
Universidade Federal de Goiás, Brasil
E-mail: asquieri@gmail.com
Eduardo Valério de Barros Vilas Boas

ORCID: https://orcid.org/0000-0002-0252-695X
Universidade Federal de Lavras, Brasil
E-mail: evbvboas@dca.ufla.br

Resumo

A farinha da polpa de marolo (*Annona crassiflora* Mart.) é uma importante fonte de fibras, porém, a sua utilização como ingrediente alimentar necessita de investigações quanto à sua funcionalidade. Desta forma, este trabalho teve como objetivo, avaliar as características físicas, químicas, nutricionais e propriedades funcionais tecnológicas da farinha obtida da polpa de marolo, verificando assim, seu potencial de aplicação em produtos alimentícios. As análises realizadas na farinha foram composição proximal, composição mineral, teor de vitamina C, carotenóides totais, betacaroteno, atividade antioxidante e propriedades funcionais tecnológicas. A farinha apresentou quantidades consideráveis de fibras, especialmente a fração insolúvel, sendo 25,47 $g.100g^{-1}$, 8,57 $g.100g^{-1}$ para a fibra alimentar solúvel e 34,04 $g.100g^{-1}$ para a fibra alimentar total. Os teores de vitamina C e carotenóides totais, observados na farinha da polpa de marolo, foram de 173,77 $mg.100g^{-1}$, 0,56 $mg.100g^{-1}$ e 0,08 $mg.100g^{-1}$, respectivamente. Os minerais que apresentaram maior concentração na farinha de polpa de marolo foram o fósforo (1768,53 $mg.kg^{-1}$) e cálcio (1512,73 $mg.kg^{-1}$). A atividade antioxidante apresentou maior efetividade quando realizada na extração aquosa. A farinha demostrou possuir importantes propriedades funcionais tecnológicas, como a solubilidade em água e a capacidade de formar emulsão. Portanto, a farinha da polpa de marolo possui potencial para comercialização e utilização em produtos alimentícios com a finalidade de melhorar e enriquecer suas qualidades nutricionais e tecnológicas.

Palavras-chave: *Annona crassiflora* Mart.; Fibra alimentar; Carotenóides; Atividade antioxidante; Propriedades funcionais tecnológicas.

Abstract

The flour from the pulp of marolo (*Annona crassiflora* Mart.) is an important source of fiber, however, its use as a food ingredient requires investigation as to its functionality. Thus, this work aimed to evaluate the physical, chemical, nutritional and technological functional properties of the flour obtained from the pulp of marolo, thus verifying its potential application in food products. The analyzes performed on the flour were proximal composition, mineral composition, vitamin C content, total carotenoids, beta-carotene, antioxidant activity and technological functional properties. The flour presented considerable amounts of fibers, especially the insoluble fraction, being 25.47 g.100g^{-1}, 8.57 g.100g^{-1} for soluble dietary fiber and 34.04 g.100g^{-1} for total dietary fiber. . The levels of vitamin C and total carotenoids, observed in the flour of the pulp of marolo, were 173.77 mg.100g^{-1}, 0.56 mg.100g^{-1} and 0.08 mg.100g^{-1}, respectively. The minerals that showed the highest concentration in the pulp flour were phosphorus (1768.53 mg.kg^{-1}) and calcium (1512.73 mg.kg^{-1}). The antioxidant activity was more effective when performed in aqueous extraction. The flour has shown to have important technological functional properties, such as solubility in water and the ability to form emulsion. Therefore, marolo pulp flour has the potential to be commercialized and used in food products in order to improve and enrich its nutritional and technological qualities.

Keywords: *Annona crassiflora Mart.*; Dietary fiber; Carotenoids; Antioxidant activity; Technological functional properties.

Resumen

La harina de la pulpa de marolo (*Annona crassiflora* Mart.) Es una fuente importante de fibra, sin embargo, su uso como ingrediente alimentario requiere investigación en cuanto a su funcionalidad. Así, este trabajo tuvo como objetivo evaluar las propiedades funcionales físicas, químicas, nutricionales y tecnológicas de la harina obtenida de la pulpa de marolo, verificando así su potencial aplicación en productos alimenticios. Los análisis realizados en la harina fueron composición proximal, composición mineral, contenido de vitamina C, carotenoides totales, betacaroteno, actividad antioxidante y propiedades funcionales tecnológicas. La harina presentó cantidades considerables de fibras, especialmente la fracción insoluble, siendo 25.47 g.100g^{-1}, 8.57 g.100g^{-1} para fibra dietética soluble y 34.04 g.100g^{-1} para fibra dietética total. . Los niveles de vitamina C y carotenoides totales, observados en la harina de la pulpa de marolo, fueron 173.77 mg.100g^{-1}, 0.56 mg.100g^{-1} y 0.08 mg.100g^{-1}, respectivamente. Los minerales que mostraron la mayor concentración en la harina de pulpa fueron fósforo (1768.53 mg.kg^{-1}) y calcio (1512.73 mg.kg^{-1}). La actividad antioxidante fue más efectiva cuando se realizó en extracción acuosa. La harina ha demostrado tener importantes propiedades funcionales tecnológicas, como la solubilidad en agua y la capacidad de formar emulsiones. Por lo tanto, la harina de pulpa de marolo tiene el potencial de ser comercializada y utilizada en productos alimenticios para mejorar y enriquecer sus cualidades nutricionales y tecnológicas.

Palabras clave: *Annona crassiflora* Mart.; Fibra dietética; Carotenoides; Actividad antioxidante; Propiedades funcionales tecnológicas.

1. Introduction

Native fruit trees occupy a prominent place in the cerrado ecosystem and its fruits are already marketed with great popular acceptance. These fruit present flavors and have high content levels of sugar, protein, vitamins and minerals and may be consumed raw or in the form of juices, liquors, ice cream, jellies etc. There are over 58 species of Cerrado native fruits known and used by the population (Avidos & Ferreira, 2005).

In addition, consumption of Cerrado fruits may be associated with numerous benefits attributed to the consumption of fruit in general, such as lower incidence of mortality due to cancer, cardiovascular and cerebrovascular diseases. The protection that the fruit offers to the body is associated, in large part, to the presence of chemical components with antioxidant properties such as carotenoids, vitamin C, folates and vitamin E (Schwartz et al., 2008).

The marolo is one of the most common fruit trees in the Cerrado biome, being exploited by local people for food and medicinal use. By presenting appreciable aroma, flavor and digestibility, the pulp of its fruit is eaten fresh, or processed into other food production (Telles et al., 2003). In addition to the organoleptic characteristics, the fruit has a high nutritional value, with significant levels of lipids, fiber, calories, magnesium, phosphorus, and antioxidants (Damiani et al., 2011). The marolo is highlighted as an important source of dietary fiber in its dried form, and this is an alternative for marketing the product to other regions.

The marolo pulp flour has good chemical characteristics, being an important source of fiber. However, its use as a food ingredient requires investigation as to its functionality. According Mizubuti et al. (2000), functionality mean any property of a food ingredient, with the exception of the nutritional property, which affects their use. Therefore, any physical and chemical properties that affect the behavior of biomolecules of a food can be considered functional property.

For this reason, this study aimed to evaluate the physical, chemical, nutritional, antioxidant activity and technological properties of flour obtained from marolo pulp.

2. Material and Methods

To conduct the study, the marolo (*Annona Crassiflora*) were acquired mature by vendors in Cerrado area of the southwestern state of Goiás - Brazil.

2.1 Preparation of Marolo Pulp Flour

After being washed, the fruits were sanitized with sodium hypochlorite at 300 ppm for 30 min, aiming at removing dirt and impurities coming from the field. The pulp was separated from the seed using a Hauber Macanuda pulper (JEM-05 model). The pulp was dewatered to 65 °C for 48 hours in an oven with forced air circulation until the final moisture of 7% and then it was milled in an industrial mixer to obtain the flour, which was then stored in a freezer at a temperature of -4 °C, until the performed of the analyzes.

2.2 Analysis

2.2.1 Nutritional and physical chemical composition

The close composition of the flour was determined according to AOAC (2012), however, the lipid content was quantified by Bligh and Dyer (1959). Humidity was estimated by drying in an oven at 105 °C until constant weight. The ash determination was made by the method of incineration in a muffle at 550 °C. The protein content was determined by the Kjeldahl method. Dietary fibers were quantified by the enzymatic-gravimetric method using the enzymes α-amylase, protease and amyloglucosidase. Total carbohydrates were calculated by difference. The results of the analysis of close composition were expressed in $g.100g^{-1}$. The total energy value was calculated using the Atwater factors (carbohydrates = 4.0 $Kcal.g^{-1}$, lipids = 9.0 $Kcal.g^{-1}$, proteins = 4.0 $Kcal.g^{-1}$) (Merrill & Watt, 1973).

The content of soluble solids was determined in a digital refractometer (AR200) (AOAC, 2012) and the results expressed in%. The pH was assessed using a digital potentiometer (TEC-3MPp) (AOAC, 2012). The titratable acidity was determined by titration with sodium hydroxide solution (0.1N NaOH), according to AOAC (2012). The results were expressed in grams of sample per 100 g of malic acid. Water activity was performed using the Aqualab device (Aqualab CX-2) at 25 ° C.

2.2.2 Vitamin C

Total vitamin C was quantified by the dinitrophenylhydrazine method (2,4 - DNPH) according to Strohecker and Henning (1967) using ascorbic acid as a standard. The results were expressed in mg of ascorbic acid per 100g of flour.

2.2.3 Total Carotenoids

Total carotenoids were quantified according to Higby (1962), using an isopropyl alcohol: hexane extraction solution (3: 1). As readings were taken at 450 nm and the results are expressed in mg.100g^{-1}.

2.2.45 Minerals

Minerals, calcium, magnesium, phosphorus, copper, iron, manganese and zinc were determined by nitroperchloric digestion, according to the methodology described by Malavolta et al. (1997), using an atomic absorption spectrophotometer.

2.2.5 Antioxidant Activity

Etheric, alcoholic and aqueous extracts were prepared, consecutively, using the methodology described by Silva et al. (2018). The antioxidant activity by the ABTS + method [2,2-azinobis- (3-ethylbenzothiazoline-6-sulfonic acid)] was quantified according to the method described by Rufino et al. (2007a) and the results expressed in µM Trolox per sample. The iron reduction method (FRAP) was determined as described by Rufino et al. (2006) and the results were expressed in µM of ferrous sulfate per g sample of sample. The antioxidant activity of the radical 2.2-diphinyl-1-picryl-hydrazil (DPPH) was determined according to Rufino et al. (2007b) and the results expressed in the amount of antioxidant needed to decrease the initial concentration of DPPH by 50% (IC50).

2.2.6 Coloration

The determination of staining was performed by reading three points of the sample, with ten repetitions, by reading three parameters defined by the CIELAB system. The parameters L, a* and b*, provided by the colorimeter (Hunterlab, ColorQuest II) were read, in which L defines how light or dark the sample (L = 0 black and L = 100 white) and a* and b* define the chromaticity (+a* red and –a* green, +b* yellow and –b* blue).

2.2.7 Technological functional properties

The absorption index of water and oil were obtained, according to the methodology described by Okezie and Bello (1988). Water solubility analysis was performed according to Okezie and Bello (1988). Emulsifying activity and emulsion stability were determined, according to the method described by Yasumatsu et al. (1972). Foaming capacity, foam stability and gel formation capacity were analyzed according to the standards recommended by Coffman and Garcia (1977). All results obtained for technological functional properties of marolo pulp flour were expressed in%.

32.3 Statistical Analysis

Analyses of marolo pulp flour were carried out in triplicate and the data were expressed as mean, standard deviation and coefficient of variation. The antioxidant activity analysis data were submitted to analysis of variance followed by Tukey test at 5% probability with the help of SISVAR software (Ferreira, 2014). All analyzes were performed in triplicate.

3. Results and Discussion

Brazilian legislation establishes a 15% moisture limit for flours (Brazil, 2005). The flour produced from marolo pulp was within the established standards (Table 1). Water, even in dried products such as flour, where it occurs in low concentrations, is an important parameter, since it has great influence on storage characteristics. Low water content makes for better conservation of the product, since it reduces the water available for the proliferation of microorganisms and chemical reactions (Ethur et al., 2010).

The ash content of the marolo pulp flour was within the limit established by the brazilian legislation for flour (maximum 6%) (Brasil, 2005). Ashes represent the mineral contents incorporated in the sample and soil nutrients can cause changes in concentrations.

For the total lipid content, brazilian legislation does not dictate limit values. According to Brazilian legislation (Brasil, 2012), for a product to have a low total lipid content, it should contain a maximum of 3g of total lipids per 100g of product. The marolo pulp flour presented total lipid content above that established in this resolution.

The protein content of the marolo pulp flour is within the minimum limit established by Brazilian legislation (1.5%) (Brasil, 2005). This flour can not be considered a source of protein according to Brazilian legislation (Brasil, 2012), which determines, for protein source products, a minimum of 6g of protein per 100g of product.

Table 1 - Proximate composition, total energetic value, nutritional parameters and mineral composition of marolo pulp flour coming from the southwest region of Goiás - Brazil, on a wet basis.

Parameter	Mean
Moisture ($g.100g^{-1}$)	7.68 ± 1.38 (0.18)
Ashes ($g.100g^{-1}$)	2.83 ± 0.05 (0.02)
Total lipids ($g.100g^{-1}$)	12.22 ± 0.84 (0.07)
Proteins ($g.100g^{-1}$)	5.45 ± 0.13 (0.02)
Insoluble dietary fiber ($g.100g^{-1}$)	23.52 ± 0.11 (0.0)
Soluble dietary fiber ($g.100g^{-1}$)	7.91 ± 3.08 (0.39)
Total dietary fiber ($g.100g^{-1}$)	31.43 ± 3.20 (0.10)
Total carbohydrates ($g.100g^{-1}$)	71.82 ± 1.88 (0.03)
Total energetic value ($Kcal.100g^{-1}$)	419.07 ± 6.33 (0.02)
Titratable acidity ($g.100g^{-1}$ malic acid)	0.24 ± 0.01 (2.78)
pH	4.74 ± 0.01 (0.25)
Soluble Solids (%)	56.30 ± 0.03 (0.06)
Water activity	0.37 ± 0.00 (0.96)
Vitamin C (mg ascorbic $acid.100g^{-1}$)	173.77 ± 2.88 (1.66)
Total carotenoid ($mg.100g^{-1}$)	0.56 ± 0.02 (2.78)
Phosphorus ($mg.kg^{-1}$)	1768.53 ± 0.45 (0.03)
Calcium ($mg.kg^{-1}$)	1512.73 ± 0.25 (0.02)
Magnesium ($mg.kg^{-1}$)	1067.87 ± 0.81 (0.08)
Copper ($mg.kg^{-1}$)	92.27 ± 0.38 (0.41)
Iron ($mg.kg^{-1}$)	18.6 ± 0.26 (1.42)
Manganese ($mg.kg^{-1}$)	9.53 ± 0.25 (2.64)
Zinc ($mg.kg^{-1}$)	6.27 ± 0.21 (3.32)

Mean values ± standard deviation and coefficient of variation for three repetitions.

Also according to the Brazilian legislation, for a product to be considered "high in fiber" it is necessary that its formulation contains 6g of fiber per 100g, for solid foods (Brasil, 2012), so the marolo pulp flour, evaluated in this study can be considered as a food rich in fiber. The daily recommendations for total dietary fiber for men and women 19-50 years is 38 and 25g, respectively (IOM, 2005). Based on these figures it is clear that a portion of 50g of marolo pulp flour meets the recommended daily intake with 41.36% for men and 62.86% women. The high fiber content, associated with the exotic flavor and aroma, allows for this flour to be potentially utilized in various food preparations. Adam et al. (2001) examined flours with high insoluble fiber content and found that they are effective in reducing LDLcholesterol in experimental animals, demonstrating functional effects. In general, water-soluble fibers (pectins, gums, mucilages and some hemicelluloses) delay intestinal transit, gastric emptying and glucose uptake, to help in reducing cholesterol in blood serum. Fibers insoluble in water (lignin, cellulose and hemicellulose) accelerate intestinal transit, increasing stool weight, slowing hydrolysis of starch and the absorption of glucose, which contributes for reduction of risk of disease (Leonel et al., 1999).

The acidity of marolo pulp flour showed results compatible with Brazilian legislation, which sets a maximum of 5% acidity for flour (Brasil, 2005). Damiani et al. (2011), studied the titratable acidity of marolo pulp and observed results of 0.5 $g.100g^{-1}$, and found, also, the predominant presence of malic acid in the fruit (958.5 $\mu g.g^{-1}$).

The pH of the marolo pulp flour was similar to what was found by Munhoz et al. (2010) for guava pulp flour (4.28), being considered an acidic product, which is unfavorable for the growth of pathogenic microorganisms.

The total soluble solids content was higher than what was found by Damiani et al. (2011) for the marolo pulp (21.4%). The increase in the concentration of soluble solids in the flour in comparison to the pulp is justifiable by the elimination of part of the pulp water in the drying process. The soluble solids content is used in the agricultural industry to enhance the quality control of the final product, for process control, ingredients and others such as sweets, juices, nectar, pulp, ice cream, liquor and beverages in general, among others (Chaves et al., 2004).

The water activity of the marolo pulp flour was similar to what was found by Munhoz et al. (2010) for guava pulp flour (0.40). Water activity values below 0.6 guarantee prevention of growth of microorganisms such as molds and yeasts according to Troller (1980).

Silva et al. (2014) observed vitamin C content of 183.06 $mg.100g^{-1}$ for marolo pulp flour, similar to what was found in this study. FAO (2001) recommends a daily intake of 45 mg of vitamin C for adults. This vitamin, as well as enrich nutritionally food also has antioxidant action, preventing the action of free radicals.

The total carotenoid content of the marolo pulp flour was lower than what was found by Almeida et al. (2008) for the marolo pulp, which showed contents of 0.84 $mg.100g^{-1.}$ The lower level found for the flour can be a result of degradation of this pigment caused by the temperature of the drying process. Carotenoids in food can act as antioxidants associated with reduced risk of many chronic diseases (Trumbo & Ellwood, 2006).

The mineral with the highest concentration in marolo pulp flour were phosphorus (1768.53 $mg.kg^{-1}$), calcium (1512.73 $mg.kg^{-1}$), and magnesium (1067.87 $mg.kg^{-1}$). Villela et al. (2013) studied marolo pulp flour and found lower values for calcium (1174.5 $mg.kg^{-1}$), magnesium (598.6 $mg.kg^{-1}$), and phosphorus (620.9 $mg.kg^{-1}$), and higher results for copper (392.2 $mg.kg^{-1}$), iron (20.6 $mg.kg^{-1}$), manganese (18.5 $mg.kg^{-1}$), and zinc (34.10 $mg.kg^{-1}$). The soil nutrients can be the main cause of the difference in mineral profile (Damiani et al. 2011).

Regarding the antioxidant activity in Table 2 are listed the results for different methods used in flour marolo pulp in ether, ethanol and aqueous extracts.

Table 2 - Antioxidant activity of marolo pulp flour coming from the southwest of the state of Goiás - Brazil.

Method	Ether extract	Ethanol extract	Aqueous extract
ABTS (µM trolox . g^{-1})	$596.55^{b} \pm 5.40$	$576.56^{b} \pm 7.98$	$1353.22^{a} \pm 6.45$
FRAP (µM ferrous sulphate. g^{-1})	$375.24^{c} \pm 3.04$	$1510.48^{b} \pm 5.99$	$3133.81^{a} \pm 7.43$
DPPH (IC50*)	$512.04^{a} \pm 2.53$	$337.78^{b} \pm 3.32$	$193.91^{c} \pm 3.21$

Mean values ± standard deviation of three repetitions. Same letters on the same line do not show statistical difference between them (Tukey's test, $p < 0.05$).

IC50 - Extract concentration (mg/ml) capable of reducing 50% of DPPH.

In the method of ABTS radical, the aqueous extract was different from the others. This method measures the antioxidant activity of both lipophilic and hydrophilic compounds (Kuskoski et al. 2005). The higher result was found in the aqueous extract. These results for the antioxidant activity by this method were higher than those found by Vieira (2011) for pulp of fruits like guava 198 µM $trolox.g^{-1}$ in aqueous extract and 401 µM $trolox.g^{-1}$ in ethanol extract; hog plum 140 µM $trolox.g^{-1}$ in aqueous extract and 219 µM $trolox.g^{-1}$ in ethanol extract, however, the results for acerola pulp were higher than what was found in this study, both in the ethanol extract (3690 µM $trolox.g^{-1}$) and aqueous extract (1605 µM $trolox.g^{-1}$).

For the results of antioxidant activity by reduction of iron ions method (FRAP - Ferric Reducing Antioxidant Power), all extracts differ. This method is based on the ability that antioxidant compounds present of reducing the ions Fe^{3+} to Fe^{2+}, and this reduction is accompanied by the formation of an intense blue colored (Rufino et al., 2006). Antioxidants detected by FRAP are limited to those soluble in water or aqueous solutions of ethanol, which explains the greater reducing power of iron ions in the aqueous extract with 3233.81 µM ferrous $sulfate.g^{-1}$. This result indicates that each 1.0g of marolo pulp flour is able to reduce 3233.81 µM $Iron^{3+}$ to $Iron^{2+}$. Morais et al. (2013) determined the in vitro antioxidant potential of fruits of the Brazilian cerrado, and for the FRAP method, in hydro-alcoholic extract, found values lower than detected in this study, namely 2085 μM ferrous sulfate.g^{-1} for the mesocarp of pequi and 148.42 μM ferrous sulfate.g^{-1} for murici pulp.

In DPPH method, all extracts differed. This method has advantages when analyzed antioxidants are more soluble in organic solvents. The aqueous extract was found significantly lower inhibitory concentration (IC 50) of DPPH, showing greater effectiveness in the extraction of antioxidants compounds. The antioxidant activity of marolo pulp flour, by the DPPH method, was lower than in other studies, such as Soquetta et al. (2016) for kiwi rind flour (39.45), in the ethanol extract and by Vieira et al. (2011) for pulp of fruits like acerola (24.42) and cashew (154.95) in the aqueous extract, but was higher when compared to aqueous extract of cajá (535.53) and guava (433.36).

Most of the antioxidant activity of marolo pulp flour was found in the aqueous extract, indicating the presence of compounds with high antioxidant potential in this extract. Damiani et al. (2011) studied the antioxidant activity of marolo fruit and also found higher antioxidant potential for the aqueous extract.

The results of the color parameters L, a* and b* and technological properties of marolo pulp flour are shown in Table 3.

Table 3 - Color parameters and technological properties of marolo pulp flour, coming from the southwest of the state of Goiás - Brazil.

Parameter	**Mean**
L	55 ± 1.02 (1.85)
a*	10.8 ± 0.21 (1.94)
b*	16.19 ± 0.51 (3.14)
Water absorption index (%)	1.36±0.05 (3.6)
Oil absorption Index (%)	1.24±0.09 (7.07)
Water solubility index (%)	37.93±0.86 (2.27)
Emulsifying activity (%)	82.96±513 (6.19)
Emulsion Stability (%)	54.52±5.07 (9.29)
Foaming capacity (%)	2 ± 0.00 (0.00)

Mean values ± standard deviation and coefficient of variation of three repetitions.

According to Roesler et al. (2007), marolo presents unclear pulp, with predominant red-yellowish color due to the presence of carotenoids. Damiani et al. (2011) studied the coloring of marolo pulp and found results of 70.92 for L, 2.17 for a* and 33.90 for b*. In comparison with the pulp, it is observed that the flour showed a lower value for L, i.e. it presented darker color, which was expected, due to the drying process and the probable occurrence of the Maillard reaction and/or caramelization. All dehydrated products showed a variation of a yellowish color. The Maillard reaction often occurs when foods are heated. The parameters which affect the Maillard reaction are mainly proteins, sugars, temperature and duration of thermal treatment (Chua et al., 2001). The caramelization may also have occurred because the fruit has a high level of sugars (12.38 $g.100g^{-1}$) (Damiani et al., 2011). In products with high concentrations of reducing sugars, these bind to free amino acids or amino acids which are composing the protein chains, forming dark compounds, and in pH below 5, an intermediate product originates and undergoes dehydration, yielding hydroxymethylfurfural (HMF). This may have occurred during the heating in the process of drying the pulp to obtain flour. Therefore, with darkening of the flour, the value of a* increased, generating an increase in red color, and the value of b* decreased, leading to reduction of yellow color.

The functional properties are physico-chemical characteristics of foods which contribute to having the characteristics desired by the consumer. These properties reflect the full interaction between the amino acid composition, structure, conformation and physico-chemical properties of proteins, as well as interaction of these with lipids, carbohydrates and other food components (Kinsella, 1976).

The value found for the water absorption index of marolo pulp flour was 1.36% which is lower than what was found by Souza et al. (2008) for passion fruit peel flour (6.02%). According to Costa et al. (2008) the greater the amount of protein and fiber, the higher the water absorption. Based on this theory, it is possible to justify the low value found for the water absorption of marolo pulp flour, which has high fiber content but low protein. The water absorption is a characteristic related to the amount of moisture and internal porosity of the sample, availability of suitable hydrophilic groups to bind water molecules and gel forming ability of starch molecules (Filli & Nkama, 2007). This property is important in foods such as cakes, breads and other bakery products.

The oil absorption index of marolo pulp flour was 1.24%. This value is similar to that found by Trill et al. (2014) for tamarind powder extract (1.35%). According to Ravi and Sushelamma (2005), the oil absorption is the ability of nonpolar sites of protein chains to imprison oil. Thus, the content and type of protein present in the flour determine the ability of oil absorption. Knowledge of oil absorbency capacity for flours is important for the development and determination of storage stability of new food products, especially in relation to the development of the characteristic flavor of oxidative rancidity (Siddiq et al., 2009). The oil absorption property is important in viscous products and meat products such as sausage and bologna.

The water solubility of marolo pulp flour was 37.93% which is higher than what was found by Bezerra et al. (2013) for green banana flour (from 1.22 to 1.92%). Solubility is a key physicochemical property of proteins, because of the importance it has on other properties of proteins in food. In general, protein solubility is influenced by the greater or better affinity of the protein molecules to the solvent, which in the case of food is water, which is why the solubility is classified as hydrophilic property (Sgarbieri, 1996). This property is important for foods that require lower temperatures to be prepared, such as instant food, liquids and beverages.

The marolo pulp flour showed good emulsifying activity to 82.96%, indicating the suitability of using as a possible replacement ingredients emulsion systems, such as cream, icings, butter, processed cheese, mayonnaise, salad dressing, frozen desserts and finely ground meat of the type used in sausages and other meat (Cheftel et al., 1989). The emulsifying property of flour is related to the interphase property of proteins which compose it, and this property depends on the ability of the protein molecules have to form a film between two immiscible phases. This result was higher when compared to the value found by Goldmeyer et al. (2014) for blueberry pulp flour (30%) and Porte et al. (2011) for the pumpkin and papaya seed flour, being 48.06 and 48.14% respectively. The stability of the flour emulsion evaluated in this study was 54 and 52%, and in the study by Porte et al. (2011) these values were 48.06 and 48.14% for pumpkin seed and papaya flour, respectively.

The marolo pulp flour showed low foaming capacity (2%), and did not have the ability to form gel, thus indicating its inadequacy in products that require these properties, such as ice creams, meringues and mousses.

4. Conclusion

The flour, made from marolo pulp, showed high levels of dietary fiber especially the insoluble dietary fiber, as well as having antioxidant activity, vitamin C, minerals such as potassium, phosphorus and calcium, showing also have important functional properties technology, such as solubility in water and ability to form emulsion.

Therefore, the marolo pulp flour has potential for commercialization and use in food products in order to enhance and enrich their technological and nutritional qualities.

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Porcentagem de contribuição de cada autor no manuscrito

Jéssyca Santos Silva – 16%

Clarissa Damiani – 14%

Thays Lorrayne Lavrinha e Silva – 14%

Edson Pablo da Silva – 14%

Mariana Crivelari da Cunha – 14%

Eduardo Ramirez Asquieri – 14%

Eduardo Valério de Barros Vilas Boas – 14%