PHYSICOCHEMICAL PROPERTIES OF JABOTICABA SKIN FLOUR STORED AT ROOM TEMPERATURE

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The stability of jaboticaba skin flour was evaluated during 12 months of storage, for the purpose of extending the use of this flour throughout the year, because jaboticaba production is seasonal. Ripe *Plinia jaboticaba* (Vell.) Berg fruits, of the Sabará genotype, were collected and the separated skins were dried at a temperature of 45 ºC. They were then ground and stored in hermetically sealed flasks and protected from light at room temperature for 0, 3, 6, 9 and 12 months. At each storage time, analyses of proximate composition, vitamin C, phenolic compounds, anthocyanins, soluble solids, water activity, color, pH and microbiological analysis were conducted. It was possible to observe a significant increase in the following parameters during the 12 months of storage: humidity, 34 %; water activity, 31.23 %; a color coordinates,12.37 % and b color coordinates, 24 %; pH, 7.35 %. There was a decrease in phenolic content of 9.91 %; anthocyanins 29 % and vitamin C 20 %. There was no significant difference in the levels of lipids, protein, ash, fiber and soluble solids, and the presence of microorganisms was not detected for any storage period. Therefore, it is possible to conclude that the jaboticaba skin flour did not show significant changes in nutritional parameters, and showed a small reduction in antioxidant compounds when stored for periods up to 12 months. This flour can therefore be considered as an alternative for the enrichment of food products throughout the year.

KEY-WORDS: Plinia jaboticaba; STABILITY; STORAGE; FLOUR; CHEMICAL CONSTITUENTS.

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1 INTRODUCTION

The Jaboticaba tree is a plant native to Brazil, which belongs to the Myrtaceae family; it can be found from the state of Pará to Rio Grande do Sul, but the states of São Paulo, Rio de Janeiro, Minas Gerais and Espírito Santo have the highest production. The species that are currently known, include *Plinia trunciflora* Berg, known as *jaboticaba de cabinho*; *Plinia cauliflora* (DC) Berg, known as jaboticaba *paulista* or *jaboticaba-açu* and *Plinia jaboticaba* (Vell.) Berg, known as *jaboticaba-sabará*, which is the most marketed species in Brazil (MATTOS, 1983).

The marketing potential of jaboticaba is due to its organoleptic characteristics (MAGALHÃES, BARROS & FINGER, 1996). According to the Instituto de Economia Agrícola (IEA), in 2012 the cultivation of jaboticaba in the state of São Paulo occupied 270 hectares and yielded 2.560 t of fruit, and the city of Casa Branca was responsible for 78 % of state production. Approximately 60 % of the annual production and commercialization is concentrated in the months of September and October (SASSO, CITADIN & DANNER, 2010). However, the skin is usually discarded and this can represent up to 43 % of the fruit (LIMA *et al*., 2008). The skin contains high levels of phenolic compounds - 11.99 g 100 g^{-1} dry matter (DM), dietary fiber (soluble fiber - 6.8 g 100 g^{-1} DM and insoluble fiber - 26.43 g 100 g^{-1} DM) and minerals, such as iron (1.68 mg 100 g^{-1} DM), potassium (1.496.67 mg 100 g^{-1} DM), magnesium (90.00 mg 100 g^{-1} DM) and manganese (1.71 mg 100 g^{-1} DM) (LIMA *et al*., 2008).

According to Lima *et al*. (2011), anthocyanins comprise a significant fraction of the total phenolic content in Sabará jaboticaba skin (20.57 mg g^{-1} DM), and cyanidin 3-glucoside and delphinidin 3-glucoside have been identified. The same authors also measured the antioxidant capacity in ethanol extracts and found it was high; they confirmed that anthocyanins in jaboticaba skins have the potential to be used as an additive in the food industry, with possible benefits to consumer health.

The use of waste in food processing has become an important concern for the food industries, especially regarding the demand for products for special diets because they are primarily composed of organic matter that is rich in sugars and fibers, with high nutritional value and low economic cost (OLIVEIRA *et al*., 2002). Alves *et al*. (2013) studied the addition of flour and anthocyanin extracts of jaboticaba skin in yogurts. The results of the acceptance test for the yogurt samples ranged from “like slightly” to “like moderately”. The color retention for all the yogurt samples was higher than 70 %. The average half-life was more than 2,500 hours, which is considered high. They confirmed that the use of jaboticaba skin flours and extracts as additives in yogurt can be an alternative use of this waste product.

The use of jaboticaba skin flour as a source of phenolic compounds, fibers and minerals in the formulation of new products is an option to combat the waste of this important raw material. Furthermore, it provides enrichment and diversification of diet and meets the interests of consumers for products with added nutritional value and/or health benefits.

Due to the seasonality of jaboticaba production it is relevant to study the most economical storage conditions in order to examine the possibility to using this waste throughout the year. Therefore, the objective of this study was to evaluate the stability of the nutritional and bioactive compounds present in jaboticaba skin flour stored for 12 months at room temperature.

2 MATERIAL AND METHODS

2.1 JABOTICABA HARVEST AND SAMPLE PREPARATION

Ripe *Plinia jaboticaba* (Vell.) Berg fruits of the Sabará genotype were hand-picked on a morning in October, 2011, on São José do Ismeril Farm, in the municipality of Coqueiral, MG, Brazil (21°14” S latitude, 45°27’2” W longitude and 823 m altitude), in a region near Lavras, MG (Brazil). The local climate, according to the Köppen classification, is Cwa (mild and rainy summer, with moderate

temperature, annual average below 21 °C). The average annual rainfall and relative humidity are respectively 1,500 mm and 70 % (EMATER, 2002).

The healthy fruits were selected, washed in tap water to remove impurities, sanitized with a sodium hypochlorite solution (200 mg kg^{-1}) by immersion for 10 minutes, squeezed obtaining 13 kg of skins separated. The fruits were then dried in a forced air oven at a temperature of 45 °C until obtained constant weight (2.1 kg). According to Alves *et al*. (2014), this drying temperature results in lower losses of nutrients and bioactive compounds for jaboticaba skins.

After drying, the skins were ground and passed through 35-mesh sieve, and the flour obtained was divided into 20 bottles (each containing 60 g of flour). The polyethylene bottles were wrapped in aluminum foil, and stored at room temperature (average of 21.38 ± 2.21 ºC), with an average relative humidity of 71 % ± 8.56 (BDMEP-INMET, 2011/2012), on a metal shelf for 5 different time periods of 0, 3, 6, 9 and 12 months, with 4 repetitions. Table 1 shows the average maximum and minimum temperatures, as well as the average relative humidity for each month of storage.

TABLE 1 - AVERAGE MINIMUM AND MAXIMUM TEMPERATURES AND AVERAGE RELATIVE AIR HUMIDITY DURING THE TWELVE MONTHS OF STORAGE OF JABOTICABA SKIN FLOUR

MONTH	Average minimum temperature ºC	Average maximum temperature ºC	Average relative humidity %
December 2011	18.12	27.46	80.76
January 2012	17.88	27.18	80.16
February 2012	18.29	29.29	70.12
March 2012	17.71	28.80	73.11
April 2012	17.08	27.48	76.19
May 2012	13.30	23.91	75.85
June 2012	13.45	24.21	79.92
July 2012	11.02	24.60	68.49
August 2012	12.26	25.19	62.07
September 2012	14.05	28.46	56.68
October 2012	16.78	30.59	56.87
November 2012	17.66	27.93	71.74

Source: BDMEP-INMET, 2011/2012.

At each storage time the flours were subjected to analyses.

2.2 ANALYSES

The analysis of the humidity of the jaboticaba skins and the proximate composition of the jaboticaba skin flour were performed according to the methods described by the AOAC (2005). The water activity was measured with an Aqualab device (water activity pattern of 0.5) at a temperature of 25 °C (AOAC, 2005). The color was determined using a colorimeter (Minolta Chroma Meter CR-3000), using the CIELAB system in which L* indicates how light or dark the sample is and a* and

b* represent the red(+)/green(-) and yellow(+)/blue(-) color attributes. The extraction of phenolic compounds in the flours was performed using 50 % methanol (1:25 w/v), and tannic acid was used as a standard (AOAC, 2005). The anthocyanins were extracted and quantified using the method proposed by Lees and Francis (1972), with modifications made by Lima *et al*. (2011). The vitamin C content was determined by the colorimetric method described by Strohecker and Henning (1967), using ascorbic acid as a standard. Soluble solids were determined using a bench refractometer (Quimis), in which the humidity loss during the drying process was restored in the samples. The measurements of pH and soluble solids were determined in the same extract, using a TECNAL potentiometer, model Tec-3MP (BRASIL, 2005). Microbiological analyses of the total bacteria and yeast were performed following the methodology described by Silva, Junqueira and Silveira (1997).

The physicochemical parameters of the flours evaluated at different storage times were submitted to a completely randomized design with 5 treatments (times) and 4 replications, using the SISVAR computer program (version 4.6, build 61). When the analysis of variance showed significant differences, regression analysis was used to determine the influence of time on the different parameters analyzed (FERREIRA, 2003). The results were processed using the Octave 3.4.3 program (EATON, 2012), and principal component analysis (PCA) was performed.

3 RESULTS AND DISCUSSION

The length of storage time did not significantly change the levels of lipids, crude protein, ash and fiber (Table 2). Lima *et al*. (2008), analyzed lyophilized jaboticaba skin flour (Sabará genotype) and found lower levels of lipids (0.57 g 100 g^{-1} DM), crude protein (1.16 g 100 g^{-1} DM), insoluble fiber (26.43 g 100 g^{-1} DM), soluble fiber (6.80 g 100 g^{-1} DM), and a similar ash content (4.40 g 100 g^{-1} DM). Alves *et al*. (2014) reported lower levels of lipids (0.62 g 100 g^{-1} DM) and ash (3.05 g 100 g^{-1} DM) for jaboticaba skins dried at 45 °C, while the levels of crude protein (6.06 g 100 g^{-1} DM), insoluble fiber (29.50 g 100 g^{-1} DM) and soluble fiber (8.43 g 100 g^{-1} DM) were very close to those found in the present study. These differences are probably related to the crop, which is influenced by several factors.

TABLE 2 - PROXIMATE COMPOSITION, IN g 100 g^{-1} DRY MATTER, OF THE JABOTICABA SKIN FLOUR AT DIFFERENT STORAGE PERIODS

Storage period (months)	Constituents				
	Lipids	Crude protein	Ash	Insoluble fiber	Soluble fiber
0	1.30 ± 0.09	5.64 ± 0.13	4.67 ± 0.30	30.12 ± 0.84	8.68 ± 0.33
3	1.27 ± 0.07	5.60 ± 0.05	4.77 ± 0.22	29.96 ± 0.74	8.56 ± 0.36
6	1.20 ± 0.13	5.65 ± 0.10	4.62 ± 0.28	30.09 ± 0.76	8.54 ± 0.25
9	1.14 ± 0.06	5.52 ± 1.12	4.53 ± 0.30	29.91 ± 0.46	8.73 ± 0.58
12	1.21 ± 0.16	5.47 ± 0.16	4.66 ± 0.25	30.02 ± 0.26	8.90 ± 0.56
Coefficient of variation (%)	8.84	2.47	5.90	2.16	5.02

Data are the average of four replicates ± standard deviation.

After drying, the flour showed a humidity content of 9.28 g 100 g^{-1} at time zero and this increased significantly during the storage of the flour, with a content of 14.01 g 100 g^{-1} recorded at 12 months of storage (Figure 1A). ANVISA requires a maximum humidity of 14 g 100 g^{-1} in flours (BRASIL, 2005), therefore, the jaboticaba skin flour stored for up to 12 months met the requirements regarding this aspect. Santos *et al.* (2010) studied the stability of green banana flour placed in polyethylene terephthalate (PET) packaging at room temperature (± 26 °C) for 90 days and found a significant increase of approximately 40 % in the humidity of the flour, which is higher than the level found in this study at 360 days of storage (approximately 34 %). The increase in humidity can be attributed to the conditions of temperature and relative humidity in the storage location (TEIXEIRA NETO, VITALI & QUAST, 2004).

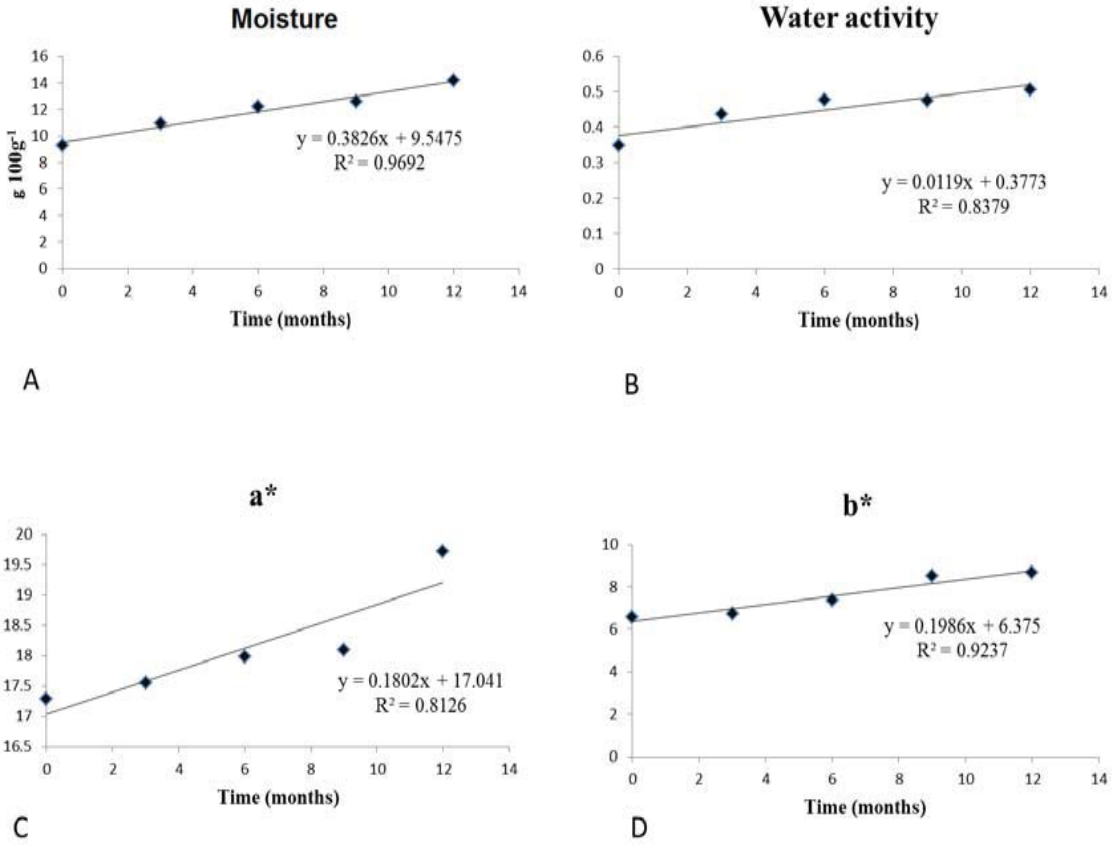


FIGURE 1- EFFECT OF STORAGE ON THE HUMIDITY CONTENT (A), WATER ACTIVITY (B) AND CHROMATICITY COORDINATES a* (C) AND b* (D)

Water activity increased significantly during storage (Figure 1B), but the flours had initial and final water activities of 0.348 and 0.506, respectively. This is lower than 0.60 which, according to Chisté *et al.* (2006), is considered the maximum limit to prevent the development of microorganisms. The increase in water activity can be attributed to time, conditions of relative humidity, and the temperature at which the flour was stored, all of which are factors that interfere with packaging permeability, and thus allow water absorption during storage, as reported by Teixeira Neto, Vitali and Quat (2004).

Regarding the chromaticity coordinates a* and b* (Figure 1C and 1D), there was a significant increase starting at 9 months of storage. A reduction in L* values (lower brightness), although not significant (Table 3), and an increase in the values of a* (redshift) and b* (yellowshift) was indicated

the darkening of the flour. The increase in the intensity of red in the jaboticaba skin flour between time zero and the end time (12 months) was 12.37 %, and the increase in the intensity of yellow at the end of storage, in relation to the initial time, was 24 %. No change in the soluble solids content was observed in the flours during the storage period (Table 2). Lima *et al.* (2008) found 11.60 ºBrix for lyophilized jaboticaba skin flour, close to that recorded in the present study.

TABLE 3 - LIGHTNESS COMPONENT (L*) AND CONTENT OF SOLUBLE SOLIDS (°BRIX) IN JABOTICABA SKIN FLOUR AT DIFFERENT STORAGE PERIODS

Storage period (months)	L*	Soluble solids
0	37.10 ± 0.77	11.43 ± 0.52
3	37.10 ± 0.66	11.85 ± 0.13
6	36.95 ± 0.42	11.75 ± 0.15
9	36.80 ± 0.63	11.77 ± 0.17
12	36.13 ± 0.65	11.80 ± 0.17
Coefficient of variation (%)	1.73	2.16

Data are the average of four replicates ± standard deviation.

The jaboticaba skin flour showed lower levels of phenolic compounds at 3, 6, 9 and 12 months of storage than at time zero (Figure 2A). It was possible to observe a downward trend in the content of phenolic compounds with the course of time, with a coefficient of determination of the equation higher than 0.77, showing a good adjustment of the regression model. Alves *et al.* (2014) recorded a phenolic content of 8.05 g 100 g^{-1} DM in the jaboticaba skin flour dried at 45 °C, which is similar to the level found in this study.

Anthocyanins, which belong to the class of phenolic compounds, showed a significant reduction of up to 29 % (Figure 2B), and differed statistically from the flour without storage. Alves *et al.* (2014) found a content of anthocyanins close to the level found in this study (6.46 mg g^{-1} DM) in jaboticaba skin flour dried at 45 °C. These levels were lower than those found by Lima *et al.* (2011), which was 20.57 mg g^{-1} DM in lyophilized jaboticaba skin flour. This difference is probably due to the harvest in different crops and to the drying process of the skins.

For vitamin C, a reduction was also observed after storage (Figure 2C). Lima *et al.* (2011) reported vitamin C contents of 298.23 mg 100 g^{-1} DM for the lyophilized jaboticaba skin flour, which is close to the result found in the present study. On the other hand, Alves *et al.* (2014) recorded a higher content than that found in this study for skin dried at 45 ºC, i.e. 342.27 mg 100 g^{-1} DM.

The highest pH value was found at 12 months of storage, i.e. 3.13 (Figure 2D), and did not differ from the pH in the flours analyzed at 6 and 9 months of storage. This pH value was close to the that recorded by Lima *et al.* (2008) for the jaboticaba skin flour, i.e. 3.39. An advantage of low pH values is that they hinder the development of microorganisms. According to Sarantópoulos, Oliveira and Canavessi (2001), the more aggressive the environment, the higher the required minimum water activity for microbial growth. The presence of microorganisms was not detected during storage.

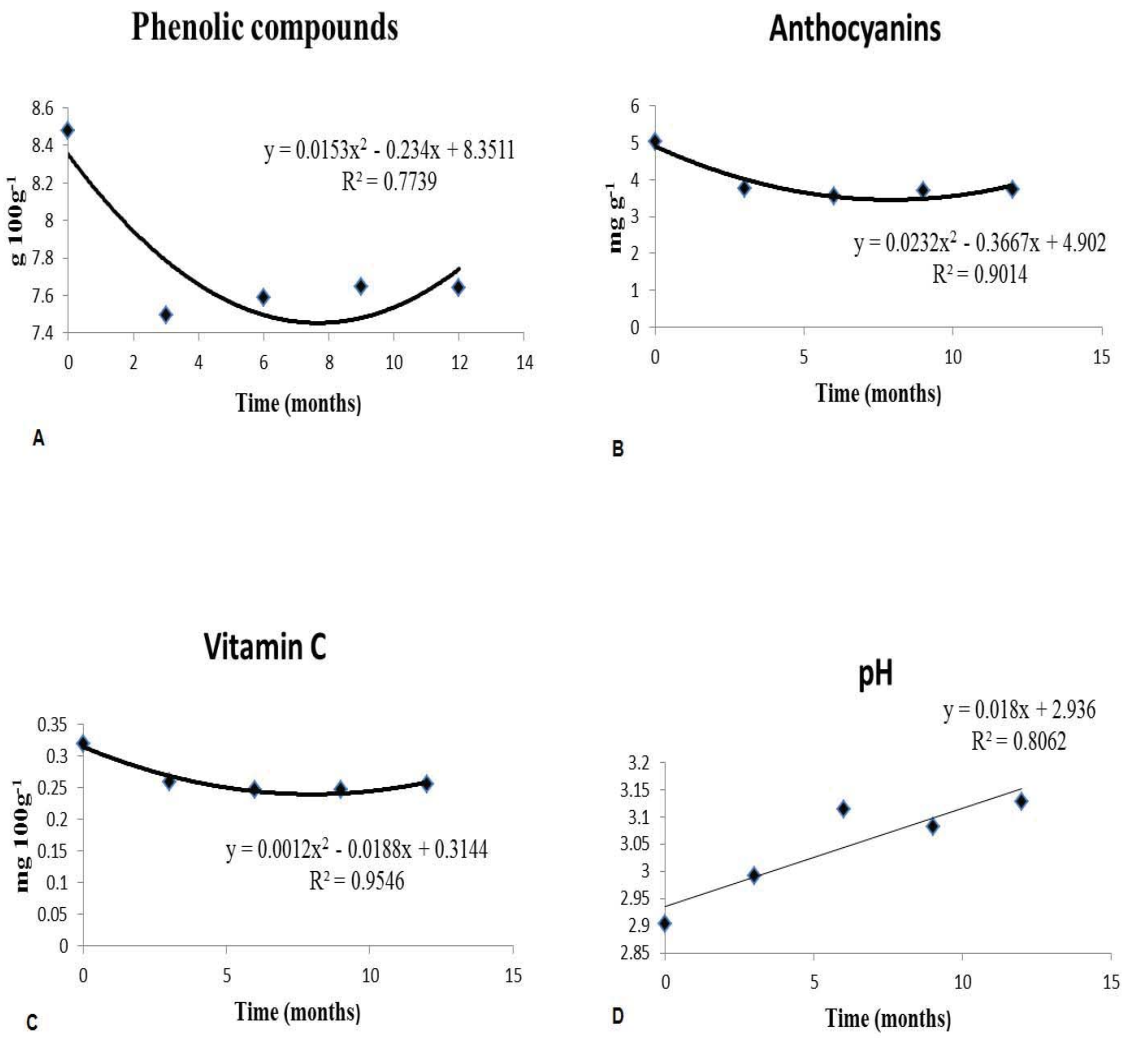
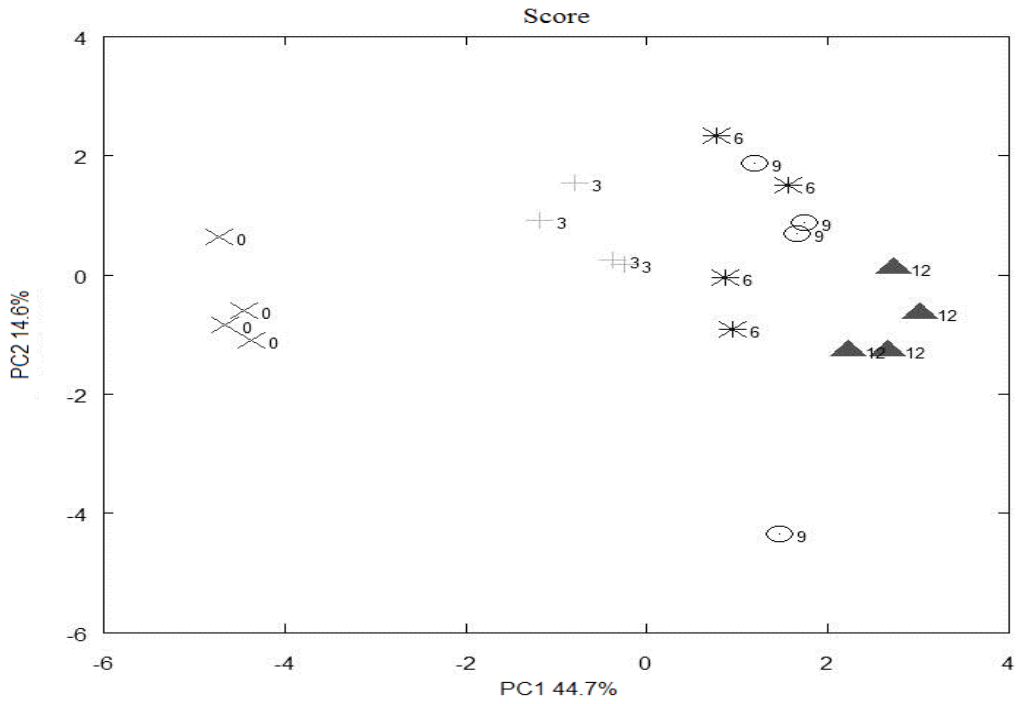


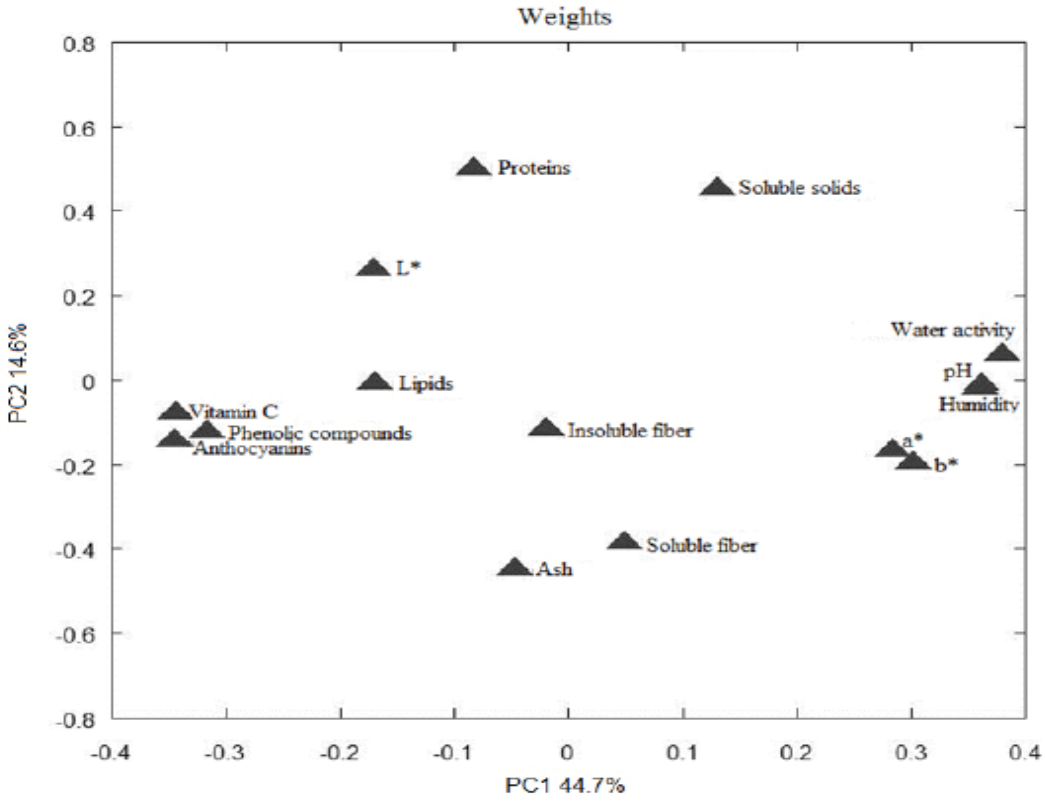
FIGURE 2 - EFFECT OF STORAGE ON THE CONTENT OF PHENOLIC COMPOUNDS (A), ANTHOCYANINS (B), VITAMIN C (C) AND pH (D)

Principal component analysis (PCA) was performed with the intention of facilitating the visualization of the variation in the analyzed parameters; this is a statistical method that analyzes multiple variables at once and facilitates the perception of variation in the data of interest. In the PCA (Figure 3), Components 1 and 2 explained about 60 % of the total variance in the analyses performed in the jaboticaba skin flour during storage. PC1, in this case, was responsible for the variable time and was the one that most influenced the analysis. In the graph of scores (Figure 3A) which explains the relationship between the samples themselves, it is possible to see that the samples analyzed in month 0 were most different from the others; on the other hand, the samples in months 6 and 9 hardly differed.

From the graph of weights, which explains the parameters into which the samples were separated, it is possible to notice that the factors that had the highest relationship with the analyzed samples in month 0 were phenolic compounds, anthocyanins, vitamin C and L*, whereas the highest relationship in the last month of storage was with humidity, water activity, coordinates a* and b* and pH. In the case of lipids, crude protein, ash and fiber, which are represented in the center of the graph, it is possible to say that they varied very little during storage.



(A)



(B)

FIGURE 3 - GRAPHICAL REPRESENTATION OF THE WEIGHTS (A) AND SCORES (B) FOR THE ANALYSES PERFORMED IN THE JABOTICABA SKIN FLOUR AT DIFFERENT STORAGE TIMES IN RELATION TO THE AXES DEFINED BY THE PRINCIPAL COMPONENTS (PC1 AND PC2)

4 CONCLUSION

After 12 months of storage at room temperature, the jaboticaba skin flour did not show significant changes in nutritional parameters and showed a small reduction in antioxidant compounds. It can therefore be considered as an alternative for the enrichment of food products throughout the year.

RESUMO

PROPRIEDADES FÍSICO-QUÍMICAS DA FARINHA DE CASCA DE JABUTICABA ARMAZENADA À TEMPERATURA AMBIENTE

Avaliou-se a estabilidade de farinha de cascas de jabuticaba durante 12 meses de armazenamento, visando estender a utilização dessa farinha durante o ano todo, uma vez que a produção de jabuticaba é sazonal. Os frutos da jabuticaba, *Plinia jaboticaba* (Vell.) Berg, da variedade Sabará, foram coletados maduros e suas cascas secas à temperatura de 45 ^{o}C. As cascas secas foram moídas e armazenadas em frascos hermeticamente fechados e protegidos da luz à temperatura ambiente por 0, 3, 6, 9 e 12 meses. Em cada tempo de armazenamento foram realizadas análises microbiológicas, de composição centesimal, vitamina C, compostos fenólicos, antocianinas, sólidos solúveis, atividade de água, cor e pH da farinha. Verificou-se aumento significativo nos seguintes parâmetros durante os 12 meses de armazenamento da farinha: umidade, 34 %; atividade de água, 31,23 %; coordenadas de cor (a, 12,37 % e b, 24 %); e pH, 7,35 %. Por outro lado, constatou-se decréscimo no seu teor de compostos fenólicos, 9,91 %; antocianinas, 29 % e vitamina C, 20 %. Não se observou diferença significativa nos teores de lipídios, proteínas, cinzas, fibras e sólidos solúveis, assim como não se detectou a presença de micro-organismos em qualquer período de armazenamento da farinha. Concluiu-se que a farinha de casca de jabuticaba não apresentou alteração significativa nos parâmetros nutricionais, ocorrendo pequena redução nos compostos antioxidantes durante os 12 meses de armazenamento. Essa farinha pode ser considerada como alternativa para o enriquecimento de produtos alimentícios durante o ano todo.

PALAVRAS-CHAVE: Plinia jaboticaba; ESTABILIDADE; ESTOCAGEM; CONSTITUINTES QUÍMICOS; FARINHA.

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