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Nutritional properties of yellow mombin (*Spondias mombin* L.) pulp

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ABSTRACT

Yellow mombin (*Spondias mombin* L.) is a tropical fruit with increasing acceptance in both national and international fruit markets. The aim of this work was to evaluate the centesimal composition, mineral content, total phenolics, antioxidant activity, and characterize the carotenoids of frozen yellow mombin pulp. Results indicated that the yellow mombin pulp contained an important amount of potassium and copper. The antioxidant activity and total phenolic values scored 17.5 mmol TEAC g^{-1} and 260 mg galic acid/100 g respectively, higher than those reported for other fruits. Five carotenoids were identified, β-cryptoxanthin, lutein, zeinoxanthin, α and β carotene, being β-cryptoxanthin the major one, accounting for the high level of pro-vitamin A activity in the pulp. A 100 g portion of yellow mombin pulp can provide more than 37% of the recommended daily allowance of vitamin A.

1. Introduction

In the Northeast of Brazil, there are many areas where the climate and the characteristics of the land are especially favorable for the production of tropical fruits. The fruit production and processing in these areas represent important economical activities not only due to the relevant regional commercialization, but also due to the increasing national and international market. The attractiveness of the flavor and aroma of these exotic fruits produced in enormous diversity is mainly responsible for the high acceptance related to their sensory attributes. However, the knowledge of the nutritional value of these fruits has also a great importance and potential contribution for the consumption enhancement, considering the great concern of the consumers worldwide about healthy eating habits (Sloan, 2003) and by associating fruits with a primary source of nutrients and functional compounds. Also, the choice of efficient technological methods for their processing depends on this kind of information.

The yellow mombin (*Spondias mombin* L.) belongs to the Anacardiaceae family and it is found in the tropical areas of America, Asia and Africa and in Brazil mainly in the regions North and Northeast. It is known as *cajá* or *taperebá* in Brazil; *ciruela amarilla* in Mexico and Ecuador; *jobo* in Central America and hogplum or yellow mombin in North America. The fruit is a small ovoid drupe (3 to 5 cm long) with thin yellow skin and a sour–sweet taste (Bosco, Soares, Aguiar Filho, & Barros, 2000).

No commercial orchards occur in Brazil and all fruits are collected from wild plants. The fruit has been harvested not only to supply local market demands in the region of production, but also in other parts of the country where it is highly appreciated and mainly commercialized as frozen pulp. The yellow mombin frozen pulp is one of the most prized in Brazilian markets due to its exotic and appreciated flavor besides its excellent nutritional quality which is more and more valued by consumers. It is used for the preparation of juices, popsicles, ice creams, yogurts and jams (Janick & Paull, 2008; Soares et al., 2006).

However, an extensive and global characterization that points out the actual nutritional value of the pulp of yellow mombin has not yet been done. The aim of the study was to determine the chemical composition and the mineral content, to quantify the total phenolics, the antioxidant activity and to characterize the carotenoids from the frozen pulp of yellow mombin, aiming at contributing to the study of nutritional aspects in order to further exploit the technology of fruits produced in northeastern Brazil and others producing regions in the world.

2. Materials and methods

Frozen non-pasteurized yellow mombin fruit (*Spondias mombin* L.) pulp was provided by a fruit pulp processor from Aracaju (Brazil). The fruits were ripe and uniform regarding the size and color. They were harvested and immediately washed, deseeded and processed with a pulp extractor. The pulp was conditioned in 1 kg plastic bags, sealed, stored at −18 °C. The frozen pulp was transported by plane to

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Embrapa Food Technology, Rio de Janeiro (Brazil) in freezing conditions, which were achieved by using dry ice and an adequate portable thermal food container. Samples have arrived at the laboratory still frozen, and were immediately transferred to freezing chamber at −18 °C where they stayed stored up to 3 months, until analyses were carried out.

2.1. Chemical composition and physicochemical properties

The chemical composition and the physicochemical properties of the yellow mombin pulp were assessed using the standard methods of the Association of Official Analytical Chemists (AOAC, 2005), as follows: water content (920.151), ashes (923.03), fat (922.06), total nitrogen (920.123), dietary fiber (985.29), pH (981.12), titrable acidity (942.15) and soluble solids (932.12). All analyses were made in triplicate.

2.2. Mineral analysis

The minerals analyzed in the yellow mombin pulp were: sodium, magnesium, potassium, phosphorus, calcium, manganese, copper, iron, aluminum, chrome, cobalt, selenium, cadmium, lead, strontium and barium. The digestion of the sample was made by wet ashing and the quantification by atomic spectroscopy and mass spectrometry (ICP-MS, Spectro Analytical Instruments GmbH, Germany) according to the AOAC methods 997.15 and 990.08 (AOAC, 2005). The results were expressed in mg/100 g. All analyses were performed in duplicate.

2.3. Antioxidant activity assay

The antioxidant activity was determined by the TEAC assay following the procedure proposed by Re et al. (1999) using the radical cation $ABTS^{+\bullet}$ (Sigma, St. Louis, MO). The $ABTS^{+\bullet}$ stock solution (7 mM) was prepared using $K_2S_2O_8$ (Sigma, St. Louis, MO) as the oxidant agent. The working solution of $ABTS^{+\bullet}$ was obtained by diluting the stock solution in ethanol to give an absorption of 0.70 ± 0.02 at k = 734 nm. The extraction of the antioxidants was performed in triplicate and in two steps, as follows: the first extraction with methanol (50%) and the second with acetone (70%). It is important to combine extraction cycles with solvents with different polarities in order to maximize the extraction of antioxidant compounds with different polarities (Pérez-Jiménez et al., 2008). The two extracts were combined for the quantification assay. For each session of measurements, a standard curve with trolox was plotted.

The total antioxidant activity assay was carried out on the UV-1800 at 734 nm (Shimadzu, Japan). 30 µl of yellow mombin extracts was added to 3 ml of the ABTS working solution and the decrease in the absorbance was recorded for 6 min. The antioxidant activity was expressed as mg of trolox equivalents per gram.

2.4. Total phenolics assay

The concentration of total phenolics was determined by the Folin–Ciocalteau colorimetric method (George, Brat, Alter, & Amiot, 2005). Measurements were carried out in triplicate and calculations based on a calibration curve obtained with gallic acid. The total phenolics were expressed as milligram of gallic acid equivalents (GAE) per gram of fresh weight.

2.5. Carotenoid assay

Extraction, quantification and characterization of carotenoids were performed according to Rodriguez-Amaya (2001). The carotenoids were extracted with cold acetone and celite and then partitioned to petroleum ether. Saponification was done overnight with 10% KOH methanol to release esterified xanthophylls and to eliminate interfering substances. The saponified extract was washed and filtered through a funnel containing anhydrous sodium sulfate and then analyzed by spectrophotometry (Shimadzu UV-1800, Shimadzu, Japan) to quantify the total carotenoid content. The extract was then concentrated in a rotatory evaporator with temperature under 40 °C and the concentrated extract was used in the separation step. Individual carotenoids were separated by liquid chromatography using a Waters HPLC equipped with a photodiode array detector (Waters, 996), on-line degasser, and an automatic injection (Autosampler 717 Plus) was used. The separation was carried out on a C30 column (YMC Carotenoid 3um (4.6 × 250 mm)), with 80% MeOH 20% methyl t-butyl ether as mobile phase and the temperature of the column settled at 33 °C. The chromatograms were processed at wavelengths of maximum absorption.

Lutein, β-cryptoxanthin, α-carotene and β-carotene standards were extracted and purified from fruits and vegetables rich in carotenoids (data not shown). Zeinoxanthin standard however, was prepared from 60 g frozen pulp of yellow mombin following methodology described by Kimura and Rodriguez-Amaya (2002). Briefly, the saponified carotenoid extract was applied to an open chromatography column packed with celite and MgO (1:1) and eluted with a gradient of acetone and petroleum ether. The third fraction was collected, extracted with acetone and its purity was tested by HPLC. The concentrations of the standard were determined spectrophotometrically using the $A1\%_{1\ cm}$ value of 2636 in hexane. The pro-vitamin A values were calculated according to the conversion factor, whereas 6 µg of β-carotene were equivalent to 1 µg of retinol equivalent (RE), and the activities were related as follows: 100% for β-carotene, 50% for β-cryptoxanthin and for α-carotene (Bauernfeind, 1972).

3. Results and discussion

3.1. Physicochemical analyses' results

According to the Brazilian Legislation (Brasil, 2000), the yellow mombin pulp must have a pH over 2.2, soluble solid content over 9.0 and an acidity of at least 0.90%. Results for the chemical composition and physicochemical properties of yellow mombin pulp are showed in Table 1, and reveal that the pulp used in this study has reached all the legislation requirements. The moisture, fat, ash and protein content and the pH and acidity were within the range found by other authors, only the fiber content of the pulp was slightly higher, 1.87 g/100 g, while the other studies found values ranging from 1.00 to 1.18 g/100 g (Brasil, 2002; Dias, Schwan, & Lima, 2003; Mattieto, 2005; Sacramento & Souza, 2000; Silva, Maia, Oliveira, Figueiredo, & Brasil, 1999). The energy value provided by the yellow mombin, 65.42 kcal/100 g, is similar to that obtained from other tropical fruits as guava and mango (USDA, 2008).

Table 1
Chemical composition and physicochemical properties of the yellow mombin pulp.

Analysis	Mean[a] ± SD
Moisture (g/100 g)	83.66 ± 0.04
Fat (g/100 g)	0.62 ± 0.05
Protein (F = 5.75) (g/100 g)	1.06 ± 0.04
Ash (g/100 g)	0.76 ± 0.01
Carbohidrate (g/100 g)	13.90 ± 0.04
Fiber (g/100 g)	1.87
Energy (Kcal/100 g)	65.42
Total acidity	20.85 ± 0.09
Acidity in citric acid (%)	1.46 ± 0.01
pH	2.83 ± 0.01
Soluble solids (°brix)	14.9 ± 0.1
Brix/acidity (*Ratio*)	10.2 ± 0.1

[a] averaged accross three replications.

The soluble solids found in the pulp were relatively high, since several authors found levels close to 10° Brix (Dias et al., 2003; Silva et al., 1999). Soares (2005) evaluated the physicochemical characteristics of fruits of 14 genotypes of yellow mombin which had average soluble solid levels of 14.06° Brix, acidity as citric acid of 1.56% and a ratio index of 10.41, which were close to those found in this study. This value of ratio is suitable for industrial processing once this index is often used as an indicator of ripeness and developed flavor of fruits and the lower the index, the more acidic and/or less sweet will be the pulp or juice (Hui & Barta, 2006).

The acidity of fruits can vary considerably from one species to another, and while some low acid fruits such as melons, bananas and avocados have an acidity between 0.1 and 0.3%, high acid fruits show acidity between 3 and 8%, like lemon, passion fruit and *umbu* (*Spondias tuberosa*). The yellow mombin can be considered of medium acidity (1.46%) once it varies from 1 to 3% as well as in cherry, strawberry, raspberry and orange (Mattieto, 2005; Nielsen, 2003).

3.2. Mineral content results

Minerals are inorganic elements that remain behind in the ash when food is incinerated. They are usually divided in two groups — macro-minerals and micro-minerals (or trace elements), and also classified as either essential or non-essential, depending on whether or not they are required for human nutrition and have metabolic roles in the body (Reilly, 2002). Fruits generally have in their composition a great variety of vitamins and essential minerals, which makes them a rich contribution to our diet.

The quantification of the minerals found in the yellow mombin pulp is presented in Table 2. Regarding the macro-minerals, Na, Mg, P, K and Ca, the pulp showed low levels of sodium and calcium, minerals normally found in low concentrations in fruits. There was a high content of magnesium, potassium and phosphorus in comparison with other fruits. Albino, Barreto, Coelho, Coelho, and Mendes (1999) confirmed the yellow mombin as a fruit with a high content of potassium, along with jackfruit, soursop, *jenipapo* (*Genipa americana*) and *mangaba* (*Hancornia speciosa*). The phosphorus content is one of the highest among the fruits with levels close to those of *ceriguela* (*Spondias purpurea*), *pequi* (*Caryocar brasiliense*) and passion fruit (NEPA-UNICAMP, 2006). The magnesium content was lower than the one found by Mattieto (2005), 24.33 mg/100 g, although higher than that reported by Leterme, Buldgen, Estrada, and Londoño (2006), 12 mg/100 g. Those differences can be attributed to the origin of the fruit, Para (North of Brazil) and Colombia, respectively, while the fruits in this study were collected from Sergipe (Northeast of Brazil). According to Leterme et al. (2006), the mineral composition is dependent on the fertility conditions of each region, since the minerals are absorbed from the soil, besides genetic factors and the use of fertilizers (Sanchez-Castillo et al., 1998). A portion of 100 g of pulp of yellow mombin is needed for the preparation of 300 ml of the fruit juice, which provides 5.8% of the recommended daily intake (RDI) for magnesium (for adults), 4.6% of the phosphorus RDI and 8.2% of potassium RDI. In addition, 100 g of pulp provide 4% of the RDI for iron for men (Brasil, 1998; USDA, 2002).

Table 2
Mineral content of the yellow mombin pulp.

Minerals	Mean ± SD (mg/100 g)
Sodium (Na)	5.551 ± 2.352
Magnesium (Mg)	15.095 ± 0.863
Phosphorous (P)	32.849 ± 2.401
Potassium (K)	288.276 ± 23.895
Calcium (Ca)	11.038 ± 0.767
Manganese (Mn)	0.025 ± 0.001
Iron (Fe)	0.327 ± 0.001
Copper (Cu)	0.118 ± 0.037
Aluminum (Al)	0.394 ± 0.086
Barium (Ba)	0.069 ± 0.006

Five micro-minerals were quantified in the yellow mombin pulp, including three essential, manganese, iron and copper, and two non-essentials to our body metabolism, barium and aluminum. Mattieto (2005) and Leterme et al. (2006) cite the presence of zinc in the pulp of caja, but in the present study this mineral was not found. Its presence (or absence) may also be related to different growing conditions of plants. The pulp of the yellow mombin showed significant amounts of copper and iron and low manganese content, but both values were well below those found by Mattieto (2005), which were 1.16, 0.18 and 0.35 mg/100 g, respectively.

The micro-minerals zinc, chromium, cobalt, selenium, cadmium, lead and strontium were not detected in the yellow mombin pulp. On the other hand, barium and aluminum were detected, and those two metals are considered toxic to plants and to the human body. However, the amount of barium in the pulp can be considered irrelevant, once it was much lower than the average value found in fruits, 0.5 to 3.1 mg/kg (Kabata-Pendias, 2000).

Amounts of aluminum similar to those found in the yellow mombin pulp were found by Ekholm et al. (2007) in other fruits commercialized in Finland, but the researchers reported that the referred quantity is not relevant, since most of the aluminum in the diet comes from additives and from packages migration. A study conducted in Spain also found high amounts of aluminum (up to 1144 mg/l) in fruit juices (López, Cabrera, Lorenzo, & López, 2002). The presence of aluminum is a strong indicator of acid soils with low fertility (Gerhardsson, Oskarsson, & Skerfving, 1994), characteristic of the region of Tabuleiros Costeiros (Northeast Brazil), where the pulp used in this study came from (Corrêa & Filho, 2001).

3.3. Antioxidant activity and total phenolics results

Antioxidant compounds, including phenolic acids, caroteinds and vitamins, are naturally present in fruits, vegetables, herbs and spices (Ali et al., 2008; Liu, Qiu, Ding, & Yao, 2008; Lu, Yuan, Zeng, & Chen, 2011; Schinella et al., 2009; Sreeramulu & Raghunath, 2010; Vasco, Ruales, & Kamal-Eldin, 2008). It has been hypothesized that bioactive components with antioxidant capacities present in these foods may contributed to lower incidence of cardiovascular disease (Wang, Melnyk, Tsao, & Marcone, 2011). The content of these compounds varies according to the maturation stage, culture practices and processing (Faller & Fialho, 2009; Gayosso-García Sancho, Yahia, & González-Aguilar, 2011; Villa-Rodríguez, Molina-Corral, Ayala-Zavala, Olivas, & González-Aguilar, 2010).

The results of the antioxidant capacity and phenolic compounds are shown in Table 3. One can see that the antioxidant activity of the yellow mombin pulp was 17.47 ± 3.27 mmol TEAC/g. According to Vasco et al. (2008) this result allows us to classify the yellow mombin as a fruit with antioxidant activity above average, along with guava, plum, strawberry and *cherimoya* (*Annona cherimola*). Contreras-Calderón, Calderón-Jaimes, Guerra-Hernández, and García-Villanova (2010) evaluated the antioxidant activity of yellow mombin from Colombie and found 8.60 mmol TEAC/g, which is lower than the quantity found in this study. The antioxidant activity of the yellow mombin was superior to other typical fruits from the Northeast of Brazil as *umbu* (*Spondias tuberosa*) (1.07 mmol TEAC/g), soursop

Table 3
Antioxidant and phenolic content of the yellow mombin pulp.

	Mean ± SD
Antioxidant activity (mmol TEAC/g)	17.47 ± 3.27
Phenolic compounds (mg GAE/100 g)	260.21 ± 11.89

(6.09 mmol TEAC/g), *sapodilla* (*Manilkara zapota*) (0.99 mmol TEAC/g), papaya (7.6 mmol TEAC/g) and pineapple (3.78 mmol TEAC/g) (Sousa, Almeida, Fernandes, Maia, & Magalhaes, 2007) and similar to some brands of the *açai* cherry pulp studied by Santos et al. (2008).

The yellow mombin pulp presented a total phenolic content of 260.21 ± 11.89 mg GAE/100 g, as shown in Table 3, which was superior to that found in most fruit pulps consumed in Brazil. According to Kuskoski, Asuero, Morales, and Fett (2006), *açaí* berry (*Euterpe oleracea*, Mart) has a phenolic content of 136.8 mg GAE/100 g, while guava has 83.1 mg GAE/100 g, strawberry has 132.1 mg GAE/100 g, pineapple has 21.7 mg GAE/100 g, soursop has 84.3 mg GAE/100 g, and passion fruit has 20.2 mg GAE/100 g. In comparison with other exotic fruits, the yellow mombin has a higher total phenolic content than *mamey* (*Pouteria sapota* Jacq. H.E. Moore & Stearn), which was reported to be 28.5 ± 0.6 mg GAE/100 g (Yahia & Ornelas-Paz, 2010). The phenolic content of the yellow mombin is inferior only to those of *acerola* (*Malpighia emarginata*) (580.1 mg GAE/100 g), *camarinha* (*Gaylussacia brasiliensis*) (492.87 mg GAE/100 g) and mango (544 mg GAE/100 g) (Bramorski et al., 2010; Kuskoski et al., 2006).

Other authors have analyzed the phenolic content in the yellow mombin. Vasco et al. (2008) found a value close to the present study (249 mg/100 g), while Filgueiras et al. (2001) and Melo, Maciel, Lima, and Nascimento (2008) found lower values, 150 mg/100 g and 126 mg/100 g, respectively.

Phenolic acids and flavonoids, although are not essential for survival, may provide protection against a number of chronic diseases over the long term consumption (Bravo, 1998). The phenolic acids potentially involved in these beneficial effects are gallic acid, hydroxycinnamates including coumaric acid, caffeic acid, and derivatives such as chlorogenic acid (Crozier et al., 2006; Contreras-Calderón et al. 2010).

3.4. Results on carotenoids

Carotenoids play a very important role in human health and nutrition and can reduce the risk of cancer and coronary disease due to the pro-vitamin A activity of some of them (β-carotene, α-carotene, γ-carotene, and β-cryptoxanthin) (Yahia & Ornelas-Paz, 2010), as have been demonstrated in *in vivo* and *in vitro* studies (Stahl & Sies, 2005; Yuan, Stram, Arakawa, Lee, & Yu, 2003).

Fig. 1 shows the HPLC chromatogram of the isolated zeinoxanthin standard and the spectrogram confirming the identity of the peak. The purity calculated as the area percentage of the carotenoid peak in relation to the total area was 99.6% which was considered highly satisfactory. The standard curve passed through the origin and showed linearity, presenting correlation coefficient of 0.9993. Five different carotenoids were identified in the pulp (Fig. 2), β-cryptoxanthin being present in the highest amount, with 48% of the total, followed by lutein, α-zeinoxanthin and β-carotene. Yellow mombin carotenoids were first identified and quantified by Rodriguez-Amaya and Kimura (1989). This study was able to differentiate α-cryptoxanthin from zeinoxanthin through chemical tests; despite the referred authors' report that they are often misidentified. The correct identification of these carotenoids is essential, since the α-cryptoxanthin has a pro-vitamin A activity, while zeinoxanthin doesn't have.

Among these carotenoids, only the α-carotene, β-carotene and β-cryptoxanthin have pro-vitamin activity (Gayosso-García Sancho et al., 2011). The calculation of pro-vitamin A value was made from the activity of each precursor carotenoid, using a ratio of 1 RE (retinol equivalent) corresponding to 6 μg of β-carotene or 12 μg of α-carotene and β-cryptoxanthin. The levels of carotenoids identified in the pulp of the yellow mombin are shown in Table 4.

The content of carotenoids in the pulp was higher than those reported by Rodriguez-Amaya and Kimura (1989) who obtained 210 μg/100 g of α-carotene, 260 μg/100 g of β-carotene, 170 μg/100 g of zeinoxanthin, 830 μg/100 g of β-cryptoxanthin and lutein 200 μg/100 g. Hamano and Mercadante (2001) found values close to the present work for the content of lutein, 510–616 μg/100 g, but the levels of other carotenoids ranged from 364 to 379 μg/100 g for zeinoxanthin, 597–819 μg/100 g for β-criptoxanthin, 79–148 μg/100 g for α-caroteno and 164–212 μg/100 g for β-caroteno. These results show that the pulp of yellow mombin can be considered a source of pro-vitamin A, since a portion of 100 g provides 37.2% of the RDI for adults (Brasil, 1998).

4. Conclusion

Based on these results, we conclude that the pulp of yellow mombin has high levels of potassium, magnesium, phosphorus and copper when compared to other fruits. It also presents higher levels of phenolics and antioxidant compounds than the majority of fruits consumed in Brazil,

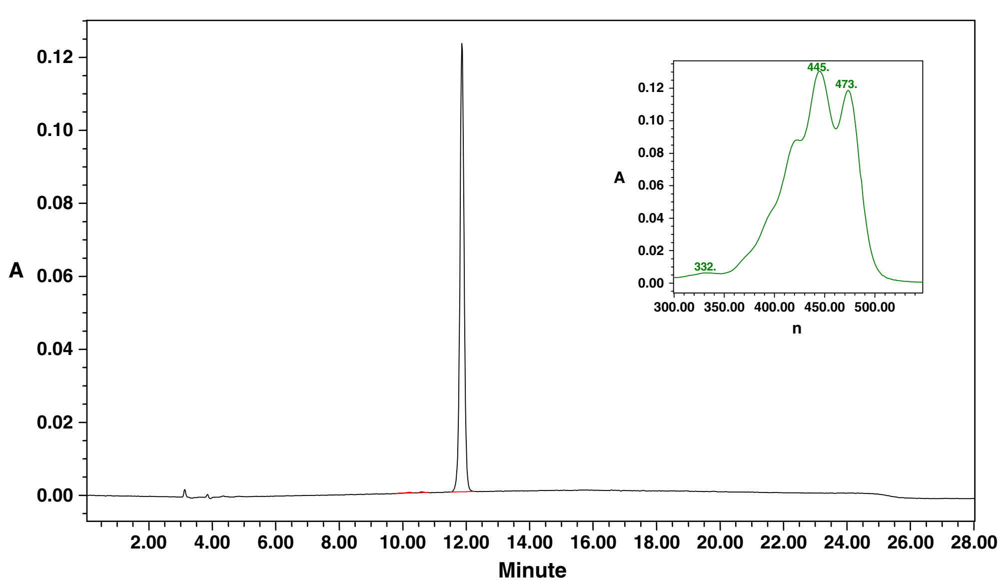

Fig. 1. 1.HPLC chromatogram of zeinoxanthin standard isolated from yellow mombin.

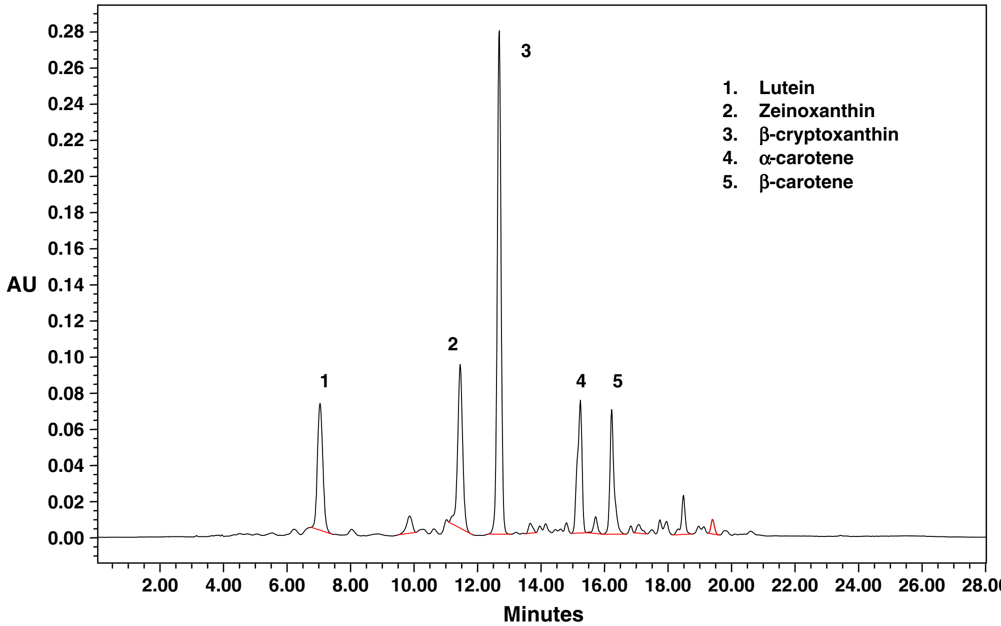

Fig. 2. HPLC chromatogram of yellow mombin pulp.

Table 4
Carotenoid content of the yellow mombin pulp.

	Mean ± SD
Total carotenoids (μg/100 g)	4869.5 ± 157.7
Lutein (μg/100 g)	634 ± 0.7
Zeinoxanthin (μg/100 g)	547.5 ± 6.4
β-criptoxanthin (μg/100 g)	1708.5 ± 21.9
α-carotene (μg/100 g)	340 ± 5.7
β-carotene (μg/100 g)	314 ± 9.9
Pro-vitamine A (RE/100 g)	223 ± 3

showing a high content of carotenoids as well. Briefly, it has a composition that confers high nutritional and functional value, which can be associated with the prevention of various diseases. One can say that it may have a promising place in the market and further studies focusing on sensory properties and consumer acceptance of yellow mombin-based products are recommended.

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