

## Improvement of phytochemicals compounds content in mango jelly with the incorporation of co-products generated in the pulp processing

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### Abstract

The objective of this work was to evaluate the physicochemical parameters of mango jellies with different concentrations (0% to 3.5%) of mango peel powder obtained from residues generated in the processing of “Keitt” mango (*Mangifera indica* L.). The results showed a 1.3- to 1.6-fold increase in the concentration of carotenoids and a 3.2- to 4.8-fold increase in the concentration of phenolic compounds. Regarding colour results, all samples incorporating by-products showed darkening visible to the human eye when compared to samples without by-product. The pH, total soluble solids, total titratable acidity and moisture were similar between jellies produced with and without the addition of by-product. Thus, the use of mango peel powder in the formulation of mango jelly was shown to be a good alternative for increasing the content of phytochemical compounds in thermally processed products.

### Keywords

*Mangifera indica* L.

Jelly

Carotenoids

Phenolic compounds

Mango peel powder

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### Introduction

Mango is one of the most widely cultivated fruits in the world and currently ranks among the ten most widely planted tropical fruit crops, being found in more than 90 countries. Allied to its economic importance, mango also possesses favourable nutritional characteristics as a source of phenolic compounds, carotenoids and vitamin C, excellent flavour, aroma and colour, which give it high acceptability among consumers. However, during processing, the peel is not exploited and represents 10-30% of the initial weight of the fruit. Therefore, discovering ways of employing this residue is of great economic and environmental interest and also represents a new source of phytochemical compounds.

Several studies have focused on the utilisation of post-harvest residues of crops, including residues produced during mango processing. These by-products could be valuable sources of dietary fibre, antioxidant compounds, and single carbohydrates (Larrauri *et al.*, 1996; Berardini *et al.*, 2005; Ajila *et al.*, 2007; Ribeiro *et al.*, 2008; Kim *et al.*, 2010; Ajila *et al.*, 2010a; Ajila *et al.* 2010b; Ajila and Prasada Rao 2013; D'Alessandro *et al.*, 2013; García-Magaña *et al.*, 2013; Ruiz-Montañez *et al.*, 2014; Jahurul, 2015).

Keitt mangos are commonly used for juices, nectars and candies. However, there are few studies on the use of mango peel in food formulations, with most studies focusing on mango candies and bakery product substituted, despite being a widely consumed product (Vergara-Valencia *et al.*, 2007; Ajila *et al.*, 2008; Damiani *et al.*, 2008; Damiani *et al.*, 2009; Ajila *et al.*, 2010a; Ramírez-Maganda *et al.*, 2015). The addition of mango peel powder to food products can improve the products' nutritional content by increasing dietary fibre and phytochemical levels without reducing their quality.

The development of foodstuffs enriched with co-products have been increased in the last years; as examples may be mentioned the incorporation of banana peel in semisolid jelly (Rasidek *et al.*, 2016), pomegranate peels in reduced-sugar juice jelly (Ventura *et al.*, 2013), watermelon rinds and sharlyn melon peels in cakes (Hanan *et al.*, 2013), stalks and peels of vegetables in salted pies (Alves *et al.*, 2007), and watermelon peel in sweets (Santana and Oliveira, 2005). Thus, this work aimed at extending the state-of-the-art by developing a new foodstuff containing mango peel powder obtained from peel, which is considered a by-product and to analyse certain physicochemical parameters of the produced mango jellies.

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## Material and Methods

### Preparation of mango jelly with incorporation of its co-product

The mangoes (Keitt cultivate) used in this study were purchased at a local market (Porto Alegre, RS, Brazil). Mangoes were selected at harvest maturity, and excessively green fruits or fruits spoiled, rotten or attacked by insects and larvae were excluded. The selected fruits were then sanitised by bath immersion in chlorinated water (10 ppm sodium hypochlorite water for 20 min). After this process, the fruits were peel and the pulp was removed; thus, the raw material was divided into two distinct segments: mango pulp and peel. The peel was removed using a sharp knife, and the underlying pulp was removed by gently scraping the fruits with the knife's blunt edge. The pulp was ground in a blender and stored in polyethylene bags at freezing temperatures. The mango peel was dried in an oven with air circulation at 40°C for 72 h. After drying, the samples were milled in a domestic blender as many times as was necessary to pass the samples through a 100-mesh screen and stored in sealed plastic bags at -40°C.

Jellies were prepared according to the experimental plan reported in Table 1. Initially, pulp, mango peel powder (concentrations of 0, 1.5, 2.5 and 3.5%) and half of the prescribed quantity of commercial sucrose were placed in a beaker. These ingredients were homogenised and heated on a hotplate (100°C) under magnetic stirring. The remaining sucrose was added at the boiling point at the onset of mixing. The jellies reached an average temperature of 90°C. The determination of the end point of cooking was determined by measuring the refractive index, which had to reach 65°Brix. The pH of the jellies was adjusted to 3.4 by the addition of citric acid (Basu and Shivhare, 2010) and measured using a pH meter. The jellies prepared were then placed in sterilised glass containers (50 g) and cooled to room temperature. The products were then immediately stocked at 7±1°C for 24 h prior to their analysis.

### Physicochemical quality parameters

The jellies and mango peel powder were analysed according to the following parameters: moisture content (g/100 g), which was determined by drying the samples at 105°C until they reached a constant weight (AOAC 1997); ash content (g/100 g), which was measured by heating the samples in an oven at 550°C for 6 h; total soluble solids (°Brix), which was measured directly using an Abbe refractometer at 20°C (Carl Zeiss, Jena); pH values, which were

Table 1. Formulations of mango jelly without and with incorporation of mango peel powder (1.5, 2.5 and 3.5%) at pH 3.4.

Treatments*	mango peel powder (g)	mango pulp (g)	sucrose (g)	citric acid (g)
J0	0	100	100	0.88
J1.5	3	97	100	0.80
J2.5	5	95	100	0.88
J3.5	7	93	100	0.78

\*treatments: J0: mango jellies without mango peel powder; J1.5: mango jelly with incorporation of 1.5% mango peel powder; J2.5: mango jelly with incorporation of 2.5% mango peel powder; J3.5: mango jelly with incorporation of 3.5% mango peel powder.

obtained by using a digital pH meter (Quimis Q400 M, São Paulo, Brazil); and total titratable acidity was determined by titration with 0.1 M sodium hydroxide until the samples reached pH 8.1 and expressed as g/100 g of citric acid (AOAC, 1997). The water activity was determined in a TH-500 Sprint Novasina Thermoconstanter (Pfäffikon, Switzerland) at 25°C, and the particle size distribution was determined using a MasterSizer Laser Diffraction Particle Size Analyzer (Malvern Instrument Ltd, Malvern, England). The phenolic compound extraction procedure was carried out in accordance with Kim *et al.* (2003) with minor modifications: first, 2 g of sample was extracted with 10 mL methanol/water solution (80:20, v/v) in a vortex mixer for 10 min, followed by 10 min of centrifugation (5200 g). This procedure was repeated five times. The same procedure was then repeated five times with acetone/water (70:30, v/v). The supernatants were combined and made up to 100 mL with distilled water. The phenolic compounds were determined by the Folin-Ciocalteu method described by Singleton and Rossi (1965) and expressed as g gallic acid equivalent per 100 g.

The carotenoids in the jellies were exhaustively extracted with cold acetone, partitioned into petroleum ether and washed with distilled water. The quantification of total carotenoids was carried out using a spectrophotometer. The concentration of total carotenoids was calculated by Beer's law at 442 nm, assuming an absorptivity coefficient of 2400, with respect to an all-*trans*-violaxanthin standard (Britton *et al.*, 1995).

Colour was quantified through CIELAB parameters ( $L^*$ ,  $a^*$  and  $b^*$ ) obtained by a colorimeter (Minolta, model CR 400, Konica Minolta Sensing,

Japan) with a D65 light source using an observation angle of 10°. In the CIELAB colour space, the colour coordinates  $a^*$  and  $b^*$  and a psychometric index of lightness  $L^*$  are defined. The coordinate  $a^*$  is positive for reddish colours and negative for greenish ones. The coordinate  $b^*$  is positive for yellowish colours and negative for bluish ones. The coordinate  $L^*$  is an estimation of luminosity and allows any given colour to be made equivalent to a component on a grey scale between black ( $L^*=0$ ) and white ( $L^*=100$ ). Additionally, values of  $C^*_{ab}$  (chroma) and total colour difference ( $\Delta E^*$ ) were calculated according to equations 1, 2 and 3, respectively.

$$C^*_{ab} = [(a^*)^2 + (b^*)^2]^{1/2} \tag{1}$$

$$h_{ab} = \arctan(b^*/a^*) \quad \text{when } +a^* \text{ and } +b^* \text{ (quadrant I)} \tag{2}$$

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \tag{3}$$

**Results and Discussion**

To evaluate the effect of the partial replacement of mango pulp by mango peel powder in jellies, the results of certain quality parameters are shown in Table 2. Additionally, physicochemical characteristics relevant to the quality of mango peel powder are presented in the text that follows. Total soluble solids consist primarily of sugars; other soluble solids in mango include organic acids and soluble pectin. The results obtained for mango pulp without added peel in all experiments remained between 11 and 13°Brix. After the addition of different amounts of peel powder, the total soluble solids ranged from 15 to 17°Brix. However, regardless of the proposed formulation, all of the jellies were concentrated until they showed the content of 65°Brix.

Increasing the amount of mango powder, the cooking time had to be prolonged to reach 65°Brix. Nevertheless, the formulations with different concentrations of mango peel powder showed similar levels of moisture. The pH of the jellies was corrected by the addition of citric acid dissolved in drinking water until it reached a value between 3.4 and 3.5, as indicated in the materials and methods section. pH is an important parameter to monitor because it can slow the growth of microorganisms and also promote the pectin gelation (Basu and Shivhare, 2010). The measured acidity levels, expressed as a percentage of citric acid, were between 0.74 and 0.80%, with very little variation among the different formulations. Benevides *et al.* (2008) and Granada *et al.* (2005) observed values that ranged between 0.09 and 2.90% citric acid in mango jellies. Regarding the

Table 2. Quality parameters of mango jelly preparations with incorporation of mango peel powder.

Treatments <sup>a</sup>	J0	J1.5	J2.5	J3.5
moisture (g/100 g)	25.0±0.4	20.3±0.3	26.6±0.1	26.7±0.2
soluble solids (°Brix)	65	65	65	65
pH	3.35±0.01	3.43±0.03	3.49±0.01	3.50±0.01
total acidity (g citric acid/100 g)	0.74±0.08	0.78±0.03	0.79±0.02	0.79±0.02
total carotenoids (µg/g all-trans-violaxanthin/g)	5.79±0.15	8.48±0.29	7.56±0.43	9.06±0.54
total phenolic content (g gallic acid/100 g)	17.95±2.61	58.16±3.63	79.83±8.24	85.66±4.40
$L^*$	29.68	25.9	26.2	25.4
$a^*$	3.27	2.36	1.43	1.69
$b^*$	14.09	7.9	5.36	6.37
$C^*_{ab}$	14.46	8.24	5.55	6.59
$h_{ab}$	76.93	73.36	75.06	75.14

<sup>a</sup>treatments: J0: mango jellies without mango peel powder; J3: mango jelly with incorporation of 1.5% mango peel powder; J2.5: mango jelly with incorporation of 2.5% mango peel powder; J3.5: mango jelly with incorporation of 3.5% mango peel powder.

characteristics of the peel mango powder, the powders showed an average particle diameter of 196.60 µm, moisture content of 7.59±0.56, water activity of 0.448, ash content of 3.14±0.08%, pH of 2.65±0.13, total acidity of 0.43±0.05%,  $L^*$  of 47.42±0.72,  $C^*_{ab}$  of 33.01±0.34 and  $h_{ab}$  of 1.44±0.

In all formulations, the UV-visible spectra obtained during the analysis of the total carotenoids in different samples showed the  $\lambda_{max}$  ranged from 430 to 450 nm. Although the carotenoids extracted were a mixture of carotenoids, it was observed that the spectrum was very similar to that presented in the literature for the UV-visible spectrum of all-trans-violaxanthin. Mercadante and Rodriguez-Amaya (1998) studied the profile of carotenoids from Keitt mango produced in Brazil. In their study, the authors analysed the carotenoid composition by high-efficiency liquid chromatography with a photodiode array detector and mass spectrometry and observed that the major carotenoid was all-trans-violaxanthin, which constituted 40% of total carotenoids, followed by all-trans-β-carotene, which constituted 26% and 19% of the isomers 13 and 9-cis-violaxanthin. The addition of mango peel powder in the formulation of the jellies did not promote changes in UV-visible spectrum features such as the maximum absorption wavelength, spectral fine structure or “cis peak” intensity. A 1.3- to 1.6-fold increase in the concentration of carotenoids in treatments with

different levels of peel powder substitution was observed due to the presence of carotenoids in the mango peel powder. The degradation of carotenoids was affected by the type and physical condition of the carotenoids present, available oxygen, light, metal, acids, enzymes, peroxides and especially high temperature. As a result, the increase in the peel content was not followed by a linear increase in total carotenoids measured by spectrophotometry because longer heating times were necessary to cook the jellies containing higher powder contents. According to Table 2, the values of total carotenoids remains constant with 1.5, 2.5 and 3.5 % of peel, i.e, the samples did not show large differences.

As previously mentioned, another class of phytochemical compounds analysed corresponded to phenolic compounds that are related to antioxidant activity. Dorta *et al.* (2014) demonstrated the presence of five phenolic families in Keitt mango extracts: gallates and gallotannins; flavonoids, mainly quercetin derivatives; ellagic acid and its derivatives; xanthenes, principally mangiferin; and benzophenones and their derivatives. The phenolic content can be used as an indicator of antioxidant capacity and thus as a preliminary way to screen for any intended product as a natural source of antioxidants in functional foods (Viuda-Martos *et al.*, 2011). The phenolic content of the mango peel powders, determined by the Folin-Ciocalteu method, was  $33.84 \pm 1.0$ , whereas that of the mango jellies varied from 17.95 g/100g (J0) to 85.66 g/kg (J3.5), expressed in gallic acid (Table 2). Therefore, the concentration of phenolic compounds increased 3.2- to 4.8-fold with the mango peel powder content. It is important to note that the Folin-Ciocalteu analysis method is not specific to phenolic groups because it suffers interference from other reducing substances, such as reducing sugars and citric acid, that may overestimate the quantification results. However, it was verified that these factors did not cause any interference.

Other authors have also observed an increase in the content of phenolic compounds with the addition of mango peel in products such as biscuits and macaroni. Soft-dough biscuits were prepared using different contents (5.0, 7.5, 10.0, 15.0 and 20.0%) of mango peel powder by Ajila *et al.* (2008), and it was observed that the content of polyphenols increased 8.3-fold and the carotenoid content increased 14.5-fold with the addition of 20% mango peel powder. Ajila *et al.* (2010a) studied the incorporation of 2.5, 5.0 and 7.5% peel mango powder and also observed a 3.9-fold increase in the phenolic compounds content.

Table 2 shows the colour parameters ( $L^*$ ,  $a^*$ ,  $b^*$ ,

$C_{ab}^*$  and  $h_{ab}$ ) and demonstrates that jellies without added peel powder had a lighter colour than the other jellies. The substitution of pulp for peel powder caused an increase in darkness due to the colour of the peel and due to the higher cooking temperature applied, which promoted sugar caramelisation. All of the jellies were located in the 2<sup>nd</sup> quadrant of the CIELAB  $a^*b^*$  plane (with values of  $a^*$  ranging from 1.43 to 3.27 and values of  $b^*$  ranging from 5.36 to 14.09) and were classified as being yellowish. Concerning lightness ( $L^*$ ), it was observed that the treatment without peel powder yielded a value of 29.6, whereas all treatments involving the addition of peel powder yielded similar values, between 25.4 and 26.2 - with lower luminosity. Similarly, the differences in chroma ( $C_{ab}^*$ ) values and hue angle ( $h_{ab}$ ) also varied among the samples. Because the jellies were yellowish, the values of  $C_{ab}^*$  were very similar to those described for  $b^*$ .  $C_{ab}^*$  and  $h_{ab}$  are parameters used to quantify and qualify colour, respectively. The colour properties of the mango peel powders ( $L^*$   $47.42 \pm 0.72$ ,  $C_{ab}^*$   $33.01 \pm 0.34$  and  $h_{ab}$   $1.44 \pm 0$ ) demonstrated the powders' suitability to serve as an ingredient in a large variety of food products, especially pasta, breads, desserts biscuits and dairy products. The results obtained for colour without the addition of peel powder were very similar to the values obtained by Damiani *et al.* (2008), who examined the colour of sweet mango. The values of  $L^*$ ,  $a^*$  and  $b^*$  obtained were 28.08, 15.3 and 8.5, respectively.

The total colour difference ( $\Delta E^*$ ) are dependent on the differences in the colour coordinates  $L^*$ ,  $a^*$  and  $b^*$  (Equation 3) and are related to colour changes perceived by the human eye. Lee and Coates (2003) reported that a value of  $\Delta E^*$  equal to or greater than two indicates that the change can be detected by the human eye. Thus, all jellies with added mango peel powder showed variations in colour perceptible to the human eye when compared to jellies not treated with mango peel powder. Jellies containing 1.5%, 2.5% and 3.5% peel mango powder showed overall colour differences of 7.26, 9.57 and 8.96, respectively.

## Conclusion

The present work demonstrates that mango jelly with co-product of mango could be potentially used to improve the nutritional quality of jellies, being an alternative to reduce waste by-products from the food industry. However, further analyses and studies should be performed to further characterise the peel powder added and the jellies developed.

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