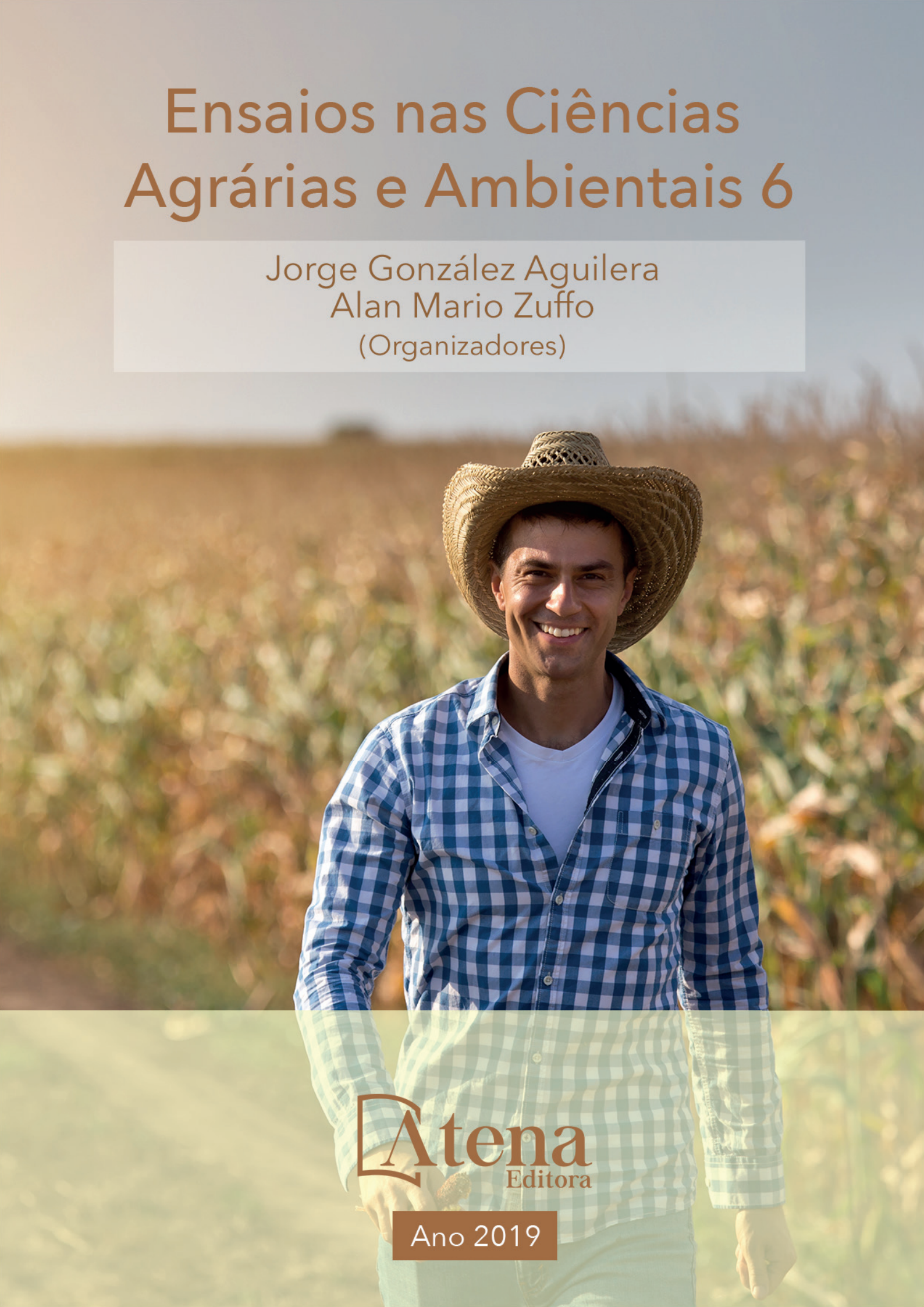
Ensaios nas Ciências Agrárias e Ambientais 6

Jorge González Aguilera
Alan Mario Zuffo
(Organizadores)



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APRESENTAÇÃO

A obra "*Ensaios nas Ciências Agrárias e Ambientais*" aborda uma série de livros de publicação da Atena Editora, em seu Volume VI, apresenta, em seus 21 capítulos, conhecimentos aplicados nas Ciências Agrárias com um grande apelo Ambiental.

O manejo adequado dos recursos naturais disponíveis na natureza é importante para termos uma agricultura sustentável. Deste modo, a necessidade atual por produzir alimentos aliada à necessidade de preservação e reaproveitamento de recursos naturais, constitui um campo de conhecimento dos mais importantes no âmbito das pesquisas científicas atuais, gerando uma crescente demanda por profissionais atuantes nessas áreas, assim como, de atividades de extensionismo que levem estas descobertas até o conhecimento e aplicação dos produtores.

As descobertas atuais têm promovido o incremento da produção e a produtividade nos diversos cultivos de lavoura. Nesse sentido, as tecnologias e manejos estão sendo atualizadas e, as constantes mudanças permitem os avanços na Ciências Agrárias de hoje. O avanço tecnológico, pode garantir a demanda crescente por alimentos em conjunto com a sustentabilidade socioambiental.

Este volume traz artigos alinhados com a produção agrícola sustentável, ao tratar de temas relacionados com produção e respostas de frutais, forrageiras, hortaliças e florestais. Temas contemporâneos que abordam o melhor uso de fontes nitrogenadas, assim como, adubos biológicos e responsabilidade socioambientais tem especial apelo, conforme a discussão da sustentabilidade da produção agropecuária e da preservação dos recursos naturais.

Aos autores dos diversos capítulos, pela dedicação e esforços sem limites, que viabilizaram esta obra que retrata os recentes avanços científicos e tecnológicos nas Ciências Agrárias e Ambientais, os agradecimentos dos Organizadores e da Atena Editora.

Por fim, esperamos que este livro possa colaborar e instigar aos professionais das Ciências Agrárias e áreas afins, trazer os conhecimentos gerados nas universidades por professores e estudantes, e pesquisadores na constante busca de novas tecnologias e manejos que contribuíam ao aumento produtivo de nossas lavouras, assim, garantir incremento quantitativos e qualitativos na produção de alimentos para as futuras gerações de forma sustentável.

Jorge González Aguilera
Alan Mario Zuffo

SUMÁRIO

CAPÍTULO 4

MICROPARTICLES OF PURPLE BRAZILIAN CHERRY JUICE: CHARACTERIZATION, RELEASE PROFILE AND FOOD APPLICATION

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RESUMO: O objetivo do estudo foi microencapsular suco de pitanga roxa pela técnica de liofilização. Goma xantana, quitosana e um hidrogel formado pela mistura de ambas foram utilizados como materiais de parede. Esses polímeros isolados são amplamente utilizados na encapsulação, no entanto, quando misturados podem apresentar maior eficiência. Foi avaliada a eficiência de encapsulação, comportamento térmico, perfil microestrutural e cor das micropartículas, bem como o perfil de liberação dos compostos encapsulados em fluidos que simulam condições gastrointestinais, antes e após sua aplicação em bolos. A encapsulação foi confirmada pela eficiência de encapsulação e pelas técnicas de DSC e raios-X. A goma xantana proporcionou a maior eficiência de encapsulação para ambos os grupos de compostos e apresentou as características desejadas de liberação de carotenoides nos fluidos que simulam condições gastrointestinais. A liberação de compostos fenólicos foi alta independente do material de parede. As micropartículas influenciaram a cor dos bolos e a goma xantana também liberou os compostos encapsulados de forma mais adequada após a aplicação em bolos.

PALAVRAS-CHAVE: microencapsulação; compostos bioativos; carotenoids; compostos fenólicos; bolo.

ABSTRACT: The aim of the study was to microencapsulate purple cherry juice by lyophilization technique. Xanthan gum, chitosan and xanthan gum-chitosan hydrogel were used as wall materials. These isolated polymers

are widely used in encapsulation, and by blending these polymers can enhance their efficiency. Encapsulation efficiency, thermal behavior, microstructural profile, color and release profile in fluids that simulate gastrointestinal conditions, before and after the application in cakes were evaluated. The encapsulation was confirmed by the encapsulation efficiency and by the techniques of DSC and X-ray. Xanthan gum provided the highest encapsulation efficiency for both groups of compounds and showed desired characteristics of the carotenoids released in simulated fluids. The release of phenolic compounds was high. Microparticles influenced the color of the cakes and xanthan gum that released the encapsulated compounds more adequately after the application in cakes.
KEYWORDS: microencapsulation; bioactive compounds; carotenoids; phenolic compounds; cake.

1 I INTRODUCTION

The Brazilian cherry tree is a native shrub from Brazil that is widely distributed in South America, which produces rounded fruits, called 'pitanga' or 'Brazilian cherry' (*Eugenia uniflora* L.). The fruit has approximately 3 cm in diameter, intense aroma, sweet sour taste and coloration ranging from orange to purple. These fruits have high content of bioactive compounds such as carotenoids and phenolic compounds (LIRA JUNIOR *et al*., 2007).

Carotenoids are a group of pigments widely distributed in nature that is characterized by having tetraterpenic structures. They are water-insoluble compounds that exhibit colors ranging from yellow to red, which cause pigmentation in a great number of fruits, leaves and flowers (RODRIGUEZ-AMAYA, 1997). The phenolic compounds contain in their chemical structure one or more hydroxyl groups bonded to an aromatic hydrocarbon group. These water-soluble compounds are classified as flavonoids and non-flavonoids, and they provide color, astringency, aroma and oxidative stability to many types of foods. Many of these compounds show high antioxidant capacity, but they are unstable at high temperatures and in the presence of light (JOHN; SHAHIDI, 2010).

The microencapsulation can be a way to increase the stability of phenolic compounds and carotenoids. The technique consists of packing particles such as pigments and phenolic compounds in small capsules that besides protecting the encapsulated material, enables its release of a controlled way under specific conditions (FAVARO-TRINDADE *et al*., 2008). Carbohydrates, proteins and lipids may be used as wall materials.

A polysaccharide widely used as wall material is the chitosan, which is a copolymer composed by 2-amino-2-deoxy-D-glucose and 2-acetamido-2-deoxy-D-glucose which are linked by β-1, 4. The chitosan composition varies depending by the residual degree of deacetylation. It is considered a polycationic polymer due to the presence of amino

groups in its structure. It has been used for the encapsulation of natural dyes (PARIZE *et al.*, 2008) and antioxidants, such as phenolic compounds present in olive leaf extracts (KOSARAJU *et al.*, 2006), and blackberry extracts (DA ROSA *et al.*, 2014).

Xanthan gum is an extracellular polysaccharide produced by microorganisms of the species *Xanthomonas*, which is commercially produced by *Xanthomonas campestris*. Structurally, this gum is a heteropolysaccharide, and its primary structure is a chain composed by units of β-D-glucose linked by β 1-4, containing branching formed by β-D-mannose - 1,4- β -D-glucuronic acid - 1,2-α-D-mannose, and may also contain pyruvic and acetic acid. This gum is considered an anionic polymer due to the presence of carboxylic groups in its structure (GARCIA-OCHOA *et al.*, 2000). The Xanthan gum has been employed as encapsulating material for extracts of blackberry which contains phenolic compounds (DA ROSA *et al.*, 2014).

The hydrogel is formed through interactions between the amino groups of the chitosan and the carboxylic groups of the xanthan gum, resulting in an insoluble polyelectrolyte gel (ARGIN-SOYSAL *et al.*, 2009). The hydrogel formed by the synergistic interaction between xanthan gum and chitosan has been used for encapsulation of blackberry extracts containing phenolic compounds (DA ROSA *et al.*, 2014). Some studies also suggest that these hydrogels may have the characteristic of controlled-release (KOOP *et al.*, 2009).

Applications of encapsulated materials in foods include providing supplements, changes in solubility, taste, texture and color, and also by acting as sources of antioxidants and antimicrobials agents. However, the studies relating the application of encapsulated compounds in foods generally only covers the characteristics of the microparticles in the product, evaluating the influence on its color and stability, but do not evaluate the release profile simulating gastrointestinal conditions after the incorporation of the encapsulated compounds into the food matrix.

Therefore, the aim of this study was to microencapsulate purple Brazilian cherry juice, which is rich in carotenoids and phenolic compounds, by using xanthan gum, chitosan and xanthan gum-chitosan hydrogel as wall materials, to characterize the microparticles, to apply the microparticles in cakes and to evaluate the release profile in fluids that simulate gastrointestinal conditions.

2 I MATERIAL AND METHODS

Purple Brazilian cherry juice extraction

Purple Brazilian cherry juice (J) was extracted with a fruit centrifuge (Britânia BRCT 800), conditioned in a polyethylene terephthalate bottle and stored in an ultrafreezer at -80 ºC.

Xanthan-chitosan hydrogel (H) preparation

The xanthan-chitosan hydrogel was obtained according the method described by Da Rosa *et al*. (2014). Approximately 6.5 g of chitosan were dissolved in 300 mL of HCl (0.1 M) under constant stirring, during 2 h. The solution was neutralized with NaOH 0.2 M; than the volume was completed to 1000 mL with distilled water and the pH was adjusted to 5.6. The same concentration of xanthan was dissolved in 1000 mL of distilled water. The hidrogel was obtained by mixing the two solutions and stirring for 10 min; and then it was filtered in a kitazato with paper filter (400 mm) and after lyophilized in LIOBRAS L101.

Preparation of the microparticles and of the physical mixtures (PM)

The microencapsulation of purple Brazilian cherry juice using xanthan (X), chitosan (C) and hydrogel (H) as wall materials was performed by lyophilization technique, following the method described by Pralhad and Rajendrakumar (2004) and Laine *et al*. (2008), adapted by Rutz *et al*. (2013). The microparticles were prepared by first dissolving the wall materials and then adding juice at the proportion of 1:1 to solid rates. The mixtures were stirred for 3 hours, frozen at -80 ºC and then lyophilized (LIOBRAS L101). Physical mixtures were made by homogenizing the lyophilized juice with the respective wall material (X, C and H) by mortar and pestle at proportion of 1:1 w/w.

Encapsulation efficiency (EE)

Encapsulation efficiency of the carotenoids followed the method described by Sutter *et al*. (2007). Carotenoids on the microparticles' surface were quantified by adding 0.1 g of the sample and 5 mL of hexane in a test tube, which was stirred by vortex for 10 s, centrifuged at 3420 × g for 10 min, and finally the supernatant was separated. Total carotenoids within and outside of the microparticles were quantified by the dispersion of microparticles in 5 mL hexane, stirred strongly for total removal of carotenoids and filtered with 10 mL hexane. The two fractions were evaluated by spectrophotometer (JENWAY 6705 UV/Vis.) at 470 nm using hexane as control.

Encapsulation efficiency of phenolic compounds was performed following the method described by Deladino *et al*. (2008) and Laine *et al*. (2008), with few modifications. The quantification of the compounds on the surface was obtained by weighing 0.1 g of microparticles, adding 5 mL methanol, stirring in a vortex for 10 s and centrifuged at 3420 × g for 10 min. The methanol fraction was removed. Total compounds within and outside of the microparticles were quantified by weighing 0.1 g of the microparticles, adding 5 mL water when gums were used (LAINE *et al*., 2008) and 5 mL hydrochloric acid 0.1 M for chitosan microparticles (KOSARAJU *et al*., 2006) to break up the particles. The two collected fractions were evaluated for total phenolic compounds following the Folin–Ciocalteau methodology (SWAIN, HILLIS, 1959). The

method consisted of adding 4 mL of distilled water, 250 μL of extract and 250 μL of Folin–Ciocalteau 0.25 M solution in a Falcon tube, stirred and left to react for 3 min. Further, 500 μL of sodium carbonate 1 M were added, left to react for 2 h and read in spectrophotometer (JENWAY 6705 UV/Vis.) at 725 nm. The encapsulation efficiency was expressed in percentage of the encapsulated compounds, which was calculated by equation 1.

$$\%EE = \frac{total\ compounds - surface\ compounds}{total\ compounds} \times 100 \quad \text{(Eq.1)}$$

Differential Scanning Calorimetry (DSC) and X-ray diffractometry

DSC analysis of the purple Brazilian cherry juice, xanthan, chitosan and hydrogel; of the physical mixtures of juice and xanthan gum (PMJX), juice and chitosan (PMJC) and juice and hydrogel (PMJH); and of the microparticles of juice and xanthan gum (JX), juice and chitosan (JC) and juice and hydrogel (JH), were performed using a DSC Q20 TA Instruments. Further, 10 mg of each sample were warmed in aluminum containers at a rate of 10 ºC min^{-1}, between 25 and 280 ˚C, with a 40 mL min–1 nitrogen flow.

Microstructural profile of purple Brazilian cherry juice, xanthan, chitosan and hydrogel; of the physical mixtures of juice and xanthan gum (PMJX), juice and chitosan (PMJC) and juice and hydrogel (PMJH); and of the microparticles of juice and xanthan gum (JX), juice and chitosan (JC) and juice and hydrogel (JH), were characterized by X-ray diffractometry (X'pert PRO Multi-Purpose, PanAnalytical) in which the x-ray source was the radiation of Cu Kα (λ = 1.5418 Â), with 45 kV and 40 mA, measured at angle 2θ, ranging between 10 and 100º.

Release profile of the encapsulated compounds

The release profile of the encapsulated compounds were evaluated by *in vitro* assay, simulating gastric and intestinal fluids (CHIU *et al.*, 2007; PARAMERA *et al.*, 2011; ZHENG *et al.*, 2011) and in distilled water (BELŠČAK-CVITANOVIĆ *et al.*, 2011, adapted by RUTZ *et al.*, 2013). Solutions of citric acid 0.1 M and di-sodium phosphate were mixed in adequate proportions for solutions with final pH of 2.00 and 8.00 (CHIU *et al.,* 2007). Solution at pH 2.00 (gastric fluid simulation - GFS) comprised 0.3 % of pepsin enzyme, whereas solution at pH 8.00 (intestinal fluid simulation - IFS) comprised 0.1 % of pancreatic enzyme (PARAMERA *et al.*, 2011).

Preparation of cakes with microparticles

To elaborate the cake 60 g of flour; 40 g of sucrose; 0,5 g of baking powder; 50 mL of milk; 20 mL of soy oil and 2,5 g of microparticles were used. The solid ingredients were homogenized, after milk and soy oil were added, and then mixed until the formation of a homogeneous mass that was baked in an electric oven at 200 °C for 30 minutes.

Thereafter the cake was stored at room temperature, in polyethylene packaging until the analysis. A sample of cake without the addition of microparticles was prepared as a control.

Color of the microparticles and cakes

The color of the microparticles and cakes with and without microparticles was determined by the CIE L * a * b * method, proposed by the Commission Internacionale l'Eclairage (CIE). The analysis was performed using a colorimeter (Minolta CR-300).

Release profile of microparticles applied in cakes, in fluids that simulate gastrointestinal conditions

The release profile of the microencapsulated bioactive compounds applied in cakes when they were exposed to conditions simulating the gastric and intestinal characteristics of the human body was performed out similarly as described before (item 2.7).

The cakes analysis were performed using 2,5 g of each sample, in triplicate, for each of seven time periods (0, 20, 40, 60, 120, 180 and 240 minutes) and the fluids that simulated gastric (SFG) and intestinal (SFI) conditions were added.

The samples were incubated at 37 °C, and at each time, the samples were removed, centrifuged (Eppendorf 5430 R) at 7000 *g* for 3 minutes and the volume was set to 10 mL. The supernatant was used for the analysis of bioactive compounds released. The analysis was performed out similarly as described before in item 2.6.1 for the bioactive compounds content.

Statistical analysis

Results were given in means of assays done in triplicates and submitted to analysis of variance.

Tukey´s test ($p<0.05$) was used to evaluate the encapsulation efficiency, color of microparticles and color of cakes, to compare wall materials and the profile of the release of encapsulated compounds, and to compare wall materials and the gastrointestinal fluids.

LSD (Least Significant Difference) test ($p<0.05$) was used to evaluate the encapsulation efficiency by comparing the groups of encapsulated compounds and the release profile of the encapsulated compounds after that the microparticles have been applied in cakes, to compare fluids.

Dunnett test ($p<0.05$) was used to compare the cakes color with microparticles in relation to the control cake.

3 I RESULTS AND DISCUSSION

Encapsulation efficiency (EE)

The encapsulation efficiency of the purple Brazilian cherry juice was dependent on the wall material and the group of encapsulated compounds, with the highest values obtained by the encapsulation of carotenoids (table 1). For both groups, phenolic compounds and carotenoids, the use of xanthan gum as wall material was significantly the most efficient. Chitosan as wall material showed the lowest encapsulation efficiency; however, when the gum was combined with xanthan, the efficiency increased significantly.

Wall Material	Bioactive compounds (%)	
	Carotenoids	Phenolic Compunds
Xanthan	91.52 aA	76.37 aB
Hydrogel	79.49 cA	61.20 cB
Chitosan	84.52 bA	68.80 bB

Table 1. Encapsulation efficiency of the purple Brazilian cherry juice bioactive compounds.

Means followed by the same small letter in the column did not differ at 5% significance. Means followed by the same capital letters on the line did not differ at 5% significance.

Chitosan has been used as wall material in encapsulation of phenolic compounds, both alone or in combination with other wall materials (KOSARAJU *et al*., 2006; DELADINO *et al*., 2008; DA ROSA *et al*., 2014). In these studies, the efficiency changed between 27 % and 81.4 %. However, in the present study the microcapsule with chitosan showed the lowest encapsulation efficiency of these compounds when compared with the xanthan and hydrogel wall materials. The study described by Da Rosa *et al*. (2014), in which was encapsulated blackberry extracts rich in phenolic compounds by lyophilization, showed that the efficiency was dependent on the wall material used. The same behavior was observed with xanthan gum, chitosan and xanthan gum-chitosan hydrogel as wall materials, and the best efficiency results was also obtained with xanthan gum as wall material (70.6 %).

It is suggested that during the encapsulation process may have occurred hydrogen bonding and dipole-dipole interactions between encapsulating materials and the phenolic compounds, mainly due to the presence of free hydroxyl groups in the major phenolic compounds of the juice and also in the polymers of xanthan gum, chitosan and hydrogel. However, in relation to the carotenoids, it is more likely that occurred induced dipole-dipole interactions between the methyl groups of the major carotenoids of the juice with the methyl groups of the polymers. Moreover, because of xanthan gum and chitosan are considered anionic and cationic compounds, respectively, may also have occurred ion-permanent dipole interactions with the phenolic compounds and ion-induced dipole with the carotenoids (RUTZ *et al*., 2013).

Thermal behavior

The purple Brazilian cherry juice showed two endothermic events (175.03 °C and 195 °C), and the wall materials (xanthan gum, chitosan and hydrogel) showed endothermic peaks at temperatures of 129.01 °C, 182.41 °C and 161.77 °C, respectively (Figure 1a). Generally, the thermograms of physical mixture shows events related to encapsulating wall material and the encapsulated compound. Non-occurrence of these events indicates interaction of both during heating (WU *et al.*, 2008). This phenomenon was observed in our study when the physical mixtures were analysed.

It can be observed in the thermogram of the xanthan microparticles that occurred the disappearance of the endothermic events related to the purple Brazilian cherry juice; therefore, suggesting the juice protection and interaction with the nucleus. The result agrees with the encapsulation efficiency, in which the xanthan gum was considered the best encapsulating material for both group of compounds. Chitosan microparticles showed a peak with smaller intensity related to non-encapsulated purple Brazilian cherry juice, suggesting in this case only partial encapsulation. The hydrogel microparticles showed only a thermal profile of the polymer, which also suggests the encapsulation of the purple Brazilian cherry juice. These results agree with that found by Rutz *et al.* (2013) in a study with microparticles coated with tara gum.

Microstructural profile

X-ray diffraction patterns of amorphous substances usually show a diffuse halo, as seen in Figure 1b. According to Takahashi (2009), it is possible to evaluate a complex formation by assessing the peak size of the encapsulated compounds and microparticles, because the intensity reduction of the peaks represents a partial complexation.

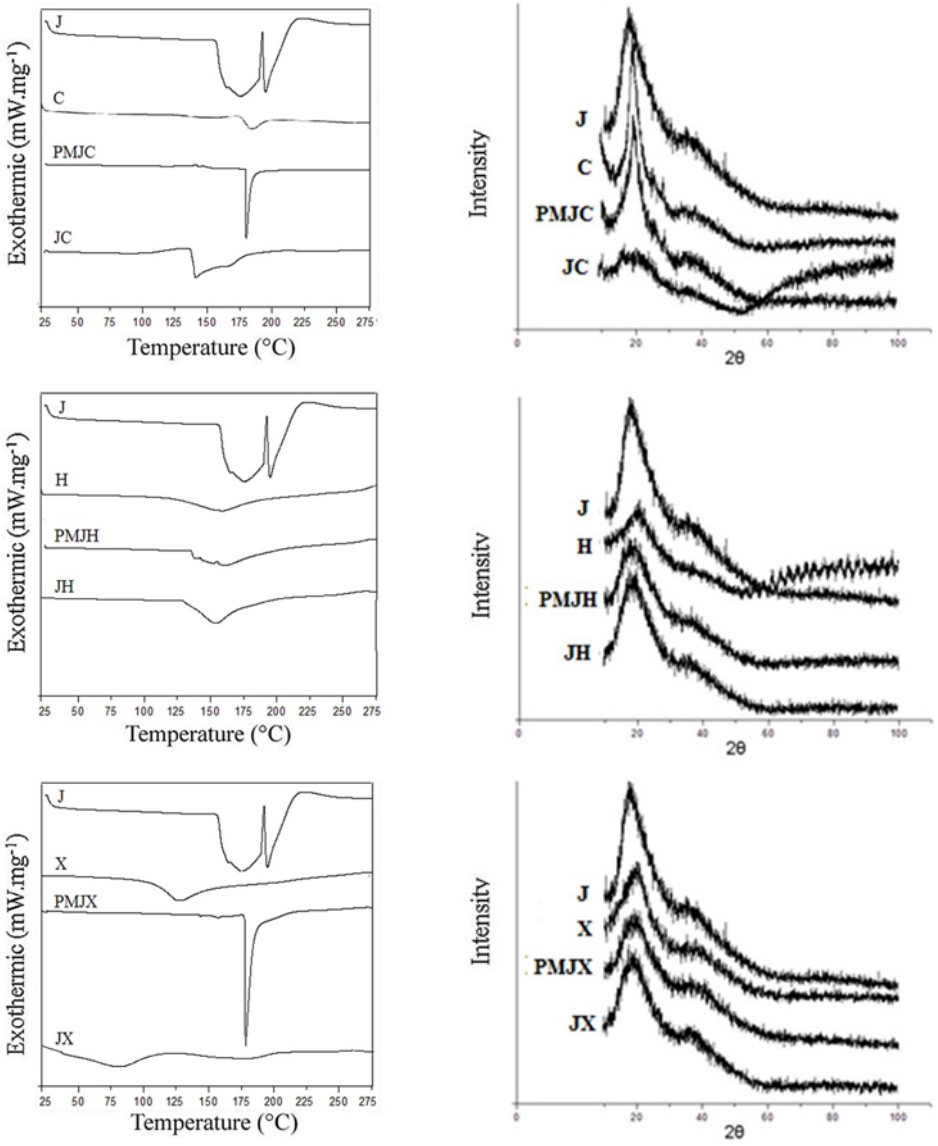

Figure 1. a) DSC thermograms and b) X-ray diffractograms of the purple Brazilian cherry juice, wall materials used in encapsulation, physical mixtures and microparticles

There was a reduction in the peaks intensity in the microparticles when compared to peaks obtained for the purple Brazilian cherry juice. The microparticles with lower relative intensity were coated with chitosan, with 28.03 %. The microparticles of xanthan gum and hydrogel showed peak intensity of 65.55 % and 70.14 %, respectively.

Release profile of the encapsulated compounds

The release profile of the bioactive compounds of microencapsulated purple Brazilian cherry juice, in water and in gastric and intestinal fluid, can be seen in Figure 2.

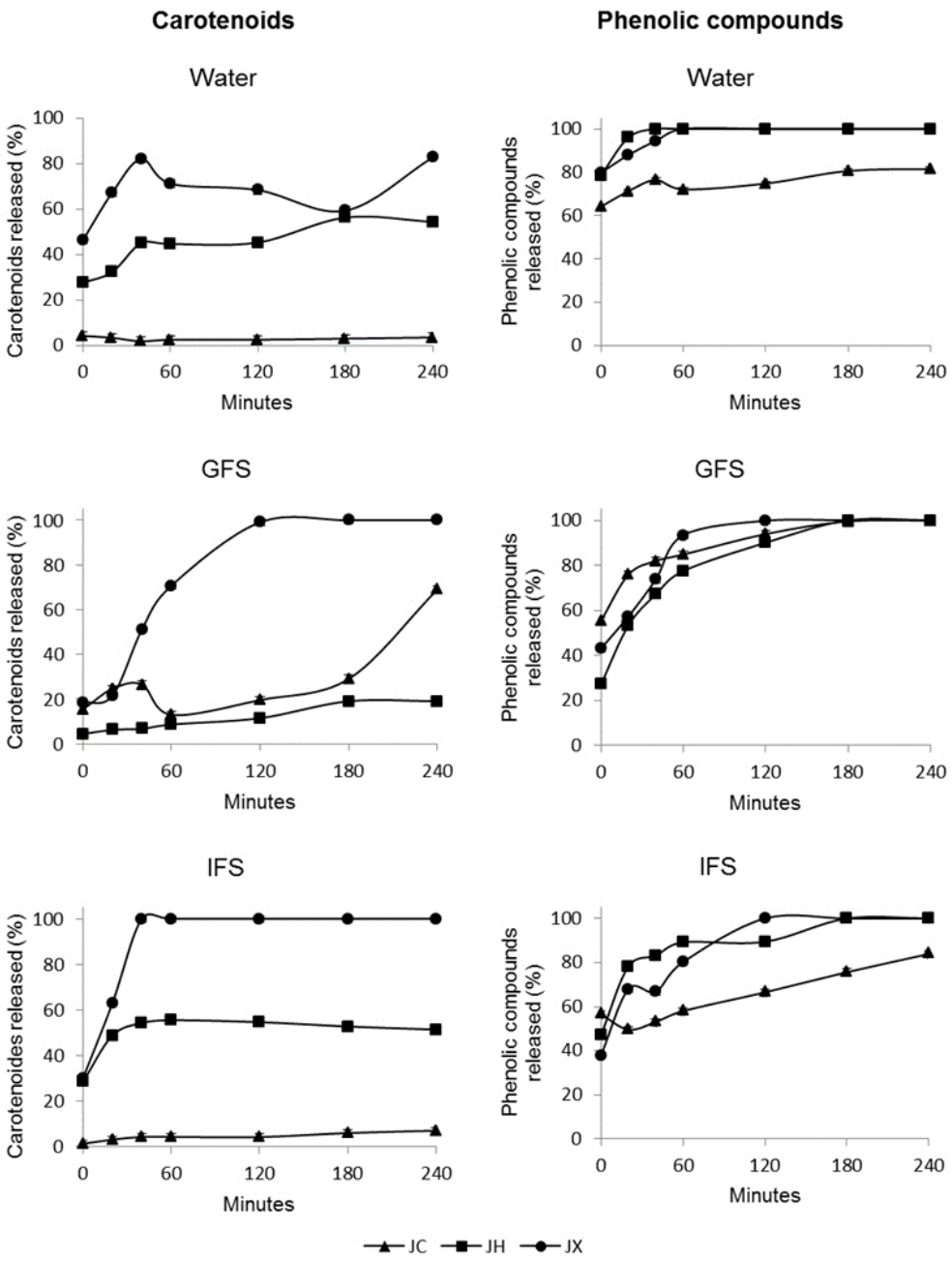

Figure 2. Release profiles of carotenoids and phenolic compounds from microparticles in water and in fluids that simulated gastric and intestinal conditions

Release in water

The polymer used for encapsulation influenced the release profile of the bioactive compounds. Microparticles coated with xanthan gum during the contact with water released more than 40% of the carotenoids at the time of dissolution, and the maximum release was 82% after 40 minutes. Different behavior was observed with chitosan microparticles, which ones released low content of carotenoids in water, only about 4%. The hydrogel promoted gradual release, reaching 86% in 180 minutes.

The microparticles with xanthan gum and hydrogel released high percentage of phenolic compounds at the time of dissolution, and approximately 80% of the total was released at 60 and 40 minutes, respectively. Chitosan microparticles released the maximum of 81% in 240 minutes.

Release in gastric (GFS) and intestinal (IFS) fluid

The microparticles coated with xanthan gum released 100% of the carotenoids in 180 minutes in the gastric fluid, and that coated with chitosan released up to 180 minutes 69%. Different behavior was observed for microparticles coated with hydrogel, which showed low release of carotenoids in gastric fluid, reaching a maximum of only 19% in 180 minutes.

In the intestine fluid, the microparticles coated with chitosan showed 7% release of carotenoids, in 240 minutes, while the microparticles coated with xanthan gum released 100% of the content in only 40 minutes. The carotenoids release in the hydrogel microparticles was greater than that obtained in the gastric fluid, reaching 55% in 60 minutes.

The release of phenolic compounds, in both fluids, was higher for all microparticles, reaching release at least of 50% after 20 minutes.

Because most nutrients and vitamins are better absorbed in the intestine, it is recommended low release in gastric conditions and a gradual and complete release in the intestinal conditions (SOMCHUE *et al*., 2009). The microparticles coated with hydrogel showed this behavior only in relation of the carotenoids release.

Color of the microparticles and cakes

The results relative to color of the microparticles and the cakes in which they were applied are in the table 2. The L indicates luminosity, while the chromaticity coordinates are identified with a * (+ a = red, -a = green) and b * (+ b = yellow, -b = blue). Therefore, in relation to the microparticles, the highest luminosity was observed in the hydrogel microparticles. When the microparticles were applied in cakes it was observed a reduction of their luminosity in relation to control, especially when chitosan microparticles were added.

Samples	Color		
	L	a	b
	Microparticles		
Xanthan	43,33 c	21,47 a	3,08 a
Hydrogel	50,92 a	22,60 a	3,12 a
Chitosan	47,20 b	2,42 b	-5,21 b
	Cakes with microparticles		
Control	71,49	-0,04	17,32
Xanthan	57,69 a*	5,08 a*	14,40 a*
Hydrogel	56,13 a*	5,15 a*	14,16 a*
Chitosan	54,20 b*	2,65 b*	11,17 b*

Table 2. Color of microparticles and of cakes in which they were applied.

Means followed by different lowercase letters in the column differ by Tukey test, comparing wall materials.* Significant in relation the control (cake without microparticles) by Dunnett test (p≤0,05).

The values for the coordinate a* indicates that xanthan and hydrogel microparticles have red color more intense and did not differ among themselves. These microparticles also intensified the red coloration of the cakes, differing statistically of the control cake and the cake with chitosan microparticles.

These microparticles did not differ in respect of b* coordinate, tending to yellow color, whereas the chitosan microparticles showed tendency to blue color. Control cake showed higher b* value and after the application of the microparticles was observed a reduction in values for this coordinate, mainly for the cakes with chitosan microparticles.

In the comparison of the color of the cakes with microparticles and the color of control cake, it was observed significant differences, which were caused due to the presence of pigments of the purple Brazilian cherry juice.

Release profile of microparticles applied in cakes, in fluids that simulate gastrointestinal conditions

The release of carotenoids by the xanthan microparticles was around 0.5% throughout the period evaluated in GFS (Figure 3). The behavior was similar to that obtained for the hydrogel microparticles, which released an average of 3.6% during the 180 minutes, after this period were released 16% of carotenoids. The chitosan microparticles showed no significant changes during the 240 minutes, releasing around 54% of the carotenoids.

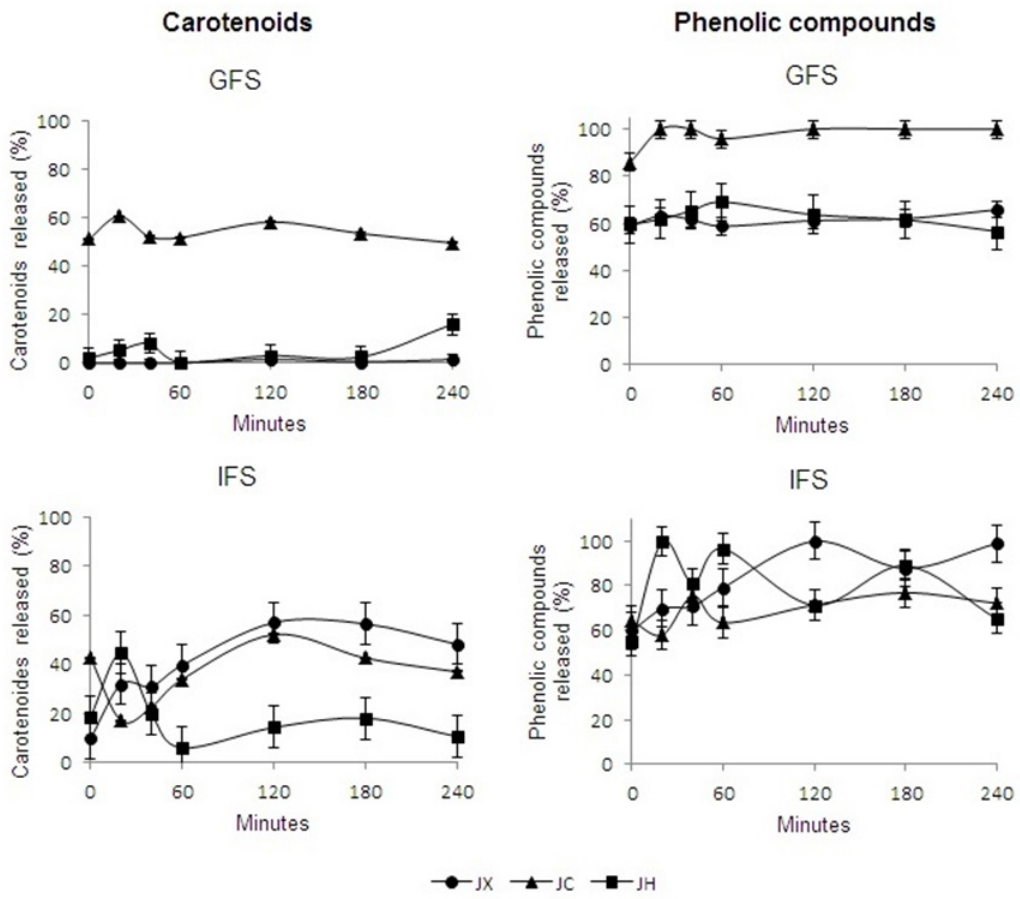

Figure 3. Release profiles of carotenoids and phenolic compounds from microparticles applied in cakes, in fluids that simulated gastric and intestines conditions

The xanthan microcapsules initially released 9% of carotenoids in SFI, and 57% were gradually released until 120 minutes, and did not vary significantly after this period. The hydrogel released 45% in the first 20 minutes, then decreased to 20% and did not vary until the end of period. The chitosan microcapsules released 43% of the carotenoids upon dissolution, between 20 and 60 minutes there was carotenoid degradation, and after this period the release was gradual until 52 %.

Xanthan and hydrogel microcapsules showed similar release profile in GFS, releasing on average 63 % of phenolic compounds, without significant variations during the 240 minutes. The chitosan microcapsules released 85% upon dissolution and after 20 minutes the entire content had been released. The xanthan microcapsules initially released 60% of the phenolic compounds in SFI, the release was gradual until fully release at 120 minutes. The hydrogel microcapsules released upon dissolution 55% of the compounds, and after the release remained on average 84% until the end of 240 minutes. The chitosan microcapsules showed no significant changes in phenolic compounds release, remaining close to 69%.

It is desirable that the encapsulation be capable of protecting the compounds during processing and that they can be released at the ingestion upon reaching the intestine to achieve better absorption. If the encapsulated compounds are released during processing or as soon as they come into contact with gastric fluid, their degradation may occur. As foods tend to remain in the stomach for 2 to 3 hours, it is interesting that the compounds remain encapsulated for this period of time in contact with the low pH fluid.

For both compounds, xanthan was the wall material that presented the most satisfactory performance, showing lower release rate in SFG and high release rate on a gradual way in SFI, particularly in relation to the carotenoids. The different release behavior of the encapsulated compounds before and after the application of the microparticles in cakes may have occurred due to the fact that the food matrix has the capacity to interact in different ways with the bioactive compounds, protecting them. The results suggest that the effects of processing are different for each type of microparticle (SUCUPIRA *et al.*, 2012).

Therefore, it was observed that the different release behavior of the encapsulated components before and after application on the cakes it was influenced by processing condition, food matrix and/or water content.

4 I CONCLUSION

The encapsulation of purple Brazilian cherry juice in matrices of xanthan, chitosan and hydrogel was confirmed by DSC and X-ray. The type of wall material and the group of encapsulated compounds influenced the results. Xanthan gum provided the highest encapsulation efficiency for carotenoid and phenolic compounds.

The hydrogel microcapsules showed desired characteristics of carotenoids release in gastric and intestinal fluids, and also showed a gradually release in water. Regardless of wall material and gastrointestinal fluids analyzed, the release of phenolic compounds was high and not gradual.

The application of the microparticles influenced significantly the color of cakes. After application of the microparticles in cakes, the most appropriate release profile was obtained from xanthan microparticles, for both group of compounds.

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