Influence of combined hydrolyzed collagen and maltodextrin as carrier agents in spray drying of cocona pulp

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Abstract

This work aimed to evaluate the effect of carrier agents containing maltodextrin and protein, represented by hydrolyzed collagen on the spray drying process of cocona (Solanum sessiliflorum Dunal), and on the properties of the resulting powders. We used pre-established proportions between the solids of cocona pulp and the carrier agents (P:CA), and among carrier agents themselves, maltodextrin and hydrolyzed collagen, (MD:HC). The process was carried out in a spray dryer at an inlet air temperature of 120 ºC. We prepared twelve feed solutions containing 20% of total solids, with P:CA ratios of 1:3, 1:4, 1:5 and 1:6, and MD:HC ratios of 0:100, 50:50, and 100:0. Solids recovery was obtained for the evaluation of the spray drying process. The cocona pulp powders were analyzed for moisture content, water activity, particle size distribution, mean particle diameter, chemical structure (FTIR) and color. For a P:CA of 1:6, for the sample formulated with hydrolyzed collagen only, solids recovery (96.2%) was much higher than that of the sample with maltodextrin only (39.2%). The chemical structure of cocona powders can be considered a sign of a good encapsulation process. The color of the cocona pulp powder was similar to that of the carrier agents. The formulation with highest content of hydrolyzed collagen improved the recovery of solids, guaranteed the cocona pulp encapsulation, and obtained fruit powders with bioactive properties.

Keywords: Solanum sessiliflorum; Powder; Microencapsulation; Protein; Particles; Recovery solids; FTIR.

Resumo

O objetivo deste trabalho foi avaliar diferentes tipos de formulações com maltodextrina e colágeno hidrolisado na secagem por atomização de cocona (Solanum sessiliflorum Dunal), e nas propriedades dos pós resultantes. Foram avaliadas proporções pré-estabelecidas de sólidos de polpas sólidos de agente carreador (P:AC) e relação entre...
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agentes carreadores maltodextrina 10DE:colágeno hidrolisado (MD:HC). O processo foi realizado na secagem por
atomização a 120 °C como temperatura de ar de entrada. Foram preparadas 12 soluções de alimentação com 20%
de sólidos, variando-se a proporção de P:AC (1:3, 1:4, 1:5 e 1:6) e a relação MD:CH (0:100, 50:50 e 100:0). A
recuperação de sólidos foi determinada para avaliar o processo de secagem. Os pós de cocona foram analisados
quanto a umidade, atividade de água, distribuição de tamanho e diâmetro médio de partícula, estrutura química
(FTIR) e cor. Na proporção P:CA de 1:6, a recuperação de sólidos foi de 96,2% para a amostra com colágeno
hidrolisado, valor bem maior quando comparado com o valor da amostra com maltodextrina, que foi de 39,2%.
A estrutura química dos pós de cocona pode ser considerada um sinal de um bom processo de encapsulamento.
A cor dos pós foi similar à dos agentes carreadores. A formulação com maior teor de colágeno hidrolisado foi capaz
de melhorar a recuperação de sólidos, garantir que a polpa de cocona fosse encapsulada e obter pós de frutas com
propriedades bioativas.

Palavras-chave: Solanum sessiliflorum; Pó; Microencapsulação; Proteína; Partículas; Recuperação de sólidos; FTIR.

1 Introduction

Cocona (Solanum sessiliflorum Dunal) is a fruit from Amazon, that is spread around several countries,
including the Pacific coast of Colombia, Venezuela, Ecuador, Peru, and Brazil. In these regions, it is used as
medicine, food or as a cosmetic (Jiménez, 2018; Serna-Cock et al., 2015). The taste and aroma of cocona are
very exotic. Due to its phenolic compounds, carotenoid, pectin, citric acid, iron, and niacin (vitamin B5)
content and its antioxidant capacity, cocona has a market potential because of the population current concern
with a healthy diet (Cardona et al., 2011; Mascato et al., 2015; Rodrigues et al., 2013; Sereno et al., 2018;
Silva et al., 2016). This fruit is recommended for people who have energy intake restrictions (Silva
Filho et al., 2005) or high levels of cholesterol and triglycerides in their blood (Pardo, 2004; Yuyama et al.,
2005).

This fruit has a climacteric respiration pattern and, thus, storage, transport, and handling may affect its
cellular turgor, weight and mechanical properties. It is, therefore, suitable for consumption, in average, up to
the fifth day of storage after harvest (Andrade Junior et al., 2017). Spray drying of cocona can be an
alternative process to extend its shelf-life (Ferrari et al., 2012a; Oliveira et al., 2013). However, this process
is hindered due to the low molecular weight (LMW) sugars and organic acids present in the fruits. These
compounds have low glass transition temperature (Tg) and high hygroscopicity (Moser et al., 2017;
Samborska et al., 2015), which, upon drying, lead to high stickiness in the drying chamber, causing
operational issues and low solids recovery (SR) of the final product. Therefore, the use of a carrier agent of
high molecular weight (HMW) is required (Can Karaca et al., 2016).

Carrier agents such as starches, gums, proteins, and cyclodextrins can be used in the spray drying of fruit
juices and pulps to reduce the stickiness phenomenon, thereby improving the SR and, in addition, ensuring
the stability of the bioactive compounds (Akhavan Mahdavi et al., 2016). A single carrier agent does not
present all these features and, therefore, many studies currently use different proportions of combined
starches and proteins to improve the powder’s properties, the bioactive compounds protection, and SR
(Du et al., 2014; Moser et al., 2017; Robert et al., 2015; Shi et al., 2013). The juice and fruit pulp industry
requires high amounts of carrier agents to enhance process yield. Maltodextrin (MD) (40-60%, g/100 g feed
solution) is generally used because it is inexpensive and film-forming material. However, it has an amorphous
nature under high relative humidity, hence becoming sticky after absorbing water (Wang et al., 2013). On the
other hand, proteins form smooth and non-sticky films, resulting in higher SR values, even when added in
small amounts (Fang & Bhandari, 2012; Fang et al., 2013). Currently, protein is combined to starches as a
carrier agent in order to increase the emulsifying properties, solubility, antioxidant effect, SR and powder
fluidity (Moser et al., 2017; Muzaffar & Kumar, 2016).
Hydrolyzed collagen (HC) is a natural protein derived from collagen found in animal skins and bones (bovine, pig, poultry, and fish). It is colorless and has emulsifying, stabilizing, film-forming properties, among others; while also increasing the solubility of the encapsulated product. Its biological properties are notorious for protection of articular cartilages under stress conditions; relief of osteoarthritis and osteoporosis symptoms (Garcia-Coronado et al., 2019; Puigdellivol et al., 2018); stimulation of bone-forming cells; improvement of calcium absorption (Daneault et al., 2017); protection and recovery of connective tissue in response to intense strength and cardiovascular training (Lopez et al., 2015); and, lastly, reduction of visible signs of skin natural aging (Borumand & Sibilla, 2014, 2015; Proksch et al., 2014). Due to its physicochemical and biological properties, HC has been used in the elaboration of functional fruit pulp beverages, hence improving their nutraceutical characteristics (Bilek & Bayram, 2015; Butzge et al., 2014; Rigoto et al., 2018).

This study aimed to evaluate the effects of different proportions of solids of cocona pulp and carrier agents (P:CA), and of different ratios of the carrier agents maltodextrin 10DE and hydrolyzed collagen (MD:HC) on SR, and on the powder characteristics of moisture content, water activity, size distribution, mean particle diameter, chemical structure (FTIR) and color of particles obtained by spray drying.

2 Materials and methods

2.1 Material

Cocona (Solanum sessiliflorum Dunal) fruits were acquired from General Warehouses Company of São Paulo (CEAGESP), São Paulo, Brazil, with maturation degrees between 4 and 5, in which peels presented a green to yellowish coloration. The fruits were processed with knife pulping, discarding their peels and seeds. Cocona pulp was filtered through a Tyler sieve of 115 mesh, with an opening of 0.125 mm, in order to withdraw large solids and facilitate their passage through the atomizer nozzle of the spray dryer. The pulp was stored in a freezer at -18 ºC and thawed according to the amount required for each test. Maltodextrin MOR-REX®1910 (10DE) from Ingredion (MD; Mogi-Guaçu, SP, Brazil) and hydrolyzed collagen powder of bovine origin NovaProm® hidro from NovaProm Food Ingredients (HC; gel strength (bloom) = 0); Lins, SP, Brazil) containing 5.5% and 8.0% moisture content, respectively, were used as carrier agents.

2.2 Physicochemical composition of cocona (Solanum sessiliflorum Dunal) pulp filtered

The cocona pulp filtered was analyzed for moisture (Method 934.01, vacuum oven), protein content multiplying the conversion factor of 6.25 (Method 984.13), lipid content (Method 920.39), total fiber (Method 978.10), and ash content (Method 942.05), according to methods recommended by the Association of Official Analytical Chemists (2006). Carbohydrate content was calculated using the following formula: Available carbohydrate (%) = 100 – [protein (%) + Moisture (%) + Ash (%) + Fiber (%) + Crude Fat (%)]. Total sugar was quantified by DNS method (Miller, 1959). The titratable acidity was expressed as percentage of citric acid and total soluble solids were determined following the methods 947.05 and 990.20, respectively (Association of Official Analytical Chemists, 2006). pH was measured using a pH meter (Mettler Toledo MP225). The values are presented on a wet basis (w.b.).

2.3 Sample preparation

We prepared twelve feed solutions with 20% total solids consisting of both filtered pulp and carrier agents. The pre-established ratios of solids of pulp to solids of carrier agent (P:CA) were 1:3, 1:4, 1:5, and 1:6, while those for maltodextrin to hydrolyzed collagen (MD:HC) were 0:100, 50:50 and 100:0 (Table 1). The carrier agents were added directly to the pulp under magnetic stirring until complete dissolution, that is, for 30 min.
Table 1. Formulations of feed solutions and experimental values of solids recovery, moisture content, water activity and mean particle diameter D_{4,3} of powder obtained by spray dryer.

| Feed solutions | Solids recovery (%) | Moisture content (%) | Water activity | Mean diameter D_{4,3} (μm) |
|----------------|---------------------|----------------------|----------------|---------------------------|
| P:CA/MD:HC     |                     |                      |                |                           |
| 1 1:3          | 41.2 ± 0.5^Ca       | 1.6 ± 0.1^bc         | 0.156 ± 0.005^Rb | 10.343 ± 0.757^Rb         |
| 2 1:3          | 56.1 ± 2.0^Rb       | 2.1 ± 0.1^Rb         | 0.213 ± 0.015^Ab | 9.353 ± 0.110^Ab          |
| 3 0:100        | 90.2 ± 0.5^Ab       | 2.7 ± 0.1^Ab         | 0.142 ± 0.005^bc | 10.526 ± 0.039^bc         |
| 4 1:3          | 34.4 ± 0.1^Cb       | 1.1 ± 0.1^Rd         | 0.161 ± 0.004^Cb | 12.846 ± 0.651^Cb         |
| 5 1:4          | 50.9 ± 2.2^Rc       | 2.6 ± 0.1^Ab         | 0.219 ± 0.006^Ab | 11.124 ± 0.070^Ab         |
| 6 0:100        | 92.5 ± 1.1^Ab       | 2.7 ± 0.1^Ab         | 0.194 ± 0.012^Ab | 10.788 ± 0.068^Ab         |
| 7 1:5          | 39.1 ± 1.9^Ca       | 1.9 ± 0.1^Rbc        | 0.152 ± 0.004^Cb | 10.889 ± 0.074^Cb         |
| 8 1:5          | 59.1 ± 0.6^Ab       | 2.3 ± 0.3^Ab         | 0.248 ± 0.005^Ab | 9.083 ± 0.046^Ab          |
| 9 0:100        | 94.7 ± 1.5^Ab       | 3.0 ± 0.2^Ab         | 0.200 ± 0.004^Ab | 9.234 ± 0.007^Ab          |
| 10 1:6         | 39.2 ± 0.6^Ca       | 2.8 ± 0.1^Ab         | 0.247 ± 0.006^Ab | 15.683 ± 0.652^Ab         |
| 11 1:6         | 61.3 ± 0.2^Ab       | 2.4 ± 0.1^Cbc        | 0.210 ± 0.003^Cb | 8.795 ± 0.017^Cb          |
| 12 0:100       | 96.2 ± 3.0^Ab       | 2.6 ± 0.1^Ab         | 0.224 ± 0.001^Ab | 10.688 ± 0.022^Ab         |

P:CA = Proportion of solids of cocona pulp and solids of carrier agent. MD:HC = carrier agents maltodextrin and hydrolyzed collagen ratio. The values represent the average between three determinations ± standard deviation. Lowercase and uppercase letters represent the response variation with P:CA and MD:HC, respectively. Averages with the same letters, either lowercase or uppercase, represent no significant difference (p ≤ 0.05) by Tukey test.

## 2.4 Spray drying of feed solutions

The feed solutions (Table 1) were added to a cylindrical glass chamber of a laboratory scale spray dryer (SD-06, LabPlant, Reino Unido), with a diameter of 215 mm and a length of 500 mm. The spray nozzle diameter was set at 1.0 mm, the feed flow rate at 4.7 mL/min, the air velocity at 3.9 m/s, the compressed air pressure at 2 x 10^5 Pa and the inlet, and outlet air temperatures at 120 ± 2 ºC and 80 ± 2 ºC, respectively. The temperature of the feed solutions was of 20 ºC.

### 2.4.1 Solids recovery

Solids recovery was calculated as the ratio of the masses of total solids in the resulting powder (m_{sol,powder}) to the feed solution (m_{sol,feed}) (Equation 1).

\[
SR(\%) = \frac{m_{sol,powder}}{m_{sol,feed}} \times 100 = \frac{m_{powder} \times X_{sol,powder}}{m_{feed} \times X_{sol,feed}} \times 100
\]

Where: SR is solids recovery (%), m is mass (g), X_{sol} is solids content (g/g of powder or feed solution).

## 2.5 Analytical methods

### 2.5.1 Moisture content and water activity

Powder moisture content (%) was determined using a vacuum oven at 70 ºC under reduced pressure (13.3 kPa) for 48 h (Association of Official Analytical Chemists, 2006). Water activity was measured by a digital water activity meter by Aqualab (3TE, Decagon, Pullman USA) at 25 ºC.
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2.5.2 Size distribution and mean particle diameter

Particle size distribution was measured using a laser light diffraction instrument (Model Mastersizer 2000, Malvern Instruments Ltd, Malvern, UK). Powder samples were dispersed in ethanol 99.5% and each submitted to 5 readings. The mean particle size was expressed as \( D_{4,3} \).

2.5.3 FTIR spectroscopy

FTIR spectrum of MD, HC, freeze dried cocona pulp and powder of ratios 1:6 was acquired on a FTIR Spectrophotometer (Nicolet 6700, Thermo Scientific, USA). A small portion of the sample was transferred to the agate mortar. KBr was added in the proportion of 0.5:100 to prepare the pressed tablet (~7 ton for 4 min). It was then taken to the equipment for analysis. The measurement was performed in transmittance mode using the snap-in baseplate accessory (KBr method). Spectrum was recorded (32-64 scans) in the transparent mode from 4000 to 600 cm\(^{-1}\), at 4 cm\(^{-1}\) resolution.

2.5.4 Color analysis

Sample color was measured using a colorimeter (UltraScanVis, HunterLab, Reston, VA, USA), with a D65 illuminant and a 10\(^{\circ}\) observer angle, expressed by the CIELab scale (L*, a*, and b*), chroma (C*) and hue angle (H\(^{\circ}\)). Color difference (\( \Delta E \)) was calculated by Equation 2.

\[
\Delta E = \sqrt{\left( L^* - L_0^* \right)^2 + \left( a^* - a_0^* \right)^2 + \left( b^* - b_0^* \right)^2}
\]

(2)

Where: \( L^* \) is the luminosity; \( a^* \) and \( b^* \) are the intensities of the green-red color and the blue-yellow color, respectively. The variables without subscript correspond to the spray dried samples. The subscript ‘0’ denotes a reference sample. In this study, four reference samples were used: pure freeze-dried cocona pulp, each carrier agent, isolated, and its 50:50 mixture.

2.6 Statistical analysis

The tests were carried out in triplicate and the results shown as their mean ± standard error. Results were compared by analysis of variance (ANOVA), with the Tukey test at a 5% level of significance (\( p \leq 0.05 \)), using the Software Microsoft\textsuperscript{\( ^{\circ} \)} Excel 2018 (Microsoft Corporation, CA).

3 Results and discussion

The results for the physicochemical composition of cocona pulp filtered (Table 2) were similar to those previously reported in literature (Jiménez, 2018; Serna-Cock et al., 2015): a content high in sugar (48.16%) and acidity (1.94%), justifying the addition of carrier agents to reduce the stickiness during spray drying and powder storage.

Table 2. Physicochemical composition of cocona (Solanum sessiliflorum Dunal) pulp filtered.

| Analysis   | Mean value       | Method                                                      |
|------------|------------------|-------------------------------------------------------------|
| Moisture   | 94.01 ± 0.01     | (Association of Official Analytical Chemists, 2006)          |
| Protein    | 0.64 ± 0.03      | (Association of Official Analytical Chemists, 2006)          |
| Lipid      | 0.65 ± 0.04      | (Association of Official Analytical Chemists, 2006)          |
Analysis & Mean value & Method

| Analysis                        | Mean value | Method                                      |
|--------------------------------|------------|---------------------------------------------|
| Total fiber, %, w.b.            | 0.09 ± 0.04| (Association of Official Analytical Chemists, 2006) |
| Ash, %, w.b.                   | 0.39 ± 0.02| (Association of Official Analytical Chemists, 2006) |
| Carbohydrate, %, w.b.          | 4.22 ± 0.16| By difference                              |
| Total sugar, %, w.b.           | 2.88 ± 0.03| (Miller, 1959)                             |
| Titratable acidity (citric acid), %, w.b. | 1.94 ± 0.004| (Association of Official Analytical Chemists, 2006) |
| Total soluble solids, °Brix, w.b. | 4.80 ± 0.35| (Association of Official Analytical Chemists, 2006) |
| pH, w.b.                       | 3.05 ± 0.01| pH meter                                   |

w.b. = wet basis. Values represent the average of three determinations ± standard deviation.

3.1 Defining the spray drying conditions

Operational conditions of the spray dryer were chosen by preliminary tests (Supplementary Material). The feed flow rate at 4.7 mL/min was chosen, because a great amount of product adhered to the drying chamber at higher feed flow rates.

Dripping was observed inside the drying chamber when we used a maximum feed flow rate (18.17 mL/min), indicating that the compressed air was insufficient to properly atomize the feed solution into the chamber, a fundamental prerequisite for drying and subsequent formation of particles. Therefore, the minimum feed rate (4.67 mL/min) was tested to ensure the occurrence of spray drying of the feed solution and, thus, an increase in the process yield. At low feed rates, the atomized droplets in the drying chamber were smaller and, consequently, the total surface area in contact with hot air was increased. Therefore, higher heat and mass transfers occurred in the dryer. Similarly, upon evaluating the spray drying of pomegranate juice, Thirugnanasambandham & Sivakumar (2015) found that by increasing the feed rate of the process, the heat transfer between the atomized droplets and the drying air was less efficient, resulting in a moister and stickier powder.

A low temperature of the inlet air (120 ºC) was chosen since high temperatures favored the thermal degradation of bioactive compounds present in fruits (Tolun et al., 2016). Mishra et al. (2014) showed that the content of phenolic compounds in amla juice powder (*Emblica Officinalis*) decreased significantly when the inlet air temperature increased from 125 ºC to 175 ºC, and that high temperatures in spray drying of lemon juice negatively affected the structure of phenolic compounds as well, hence diminishing its antioxidant capacity (Mishra et al., 2015).

3.2 Solids Recovery (SR)

An increase in the ratio of pulp solids to hydrolyzed collagen improved the SR from 90.2% to 96.2% (Table 1), indicating that stickiness in the drying chamber was minimized. For the feed solution formulated with MD only (100:0), the increase from 1:3 to 1:6 in the P:CA proportion did not favor SR, with no significant difference found upon comparison. The low SR values for formulations with MD only indicated that most of the solids adhered to the wall of the drying chamber. For samples with both MD and HC (50:50), SR was higher than 50%. Fang & Bhandari (2012) observed a significant increase in SR when whey protein isolate (WPI) was used as a carrier agent for spray drying of bayberry juice. By adding 1% of that protein to the formulation, the authors obtained an SR superior to 50%. However, in order to achieve a similar value when MD replaced WPI as a carrier agent, the authors were required to add more than 30% of MD to the...
formulation. Shi et al. (2013) observed a positive effect of the addition of WPI on the SR in the spray drying of honey with different ratios of WPI to MD. Therefore, these proteins may totally or partially replace hydrolyzed starch in carrier formulations due to their HMW, chain flexibility, and emulsifying ability, which all contribute to increase SR (Akhavan Mahdavi et al., 2016; Robert et al., 2015).

It is noteworthy that the molecular weight (MW) of MD 10DE is 1700 g/mol (Avaltroni et al., 2004), smaller than that of HC (2000-6000 g/mol) (Daneault et al., 2017). Thus, the addition of HC can improve solids recovery on spray drying, counterbalancing the LMW of the sugars and organic acids of cocona pulp.

When subjected to hot air inside the drying chamber, protein migration to the air-droplet interface results in the formation of a high-content protein film on the surface of dried particles (Shi et al., 2013). This new layer has a high Tg, hindering the adhesion of the particles to the drying chamber and, thus, improving product yield (Muzaffar & Kumar, 2016; Samborska et al., 2015). Hence, this film may be the reason for the high recovery of the cocona pulp powder found in this study.

Moser et al. (2017) obtained similar SR values on the spray drying of grape juice when MD was used as a carrier agent combined to whey protein concentrate (WPC) and soy protein isolate (SPI). SR raised proportionally to increases in the concentration of protein, regardless of the type used. On the other hand, the effect of protein to total carrier agent ratio did not significantly change SR.

Currently, the fruit pulp powder industry has a greater interest in processes with higher yields and less waste generation (Akhavan Mahdavi et al., 2016; Muzaffar & Kumar, 2016; Shi et al., 2013; Zareifard et al., 2012). Thus, the formulation of cocona pulp containing only with HC (MD:HC 0:100) with a P:CA 1:6 ratio resulted in higher solids recovery in this study (96.2%). This result is a key factor when considering economic benefits.

3.3 Moisture content and water activity

Moisture content is a powder property to assess drying efficiency. It is related to powder flowability, stickiness and storage stability. The results showed that the moisture content presented a significant difference among cocona pulp powders, ranging from 1.1% to 3.0% (Table 1). The values are consistent to those observed in industrial spray drying (Moser et al., 2017). Higher moisture contents were observed in powders containing greater amounts of HC due to the strong ability of proteins to bind in water. Shi et al. (2013) observed a similar behavior by adding MD and SPI to spray dried honey.

All samples had water activity values below 0.3, which increased the storage stability of powders since there is little water available for microorganism growth and for biochemical reactions (Santana et al., 2017).

3.4 Distribution and mean particle diameter

Figure 1 shows the particle size distribution of the sample with the highest SR, with a P:CA of 1:6 and an MD:HC of 0:100. Particles had diameters ranging from 0.3 to 282 μm and a monomodal size distribution with a multimodal tendency, that is, a predominant peak with two small peaks. The other samples showed a similar behavior. The origin of the larger particles can be attributed to the beginning of the agglomeration process, in which the formation of irreversible link bridges between particle-particle leads to the production of large particles (Moser et al., 2017). The onset of particle agglomeration produced by spray drying of fruit pulp is a physical phenomenon that is affected by the glass transition temperature of the wall material and the hygroscopicity of the particles. Little agglomeration, demonstrated by the third peak of the particle size distribution, maybe due to the absorption of ambient humidity by the particles during packing, and the low temperature of the spray dryer air used (120 °C) as described by Wang et al. (2013) and Du et al. (2014), respectively.
The average particle diameter for all samples was less than 16 μm (Table 1), which can generate good retention of bioactive compounds of the fruit, as explained by Moser et al. (2017) in its anthocyanin retention study (94%) in powdered grape juice with a particle size of 11.57 μm. Generally, small particles are characteristics of powders obtained by spray drying (Gong et al., 2018; Kuck & Noreña, 2016). However, small particle size results in a large total surface area of the system exposed to the environment, favoring the degradation of susceptible compounds present in the fruit pulp, as described by the author. Also, powders composed by small particles lack reconstitution, such as low wettability, which can be improved with stirring and high temperatures during rehydration (Fitzpatrick et al., 2016). Other alternative is to subject spray dried powders to agglomeration process, using a fluidized bed granulator and dryer, in order to improve their reconstitution properties (Ferrari et al., 2012b).

3.5 FTIR spectroscopy

Figure 2 shows the FTIR-spectra of MD, HC, and freeze dried cocona powders, and spray dried sample (P:AC 1:6). The peak of the 2350 cm⁻¹ region was disregarded as the CO₂ (g) variation of the environment at the time of measurement. Baseline correction of the spectrum of the cocona pulp was performed. The broadband in the 3700 - 2800 cm⁻¹ region can be attributed to the stretching vibration of free and inter-associated hydroxyl groups (O– H) of carbohydrates, carboxylic acids, and residual water of the materials used (Akbarbaglu et al., 2019).

In the structure of HC (Figure 2, curve A), the peaks associated with 3363 cm⁻¹ (O-H stretch) and 2960 cm⁻¹ (N-H stretch) were shown. The spectrum showed peaks at 1652, 1550, 1455, 1404, and 1249 cm⁻¹ similar to the collagen results found in the study of Ding at al. (2015). The region between 800 and 1800 cm⁻¹ is considered as a quite useful area for analyzing protein compound, because the peaks in the 1655 and 1537 cm⁻¹ are typical of amide I, due to carbonyl stretching (C=O), and are mainly associated with random coil and amide II vibrations which are the result of deformation of the N-H bonds and the C-N bonds stretch (1550 cm⁻¹). This depends of the secondary structure of protein and peptides. The peaks at 1455 and 1404 cm⁻¹ are associated to the C-N stretch and C=O stretch vibrations in the amide II area at short peptide chains. Besides, the observed peak in the 1249 cm⁻¹ spectrum is associated with the vibrations in the plane of amide III (Hameed et al., 2015).

The maltodextrin spectrum showed the bands at 3395 cm⁻¹ (O-H stretch), 2932 cm⁻¹ (C-H stretch), 1638 cm⁻¹ (H₂O absorbed in amorphous region), 1417 cm⁻¹ (CH₂ bending), 1154 and 1079 cm⁻¹ (C-O-H bending, C-O stretch, typical of carbohydrates), 1025 cm⁻¹ (angular deformation of =CH and =CH₂ bonds, carbohydrates peak), 931 and 857 cm⁻¹ (deformation of CH₂ and C1-H), 762 and 711 cm⁻¹ (structural condition of the Pyranose ring) (Akbarbaglu et al., 2019).

No spectrum of cocona pulp has been reported in the literature. In the current work, we show, as seen in Figure 2 (curve C), that peaks at 3413 and 1400 cm⁻¹ were assigned by the O-H stretch and bending of
alcohols and phenols. The peaks at 2927 and 2848 cm⁻¹ were formed by the asymmetric and symmetric stretches of C-H (alkanes) and =CH, characteristic of aldehyde, respectively. The peak at 1725 cm⁻¹ was associated with C=O stretching (aliphatic ketone). The peak at 1636 cm⁻¹ was typical of amide I (N-H bending). The peaks at 1230 and 1078 cm⁻¹ were caused by C-N stretching (aromatic amines). The peak of 1050 cm⁻¹ was C-O stretching coupled with C-O bending of the C-OH of carbohydrates. The peak at 784 cm⁻¹ was produced by =CH-H or C-H bending (alkenes and aromatics) (Namani et al., 2016; Nnorom & Onuegbu, 2019; Rizwana et al., 2019; Talari et al., 2017).

The FTIR results for cocona spray dried powders maintained the characteristic peaks of pulp at 1725 cm⁻¹ in MD:HC 100:0 powder (Figure 2, curve D), and 1082 cm⁻¹ in MD:HC powder 0:100 (Figure 2, curve F). The other characteristics peaks of cocona pulp (3413, 2927, 2848, 1636, 1230, 1050, and 784 cm⁻¹) disappeared in the microparticles spectrums, which can be considered as a sign of a good encapsulation process (Medina-Torres et al., 2016). In the case of the powder with pure MD and HC, they maintained the characteristic peaks of carbohydrate (1154 to 1024 cm⁻¹) (Figure 2, curve D) and protein (1650, 1556, 1055, 1405, and 1249 cm⁻¹) (Figure 2, curve F), respectively. The powder with the 50:50 ratio showed the characteristic peaks of the two carrier agents used (Figure 2, curve E). The FTIR results demonstrated no change in the chemical structure of the wall materials, since no new peaks were evidenced in the powdered cocona spectrum. They can interact with each other to form the particle wall, where the cocona pulp can also associate through hydrogen bonds (Jafari et al., 2008). Similar results was observed in other studies for spray drying using maltodextrin and protein as carrier agents (Akbarbaglu et al., 2019; Delia et al., 2019; Medina-Torres et al., 2016; Shao et al., 2019; Yingngam et al., 2018).

### 3.6 Color analysis

Color results for cocona pulp powders are shown in Table 3. We observed no significant differences for L* and C* values of the spray dried powders. However, these powders presented higher brightness values than the freeze-dried pulp, due to greater luminosity of the carrier agents. The C* values indicated a lower
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intensity in the spray dried powders than in the freeze-dried pulp. The tonality of the spray dried samples was light yellow, as verified by the $H^*$ values, of approximately 90°. Caparino et al. (2012) reported similar results for $L^*$ of spray dried mango powder due to the addition of MD to its formulation.

Table 3. Experimental values of color: luminosity ($L^*$), chroma ($C^*$) and hue angle ($H^*$) of spray dried cocona pulp. Color difference ($\Delta E$) between spray dried powders, freeze-dried pulp (reference) and the carrier agents maltodextrin (MD) and hydrolyzed collagen (HC).

| Feed solutions | P:CA | MD:HC | $L^*$ | $C^*$ | $H^*$ | Color difference ($\Delta E$) | Reference sample |
|----------------|------|-------|-------|-------|-------|-----------------------------|-----------------|
|                |      |       | Mean  | SE    | Mean  | Freeze-dried pulp | Carri er agents |
| 1              | 100:0|       | 90.83 | ± 0.34 | 11.62 | 89.61 | ± 0.13 | 27.75 | ± 1.32 | 8.78 | ± 0.96 |
| 2              | 1:3  | 50:50 | 91.66 | ± 0.21 | 11.44 | 90.34 | ± 0.16 | 28.49 | ± 1.23 | 2.30 | ± 0.12 |
| 3              | 0:100|       | 90.76 | ± 0.34 | 11.64 | 89.87 | ± 0.32 | 27.69 | ± 0.46 | 4.59 | ± 0.87 |
| 4              | 100:0|       | 91.71 | ± 0.45 | 10.42 | 90.26 | ± 0.08 | 29.20 | ± 1.58 | 7.30 | ± 0.24 |
| 5              | 1:4  | 50:50 | 91.67 | ± 0.44 | 10.63 | 90.81 | ± 0.11 | 29.12 | ± 0.46 | 2.76 | ± 0.20 |
| 6              | 0:100|       | 90.43 | ± 0.56 | 11.86 | 90.48 | ± 0.09 | 27.34 | ± 0.40 | 4.42 | ± 1.04 |
| 7              | 100:0|       | 92.01 | ± 0.11 | 9.30  | 90.51 | ± 0.16 | 30.18 | ± 1.53 | 6.22 | ± 0.36 |
| 8              | 1:5  | 50:50 | 92.22 | ± 0.44 | 9.98  | 90.82 | ± 0.20 | 29.87 | ± 1.03 | 3.25 | ± 0.71 |
| 9              | 0:100|       | 91.72 | ± 0.29 | 10.95 | 91.22 | ± 0.12 | 28.89 | ± 0.42 | 5.21 | ± 1.16 |
| 10             | 100:0|       | 91.93 | ± 0.41 | 9.29  | 90.81 | ± 0.28 | 30.13 | ± 0.63 | 6.27 | ± 1.15 |
| 11             | 1:6  | 50:50 | 92.83 | ± 0.49 | 9.13  | 91.41 | ± 0.32 | 30.90 | ± 0.78 | 3.93 | ± 0.16 |
| 12             | 0:100|       | 92.31 | ± 0.17 | 9.85  | 91.90 | ± 0.09 | 30.07 | ± 1.18 | 6.36 | ± 0.25 |

P:CA = Proportion of fruit pulp solids and carrier agents. MD:HC carrier agents maltodextrin and hydrolyzed collagen. The values represent the average of three determinations ± standard deviation. Lowercase and uppercase letters represent the response variation for multiple P:CA and MD:HC, respectively. Averages with the same letters lowercase or uppercase indicate that there is no significant difference ($p \leq 0.05$) by Tukey test.

The color difference ($\Delta E$) between the powders obtained by spray drying and freeze-drying compared with the carrier agent, ranged from 2.30 to 8.78 and 27.34 to 30.90, respectively (Table 3). These results indicated little differences in color between spray dried cocona pulp and carrier agent mixture (2.30 to 3.93). This similarity of colors suggests that the carrier agents coated/encapsulated the solids of cocona (Figure 3). The increase in lightness and decrease color saturation (chroma) were due to the dilution effect (1:6) caused by carrier agent addition to cocona pulp, resulting in loss of color for pulp. Similar results were found to powdered pink guava with MD (Shishir et al., 2014), tamarind pulp with MD - SPI (Muzaffar et al., 2016), and grape juice MD, WPI - SPI (Moser et al., 2017).
4 Conclusions

We evaluated the combined use of hydrolyzed collagen and maltodextrin as carrier agents on the spray drying of cocona pulp. The addition of HC favored the solids recovery in the spray drying process, reducing losses of the product in the drying chamber. The low values for moisture content and water activity guarantee the stability of the dried product. FTIR spectra showed stretch bands of carbohydrates characteristic of maltodextrin and protein in cocona powders. The absence of most of the cocona pulp peaks shows that the spray drying of cocona pulp can be considered as a good encapsulation process. The color of the powders is very similar to that of the carrier agents. In the present study, we show that HC is an effective additive in the drying of cocona pulp and may replace MD, either partially or fully. Moreover, the addition of HC to cocona pulp powder is relevant because it has potential benefits for human health.

References

Akbarbaglu, Z., Mahdi Jafari, S., Sarabandi, K., Mohammadi, M., Khakbaz Heshmati, M., & Pezeshki, A. (2019). Influence of spray drying encapsulation on the retention of antioxidant properties and microstructure of flaxseed protein hydrolysates. *Colloids and Surfaces. B, Biointerfaces*, 178, 421-429. PMid:30908998. http://dx.doi.org/10.1016/j.colsurfb.2019.03.038

Akhavan Mahdavi, S., Jafari, S. M., Assadpoor, E., & Dehnad, D. (2016). Microencapsulation optimization of natural anthocyanins with maltodextrin, gum Arabic and gelatin. *International Journal of Biological Macromolecules*, 85, 379-385. PMid:26772915. http://dx.doi.org/10.1016/j.ijbiomac.2016.01.011

Andrade Junior, M. C., Andrade, J. S., Costa, S. S., & Leite, E. A. S. (2017). Nutrients of cubiu fruits (Solanum sessiliflorum Dunal, Solanaceae) as a function of tissues and ripening stages. *Journal of Food and Nutrition Research*, 5(9), 674-683. http://dx.doi.org/10.12691/jfnr-5-9-7

Association of Official Analytical Chemists – AOAC. (2006). *Official Methods of Analysis* (18th ed.). Gaithersburg: AOAC.

Avaltroni, F., Bouquerand, P. E., & Normand, V. (2004). Maltodextrin molecular weight distribution influence on the glass transition temperature and viscosity in aqueous solutions. *Carbohydrate Polymers*, 58(3), 323-334. http://dx.doi.org/10.1016/j.carbpol.2004.08.001

Bilek, S. E., & Bayram, S. K. (2015). Fruit juice drink production containing hydrolyzed collagen. *Journal of Functional Foods*, 14, 562-569. http://dx.doi.org/10.1016/j.jff.2015.02.024

Borunmand, M., & Sibilla, S. (2014). Daily consumption of the collagen supplement Pure Gold Collagen(R) reduces visible signs of aging. *Clinical Interventions in Aging*, 9, 1747-1758. PMid:25342893. http://dx.doi.org/10.2147/CIA.S65939

Borunmand, M., & Sibilla, S. (2015). Effects of a nutritional supplement containing collagen peptides on skin elasticity, hydration and wrinkles. *Journal of Medical Nutrition and Nutraceuticals*, 4(1), 47-53. http://dx.doi.org/10.4103/2278-019X.146161

Butzge, J. J., Godoi, F. C., & Rocha, S. C. S. (2014). Drying of hydrolyzed collagen with grape pulp in spouted bed: influence of process variables on the powder production efficiency. *Journal Drying Technology*, 32(16), 2012-2014. https://doi.org/10.1080/07373937.2014.976430.

Can Karaca, A., Guzel, O., & Ak, M. M. (2016). Effects of processing conditions and formulation on spray drying of sour cherry juice concentrate. *Journal of the Science of Food and Agriculture*, 96(2), 449-455. PMid:25641719. http://dx.doi.org/10.1002/jsfa.7110

Caparino, O. A., Tang, J., Nindo, C. I., Sablani, S. S., Powers, J. R., & Fellman, J. K. (2012). Effect of drying methods on the physical properties and microstructures of mango (Philippine ‘Carabao’ var.) powder. *Journal of Food Engineering*, 111(1), 135-148. http://dx.doi.org/10.1016/j.jfoodeng.2012.01.010

Cardona, J. E. C., Cuca, L. E., & Barrera, J. A. (2011). Determination of some secondary metabolites in three ethnovarieties of cocona (Solanum sessiliflorum Dunal). *Revista Colombiana de Química*, 40(2), 185-200. Retrieved in 2019, September 13, from http://www.scielo.org.co/pdf/rcq/v40n2/v40n2a4.pdf
Influence of combined hydrolyzed collagen and maltodextrin as carrier agents in spray drying of cocona pulp

Vargas-Muñoz, D. P. & Kurozawa, L. E.

Daneault, A., Prawitt, J., Fabien Soulé, V., Coxam, V., & Wittrant, Y. (2017). Biological effect of hydrolyzed collagen on bone metabolism. *Critical Reviews in Food Science and Nutrition*, 57(8), 1922-1937. PMid:25976422.

Delia, S. C., Chávez, G. M., León-Martínez Frank, M., Arceli, S. P., Irais, A. L., & Franco, A. A. (2019). Spray drying microencapsulation of betalain rich extracts from Escontria chiotilla and Stenocereus queretaroensis fruits using cactus mucilage. *Food Chemistry*, 272, 715-722. PMid:30309603. http://dx.doi.org/10.1016/j.foodchem.2018.08.069

Ding, C., Zhang, M., & Li, G. (2015). Preparation and characterization of collagen / hydroxypropyl methylcellulose (HPMC) blend film. *Carbohydrate Polymers*, 119, 194-201. PMid:25563960. http://dx.doi.org/10.1016/j.carbpol.2014.11.057

Du, J., Ge, Z., Xu, Z., Zou, B., Zhang, Y., & Li, C. (2014). Comparison of the efficiency of five different drying carriers on the spray drying of persimmon pulp powders. *Drying Technology*, 32(10), 1157-1166. http://dx.doi.org/10.1080/07373937.2014.886259

Fang, Z., & Bhandari, B. (2012). Comparing the efficiency of protein and maltodextrin on spray drying of bayberry juice. *Food Research International*, 48(2), 478-483. http://dx.doi.org/10.1016/j.foodres.2012.05.025

Fang, Z., Wang, R., & Bhandari, B. (2013). Effects of type and concentration of proteins on the recovery of spray-dried sucrose powder. *Drying Technology*, 31(13-14), 1643-1652. http://dx.doi.org/10.1080/07373937.2013.770011

Ferrari, C. C., Germer, S. P. M., Alvim, I. D., Vissotto, F. Z., & de Aguirre, J. M. (2012b). Influence of carrier agents on the physicochemical properties of blackberry powder produced by spray drying. *International Journal of Food Technology*, 47(6), 1237-1245. http://dx.doi.org/10.1111/j.1365-2621.2012.02964.x

Ferrari, C. C., Ribeiro, C. P., & Aguirre, J. M. (2012a). Secagem por atomização de polpa de amora-preta usando maltodextrina como agente carreador. *Brazilian Journal of Food Technology*, 15(2), 157-165. http://dx.doi.org/10.1590/S1981-67232012005000009

Fitzpatrick, J. J., van Laarw, A., Counts, M., O’Brien, A., Fitzpatrick, K. L., Ji, J., & Miao, S. (2016). Investigation of the rehydration behaviour of food powders by comparing the behaviour of twelve powders with different properties. *Powder Technology*, 297, 340-348. http://dx.doi.org/10.1016/j.powtec.2016.04.036

García-Corona, J. M., Martínez-Olvera, L., Elizondo-Omaña, R. E., Acosta-Ólivo, C. A., Vílchez-Cavazos, F., Simental-Mendía, L. E., & Simental-Mendía, M. (2019). Effect of collagen supplementation on osteoarthritis symptoms: a meta-analysis of randomized placebo-controlled trials. *International Orthopaedics*, 43(3), 531-538. http://dx.doi.org/10.1007/s00264-018-4211-5

Gong, Z., Yu, M., Wang, W., & Shi, X. (2018). Functionality of spray-dried strawberry powder: effects of whey protein isolate and maltodextrin. *International Journal of Food Properties*, 21(1), 2229-2238. http://dx.doi.org/10.1080/10942912.2018.1506477

Hameed, N., Glattauer, V., & Ramshaw, J. A. M. (2015). Evaluation of polyvinyl alcohol composite membranes containing collagen and bone particles. *Journal of the Mechanical Behavior of Biomedical Materials*, 48, 38-45. PMid:25913606. http://dx.doi.org/10.1016/j.jmbbm.2015.04.005

Jafari, S. M., Assadpoor, E., He, Y., & Bhandari, B. (2008). Encapsulation efficiency of food flavours and oils during spray drying. *Drying Technology*, 26(7), 816-835. http://dx.doi.org/10.1080/07373930802135972

Jiménez, P. (2018). Cocona—Solanum sessiliflorum. In S. Rodrigues, E. O. Silva & E. S. Brito (Eds.), *Exotic fruits* (pp. 153-158). London: Academic Press. https://doi.org/10.1016/B978-0-12-803138-4.00020-4

Kuck, L. S., & Noreña, C. P. Z. (2016). Microencapsulation of grape (Vitis labrusca var. Bordo) skin phenolic extract using gum Arabic, polydextrose, and partially hydrolyzed guar gum as encapsulating agents. *Food Chemistry*, 194, 569-576. PMid:26471594. http://dx.doi.org/10.1016/j.foodchem.2015.08.066

Lopez, H. L., Ziegenfuss, T. N., & Park, J. (2015). Evaluation of the effects of BioCell collagen, a novel cartilage extract, on connective tissue support and functional recovery from exercise. *Integrative Medicine*, 14(3), 30-38. Retrieved in 2019, September 13, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4566464/

Mascato, D. R., Monteiro, J. B., Passarinho, M. M., Galeno, D. M., Cruz, R. J., Ortiz, C., Morales, L., Lima, E. S., & Carvalho, R. P. (2015). Evaluation of antioxidant capacity of solanum sessiliflorum (Cubiu) extract: an in vitro assay. *Journal of Nutrition and Metabolism*, 2015, 1-8. PMid:26788365. http://dx.doi.org/10.1155/2015/364185

Medina-Torres, L., Santiago-Adame, R., Calderas, F., Gallegos-Infante, J. A., González-Laredo, R. F., Rocha-Guzmán, N. E., Núñez-Ramírez, D. M., Bernad-Bernad, M. J., & Manero, O. (2016). Microencapsulation by spray drying of laurel infusions (Litsaea glutinosa) with maltodextrin. *Industrial Crops and Products*, 90, 1-8. http://dx.doi.org/10.1016/j.indcrop.2016.06.009

Miller, G. L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical Chemistry*, 31(3), 426-428. http://dx.doi.org/10.1021/ac60147a030

Mishra, P., Mishra, S., & Mahanta, C. L. (2014). Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (Emblica officinalis) juice powder. *Food and Bioproducts Processing*, 92(3), 252-258. http://dx.doi.org/10.1016/j.fbp.2013.08.003

Mishra, P., Rai, G. K., & Mahanta, C. L. (2015). Spray-dried lemon juice powder and optimization of amla-lemon based RTS (ready-to-serve) drink using response surface methodology. *Journal of Food Processing and Preservation*, 39(6), 1216-1228. http://dx.doi.org/10.1111/jfpp.12338

Mosser, P., Souza, R. T. D., & Nicoletti Telis, V. R. (2017). Spray drying of grape juice from hybrid cv. brs violeta: microencapsulation of anthocyanins using protein/maltodextrin blends as drying aids. *Journal of Food Processing and Preservation*, 41(1), 1-11. http://dx.doi.org/10.1111/jfpp.12852
Influence of combined hydrolyzed collagen and maltodextrin as carrier agents in spray drying of cocona pulp

Vargas-Muñoz, D. P. & Kurozawa, L. E.

Muzaffar, K., & Kumar, P. (2016). Effect of soya protein isolate as a complementary drying aid of maltodextrin on spray drying of tamarind pulp. *Drying Technology*, 34(1), 142-148. http://dx.doi.org/10.1080/07373937.2015.1042586

Muzaffar, K., Wani, S. A., Dinkarrao, B. V., & Kumar, P. (2016). Determination of production efficiency, color, glass transition, and sticky point temperature of spray-dried pomegranate juice powder. *Cogent Food & Agriculture*, 2(1), 2-7. http://dx.doi.org/10.1080/23319192.2016.1144444

Namani, S., Paripelli, S., Chinini, S. V., Kasi, M., Subramaniam, S., & Rathinam, X. (2016). In vitro anti-oxidant assay, HPLC profiling of polyphenolic compounds, VAS and FTIR spectrum of Malaysian orange Solanum torvum fruit. *Indian Journal of Pharmaceutical Education and Research*, 50(2), S11-S20. http://dx.doi.org/10.15530/ijper.50.2.13

Nnorom, O. O., & Onuegbu, G. C. (2019). Authentication of Rothmannia whitfieldii Dye Extract with FTIR Spectroscopy. *Journal of Textile Science and Technology*, 5(2), 38-47. http://dx.doi.org/10.4236/jtst.2019.52004

Oliveira, M. I. S., Tonon, R. V., Nogueira, R. I., & Cabral, L. M. C. (2013). Estabilidade da polpa de morango atomizada utilizando diferentes agentes carreadores. *Brazilian Journal of Food Technology*, 16(4), 310-318. http://dx.doi.org/10.1590/1808-8179-201303000037

Pardo, M. (2004). Efeito de Solanum sessiliflorum dunal sobre o metabolismo lipídico e da glicose. *Ciencia e Investigacion*, 7(2), 43-48. Retrieved in 2019, September 13, from https://revistasinvestigacion.unmsm.edu.pe/index.php/farima/article/view/3350

Proksch, E., Segger, D., Degwert, J., Schunck, M., Zague, V., & Oesser, S. (2014). Oral supplementation of specific collagen peptides has beneficial effects on human skin physiology: a double-blind, placebo-controlled. *Skin Pharmacology and Physiology*, 24, 47-55. https://doi.org/10.1159/000351376

Puigdellivol, J., Berenger, C. C., Fernández, M. A. P., Millán, J. M. C., Vidal, C. C., Gil, I. G., Pagán, J. M., Rui Nieto, B., Jiménez, F. J., Figureola, F. X. C., & Hernández, M. E. A. (2018). Effectiveness of a dietary supplement containing hydrolyzed collagen, chondroitin sulfate, and glucosamine in pain reduction and functional capacity in osteoarthritis patients. *Journal of Dietary Supplements*, 18(4), 1-11. PMid:29701488.

Rigoto, J., Ribeiro, T., Stevanato, N., Sampaio, A., Ruiz, S., & Bolanho, B. (2018). Effect of agai pulp, cheese whey, and hydrolysate collagen on the characteristics of dairy beverages containing probiotic bacteria. *Journal of Food Process Engineering*, 4, article 1-10. http://dx.doi.org/10.1111/jffe.12953.

Rizwana, H., Al Othibi, F., & Al-Malki, N. (2019). Chemical composition, FTIR Studies and Antibacterial Activity of Passiflora edulis f. Edulis (Fort.) *Pure & Applied Microbiology*, 13(4), 2489-2498. http://dx.doi.org/10.22207/PAM.13.4.64

Robert, P., Torres, V., García, P., Vergara, C., & Sáenz, C. (2015). The encapsulation of purple cactus pear (Opuntia ficus-indica) pulp by using polysaccharide-proteins as encapsulating agents. *Lebensmittel-Wissenschaft + Technologie*, 60(2), 1039-1045. http://dx.doi.org/10.1007/lwt.2014.01038

Rodrigues, E., Mariutti, L. R. B., & Mercadante, A. Z. (2013). Carotenoids and phenolic compounds from Solanum sessiliflorum, an unexploited amazonian fruit, and their scavenging capacities against reactive oxygen and nitrogen species. *Journal of Agricultural and Food Chemistry*, 61(12), 3022-3029. PMid:23432472. http://dx.doi.org/10.1021/jf3034214

Samborska, K., Gajek, P., & Kaminska-Dworzicka, A. (2015). Spray drying of honey: the effect of drying agents on powder properties. *Polish Journal of Food and Nutrition Sciences*, 65(2), 109-118. http://dx.doi.org/10.2478/pjfn-2013-0012

Santana, A. A., Martin, L. G. P., de Oliveira, R. A., Kurozawa, L. E., & Park, K. J. (2017). Spray drying of babassu coconut milk using different carrier agents. *Drying Technology*, 35(1), 76-87. http://dx.doi.org/10.1080/07373937.2016.1160111

Serno-Cock, L., Vargas-Muñoz, D. P., & Rengifo-Guerrero, C. A. (2015). Chemical characterization of the pulp, peel and seeds of cocona (solanum sessiliflorum dunal). *Brazilian Journal of Food Technology*, 19(3), 192-198. http://dx.doi.org/10.1590/1981-6723.4314

Shao, P., Xuan, S., Wu, W., & Qu, L. (2019). Encapsulation efficiency and controlled release of Ganoderma lucidum polysaccharide microcapsules by spray drying using different combinations of wall materials. *International Journal of Macromolecules*, 125, 962-969. PMid:30572060. http://dx.doi.org/10.1016/j.ijbiomac.2018.12.153

Shi, Q., Fang, Z., & Bhandari, B. (2013). Effect of adding whey protein isolate on spray-drying behavior of honey with maltodextrin as a carrier material. *Drying Technology*, 31(13-14), 1681-1692. http://dx.doi.org/10.1080/07373937.2013.783593

Shishir, M. R. I., Taip, F. S., Aziz, N. A., & Talib, R. A. (2014). Physical Properties of Spray-dried Pink Guava (Psidium Guajava) Powder. *Agriculture and Agricultural Science Procedia*, 2, 74-81. http://dx.doi.org/10.1016/j.aaspro.2014.11.011

Silva Filho, D. F., Yuyama, L. K. O., Aguiar, J. P. L., Oliveira, M. C., & Martins, L. H. P. (2005). Caracterização e avaliação do potencial agronômico e nutricional de etnovariedades de cubiu (Solanum sessiliflorum Dunal) da Amazônia. *Ciencia e Investigacion*, 2(4), 399-406. http://dx.doi.org/10.1590/S0044-59672005000400003

Silva, J. K. D., Sales, M. L. F., Aum, Y. K. P. G., Ferreira, F. B., Braga, N. P., & Silvia, O. C. D. (2016). Estudo do efeito da secagem em leito de jorro na manutenção dos compostos fenólicos presentes na polpa de cubiu. In *Anais do XXI Congresso Brasileiro de Engenharia Quimica*. São Paulo: ABEQ. Retrieved in 2019, September 13, from https://www.researchgate.net/publication/313022881

Talaru, A. C. S., Martinez, M. A. G., Movasaghi, Z., Rehman, S., & Rehman, I. U. (2017). Advances in Fourier transform infrared (FTIR) spectroscopy of biological tissues. *Applied Spectroscopy Reviews*, 52(5), 456-506. http://dx.doi.org/10.1002/105704928.2016.1230863
Thirugnanasambandham, K., & Sivakumar, V. (2015). Influence of process conditions on the physicochemical properties of pomegranate juice in spray drying process: modelling and optimization. *Journal of the Saudi Society of Agricultural Sciences, 16*(4), 358-366. [http://dx.doi.org/10.1016/j.jsas.2015.11.005](http://dx.doi.org/10.1016/j.jsas.2015.11.005)

Tolun, A., Altintas, Z., & Artik, N. (2016). Microencapsulation of grape polyphenols using maltodextrin and gum arabic as two alternative coating materials: development and characterization. *Journal of Biotechnology, 239*, 23-33. [PMId:27720817](http://dx.doi.org/10.1016/j.jbiotec.2016.10.001)

Wang, W., Jiang, Y., & Zhou, W. (2013). Characteristics of soy sauce powders spray-dried using dairy whey proteins and maltodextrins as drying aids. *Journal of Food Engineering, 119*(4), 724-730. [http://dx.doi.org/10.1016/j.jfoodeng.2013.06.047](http://dx.doi.org/10.1016/j.jfoodeng.2013.06.047)

Yingngam, B., Tantiraksaroj, K., Taweetao, T., Rungseevijitprapa, W., Supaka, N., & Brantner, A. H. (2018). Modeling and stability study of the anthocyanin-rich maoberry fruit extract in the fast-dissolving spray-dried microparticles. *Powder Technology, 325*, 261-270. [http://dx.doi.org/10.1016/j.powtec.2017.10.059](http://dx.doi.org/10.1016/j.powtec.2017.10.059)

Yuyama, L. K. O., Pereira, Z. R. F., Aguiar, J. P. L., & Silva Filho, D. (2005). Study of cubiu (Solanum sessiliflorum Dunal) influence on the seric concentration of glucose. *Revista do Instituto Adolfo Lutz, 64*(2), 232-236. Retrieved in 2019, September 13, from [http://periodicos.ses.sp.bvs.br/pdf/rial/v64n2/v64n2a14.pdf](http://periodicos.ses.sp.bvs.br/pdf/rial/v64n2/v64n2a14.pdf)

Zareifard, M. R., Niakousari, M., Shokrollahi, Z., & Javadian, S. (2012). A feasibility study on the drying of lime juice: the relationship between the key operating parameters of a small laboratory spray dryer and product quality. *Food and Bioprocess Technology, 5*(5), 1896-1906. [http://dx.doi.org/10.1007/s11947-011-0689-1](http://dx.doi.org/10.1007/s11947-011-0689-1)

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Supplementary Material

Supplementary material accompanies this paper.

Table 1. Feed solutions with 20% of total solids and experimental values of solids recovery of cocona powder obtained by spray dryer under several feed flow rates.

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