VOL VI

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PESQUISA E INOVAÇÃO NAS CIÊNCIAS QUE ALIMENTAM O MUNDO

EDUARDO EUGÊNIO SPERS
(Organizador)

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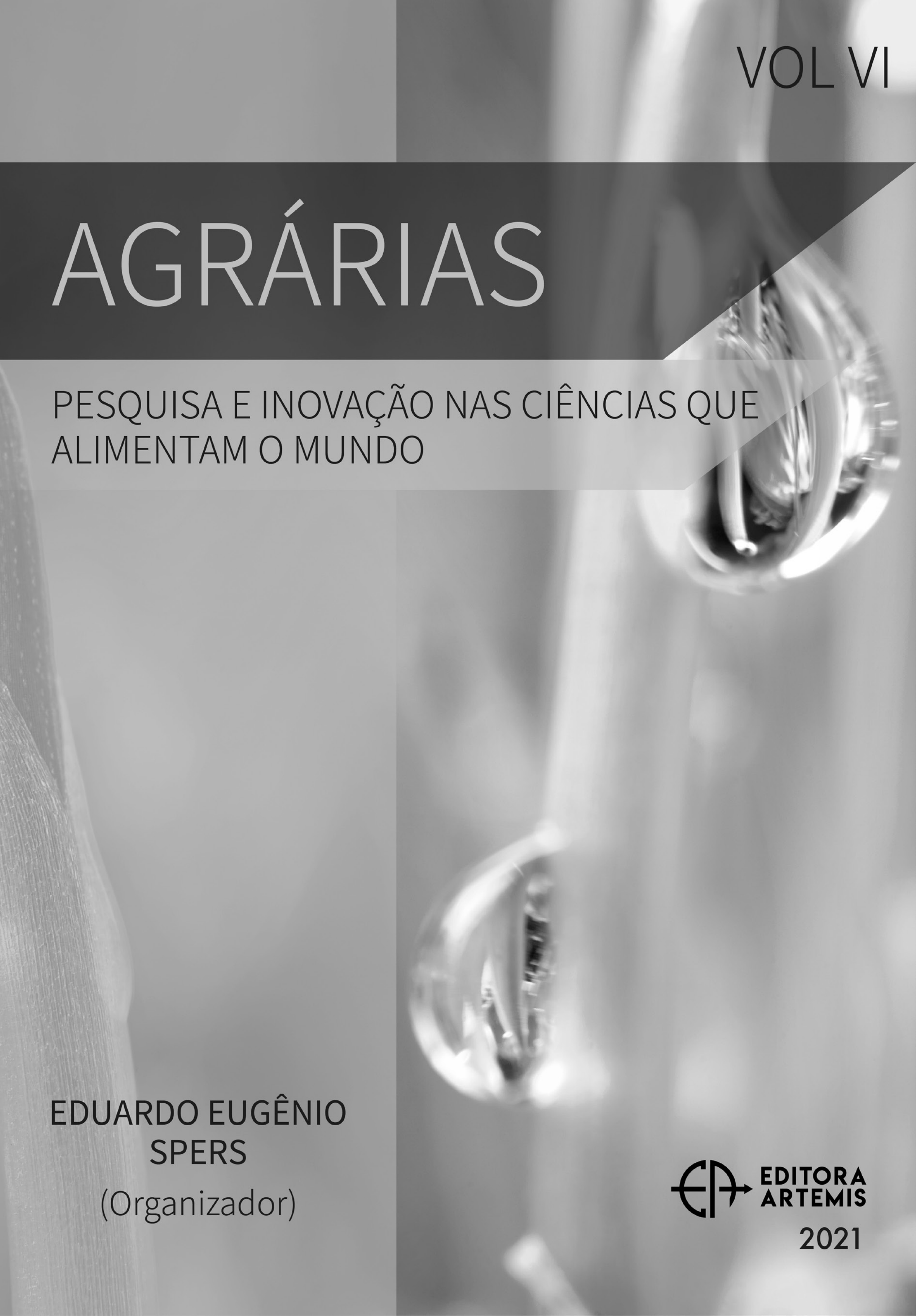

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APRESENTAÇÃO

As Ciências Agrárias são um campo de estudo multidisciplinar por excelência, e um dos mais profícuos em termos de pesquisas e aprimoramento técnico. A demanda mundial por alimentos e a crescente degradação ambiental impulsionam a busca constante por soluções sustentáveis de produção e por medidas visando à preservação dos recursos naturais.

A obra Agrárias: **Pesquisa e Inovação nas Ciências que Alimentam o Mundo** compila pesquisas atuais e extremamente relevantes, apresentadas em linguagem científica de fácil entendimento. Na coletânea, o leitor encontrará textos que tratam dos sistemas produtivos em seus diversos aspectos, além de estudos que exploram diferentes perspectivas ou abordagens sobre a planta, o meio ambiente, o animal, o homem, o social e sobre a gestão.

Este Volume VI traz 28 artigos de estudiosos de diversos países. São 14 trabalhos de autores da Argentina, China, Colômbia, Espanha, México, Peru e Portugal e 14 trabalhos de pesquisadores brasileiros, divididos em dois eixos temáticos: os primeiros 13 capítulos versam sobre **Sistemas de Produção Vegetal** e os demais tratam de temas variados dentro do eixo temático **Zootecnia e Veterinária.**

Desejo a todos uma proveitosa leitura!

Eduardo Eugênio Spers

SUMÁRIO

SISTEMAS DE PRODUÇÃO VEGETAL

CAPÍTULO 2

FUNCTIONALITY AND PHYSICOCHEMICAL PROPERTIES OF THE CHIRIMOYA FLOUR (*ANNONA CHERIMOLA MILLER*) CV. CUMBE

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ABSTRACT: The objective of the study was to take advantage of the fruits of cherimoya (Annona cherimola Miller), which presented low caliber for fresh marketing and that would allow obtaining a flour with adequate physicochemical and functional properties for the food industry. For this, the fruits of up to 3 days of collecting were manually conditioned to obtain their pulp, which was laminated to 3 ± 1 mm thick and dehydrated in a convective dryer at 50 ° C and an air velocity of ~ 3 m / s, until constant weight. Subsequently, it was ground and sieved using an 80 mesh to obtain cherimoya flour (HCh). The results expressed as the mean ± SD of at least three independent experiments; where aw values of 0.332 ± 0.025, the humidity of 12.04 ± 1.23%, pH of 5.46 ± 0.05 and °Brix of 20.00 ± 0.01 were obtained. The analysis of the CIELab Color coordinates for the HCh found a luminosity (L *) of 87.9 ± 0.9, a* value of 1.5 ± 0.3 and a b * value of 14.3 ± 2.0, defining a yellowish-white color. The functionality tests yielded values of apparent density (ρa) of 0.4746 ± 0.019, compacted density (ρc) of 0.5514 ± 0.0123, cohesiveness by the Hausner Ratio (HR) of 1.1623 and fluidity by Carr index (CI) of 13.94%; values that give "low cohesiveness" and "very good fluidity" to HCh. Likewise, the solubility index (ISA), water absorption index (IAA) and the oil retention capacity (CRA) determined obtained valuables of 27.10 ± 2.55%, 2.6036 ± 0.2466 g H2O / g and 1.0742 ± 0.0930 g oil / g, respectively. In conclusion, cherimoya

Flour has physicochemical and functional properties that make possible to use as a substitute input for other commercial flours used in various food matrices.
KEYWORDS: *Annona cherimola* Miller. Cherimoya flour. Functional properties.

FUNCIONALIDADE E PROPRIEDADES FÍSICO-QUÍMICAS DA FARINHA DE CHIRIMOYA (*Annona cherimola Miller*) CV. Cumbe

RESUMO: O objetivo do estudo foi aproveitar os frutos da cherimoya (Annona cherimola Miller), que apresentavam baixo calibre para comercialização in natura e que permitiriam obter uma farinha com propriedades físico-químicas e funcionais adequadas para a indústria alimentícia. Para isso, os frutos com até 3 dias de coleta foram condicionados manualmente para a obtenção de sua polpa, que foi laminada a 3 ± 1 mm de espessura e desidratada em secador convectivo a 50 ° C e velocidade do ar de ~ 3 m / s, até peso constante. Posteriormente, foi moído e peneirado em malha 80 para obtenção da farinha de cherimoya (HCh). Os resultados expressos como a média ± DP de pelo menos três experimentos independentes; onde foram obtidos valores de aw de 0,332 ± 0,025, umidade de 12,04 ± 1,23%, pH de 5,46 ± 0,05 e ° Brix de 20,00 ± 0,01. A análise das coordenadas de cores do CIELab para o HCh encontrou uma luminosidade (L *) de 87,9 ± 0,9, valor a * de 1,5 ± 0,3 e valor b * de 14,3 ± 2,0, definindo uma cor branco amarelada. Os testes de funcionalidade renderam valores de densidade aparente (ρa) de 0,4746 ± 0,019, densidade compactada (ρc) de 0,5514 ± 0,0123, coesividade pela Razão de Hausner (HR) de 1,1623 e fluidez pelo índice de Carr (CI) de 13,94%; valores que conferem "baixa coesão" e "fluidez muito boa" ao HCh. Da mesma forma, o índice de solubilidade (ISA), índice de absorção de água (IAA) e capacidade de retenção de óleo (CRA) determinados obtiveram valores de 27,10 ± 2,55%, 2,6036 ± 0,2466 g H2O / ge 1,0742 ± 0,0930 g óleo / g, respectivamente. Em conclusão, a Farinha de Cherimoya possui propriedades físico-químicas e funcionais que possibilitam sua utilização como substituto de outras farinhas comerciais utilizadas em diversas matrizes alimentares.
PALAVRAS-CHAVE: *Annona cherimola* Miller. Propriedades funcionais da farinha de Cherimoya.

1 INTRODUCTION

Cherimoya, scientifically known as *Annona cherimola Miller*, is a fruit that grows in the valleys of the provinces of Lima (Peru). It is a very digestive and nutritious fruit, characterized by its high water content. It has many particular characteristics given to the harmonic combination in its composition of acids and sugars. The last one is product of starch reduction during post-harvest maturation, with glucose (11.75%) and sucrose (9.4%) as predominant sugars (Kawamata, 1977); while the main organic acids in its composition are citric and malic acid. This combination results in pulp fruit with pleasant and extremely sweet taste when it reaches its physiological maturity (24 ° Brix) that consumption focused on its ripe state.

Although the cherimoya may have limitations in its processing, mainly due to the high phenolic oxidation and its tendency to darkening, the industrial products derived from this pulp are diverse and is very commonly used in the production of ice cream, beverages, and pastry products. Another great limitation is its rapid post-harvest maturity that can generate large losses in the fresh fruit trade, which increases the logistics processes for its conservation and trade due to the application of the cold chain. To which is added the factor of the sale price in the fresh state, which is related to quality criteria such as the selection by calibration, size, weight, etc. All these factors can generate a 60% discard of the national production of Peru (Lira Segura J. , 2014)

In this sense, in fruits that have a limited shelf life, the development of methods for their conservation is important to avoid losses and add value. Dehydration results in an adequate technique to achieve this objective (Verma, Singh, Kaur, Mishra, & Rai, 2015) and is commonly used at industrial scale to obtain high-moisture raw material flours, such as cherimoya.

Flour production is an alternative to prolong the shelf life of some food products, as can reduce free water and obtain less water activity; additionally, reduces undesirable physicochemical changes and the growth of microorganisms. Besides, it allows the product to have a better commercial value and adequate handling, reducing the energy costs of storage (Cuq, Rondet, & Abecassis, 2011). However, when food is dehydrated, an imbalance pressure occurs within the product, (Bejar, Kechaou,, & Mihoubi, 2011), which can cause pharmacological alterations and affect the quality of fruits; in chemical, physical and functional terms, depending on drying techniques. For example, the color of fruit pulp wastes has been affected after drying at different drying temperatures using a conventional oven (Rosnah, Nur Farhana, Amin, & Nik Suhaila, 2015), while when using the technique of lyophilization, the resulting changes are minimal.

For this reason, this research studies the physicochemical and functional properties of cherimoya flour (HCh) obtained by conventional drying method, as an alternative to preserve the fruit and contribute to its value chain.

2 MATERIALS Y METHODS

2.1 VEGETAL MATERIAL

Cherimoya fruits (Annona cherimola Miller cv. Cumbe) were collected during the May-August harvest period, from the San Mateo de Otao producing Community of the Province of Huarochirí (Lima, Peru), which was arranged daily following its collection for processing in flour at the Industrial Process Laboratory of the Pontifical Catholic University of Peru (Lima).

2.2 CHERIMOYA FLOUR PRODUCTION

The cherimoya green fruits were washed with running water and disinfected by immersion in a solution of sodium hypochlorite (100 ppm) for 5 minutes. Subsequently, they were manually stripped with a stainless steel knife and divided into 20 mm slices to facilitate the removal of the seeds. The pulp fractions were suspended in a 0.1% (w / v) sodium bisulfite solution and then laminated with the help of a stainless steel mandolin to obtain slices of 3 ± 1 mm.

The slices were evenly distributed on the surface of the equipment tray (300 mm x 300 mm) and placed in a convective dryer that operated at 50 ± 2°C and an air velocity of 3 m/s, until a constant weight was reached. Dehydrated pulp was ground in a knife grinder (Bosch, MKM6003, Slovenia), and then screened using meshes of 80 or more mesh (RETSCH, ASTM E11, Germany). The flour contained between the 80-100 meshes, with particle sizes between 150 and 179 μm, was packaged in nylon-PE bags to preserve it until analysis.

2.3 PHYSICOCHEMICAL PROPERTIES

2.3.1 Water activity and moisture (%)

The HCh a_w was measured with a water activity measuring device (NOVASINA, LabSwift-aw, SPAIN). While, the moisture content was measured by drying in a forced convection oven (MEMMERT, UN30, Germany) at 105 °C until obtaining a constant weight (Li, Zhang, & Bhandari, 2019).

2.3.2 pH y total soluble solids

The pH of HCh has measured following (Suntharalingam & Ravindran, 1993) method with some modifications. A suspension of 4% (w / v) HCh was made, at room temperature, stirred for 5 min in a vortex shaker for 30 min. The supernatant was transferred to a beaker for measure pH by a calibrated potentiometer (CRISON, Basic 20, SPAIN). Total soluble solids (TSS) were measured in the same supernatants using a digital refractometer (KRUSS, DR201-95, GERMANY). The results were expressed as °Brix.

2.3.3 CIELab color

For the measurement of the color of HCh, the CIELab coordinates obtained from a colorimeter (KONICA MINOLTA, CR 400, JAPAN) were used, using the illuminant D65 and the observer of 10 °, following the method reported by (Su, Zhang, Bhandari, & Zhang, 2018). The color measurements were expressed in terms of brightness L * from 0 to 100 (degree of lightness) and the parameters a * (degree of redness and greenness) and b * (degree of yellowness and blueness).

2.4 FUNCTIONAL PROPERTIES

2.4.1 Apparent density and compacted density

The HCh apparent density (ρ_a) was determined by measuring the weight of the HCh and the corresponding volume. Approximately 1 g of HCh was transferred to a 10 mL graduated cylinder. The apparent density was calculated by dividing the mass of the HCh by the volume occupied in the graduated cylinder. For compacted density (ρ_c), the graduated specimen was struck at a constant volume with a glass rod. The volume of HCh was measured and used in the mass calculation between volume to obtain the compacted density (Jinapong, Suphantharika, & Jamnong, 2008).

2.4.2 Carr index (fluency) and Hausner ratio (cohesion)

The fluency and cohesion of HCh were expressed in terms of the Carr Index (CI) (Carr, 1965) and Hausner Ratio (Hausner, 1967), respectively. Both CI and HR were calculated from the apparent (ρ_a) and compacted (ρ_c) densities of HCh as shown in the following equations:

$$CI = \frac{\rho_c - \rho_a}{\rho_c} x100 \text{ ... (Ec. 1)}$$

$$HR = \frac{\rho_c}{\rho_a} \text{ ... (Ec. 2)}$$

The fluidity of the powders with IC <15 is classified as "very good"; 15 <CI <20 as "good"; 20 <CI <35 as "regular"; 35 <CI <45 as "bad" and CI> 45 as "very bad" (Carr, 1965). Powders with RH below 1.2 are classified as a "low cohesivity" group; with HR between 1.2 and 1.4 it is considered as "intermediate cohesiveness" and HR of more than 1.4 is considered "high cohesivity" (Hausner, 1967).

2.4.3 Water solubity index (WSI) and Water absorption index (WAI)

The water solubility index (WSI) and water absorption index (WAI) of HCh were performed according to Rodríguez-Ambriz, Martínez-Ayala, Millán, & Dávila-Ortíz (2005) with some modifications. 1 g of HCh (P_0) was mixed with 35 mL of distilled water, at room temperature. The mixture was homogenized with a vortex shaker (KGEMMY Industrial Corp, VM300P, TAIWAN), at a maximum level for 5 minutes, then the solution was transferred to a previously weighed 50 mL centrifuge tube; the tube was left at room temperature for 1 hour and centrifuged at 4390 rpm for 20 minutes in a centrifuge (THERMO FISHER, CL10, GERMANY). The tube was drained at an angle of 45 ° for 10 minutes in a previously weighed Petri dish. The Petri dish supernatant was dried for 12 h at 105 ° C until constant weight, (P_1). The WSI was calculated by dividing the dry mass of the supernatant (P_1) by the sample mass of HCh used in the test (P_0), expressed as a percentage. The WAI was calculated as the difference between the centrifuged precipitate mass (P_2) and the HCh sample mass used in the test (P_0) divided by the HCh sample mass used in the test (P_0).

$$WAI = \frac{P_1}{P_0} \text{... (Ec. 3)}$$

$$WSI = \frac{(P_2 - P_0)}{P_0} x\ 100 \text{... (Ec. 4)}$$

2.4.4 Oil retention capacity (ORC)

To determine the oil retention capacity (ORC), the Rodríguez - Ambriz et al. (2008) method was used, 25 mL of olive oil was mixed with 1 g of HCh (P_0), placed on a vortex shaker (KGEMMY Industrial Corp, VM300P, TAIWAN) for 2 minutes and incubated at room temperature for 1 hour. The tube was centrifuged at 4390 rpm for 20 min. The supernatant was decanted and the tube was drained for 10 minutes at a 45 ° angle. The centrifuged precipitate was weighed (P_3), and the ORC was calculated as g of oil per g of HCh sample, as follows:

$$ORC = \frac{(P_3 - P_0)}{P_0} \text{... (Ec. 5)}$$

2.5 STATISTICAL ANALYSES

All measurements and analyses were performed in triplicate. The results were expressed as mean ± standard deviations, using MS Excel (2016).

3 RESULTS AND DISCUSSIONS

3.1 PHYSICOCHEMICAL PROPERTIES

The physicochemical properties (water activity, moisture, pH, soluble solids) of HCh are presented in Table 1. Moisture content and water activity of powder products are critical properties that may affect other physical and chemical properties of food. In addition, they are critical factors for shelf life and stability of food. The values obtained for humidity (12.04 ± 1.23) and water activity (0.332 ± 0.03) were within the limits for safe storage. In relation to these, (Iombor & Olaitan, 2014), (Li, Zhang, & Bhandari, 2019) and (Soquetta, et al., 2016), reported a moisture content, lower than HCh, in soursop flour (*Annona muricata*), dry yam and ripe kiwi bagasse, with values of 8.10 ± 0.06%, 6.94 ± 0.13% and 9.18 ± 0.28%, respectively. Regarding the water activity that HCh presented, it was higher than *Marolo Annona crassiflora* flour (0.176 ± 0.00) (Corrêa, et al., 2011)and for ripe kiwi bagasse (0.44) (Soquetta, et al., 2016). Despite this, HCh can be considered a stable food considering that deterioration reactions occur when water activity is greater than 0.65 for most foods (Ethur, Zanatta, & Schlabitz, 2010).

The pH results (5.46 ± 0.05) were similar to those reported for green and marolo banana flour with pH values of 5.06 and 5.42, respectively (Alkarkhi, Bin Ramli, Yong, & Easa, 2011) (Corrêa, et al., 2011).

Soluble HCh solids had a value of 20.00 ± 0.01 °Brix, much higher values than those reported for green banana flour that had 0.74 ± 0.09 ° Brix (Savlak, Türker, & Yesilkanat, 2016). Similarly, (Alkarkhi, Bin Ramli, Yong, & Easa, 2011) reported values of 1.22 ± 0.14 °Brix for green banana flour and 4.26 ± 0.24 °Brix for banana flour mature. The response in the °Brix of the HCh is mainly due to the fact that the fruit of the cherimoya at the time of its collection comes to present between 6 and 8 °Brix, reaching 25 °Brix in its senescence (data not shown), with the Dehydration increases to the total solids content, and also the soluble ones (° Brix).

Table 1. Results of the physicochemical evaluation of cherimoya flour (HCh) and those reported for flours of other fruits.

Fruit	Physicochemical properties			
	a_w	H %	pH	°Brix
Annona cherimola Miller (In this study)	0,332 ± 0,03	12,04 ± 1,23	5,46 ± 0,05	20,00 ± 0,01
Annona crassiflora (Corrêa, et al., 2011)	0,176 ± 0,00	4.2 ±0.87	5,42 ± 0,06	NR
Annona muricata (Iombor & Olaitan, 2014)	NR	8,10 ± 0,06	NR	NR
Musa spp. AAA cv Cavendish verde (Savlak, Türker, & Yesilkanat, 2016)	0.424 ± 0.015	9.07 ± 0.347	5.665 ± 0.011	0.58 ± 0.035
Musa acuminate L., cv cavendshii verde (Alkarkhi, Bin Ramli, Yong, & Easa, 2011)	NR	NR	5,06 ± 0,52	1,22 ± 0,14
Musa acuminate L., cv cavendshii maduro (Alkarkhi, Bin Ramli, Yong, & Easa, 2011)	NR	NR	5,13 ± 0,29	4,26 ± 0,24

Values are means ± standard deviation of at least three repetitions. NR, value not reported.

Regarding the color presented by the HCh (Table 2), the value of L * was 87.9 ± 0.90, a brightness value close to white (Mathias-Rettig & Ah-Hen, 2014). This value was similar to yam flour that registered an L * of 87.74 ± 0.09 reported by (Li, Zhang, & Bhandari, 2019) and that green banana flour (Musa spp. AAA) obtained by lyophilization and dried with dry air at 55 °C that registered luminosity values of 85.00 ± 0.346 and 84.62 ± 1.18, reported by (Savlak, Türker, & Yesilkanat, 2016) and ((Ahmed, Thomas, & Khashawi, 2019) respectively. However, (Alkarkhi, Bin Ramli, Yong, & Easa, 2011) reports a lower luminosity for green and ripe banana flour, with a value of 74.18 ± 4.62 and 70.85 ± 2.53, respectively, by which the flours derived from this banana species were significantly darker. This comparative color advantage is remarkable, given that the HCh had a high content of soluble solids and was dehydrated at 50 °C, while that obtained by (Alkarkhi, Bin Ramli, Yong, & Easa, 2011) had a lower content of soluble solids and was dehydrated at 60 °C. Therefore, it is likely that the use of antioxidant has not been effective, favoring the Maillard reaction and the high enzymatic activity of the polyphenol oxidase present in the banana that could contribute to a certain degree of enzymatic browning (Thipayarat, 2007). Enzymatic browning of bananas is a well-known problem, although also in cherimoya, the use of sodium bisulfite as an antioxidant result being effective for this type of Annona. Finally, in terms of color, the parameters a * (red-green axis) and b * (yellow-blue axis) of the HCh presented values of a * of 1.50 ± 0.30, which tends to neutral and b * 14.30 ± 2.00, which tends to yellow, both values added to the L * value, define it with a yellowish-white color.

Table 2. Results of colorimetric parameters of cherimoya flour (HCh) and those reported for flours of other fruits.

Fruit	L*	a*	b*	Chroma	Hue angle
Annona cherimola Miller (In this study)	87,9 ± 0.90	1,50 ± 0,30	14,30 ± 2,00	14,40 ± 2,00	84,20 ± 0,03
Annona crassiflora (Corrêa, et al., 2011)	71,20 ± 0,17	NR	NR	37.91±0.16	73.60±0.00
Mangifera indica verde (Noor Aziah, LeeMin, Rajeev, & Lai Hoong, 2012)	72.37 ± 0.20	−3.32 ± 0.05	33.71 ± 0.07	33.88 ± 0.06	95.62 ± 0.09
Musa spp.AAA cv Cavendish verde (Savlak, Türker, & Yesilkanat, 2016)	85.00 ± 0.346	1.83 ± 0.059	11.81 ± 0.125	11.95 ± 0.131	81.18 ± 0.216
Musa spp. AAA cv Mountain Verde (Ahmed, Thomas, & Khashawi, 2019)	84.62 ± 1.18	1.29 ± 0.03	11.54 ± 0.14	NR	NR
Musa acuminate L., cv cavendshii verde (Alkarkhi, Bin Ramli, Yong, & Easa, 2011)	74,18 ± 4,62	2,53 ± 0,78	17,36 ± 0,78	NR	NR
Musa acuminate L., cv cavendshii maduro (Alkarkhi, Bin Ramli, Yong, & Easa, 2011)	70,85 ± 2,53	3,2 ± 0,80	14,15 ± 2,59	NR	NR

Values are means ± standard deviation of at least three repetitions. NR, value not reported.

3.2 FUNCTIONAL PROPERTIES

The apparent density, the compacted density, the Hausner ratio and Carr index of HCh are recorded in Table 3. (Goula, Adamopoulos, & Kazakis, 2004) Explained that the decrease in these parameters is due to the adhesion of the particles during dehydration and by agglomeration of the product. On the other hand, (Abdullah & Geldart, 1999) assert that free-flowing powders have lower consolidation properties, while a fine and cohesive powder collapses rapidly due to tapping.

The HCh had an apparent density of 0.475 ± 0.019 g·cm^3, values similar to that recorded for other anonaceous flour such as soursop *Annona muricata* (0.421 ± 0.001 g·cm^3) that was reported by (Iombor & Olaitan, 2014), however it was lower than marolo flour *Annona crassiflora* reported by (Corrêa, et al., 2011) who reported density values of 1.38 ± 0.09 g·cm^3. This difference may be due to the particle size of the flours, since the study worked with a particle size of 150 and 179 µm, while the other authors do not report the particle size of their respective flours. On the other hand, in flours of other fruits such as green bananas have an apparent density of 0.251 ± 0.00 g·cm^3 when their grain size is less than 212 µm (Savlak, Türker, & Yesilkanat, 2016). This value was much lower than reported by (Rayo, y otros, 2015) who reported values of apparent density of 0.515 g·cm^3 for green banana flour of the Nanicão variety.

Regarding the compacted density of the HCh, a value of 0.551 ± 0.012 was found, a value that is between that recorded for green banana flour 0.652 and 0.403 g·cm^3, reported by (Savlak, Türker, & Yesilkanat, 2016) and (Rayo, y otros, 2015). The density value was being important in the development of the products since insoluble or instant foods a higher density is desirable since it facilitates the dispersibility of the product (Padmashree, 1987)

The results obtained for the cohesiveness by the Hausner ratio (HR) of 1.1623 and the fluidity by the Carr Index (CI) of 13.94%; they are values that give “low cohesiveness” and “very good fluidity” to HCh (Hausner, 1967) (Carr, 1965). The ratio of a good flow capacity with small particle sizes can be explained by a large surface area per unit mass of dust. There is more contact surface area between dust particles available for cohesive forces and frictional forces to resist flow (Fitzpatrick, Iqbal, Delaney, Twomey, & Keogh, 2004). Therefore, intermolecular forces are strengthened, reducing the ease of dust flow. Other authors such as (Savlak, Türker, & Yesilkanat, 2016) found in green banana flour that, the Carr index changed between 18.3% and 20.95% and the Hausner ratio between 1.22 and 1.27 in the green banana flour, which presented an intermediate fluidity.

Table 3. Apparent and compacted density of cherimoya flour (HCh) and those reported for flours of other fruits

Fruit	Functional properties			
	ρ_a (g·cm³)	ρ_c (g·cm³)	HR	CI, %
Annona cherimola Miller (In this study)	0,475 ± 0,019	0,551±0,012	1,162	13,940
Annona crassiflora (Corrêa, et al., 2011)	1,38 ± 0,09	NR	NR	NR
Annona muricata (Iombor & Olaitan, 2014)	0,421 ± 0.001	NR	NR	NR
Mangifera indica verde (Noor Aziah, LeeMin, Rajeev, & Lai Hoong, 2012)	0.69 ± 0.01	NR	NR	NR
Musa spp.AAA cv Cavendish verde (Savlak, Türker, & Yesilkanat, 2016)	0,251 ± 0,00	0.403 - 0,65	1,22-1,27	18,3 – 20,95

Values are means ± standard deviation of at least three repetitions. NR, value not reported.

On the other hand, the interaction between water and HCh as well as the formation of flour gel, is of great importance in the processing and application of flour. The hydration properties of flour and gel formation are usually affected by the drying method (Fig. 1). For HCh obtained by convective drying at 50 °C, they are presented in Table 4.

The solubility index (Corrêa, et al., 2011) (WSI) found for HCh was 27.10 ± 2.55%, relatively high compared to that found for hot air-dried yam flour (11.21%) (Li, Zhang, & Bhandari, 2019). The authors argue that the yam suffered a thermal effect that destroyed the internal cell structure and starch structure to some extent. Therefore, the low molecular weight amylose was leached, which resulted in a high content of free starch and a greater solubility. Likewise, in comparison to the flour of another anonaceous such as guanabana, it was only slightly higher (20.1 ± 0.06), having in common that both underwent dehydration by hot air at 50 ° C. In the opposite way, (Corrêa, et al., 2011) report a higher WSI value for marolo flour (*Annona crassiflora*) 43.87 ± 0.93%. Even the same authors confirm that the dehydration technique significantly influences this parameter, finding a WSI value of 51.87 ± 3.21% when dehydrated by lyophilization (Fig. 1A).

On the other hand, in other fruits of another genus the ISA of the HCh was superior for both green banana flour (7.8 ± 2.55%) (Savlak, Türker, & Yesilkanat, 2016) and that of Thai rice flour “Riceberry” (2.03 ± 0.15%) (Wiriyawattana, Suwonsichon, & Suwonsichon, 2018).

Table 4. Functional properties of cherimoya flour (HCh) and those reported for flours of other fruits.

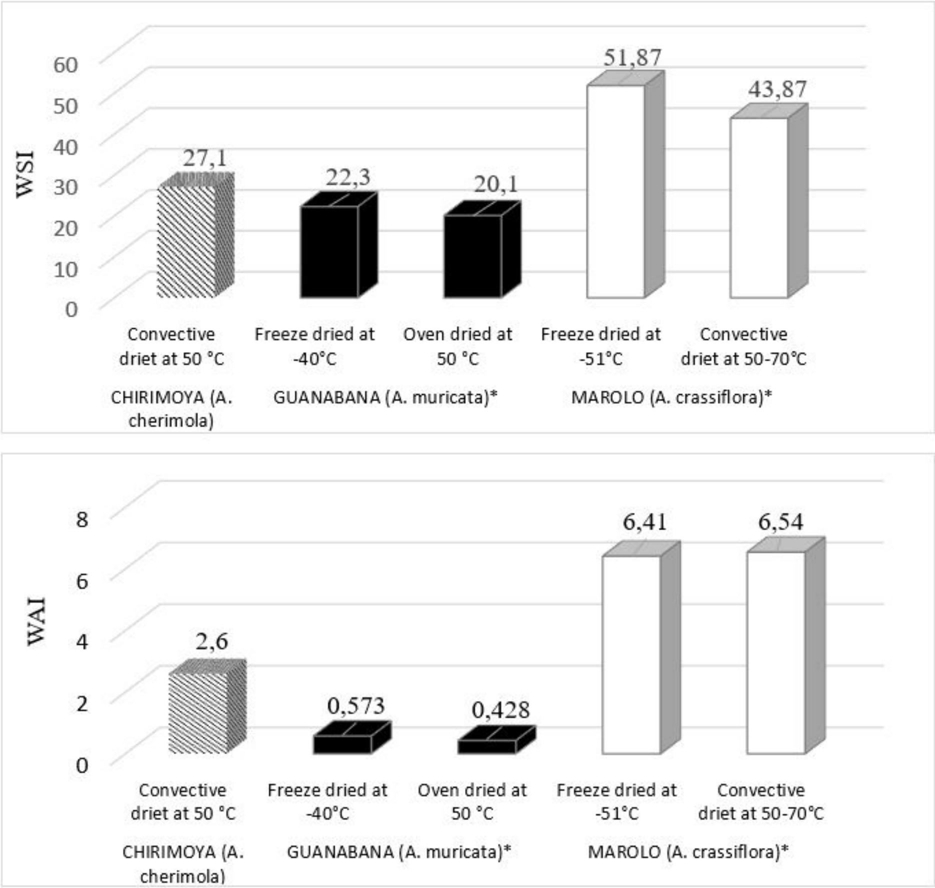
Fruit	Functional properties		
	WSI, %	WAI, g H_2O/g	CRA, g aceite/g
Annona cherimola Miller (In this study)	27,10 ± 2,55	2,60 ± 0,25	1,07 ± 0,09
Annona crassiflora (Corrêa, et al., 2011)	43,87 ± 0,93	6,54 ± 0,20	NR
Annona muricata (Iombor & Olaitan, 2014)	20,1 ± 0,06	0,428 ± 0,002	0,186 ± 0,002
Riceberry sin tratamiento (Wiriyawattana, Suwonsichon, & Suwonsichon, 2018)	6.99±0.07	2.03±0.15	NR
Ñame chino (Li, Zhang, & Bhandari, 2019)	11.21 ± 0.36	4.46 ± 0.17	NR
Mangifera indica verde (Noor Aziah, LeeMin, Rajeev, & Lai Hoong, 2012)	NR	0.54 ± 0.24	0.20 ± 0.04
Musa acuminate L., cv cavendshii verde (Alkarkhi, Bin Ramli, Yong, & Easa, 2011)	NR	5,66 ± 0,17	0,50 ± 0,07
Musa acuminate L., cv cavendshii maduro (Alkarkhi, Bin Ramli, Yong, & Easa, 2011)	NR	1,71 ± 0,10	0,82 ± 0,04
Musa spp.AAA cv Cavendish verde (Savlak, Türker, & Yesilkanat, 2016)	0,074 ± 0,00	2,922 ± 0,004	1,804 ± 0,002

Values are means ± standard deviation of at least three repetitions. NR, value not reported.

Table 4 shows the water absorption rate and oil retention capacity. The water absorption rate of HCh was 2.60 ± 0.25, this property measures the volume occupied by the starch granule after swelling in excess water (Ortiz, Carvalho, Ascheri, Ascheri, & Andrade, 2010). Many researchers report that the rate of water absorption is influenced by the degree of disintegration of native starch granules and is related to the physical state of starch, dietary fiber and proteins in fruit meal (Alkarkhi, Bin Ramli, Yong, & Easa, 2011). Comparatively, the WAI of the HCh was significantly lower for the green banana flour reported by (Savlak, Türker, & Yesilkanat, 2016) and (Alkarkhi, Bin Ramli, Yong, & Easa, 2011), with a value of 3,702 ± 0.061 and 5.66 ± 0.17 g H2O / g, respectively. The same behavior occurs when compared with the flour of other fruits such as yam (4.46 ± 0.17) and rice berry (2.03 ± 0.15), reported by (Li, Zhang, & Bhandari, 2019) and (Wiriyawattana, Suwonsichon, & Suwonsichon, 2018), respectively. In the case of yam, it is a fruit whose flour has a starch content of 64.23 ± 1.02%, thereby increasing its WAI; while HCh has a starch content of between 28-37%, being higher when it is dehydrated on the same day of fruit collection (data not shown). Also, with respect to the WAI of other anonas, marolo flour presented a value of 6.54 ± 0.20 g H2O / g (Corrêa, et al., 2011), greater than HCh and soursop flour (Fig. 1B); this phenomenon is likely due to the high content of dietary fiber that marolo flour has (18.59%). For (Savlak, Türker, & Yesilkanat, 2016), the result of lower water absorption index usually belong to finer particles, and that is explained by the collapse of the fiber matrix because of the size reduction.

Another functional property of HCh is the oil retention capacity, which had a value of 1.07 ± 0.09. This value was much lower than green banana flour (3,680 ± 0,001) (Savlak, Türker, & Yesilkanat, 2016). In this regard, (Rodríguez-Ambriz, Martínez-Ayala, Millán, & Dávila-Ortíz, 2005) reported that this property is related to the hydrophilic nature of the starch existing in green banana flour and is mainly due to the physical capture of oil within the starch structure through non-covalent bonds.

Fig. 1. Effects of drying techniques on the functionality of Annonaceae pulp flours (A) WSI: water solubility index, (B) WAI: water absorption index. * Average values of Guanabana and Marolo obtained from (Iombor & Olaitan, 2014) and (Corrêa, et al., 2011), respectively.



4 CONCLUSIONS

In this study, the functionality and physicochemical properties of cherimoya flour were investigated, and useful information was provided for its commercial applications, to be used thickeners or substitute flour in the food industry, with emphasis on the bakery industry, promoting its industrialization and reinforcing the value chain of the fruit. For further work, it is expected to explore its nutraceutical properties, as it contains a high content of natural antioxidants; as well as, the influence of particle size on rheological properties and their behavior in the design of new products.

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Índice Remissivo

A

B

C

D

E

F

G

P

R

S

EDITORA ARTEMIS