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EVALUATION OF THE MORPHOLOGICAL, PHYSICOCHEMICAL, AND FUNCTIONAL QUALITY OF PITAYA DE MAYO *(STENOCEREUS GRISEUS)* FOR OBTAINING DYES

EVALUATION OF THE MORPHOLOGICAL, PHYSICOCHEMICAL, AND FUNCTIONAL QUALITY OF PITAYA DE MAYO (STENOCEREUS GRISEUS) FOR OBTAINING DYES

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Abstract— The purpose of this project was to evaluate the effect of the origin of May pitaya fruit on its physicochemical and bromatological quality and betaine content.
May pitaya fruits from La Huerta and Xayacatlán de Bravo were weighed and measured for polar and equatorial diameter, pulp and peel yield, pH, titratable acidity, moisture, protein, ash, carbohydrates, and fiber, as well as betalain content. A completely randomized single-factor experimental design was used. To estimate the effect of fruit origin on physicochemical and bromatological parameters, an analysis of variance (ANOVA) was performed, comparing means using Tukey's method. All analyses were performed using the Minitab 19.0 statistical package, and a value of $\alpha \leq 0.05$ was considered.
A significant difference was found between equatorial diameter, acidity, pH, fruit weight, and pulp weight depending on the origin of the fruit, with fruit from La Huerta having the largest equatorial diameter (6.573 cm), titratable acidity (2.1667
%) expressed as malic acid, and pH equal to 6.207.
With regard to the bromatological analysis, a significant difference was found only in % moisture content, with fruit from the town of Xayacatlan de Bravo having a higher content of 85.2733±0.0321% on average compared to fruit from the town of La Huerta, which registered an average of 85.153±0.0451%.
On the other hand, the origin of the pitaya fruits from Mayo influences the total betaine content, with fruits from La Huerta having the highest concentration at 9.9660 mg/g sample.

Keywords-- Betalains, Betacianins, Betaxanthins, Spectrophotometry, May pitaya.

Abstract -- The purpose of this project was to evaluate the effect of the origin of May pitaya fruits on the physicochemical and bromatological quality and betalain content.
Weight, polar and equatorial diameter, pulp and peel yield, pH, titratable acidity, humidity, proteins, ash, carbohydrates and fiber, as well as betalain content were determined for May pitaya fruits from La Huerta and Xayacatlán de Bravo. A completely randomized single-factor experimental design was used. To estimate the effect of fruit origin on the physicochemical and bromatological parameters, an analysis of variance (ANOVA) was carried out, comparing means using the Tukey method. All analyses were performed in the Minitab 19.0 statistical package and a value of $\alpha \leq 0.05$ was considered.
A significant difference was found between equatorial diameter, acidity, pH, fruit weights, and pulp due to the origin of the fruit. The fruits from the town of La Huerta were those with the greatest equatorial diameter (6.573 cm), titratable acidity (2.1667%), expressed malic acid, and pH equal to 6.207.
Regarding the bromatological analysis, a significant difference was found only in % Humidity, with fruits from the town of Xayacatlan de Bravo presenting a higher content of 85.2733±0.0321% on average compared to fruits from the town of La Huerta, which recorded an average of 85.153±0.0451%.
On the other hand, the origin of the May pitaya fruits influences the total content of Betalains, with the fruits from the town of La Huerta having the highest concentration with 9.9660 mg/g of sample.

Key words – Betalains, Betacyanins, Betaxanthins, Spectrophotometry, May pitaya.

INTRODUCTION

The Mixteca region of Puebla is located in the south of the state of Puebla, bordering the Sierra Negra region to the east

Negra region to the east and the states of Oaxaca, Guerrero, and Morelos to the south [1].
The May pitaya (Stenocereus griseus H.) is a columnar cactus native to Mexico. It is generally globular in shape, 6 to 11 cm long and 5 to 7 cm in diameter, orange and red in color, with spines, and represents an important economic and nutritional source for rural producers [2]. The characteristic color of its fruits is due to betalains, natural pigments
[5] [3], which differ from others in that they contain nitrogen in their structure. They are commonly extracted from plants and fruits by solid-liquid extraction methods using solvents [4]; they are water-soluble and can therefore potentially be used as colorants (reds and yellows) that also have antioxidant activity [8] [5].
The term betalains describes two groups of pigments, highly soluble in water, chemically and biogenetically related, namely red-violet betacyanins and yellow betaxanthins [6].
The structure of betalains is shown in Figure 1.

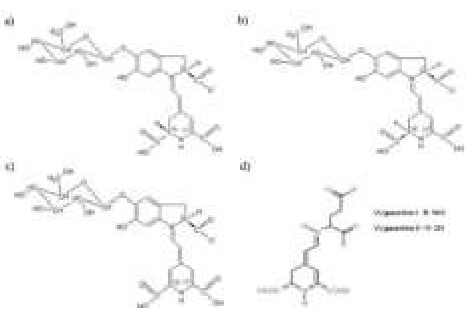

Figure 1. *Chemical structure of betalains present in Beta vulgaris spp. a: betanin, b: isobetanin, c: neobetanin, d: vulgaxanthin I and II.*

Source: *(*Sing de Ugaz, 1997).

The stability of betalains is limited because their color is altered by several factors: pH, temperature, water activity, and light. It has not been possible to stabilize these pigments through acylation or molecular substitution, although their stability can be increased by adding antioxidants such as ascorbic acid, BHT, and BHA. Betaxanthins degrade more rapidly than betacyanins, and their yellow color is generally masked by betacyanins or other compounds present [7].
According to reports [8], Mayo pitaya has the following proximate composition, physicochemical properties, and functional properties.
Red Pitaya: 82.4% moisture, 0.6% ash, 0.1% fat, 1.5% protein, 34.4 g/kg total fiber, 12.4
°Brix total soluble solids, and 250 mg/100 BH betalains.
Orange Pitaya: 83.9% moisture, 0.06% ash,
0.1% Fat, 0.5% Protein, 37.7 g/kg Total Fiber,
12.7 °Brix Total Soluble Solids, and 125 mg/100 BH Betalains.

Because of this, the food industry makes extensive use of artificial food coloring to give its products better and more attractive colors and thus ensure consumer acceptance of similar products [9]. The consumption of processed foods with added chemical pigments has disadvantages for human health [10]. There are currently reports showing that their indiscriminate use is related to the development of degenerative diseases such as cancer [11]. Legal restrictions on the indiscriminate use of synthetic colorants and consumer awareness of the dangers to their health have motivated the food industry to use a greater amount of alternative pigments. Studies on the extraction of natural colorants from plants, animals, and fruits have had positive results in recent years, as some natural extracts have been used in food products such as beverages, candies, seasonings, meat products, and baked goods, among others. The widespread acceptance of these colorants has led to the development of environmentally friendly procedures in the laboratory [12]. [13] In his publication "Obtaining and valuing natural pigments from carrots and beets," he compared conventional and unconventional techniques for extracting β-carotene, evaluating their performance and applicability on an industrial scale, such as natural dyes with great potential for replacing artificial dyes.
According to reports [14], the best soils for cultivation are loamy to sandy loam, well-drained, preventing moisture accumulation at the roots, with a maximum slope of 50%, a pH between 5.5 and 6.5, and high organic matter content. [15], the predominant soils in the area are leptosols, regosols, luvisols, and cambisols, characterized by a lithic phase. Fluvisols with a heavy phase are also present on the banks of some rivers. The origin of the soils is mainly due to the abundance of schists, limestones, sandstones, and shales. Xayacatlán de Bravo has geographical coordinates geographica
l coordinates
18°14′12.44″ N, 97°58′34.43″ W and an average altitude of 1,250 meters above sea level, with a semi-warm to warm subhumid climate. La Huerta has geographical coordinates of 18°12′12″ N, 98°2′55″ W and an average altitude of 1217 meters above sea level. It has a semi-dry to semi-warm climate with low humidity and temperatures ranging between 19° and 34°C. Although both communities belong to the Mixteca Poblana region, there are no reports confirming the type of soil in each community. What is known is that pitaya grows wild in the mountains of the Mixteca Poblana region, immersed in deciduous vegetation. It takes advantage of the sun's rays to flower and produce fruit. In the case of the May pitaya, this occurs from January to May, precisely the months when the foliage of the deciduous lowland forest is bare. The May pitaya produces its first flower buds during January and February and develops

Its fruits ripen during February, March, and April, and it matures from mid-April through May (hence its name), ending production in mid-June.

The use of this species in Mexico has mainly been through the collection of fruits from uncultivated plants grown in small numbers on plots of land (suburban and urban properties), so its cultivation in rural areas is in its infancy [16].

The purpose of this study was to evaluate the effect of provenance from two communities, La Huerta and Xayacatlán de Bravo, on the morphological, physicochemical, and bromatological quality of betalains obtained from May pitaya fruit to produce a natural dye for use in the food industry, whose production is considered an alternative for utilizing fruit from the Acatlán region. These two localities were chosen because the highest production is concentrated in these communities, with 245.94 tons and 58.80 tons per season [17].

DEVELOPMENT

Location of the research site

This work was carried out in the Basic Multifunctional Laboratory of the Food Industry Engineering Program at the National Technological Institute of Mexico, Acatlán de Osorio Puebla campus.

Plant material

The Mayo pitaya fruits *(Stenocereus griseus)* harvested in the communities of La Huerta and Xayacatlán de Bravo, in the Mixteca Poblana region, in the period May-June 2022, were selected according to color (optimal ripeness) and similar size, equatorial diameter, and average weight of 6 cm and 206 g, respectively. (Figure 2).

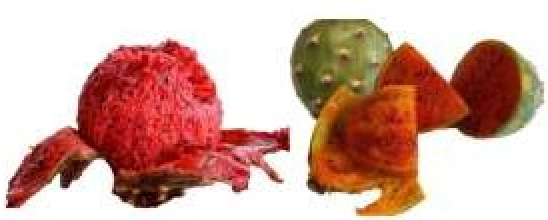

Figure 2. *Optimal maturity of May pitaya from the two communities.*
Source: *Own elaboration.*

Morphological characterization

a. **Fruit weight.** This was determined using an OHAUS SPX2201 digital scale.
b. **Polar and equatorial diameter**. This was measured using a Mitutoyo digital vernier caliper graduated in millimeters, measured from the base to the tip of the fruit (vertical) and the transverse contour of the fruit [18].
c. **Pulp and peel yield**. This was determined by weight difference, removing the peel from the pulp and weighing it on an OHAUS SPX2201 digital scale [19].

Physicochemical characterization

a. **pH.** The pH of the fruit was determined as described by [19]. A previously calibrated J.T. BAKER potentiometer, series 6630, was used with a pH 4.7 buffer solution and 10. Ten milliliters of juice were added to 100 mL of distilled water, and then a reading was taken [19].
b. **Titratable acidity.** This was determined according to the methodology described by [18], with some modifications. 100 mL of distilled water was placed in an Erlenmeyer flask, 10 mL of juice and 2 drops of phenolphthalein as an indicator were added, and titrated with 0.1N NaOH. The percentage of titratable acidity was expressed as a percentage of malic acid according to equation 1.

$$\%\ \text{Titratable acidity} = \frac{(V)(N)(PE)}{(pm)} x100 \qquad \text{Eq. (1)}$$

Where:
V= volume in mL of 0.1N NaOH used.
N= Normality of NaOH used in the titration, 0.1N.
PE= Equivalent weight expressed in grams of malic acid.
pm= Weight of the sample in grams.

Bromatological characterization of the fruit

a. Moisture determination. This was carried out in accordance with NMX-F-428-1982 [20], using a Velab thermobalance, model VE-50-5, at a temperature of 105 °C [20]. The value obtained was recorded as a percentage of moisture.
b. Protein determination. Total protein content was determined using AOAC Official Method 2001.11, with some modifications. The result was expressed as % protein [21].
c. Ash determination. This was determined using the total ash by calcination method [22].
d. Fat determination. The fat content was determined using the Soxhlet method [21].
e. Determination of crude fiber. The methodology used for crude fiber was in accordance with that described by [21].
f. Determination of carbohydrates. This was determined by the difference in components according to the AOAC 986.25 method [23].

Functional evaluation

Dehydration

The pulp was dehydrated in an ARESMA model DSH 100 convection dryer (with trays) at a temperature of 50°C until a moisture content of 1.52% was obtained.

Extraction

Extraction was performed by maceration with constant agitation using ethanol as the solvent. Five grams of dehydrated pulp were weighed and placed in a 250 ml Erlenmeyer flask, and a total volume of 50 ml of the ethanol-water solvent at the indicated concentration (40%-60%) was added. The samples were then subjected to constant agitation using a Velp Scientific stirrer for different periods of time (100, 120, and 140 minutes). After the specified time had elapsed, the extract was filtered using medium-pore filter paper, and the sample obtained was stored in amber glass bottles, sealed, labeled, and refrigerated until further analysis.

Quantification of Betalains

The quantification of betalains was performed using the UV/VIS spectrophotometric method [24], with measurements taken in duplicate. Quantification was determined with an ethanol concentration of 40%, an extraction time of 120 minutes, and a 50% dilution of the extract. The reading was performed using an absorbance of 538 nm for betacyanins and 483 nm for betaxanthins. The result was determined according to equation 2.

$$B\left(\frac{mg}{g}\right) = \frac{A * FD * PM * V * 1000}{\varepsilon * P * L} \quad \text{Ec. (2)}$$

Where B = betacyanin or betaxanthin content, A = Absorbance 538 nm for betacyanins and 483 nm for betaxanthins

FD = Dilution factor,

MW = Molecular weight 550 (g/mol) for betacyanins and 308 (g/mol) for betaxanthin,

V = Volume of extract

ε = Molar extinction coefficient 60000 (mol.L/cm) for betacyanins and 48000 (mol.L/cm) for betaxanthin, and L = Width of the spectrophotometer cuvette (1 cm). The amount of betalains was determined according to equation 3.

$$\textit{Betalainas} = \textit{betacianinas} + \textit{betaxantinas} \quad \text{Eq. (3)}$$

Statistical analysis

The results are expressed as the average value of 3 determinations ± standard deviation. The results of the morphological, physicochemical, and bromatological characteristics of the betalain content of May pitayas were subjected to a Analysis of variance (ANOVA) for a completely randomized design of 3 x 3 x 2 (ethanol concentration, extraction time, and fruit origin) was used to determine the existence of significant differences, and Tukey's test was used for the comparison between means. All analyses were performed using the Minitab statistical package (Version 19), considering a value of Alpha ≤ 0.05 as a significant effect.

DISCUSSION AND ANALYSIS OF RESULTS

Effect of place of origin on morphological characteristics of Mayo pitaya (Stenocereus griseus)

Weight

There are significant differences according to the origin of the fruit, between weights ($p = 0.023$) and pulp ($p = 0.005$); however, this is not the case for the weight of the peel. Fruit originating from the locality of the Huerta had greater weight (231 g) and pulp (183.5 g) than those from the locality of Xayacatlán de Bravo (Table 1). These results are higher than those reported by Bravo (2011) [25], who reported differences in the weights of *Stenocereus Proinosus* fruits from four locations in the Mixteca region of Puebla (San Bernardo, Galeana, Xayacatlán, and Amate). [19] reported a weight of 152.25 ± 29.14 g and 158.16 ± 52 g for red and yellow pitaya, respectively, from the community of Xayacatlán de Bravo.

Equatorial and polar diameter

A significant difference was found in the equatorial diameter ($p = 0.016$) due to the origin of the fruit, but not for the polar diameter ($p = 0.245$). Fruits Those from the town of La Huerta had a larger equatorial diameter, with an average of 6.573 cm, compared to those from Xayacatlán, which had an average of 6.007 cm. (Table 1), these results are lower than those reported by Balderas (2016) [18] for red pitaya fruits, which recorded 7.4±0.97 cm and 7.7±0.44 cm in equatorial and polar diameter, respectively. Noriega (2021) [19] reported 7.90 ± 0.61 cm and 7.95 ± 0.67 cm for polar diameter and 5.98 ± 0.39 cm and 5.96 ± 0.49 cm equatorial diameter in red and yellow pitaya, respectively.

Table 1. *Morphological properties of pitaya fruits from two locations in the Mixtec region of Puebla.*

Characteristic	Origin	
	La Huerta	Xayacatlán de Bravo
Fruit weight (g)	231± 0.08[a]	182.5±0.187[b]
Shell weight (g)	49.93 ± 6.87[a]	47.01±2.89[b]
Flesh weight (g)	183.5 ± 0.742[a]	135.3±0.247[b]
Equatorial diameter (cm)	6,573 ±1.08[a]	6,007 ± 0.051[b]
Polar diameter (cm)	8.62 ±0.479[a]	8,047+0.378[a]

Means with different letters are statistically different.
Source: *Own elaboration.*

Effect of place of origin on the physicochemical characteristics of Mayo pitaya (Stenocereus griseus)

pH, total soluble solids (TSS), and titratable acidity A significant difference was found in pH values (*p=0.000*), but not for total soluble solids (°Brix) (*p=1.000*) and titratable acidity (0.116% malic acid).
Fruits from the community of La Huerta had a higher pH (6.207) than fruits from the town of Xayacatlán, which had a pH of 5.853 (Table 2).
With regard to TSS and titratable acidity, an average of 9.667 °Brix was obtained in both communities and acidity of 2.2 and 2.3% malic acid, respectively (Table 2). The results recorded in this study differ from those reported by Mercado and Granado (2002), cited by Ramírez (2017) [3], who, when determining chemical parameters in yellow *Stenocereus griseus*, reported an average concentration of TSS and titratable acidity of 9.1 °Brix and 0.50% malic acid, respectively, in addition to a pH value of 4.46. These results are lower than those determined in the present study.

Table 2. *Physicochemical properties of pitaya fruit from two locations in the Mixtec region of Puebla.*

Characteristic	Origin	
	La Huerta	Xayacatlán de Bravo
pH	6.*201±0.173*ª	5.*853±0.427* b
SST (°Brix)	9.*667±0.251*ª	9.667+0.496 ª
Acidity (% malic acid)	2.*167±0.09* ª	2.3 ± *0.62*ª

Means with different letters are statistically different.
Source: *Own elaboration.*

Effect of place of origin on the bromatological characteristics of Mayo pitaya (Stenocereus griseus).

Table 3 shows the moisture, lipid, fiber, protein, and ash content of pitaya fruits from La Huerta and Xayacatlán de Bravo. Statistical analysis revealed a significant difference in moisture content (p = 0.020) between fruits from
from the town of Xayacatlán de Bravo had
higher water content compared to fruits from the locality of La Huerta.
These results differ from those reported by López et al. (2007) [26], who indicated that in May pitayas S. griseus there is a significant difference between the bromatological parameters of two locations in the Mixteca region of Puebla: Zapotitlán Salinas and Santo Domingo Tonahuixtla.

Table 3. *Bromatological parameters of pitaya from two locations in the Mixtec region of Puebla.*

Parameters	Origin	
	La Huerta	Xayacatlan de Bravo
Humidity	85.153 ±*0.04*ᵇ	85.273 ±*0.32a*
Lipids	0.99 ± 0.105ª	0.98 ± 0.152ª
Crude fiber	5.84±0.317ª	5.61±0.0601ª
Protein	3.871±0.349ª	3.43±0.633ª
Ash	2.838±0.320ª	2,963±0.11ª
Carbohy drates	*28.386±0.411*ª	*27,707±0.165*ᵇ

Averages with different letters are statistically different
Source*: Own elaboration.*

Betalaine concentration due to fruit origin.

A significant difference was found in the concentration of betalains due to the place of origin of the fruit. The origin of the May pitaya fruits influences the total betalain content. In this study, the fruits from the town of La Huerta had the highest concentration, with 9.966 mg/g of sample, Table 4. The data obtained are higher than those reported by García *et al.* (2012) [27] in red pitaya (3.47 mg/g) and 0.472 mg/g of Stenocereus spp pitaya reported by Gil (2019) [4]; the betalain content of both locations is similar to that obtained by Ayala & Beltran (2007) [28] in yellow pitaya (9.883 mg/g). This value is higher than that reported by Noriega (2021) [19], who obtained 42.24 ±
0.3811 and 46.7 ± 0.3140

Table 4. *Betalain concentration in pitaya fruit from two locations in the Mixtec region of Puebla.*

Parameters	Origin	
	La Huerta	Xayacatlán de Bravo
Betalains	*49.83 ±0.04*ª	41.*93±0.32*ᵇ

Means with different letters are statistically different.
Source: *Own elaboration.*

CONCLUSIONS

The fruit analyses show favorable results for pigment extraction and its subsequent application in the food industry as an alternative way to take advantage of the production of this fruit in these localities of Acatlán.
The evaluation of the May pitaya fruits from the towns of La Huerta and Xayacatlán de Bravo showed

different values in each of the physical, chemical, and bromatological parameters and betalain content.

The fruits from La Huerta stood out in terms of betalain content.

Based on the results obtained, the aim is to continue research on soil analysis in the different regions where pitaya is produced to determine whether its characteristics are influenced by soil type.

Likewise, the extraction of pigments will continue, and they will be applied to foods and subsequently subjected to sensory analysis.

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