AGRO PRODUCTIVIDAD

Colegio de Postgraduados

# Technological parameters of agroindustrial concern of prickly-pear cactus (*Opuntia* spp.) in "Cristalina" and "Pelon Blanco" varieties

**Rössel-Kipping, Erich D.[1]; Ortiz-Laurel, Hipólito[3*]; López-Martínez, Laura A.[2]; Loera-Alvarado, Gerardo[1]; Velásquez-Salas, Emmanuel[2]**

[1] Colegio de Postgraduados. Iturbide 73, Salinas de Hgo, S.L.P. México. C. P. 78600.
[2] Universidad Autónoma de San Luis Potosí. Carretera Salinas-Santo Domingo 200, Salinas de Hgo, S.L.P. México. C. P. 78600.
[3] Colegio de Postgraduados. km. 348, Carr. Fed. Córdoba-Veracruz, Congregación Manuel León, Amatlán de los Reyes, Veracruz. México. C. P. 94946.
* Correspondence: hlaurel@colpos.mx

**ABSTRACT**

**Objective**. To test and verify the main physical attributes of fresh cladodes of the prickly-pear cactus (nopal) Cristalina and Pelon Blanco varieties; and the flours obtained after they are dried and ground.

**Design/Methodology/Approach**. Physical characteristics were determined using proven and reliable tests. Data shall serve to explore the potential of this material to be used in basic and complex processes; considering the varieties requierements for growth space and quality parameters for storage. Along with the interaction with processing devices and equipment for proper handling while manufacturing new products.

**Results**. Physical characteristics of the two nopal varieties showed slight differences in the measured parameters, except length, width and electrical conductivity.

**Limitations/Implications of the study**. Researchers did not participate in the production of the evaluated *Opuntia* spp. varieties. Physical characteristics of the varieties were recorded at the time when the cladodes were separated from the plants.

**Findings/Conclusions**. With the procedure proposed, the mechanical transport of the cladodes into the facilities is improved. In addition, it generates less wear of the equipment, and reduces the costs of maintenance and handling. The quality of the flour from each variety was adequate to allow a safe storage.

**Keywords**: food agroindusty, agricultural products, physico-chemistry, measurement techniques, prickly-pear cactus (nopal).

**Citation**: Rössel-Kipping, E. D., Ortiz-Laurel, H., López-Martínez, L. A., Loera-Alvarado, G., & Velásquez-Salas, E. (2022). Technological parameters of agroindustrial concern of prickly-pear cactus (*Opuntia* spp.) in "Cristalina" and "Pelon Blanco" varieties. *Agro Productividad*. https://doi.org/10.32854/agrop.v15i10.2276

**Academic Editors**: Jorge Cadena Iñiguez and Libia Iris Trejo Téllez

**Received**: May 19, 2022.
**Accepted**: September 15, 2022.
**Published on-line**: November 14, 2022.

*Agro Productividad, 15*(10). October. 2022. pp: 131-138.



## INTRODUCTION

The prickly-pear cactus or nopal (*Opuntia* spp.) is a plant species with great roots in arid areas where it is difficult to produce conventional crops, due to adverse agroclimatic conditions, such as recurrent droughts and shallow soils and low fertility (Méndez *et al.*, 2004). In this era of modernity and innovation, a task of agroindustry is to conduct viable processes to transform agricultural and livestock products, to estimulate and promote the

Image by tulla at Pixabay

manufacturing sector, as an alternative for food security and derivative agroindustrial products; as well as for generating strategies to facilitate their transfer from the field to the dinner table (Austin, 1987).

An additional resource, based on energy efficiency principles, is achieved through the grinding of the vegetable components until reaching the point of flour. With this process, an excellent stabilization of the minerals is achieved. This becomes relevant because nopal (*Opuntia* spp.) is a plant in which only cladodes of one year (or pencas) are used, but the other cladodes (2 years-old and onwards) are not considered useful in traditional agriculture (Reyes-Agüero *et al.*, 2005).

This proposal is due to those inefficiencies in the current management scenario, which is subject at least to factors such as natural variation in the production either quantity and quality of biomass in nature; increase in such nature variability conditions due to the increase of adverse climatic effects; increase in the need to produce food and biological raw materials for other productive sectors due to the increase in world population; available technologies for processing that adds value to the agricultural organic products; and the limitation to access to greater amount of natural resources. Therefore, it is essential to pay greater attention to use the entire plant.

Some possible beneficiaries of this sector would be; food and beverages agroindustry for human and animal consumption; the cosmetic industry, the pharmaceutical industry, the synthetic and semi-synthetic food supplements, the production of natural additives, as well as: the construction, energy, producers of inputs for agriculture, tourism, the textile industry, art, among others. The fruits and the pencas contain valuable components, among which they stand out; fiber, hydricoloids (mucilage), pigments, vitamins and minerals, highlighting vitamin C. Additionally, antioxidant properties are attributed to them. On the other hand, several studies have found that cladodes are an important source of fiber, calcium and mucilages. These three components are necessary to integrate a healthy diet (Sáenz, 2004).

To preserve the ingredients of organic agricultural material, technologies for this purpose are already developed, among which there are the store in airtight containers (cans); freezing conservation; extraction of chemical compounds and minerals; and drying for grinding (flour). Through an energy balance it would be rather to prefer the product in the form of flour. The flour obtained from the products has the following advantages, drying with renewable energy (solar and wind) at the nopal production sites (dry and semi-dry areas), savings in transportation by the decentralization of the means of processing. There is available technology for the use of the material in the form of flour, the energy consumption is reduced in most cases for flour storage, when compared to other technological possibilities. Likewise, flour would be preferred because it is feasible to produce semi-synthetic foods and perhaps in the near future, synthetic products, based on organic material.

Therefore, it is feasible and profitable to conduct a more comprehensive use of the nopal (*Opuntia* spp.). Likewise, new employment would be generated and a niche of market oriented to efficiently exploit nutrients, previously unused. Hence, it is important to generate technical information, in order to add industrial use to cladodes regardless their age. Among the most useful information needed is the chemical composition and physical properties for post-harvest management that are useful in the elaboration of edible and non-edible products. For this management may begin at the first year of development, continuing onto two or three years old, depending on their attributes for the Cristalina and Peñon Blanco varieties.

Hence the importance of this study, to determine the physical-mechanical characteristics (weight, length, width, thickness, density, internal friction, electrical conductivity) of cladodes, and the flours obtained from them, of nopal varieties Cristalina and Pelon Blanco, one, two and three years of maturity. It is equally important, to supply information for agroindustrial uses. For example, regarding procedures for cleaning, storage, compacting, size reduction, dosing, mixing and screening. As long as cladodes are used in the form of flour to take advantage of the biomass of the mature ones, making them suitable to generate products of agroindustrial interest.

## MATERIALS AND METHODS

In this study, freshly cut cladodes (separated from the plant) were used, of two varieties of *Opuntia ficus-indica*, Cristalina and Pelon Blanco, each with one, two and three years of maturity. Likewise, each of them were collected in the autumn season (September-December) and immediately underwent a drying process in an oven (model DZF-6090) at 60 °C for 10 h, in order to dehydrate the samples and proceed to a grinding process to obtain flour. In this process, a Krups GX 410011 model mill was used; concluding with the screening, using a mesh of 0.00381 mm. The values for possible differences in the physical attributes between the varieties of nopal (*Opuntia ficus-indica*) were processed through an analysis of variance, using Statistica v.12 (StatSoft, Inc., Tulsa, OK, USA) in all cases at a significance level $p \leq 0.05$

### Methods of measuring physical-technical characteristics

#### Dimensions

The dimensions of the different cladodes from Cristalina and Pelon Blanco varieties were determined using a common ruler; width, length and thickness were determined (Figure 1). Length (cm) was recorded from the base to the apex, the width (cm) was determined in the widest central area of the cladode and the thickness (cm) was meassured at the thickest zone in the side of the cladode. Measurements were made to 10 cladodes of the Pelon Blanco variety of one, two and three years of maturity; while, for Cristalina variety, seven replicates were determined for each of the years of maturity.

#### Cladodes Density

To determine the density in the prickly pear cladodes of the Cristalina and Pelon Blanco varieties, a cylindrical container with a capacity of 20 L was used. The procedure was to add water inside up to 3/4 of the total volume, then the water level was marked and a ruler was placed, adhered to the inner perimeter of the container. A cladode was introduced into the container, then the height reached by the water level was marked, this was done to determine the volume of the cladode, then several replicates were made for each of the

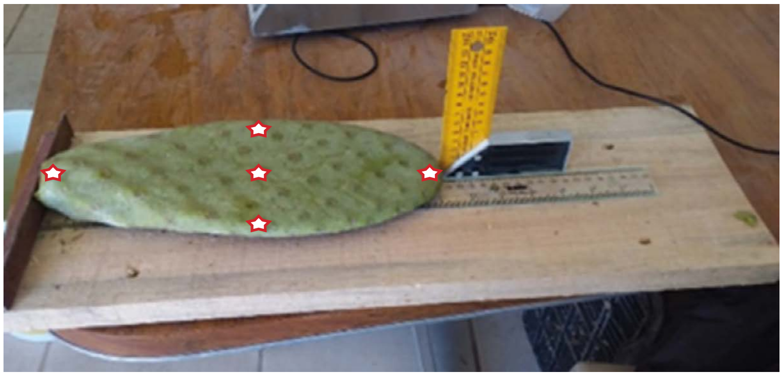

**Figure 1**. Measurement of the basic dimensions of the prickly-pear cactus (*Opuntia* spp.) cladodes. ✩ Points where measurement of electrical conductivity was done.

three ages of maturity of the cladodes of Cristalina and Pelón blanco varieties. The mass of each cladodes was also recorded with a scale, and the following equation was used to determine the density of the cladodes:

$$\rho = \frac{m}{v}$$

**Electrical conductivity**

The measurement of the electrical conductivity of the pencas of nopal variety Cristalina and Pelón, were carried out using a digital multimeter (brand Kinzo model 18d265 CE) in five different points on one side of the cladode, performing two replicates of the same points to each cladode and each variety, in the lower section, in the center, at the lateral ends and at the top of the cladode (Figure 1); repeating these same points for each of the six cladodes.

**External friction $\mu_e$ of the flour from prickly-pear cactus**

The materials in contact with the flour of the cladodes were aluminum, ceramics, glass, wood and plastic. With the flour on each of the materials in the form of a plate or thin sheet, each of these was lifted by one of its ends and, at a certain moment, an angle is reached that forms the material with the horizontal, where the flour begins to slide and when it reaches the bottom of the material, the angle formed was recorded with a protractor (Figure 2).

**Figure 2**. Method for determining the angle of external friction tan $\alpha = \mu_e$

Ten replicate measurements were performed for the flour of each variety on each of the materials.

**Internal friction ($\mu_i$) and internal friction angle ($\alpha$) of *Opuntia* spp. flours**

The determination of the internal friction and angle of internal friction was performed to the flours from prickly-pear cladodes of three ages of maturity (1, 2, 3 years) of the two previously dehydrated varieties; 10 replicates were performed for each flour coming from each particular cladode that formed an inverted cone or static triangle (Figure 3).

At this cone, the height and diameter formed were measured. This procedure was repeated 10 times for each of the flours obtained from each prickly-pear variety. The internal fiction and the angle of internal friction were determined using the following equation.

$$\tan \alpha = \mu_i = h/r$$

Where: $h$=inverted cone height; $r$=cone base radius.

During the analyses, the variance and comparison of means were determined by the Tukey method ($p \leq 0.05$) of the physical and chemical variables, between cladodes of the varieties Cristalina and Pelón Blanco (*Opuntia* spp.) of one, two and three years of maturity. These analyses were performed in R-project® 4.1.1 under RStudio® 2021.09.0, both freely distributed.

## RESULTS AND DISCUSSION

### Dimensions

Among the varieties analyzed, significant differences ($p \leq 0.05$) were found only in the width of the cladodes according to the variety; the cladodes of the Cristalina variety were wider than those of Pelon Blanco (Table 1). While the length and thickness did not present a significant difference. According to the analysis of variance, it was not found that age had a significant effect, nor interaction with variety in any of the measured dimensions.


**Figure 3**. Measurement of the internal friction of the flours.

**Table 1**. Results of the dimensions in cladodes of prickly-pear cactus, Cristalina, and Pelon Blanco varieties.

| Variety | Age (n) | Weight (g) | Length (cm) | Width (cm) | Thickness (cm) | Volume (cm$^3$) | Density (g/cm$^3$) |
|---|---|---|---|---|---|---|---|
| Cristalina | 1 | 1187 | 39.59±3.44$^a$ | 24.61±5.58$^a$ | 4.33±0.77$^a$ | 1056.83 | 1.12 |
| Cristalina | 2 | 2550 | 38.49±9.78$^a$ | 24.56±4.64$^a$ | 6.81±0.97$^a$ | 2642.08 | 0.97 |
| Cristalina | 3 | 2127 | 36.73±3.90$^a$ | 20.00±3.80$^a$ | 8.14±1.69$^a$ | 2179.72 | 0.98 |
| Pelon Blanco | 1 | 1000 | 37.21±4.47$^a$ | 19.17±3.03$^b$ | 6.99±9.19$^a$ | 936.52 | 1.07 |
| Pelon Blanco | 2 | 1620 | 38.37±6.73$^a$ | 19.09±1.27$^b$ | 5.54±0.73$^a$ | 1783.40 | 0.91 |
| Pelon Blanco | 3 | 1630 | 40.07±6.68$^a$ | 19.09±2.97$^b$ | 7.10±1.59$^a$ | 1783.40 | 0.91 |

Where: Cristalina 7 plants, Pelón Blanco 10 plants. Different letters indicate a significant difference within each column.

## Sieving

Results after sieving nopal flours are shown in Table 2.

The decimal errors of the sum result from the rounding of the values and in two cases of the addition, this is due to possible losses. The relationships of values between the years presented the same tendency for Pelon Blanco and Cristalina. Figure 4 shows the behavior of the flour of prickly-pear cactus Cristalina variety where flour particles satisfied the pre-defined standard for wheat, in which between 85 and 90% the particles had a value less than 0.37 mm.

## Internal friction of flours

The values of the internal friction of the nopal of different years of maturity are shown in Table 3.

Regarding the external friction of the prickly-pear cactus flours it should be noted that these flour particles of all ages have a size less than 0.59 mm (Figure 4). In addition, that the friction evaluation was performed on flat surfaces of steel sheet wood, glass, vitro-floor, plywood, and plastic, with 10 replicates for each flour on each material. On the other hand, Table 4 highlights that the values of the external friction obtained on the surfaces of the different materials had a value equivalent to that of flours from known grains, such

**Table 2**. Results of the sieving to define the sizes of the flour particles (100 g grind) of the *Opuntia* spp. varieties under study.

| Grind (g) | | | | | | |
|---|---|---|---|---|---|---|
| Sieve size | #30 0.59 mm | #80 0.177 mm | #100 0.149 mm | #400 0.037 mm | Fines 0 mm | Sum |
| Sample | (g) | (g) | (g) | (g) | (g) | (g) |
| Cristalina 1 | 27.7 | 22.8 | 3.3 | 42.3 | 4.5 | 100.6 |
| Cristalina 2 | 21.8 | 27.0 | 4.3 | 40.0 | 2.7 | 95.8 |
| Cristalina 3 | 22.0 | 30.4 | 4.6 | 42.6 | 3.7 | 103.3 |
| Pelon 1 | 30.4 | 23.2 | 4.4 | 40.0 | 2.5 | 100.5 |
| Pelon 2 | 27.0 | 30.5 | 5.0 | 37.2 | 3.6 | 103.3 |
| Pelon 3 | 20.0 | 30.2 | 5.0 | 35.6 | 7.5 | 98.3 |

Where: n=(1, 2, 3): age of maturity, years.

**Table 3**. Results of the internal friction of the flour of *Opuntia* spp. varieties of different age of maturity.

| Sample | Age (n) | Average $\mu_i /-/$ | S.D. (+/−) $\mu_i /-/$ |
|---|---|---|---|
| Cristalina | 1 | 0.962 | 0.15368077 |
| Cristalina | 2 | 0.911 | 0.14790763 |
| Cristalina | 3 | 0.959 | 0.08900062 |
| Pelon blanco | 1 | 0.903 | 0.13936762 |
| Pelon blanco | 2 | 0.962 | 0.13685353 |
| Pelon blanco | 3 | 0.969 | 0.08089087 |

Where: n=(1, 2,3): age of maturity, years.

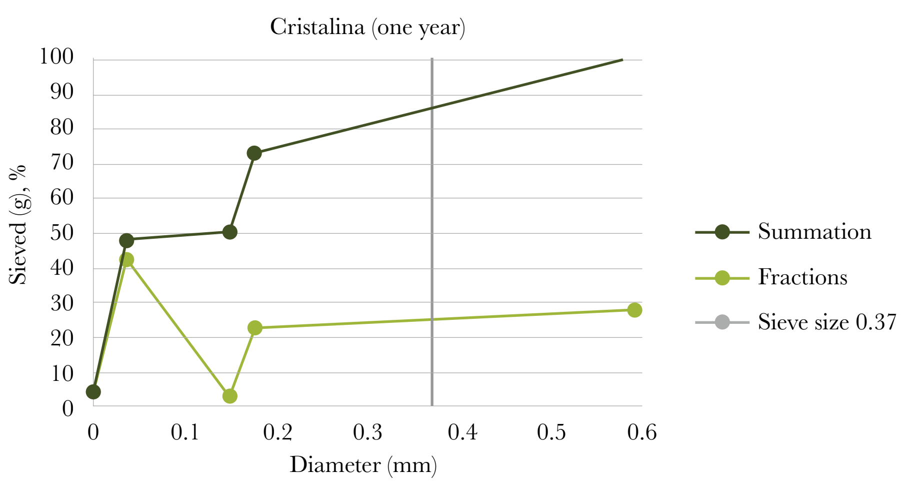


**Figure 4**. Diameters of the particles of Cristalina flour from cladodes with one year of maturity.

as cereals and maize. Therefore, they can be useful in the food industry and biomaterial generation.

Also, Figure 4 shows that about 80% of nopal flours meet the sizes necessary to achieve an adequate combination with other flours, in order to comply with a quantity of chemical components that may be previously planned for the final product. This means that the values of the external friction in relation to the different materials are suitable for the machines processing those flours selected by the standard size. In addition, flours maintain storage viability for chemical elements with an economic advantage over energy consumption, in regard to other technologies already mentioned. The values and their variation characterize each nopal flour as a technologically manageable flour with the techniques already available.

The values tan $\alpha$, as equivalents of friction, are important to determine the constructive parameters in different agroindustrial processing; for example, for the transport by gravity in inclined tubes, for the selection of particles by friction when moving them on inclined constructions or moving bands; for the interaction with the surfaces of tools of the machines that divide, mix compact, transport, among others.

**Table 4**. Results of external friction of flours of *Opuntia* spp. Varieties.

| Sample | Material | Average (°) | tan α /-/ | Max/Min (°) | Material | Average (°) | tan α /-/ | Max/Min (°) |
|---|---|---|---|---|---|---|---|---|
| Cristalina 1 | Steel sheet | 45.3 | 1.000 | 56/39 | Ceramic | 44.5 | 0.966 | 52/35 |
| Cristalina 2 | | 41.5 | 0.869 | 46/38 | | 41.6 | 0.869 | 54/34 |
| Cristalina 3 | | 42.0 | 0.900 | 45/37 | | 37.2 | 0.754 | 40/32 |
| Pelon blanco 1 | | 39.3 | 0.810 | 42/36 | | 42.3 | 0.900 | 50/35 |
| Pelon blanco 2 | | 38.3 | 0.781 | 41/35 | | 41.4 | 0.869 | 49/35 |
| Pelon blanco 3 | | 38.3 | 0.781 | 43/34 | | 43.6 | 0.933 | 49/34 |
| Cristalina 1 | Wood | 50.6 | 1.192 | 56/45 | Playwood | 54.3 | 1.376 | 59/51 |
| Cristalina 2 | | 54.5 | 1.376 | 58/50 | | 53.5 | 1.327 | 60/46 |
| Cristalina 3 | | 48.8 | 1.111 | 56/45 | | 49.1 | 1.150 | 55/44 |
| Pelon blanco 1 | | 51.3 | 1.235 | 59/43 | | 54.0 | 1.376 | 58/50 |
| Pelon blanco 2 | | 53.7 | 1.327 | 61/44 | | 52.5 | 1.280 | 58/45 |
| Pelon blanco 3 | | 53.2 | 1.327 | 59/49 | | 55.5 | 1.428 | 60/50 |
| Cristalina 1 | Glass | 48.4 | 1.111 | 55/39 | Plastic | 48.5 | 1.111 | 58/45 |
| Cristalina 2 | | 46.3 | 1.035 | 53/41 | | 53.4 | 1.327 | 59/48 |
| Cristalina 3 | | 46.1 | 1.035 | 52/36 | | 50.7 | 1.192 | 54/46 |
| Pelon blanco 1 | | 42.7 | 0.900 | 46/38 | | 50.9 | 1.192 | 58/46 |
| Pelon blanco 2 | | 43.9 | 0.933 | 55/35 | | 50.0 | 1.192 | 60/41 |
| Pelon blanco 3 | | 45.1 | 1.000 | 53/36 | | 49.3 | 1.150 | 57/41 |

Where: 1,2 and 3=age of maturity of the cladode, years.

## CONCLUSIONS

The physical-mechanical characteristics of the prickly-pear cladodes of different years of maturity can be reliably applied to select the constructive and technological parameters, for machines that reduce particle size.

Equally useful are the values of the internal and external friction of the flours of both prickly-pear varieties, when it is convenient to guarantee a continuous flow during the time of storage, dosing, mixing, among others.

This form of powdered organic material is a modern means of combining different materials, in order to adopt modern forms, from the unification of dust particle sizes. Always within the range of the equivalent standard, for example, corn or wheat, in order to provide a safe storage of renewable minerals. They can also act as a form of input for that technology to be developed in a future towards synthetic materials.

## REFERENCES

Austin, J. (1987). Análisis de proyectos agroindustriales. Madrid.

Méndez G., S. de J.; García H.J.; Rössel K., D.; Tarango A., A.; Talavera M., D. y Figueroa S,. B. (2004). Recomendaciones para el establecimiento de plantaciones de nopal tunero en el Altiplano Potosino. Coedición Colegio de Postgraduados-Comisión Nacional de las Zonas Áridas. 24 p.

Reyes-Agüero, J. A., J. R. Aguirre R., and H. M. Hernández. (2005). Systematic notes and a detailed description of *Opuntia ficus-indica* (L.) Mill. (Cactaceae). *Agrociencia, 39*(4): 395-408. https://www.redalyc.org/articulo.oa?id=30239404

Sáenz, C. (2004). Compuestos funcionales y alimentos derivados de Opuntia spp. *In*: Esparza, G., Valdez, R. y Méndez, S. eds. El Nopal: Tópicos de actualidad. Universidad Autónoma Chapingo, México, 211-222.