

## **Dalla Tradizione All'Innovazione: Dall'Arte Messicana Preispanica, Un Bioprodotto Per I Beni Culturali**

**Caratterizzazione della mucillagine di *Opuntia ficus-indica* e loro derivati per applicazione al restauro dei beni culturali**

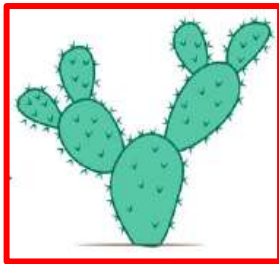
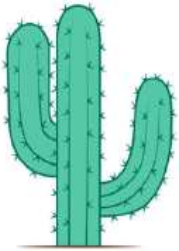
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**Laboratorio de análisis y diagnóstico del patrimonio**

Roma, Italia, 20 de Septiembre de 2017

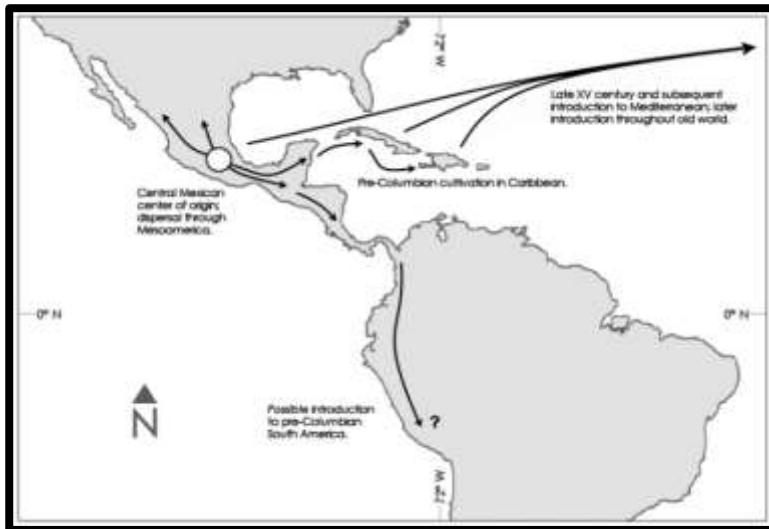
# Nopales (*Opuntia Spp.*)



- The nopal cactus belong to the genus *Opuntia* and the family of *Cactaceae*
- Cactus characterized by growing in arid and semi-arid conditions of the tropical and subtropical regions

*Cactus family*  $\approx$  1500 Species *Opuntia*  $\approx$  200 Species

Mexico: 60 native species



*Opuntia albicarpa*, *Opuntia cochinera*, *Opuntia ficus indica*, and others



*Opuntia ficus-indica*

- *Opuntia ficus indica*, the most cultivated edible cactus worldwide
- Commercial cultivation is carried out in **Mexico**, Spain, **Italy**, Brazil, Chile, Argentina and USA
- Mexico is one of the major producers and consumers of products derived from *Opuntia spp*

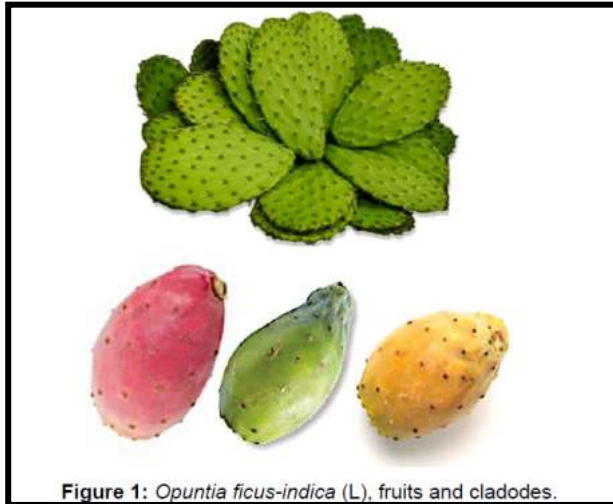


Figure 1: *Opuntia ficus-indica* (L). fruits and cladodes.



*Opuntia: mucilage production*

# Localization of mucilage in plants

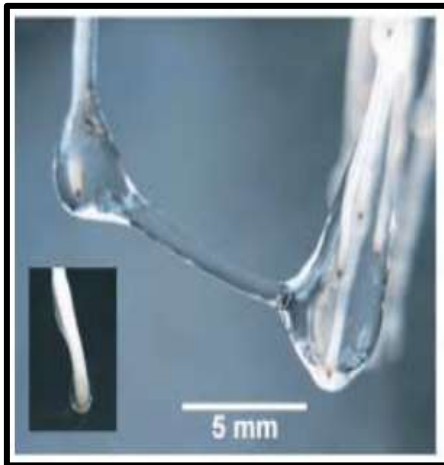
## Seeds



## Flowers



## Roots



## Leaves



## Stems

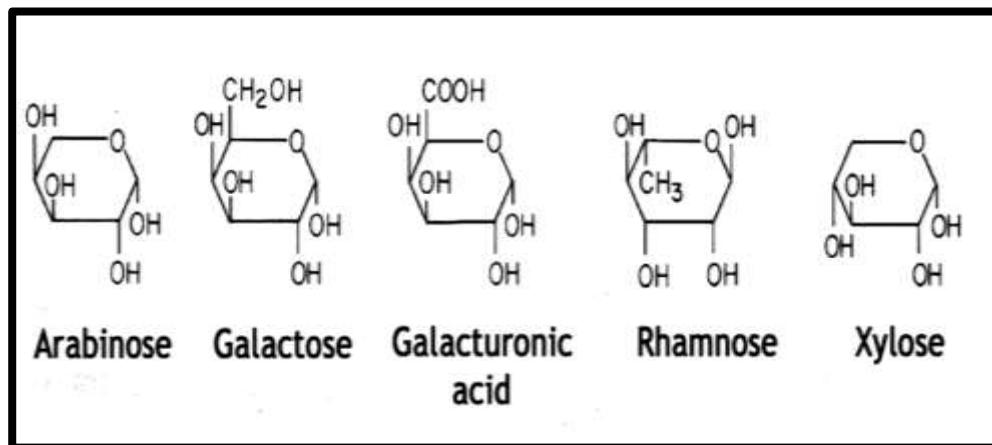


## Fruit



# Mucilage composition in nopal and other plants

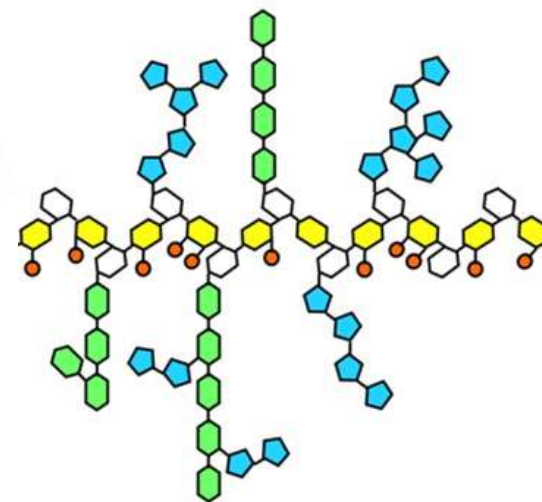
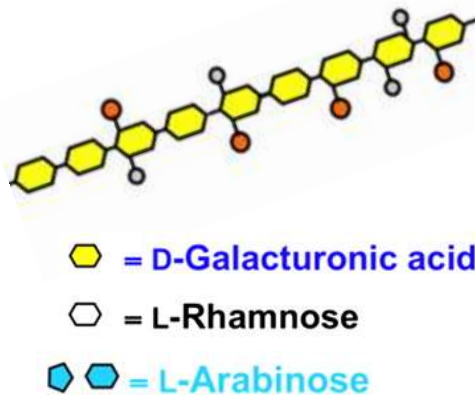
## Monosaccharides and acid monosaccharides



## Polisaccharids

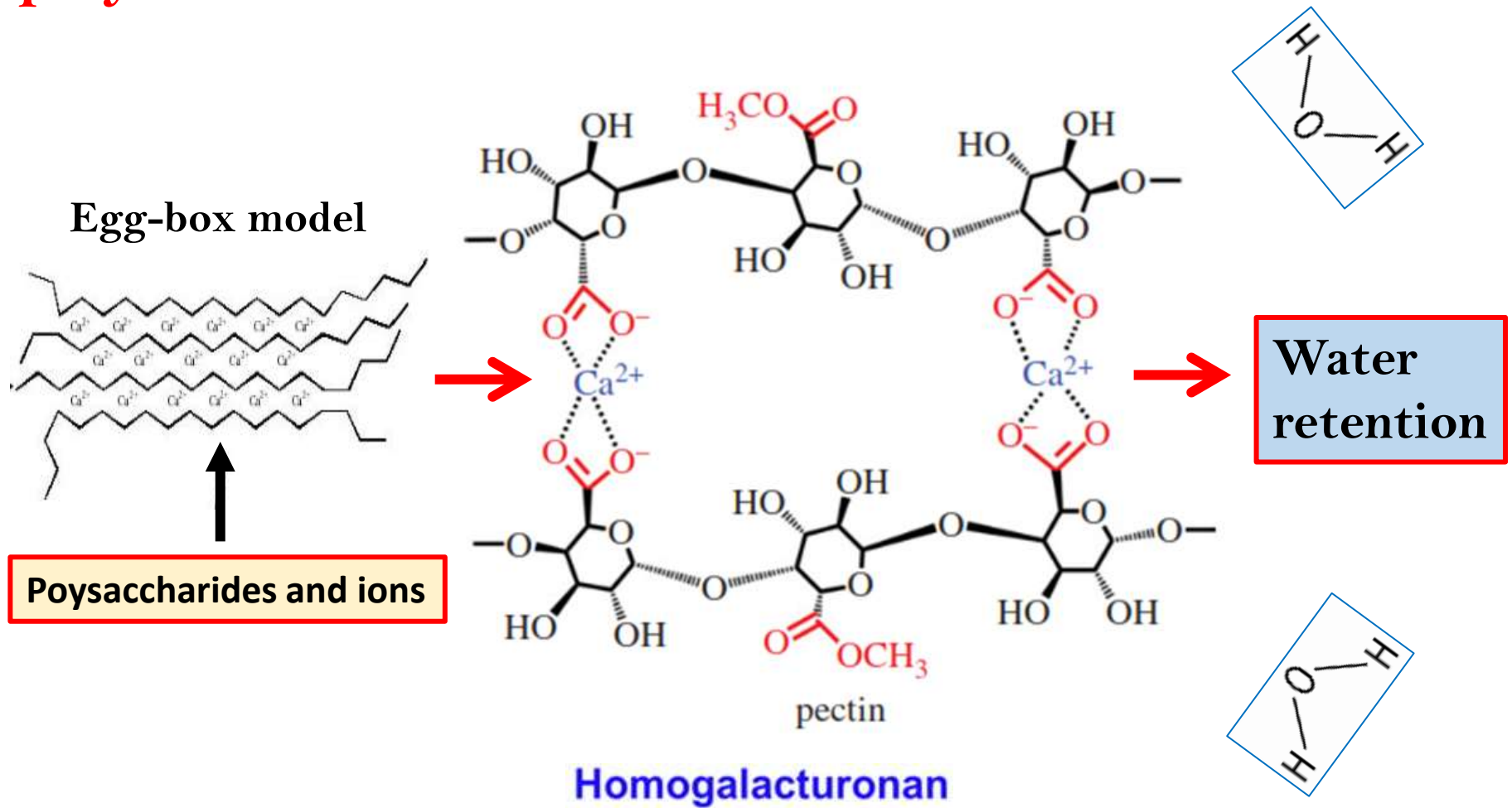
## Rhamnogalacturonan I

### Homogalacturonan



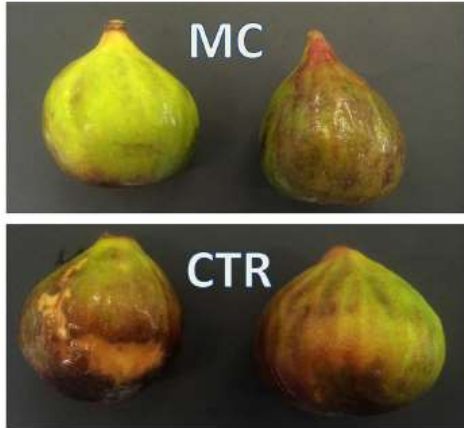
- **Cations:**  
*mono and divalents*  
( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ )
- **Proteins**
- **DNA**

# The egg-box model of calcium crosslinking in polysaccharides



# Uses of nopal mucilage

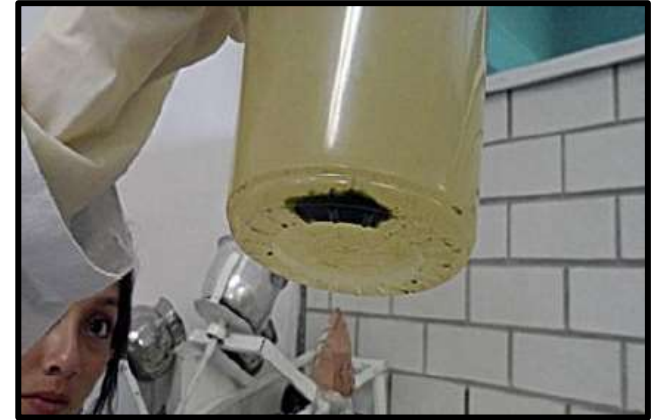
## Biofilms post-harvest



## Bioplastics



## Bioremediation



## Food, cosmetic and pharmaceutical industry



## Building construction

Mezcla de concreto autoconsolidable conteniendo ceniza volante tipo F. a) Mezcla control. Nótese la segregación de los constituyentes (pasta de cemento alrededor del círculo). b) Mezcla estabilizada conteniendo solución de extracto de nopal que sustituyó el 100% del agua de mezclado.



Segregación de la pasta de cemento.

a)



Mezcla de concreto estable

b)

## Other uses of nopal mucilage



**In the pre-Hispanic tradition of Mexico:**

The use of the nopal (*Opuntia spp.*) mucilage and other plants as an additive and organic binder to improve the mechanical properties of the materials used in different cultural heritage (Kita et al., 2013)

### **Aims**

**To characterize the physicochemical properties of the mucilage extracted from the nopal cladodes (*O. ficus indica*) and to standardize different extraction methods of the nopal mucilage, including the traditional method through a temporary course**

**Obtain nopal products that can be used as materials for the restoration of cultural property.**



# Materials and methods

## □ Plant material

*Opuntia ficus-indica* cladodes were bought in a local market (La Piedad, Mexico), cut and cubed (0.3-0.5 cm<sup>3</sup>)

## □ Traditional method: **nopal- water 1:1 (P/V)**

The recovery of mucilage-water extract was performed at different times: **2, 4, 8, 16, 20 and 24 hours.**

### Time course (hrs)



°Brix, Conductivity and pH

Mucilage Freeze-Dried

FTIR-ATR



# Results

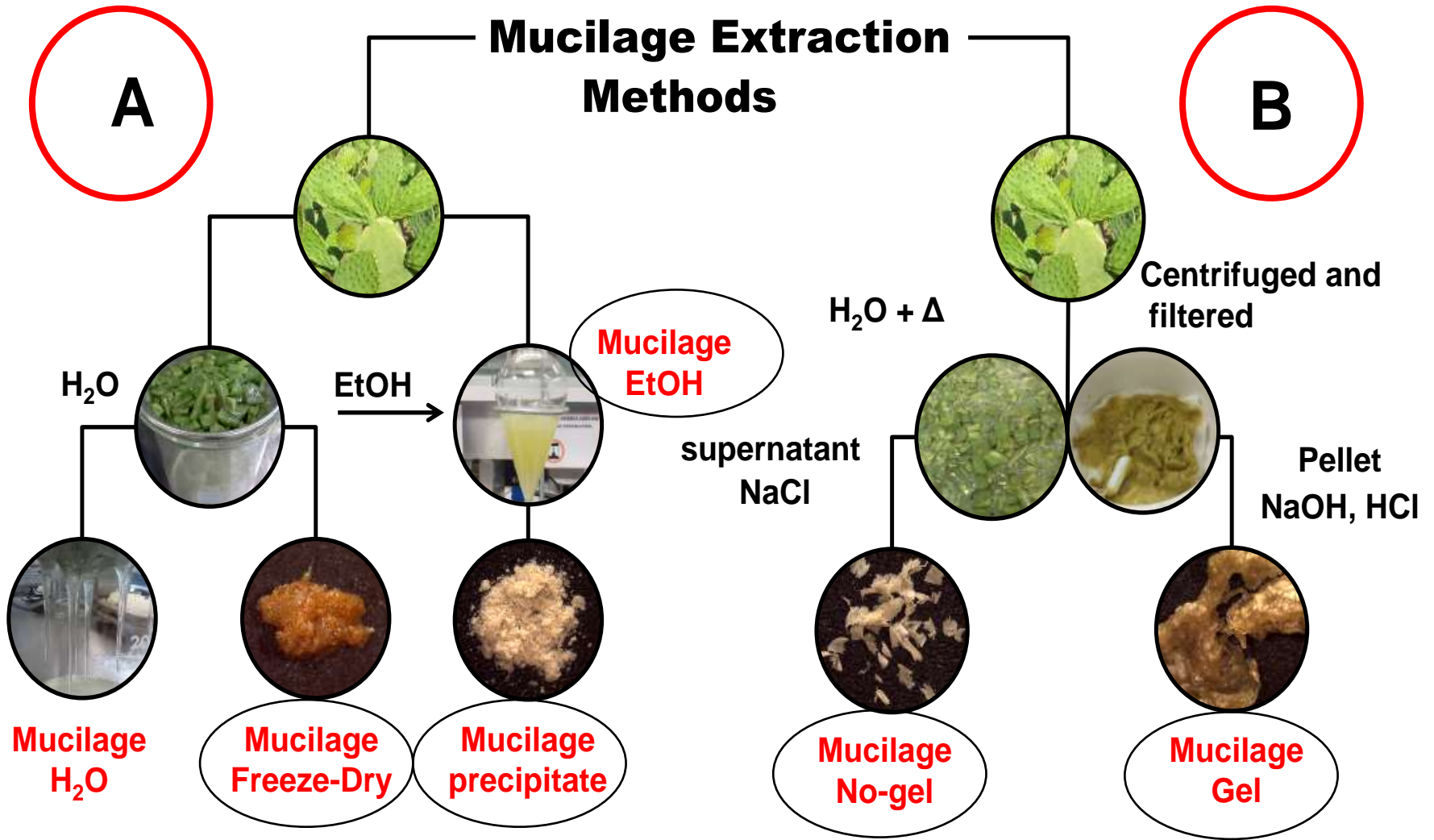
Treatments Time (hrs)	Mucilage recovered (mL)	°Brix % Sugar	pH	Conductivity $\mu\text{Scm}^{-1}$	Mucilage freeze-drying (mg mL <sup>-1</sup> )
2	15.36±0.76	0.94±0.042	4.45±0.024	2609.2±105.05 (a)	3.83± 0.37 (a)
4	13.40±0.89	0.96±0.022	4.50±0.030	2819.6±84.23 (ab)	7.30± 1.06 (b)
8	14.50±0.50	1.00±0.035	4.42±0.025	3119.8±102.9 (bc)	10.92±2.91 (b)
16	14.70±0.84	0.99±0.022	4.46±0.308	3467.6±97.83 (d)	10.12±0.44 (b)
20	14.30±1.72	1.00±0.035	4.27±0.030	3479.6±262.42 (d)	13.63±1.10 (b)
24	13.50±1.17	1.01±0.055	4.26±0.018	3671.4±252.24 (d)	12.98±0.67 (b)

- The conductivity was higher after the eight hours of extraction
- Four hours are sufficient to obtain the greatest yield of the mucilage of the cladodes of cactus when it is extracted by traditional methods

Nopal:H<sub>2</sub>O

Nopal:H<sub>2</sub>O:Heat

### Mucilage Extraction Methods



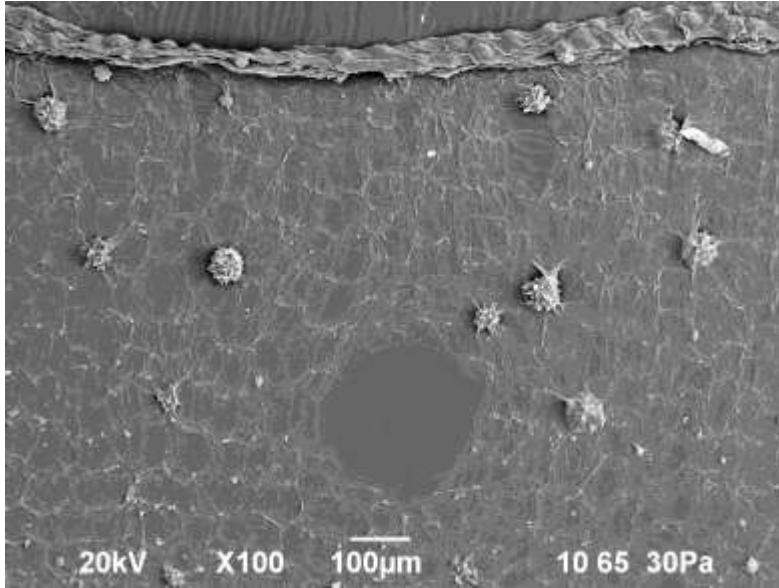
FTIR-ATR

Viscosidad, maleabilidad y color

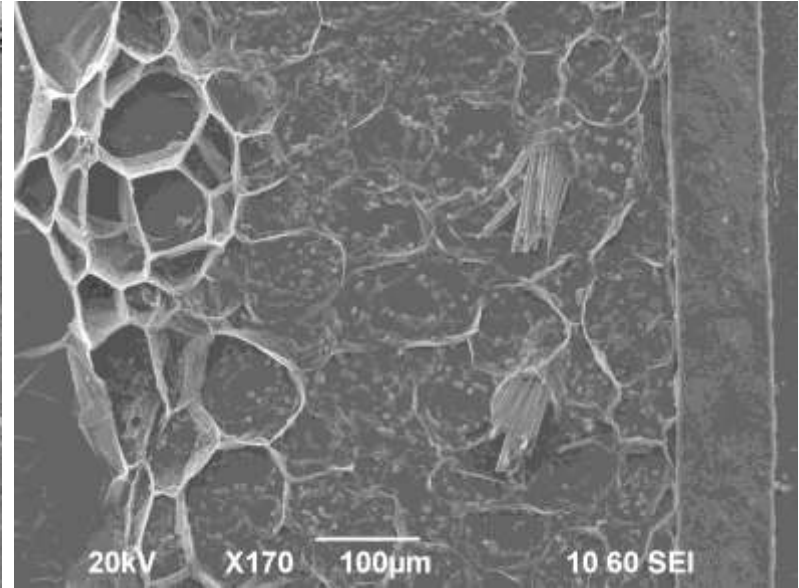
*Opuntia ficus indica*

*Aloe vera*

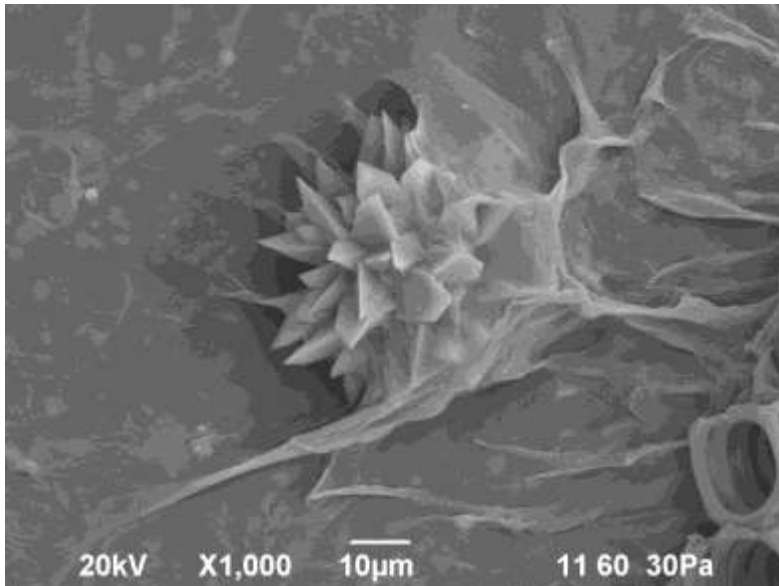
**A**



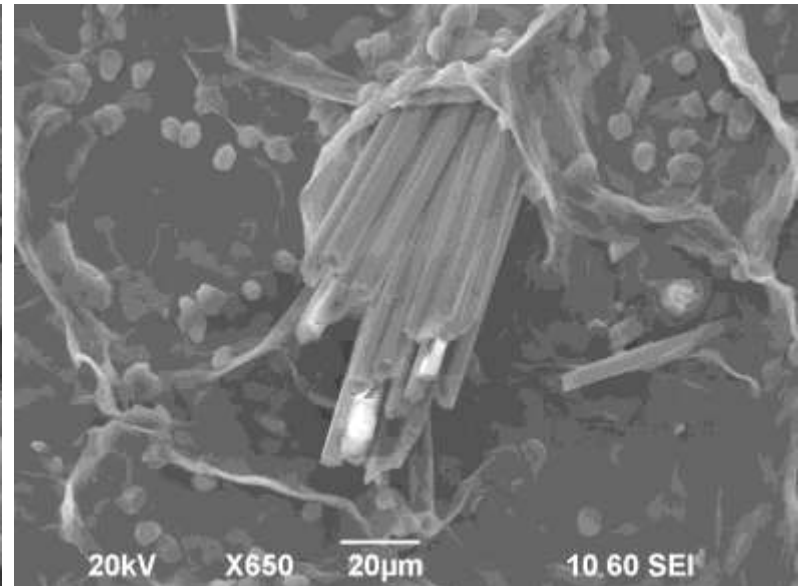
**B**



**C**



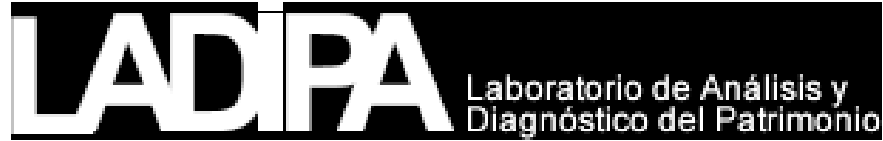
**D**



# Conclusions

- The results presented here indicate that four hours are sufficient to obtain the highest yield of the mucilage of the cactus cladodes when it is extracted by traditional methods.
- On the other hand, from the extraction methods with water and temperature were obtained five different materials that compose the mucilage of the cladodes of nopal.
- These mucilage derivatives had different physical characteristics (viscosity, color) and infrared absorption spectra, with defined peaks characteristic of the polysaccharides.
- These mucilage products could be used as materials for the restoration of cultural property.

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