A glance about the industrial possibilities of cactus pear

Un coup d'oeil au sujet des possibilités industrielles du cactus

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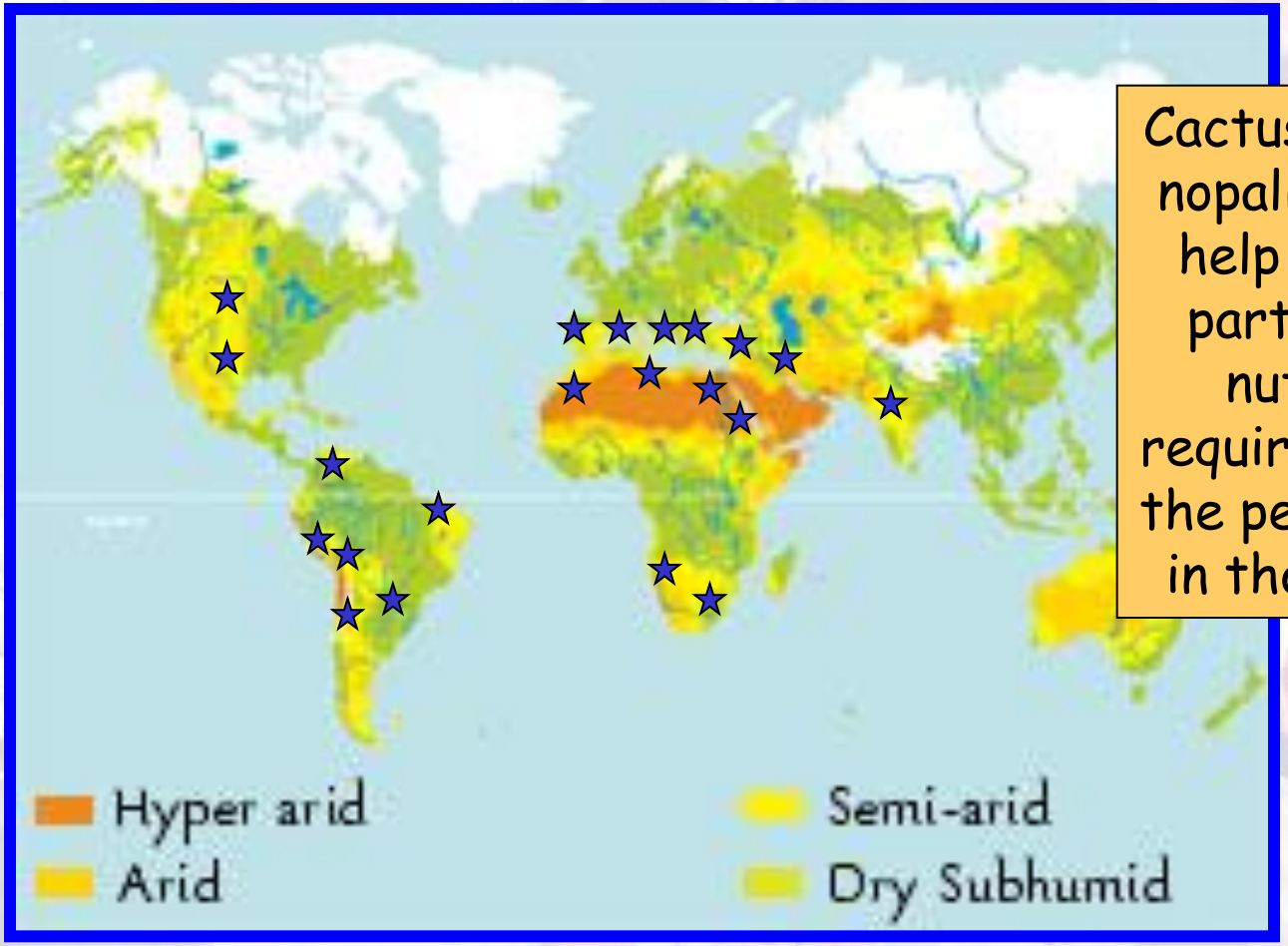
VII International Congress on cactus pear and cochineal
Agadir, Maroc, 17-23th October, 2010

After 25 years researching on cactus pear I agree with a Sicilian journalist that has called *Opuntia* "A treasure under the thorns"

"Un trésor sous les épines"

Arid and semiarid regions and their relation with cactus (*Opuntia* sp.)

★ Cactus pear



Cactus pear and nopalitos could help to cover partially the nutrients requirements of the people living in those areas

Contribution to a best cactus pear and cladodes utilization from R&D+i…+ training

Technical workshop for training little farmers in Chile

Arid and semiarid regions in Chile

In **Chile**, more than 50% of our country are desert areas (arid, semiarid….).
Those areas are located in the north of the country where is the Atacama desert, one of the most arid regions on the world (parallels 29°02'and 32°16' latitude South and 69°49' and 71°45' longitude West) with 40.656 km².

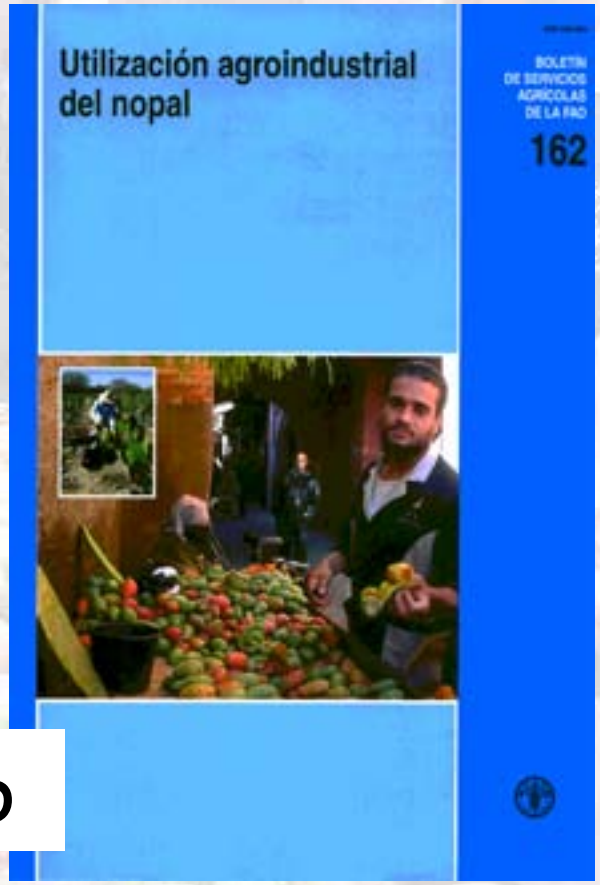
In this lecture I want to give you a glance about the book : "Industrial possibilities on cactus pear" published in 2006 (FAO N°162).

Translated to the English and I hope soon available for all of you

Now is available free in the FAO web site

The results of our research and that of many other groups is compiled in this book

1985-2005



The time go quickly and there are new researches that are not included in the book

2006

Utilización agroindustrial del nopal

BOLETÍN DE SERVICIOS AGRÍCOLAS DE LA FAO

162

Cover

Utilización agroindustrial del nopal

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ORGANIZACIÓN DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACIÓN
Roma, 2006

BOLETÍN DE SERVICIOS AGRÍCOLAS DE LA FAO

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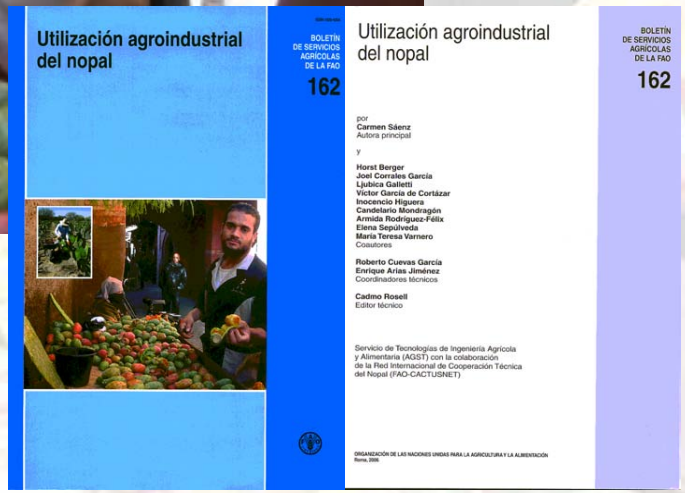
The aim of the book is to give details of several technologies that can be use to process cactus pear and cladodes for foods and for other uses



In this picture, this young man seems to ask us : What can I do with this fruit?

Aspects to be considered before applying different technologies to preserve fruits or *nopalitos*

Raw materials knowledge

Chemical composition, technological characteristics, bioactive compounds

Chemical composition of colored cactus pear pulps (g $100g^{-1}$)

Characteristic	Green*	Purple**	Orange***
Moisture	83.8	85.98	85.1
Protein	0.82	0.38	0.82
Fat	0.09	0.02	---
Fiber	0.23	0.05	---
Ash	0.44	0.32	0.26
Total sugars	14.06	13.25	14.8
	mg $100g^{-1}$		
Vitamin C	20.33	20.0	24.1
β-carotene	0.53	---	2.28
Betalain (Betanine)	---	100	---

*Sepúlveda and Saénz (1990); **Sáenz, Sepúlveda and Moreno (1995); *** Sepúlveda and Sáenz, (1999)

Cladodes: chemical composition

(% dry matter)

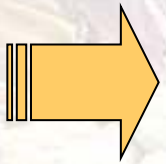
Dietary fiber

Age (year)	Protein (%)	Fat (%)	Ash (%)	Crud (%)	fiber	NNE (%)
1	5.4	1.29	18.2	12.0		63.1
2	4.2	1.40	13.2	14.5		66.7
3	3.7	1.33	14.2	17.0		63.7
4	2.5	1.67	14.4	17.5		63.9

Source: López *et al.* (1977) cited by Pimienta (1990)

TECHNOLOGICAL CHARACTERISTICS

- pH
- Colour
- Acidity
- Texture
- °Brix



- Heat treatments
- Sensory quality
- Functional compounds
- Harvest maturity
- Taste…

BIOACTIVE COMPOUNDS

- Pigments in fruit: Betalains and Carotenoids with antioxidant activity
  -Polyphenols; -Ascorbic acid
- Dietary fiber, mainly in cladodes, hydrocolloids (mucilage), polyphenols,…
- Extracts with potential use in medicine from the flowers

Processing Technologies

Post-harvest technologies to extend the shelf-life of fresh fruit and nopalitos

Besides the post-harvest traditional technologies ……

Minimally processing technologies

Fresh cut fruits and vegetables

Hygiene

Cold atmosphere

Package permeability

Consist in a minimum number of unit operations (wash, peel, cut…), packaging and storage at low temperatures

Fresh cut fruits and vegetables

Market in Mexico

Refrigeration (4-6°C) for 7-14 days

Technologies based on the a_w reduction

a_w: measure of the water available for microorganism growth, chemical reactions, etc

- Drying
- Evaporation
- Freezing

Technologies that use different equipments and flow-sheet process

Drying

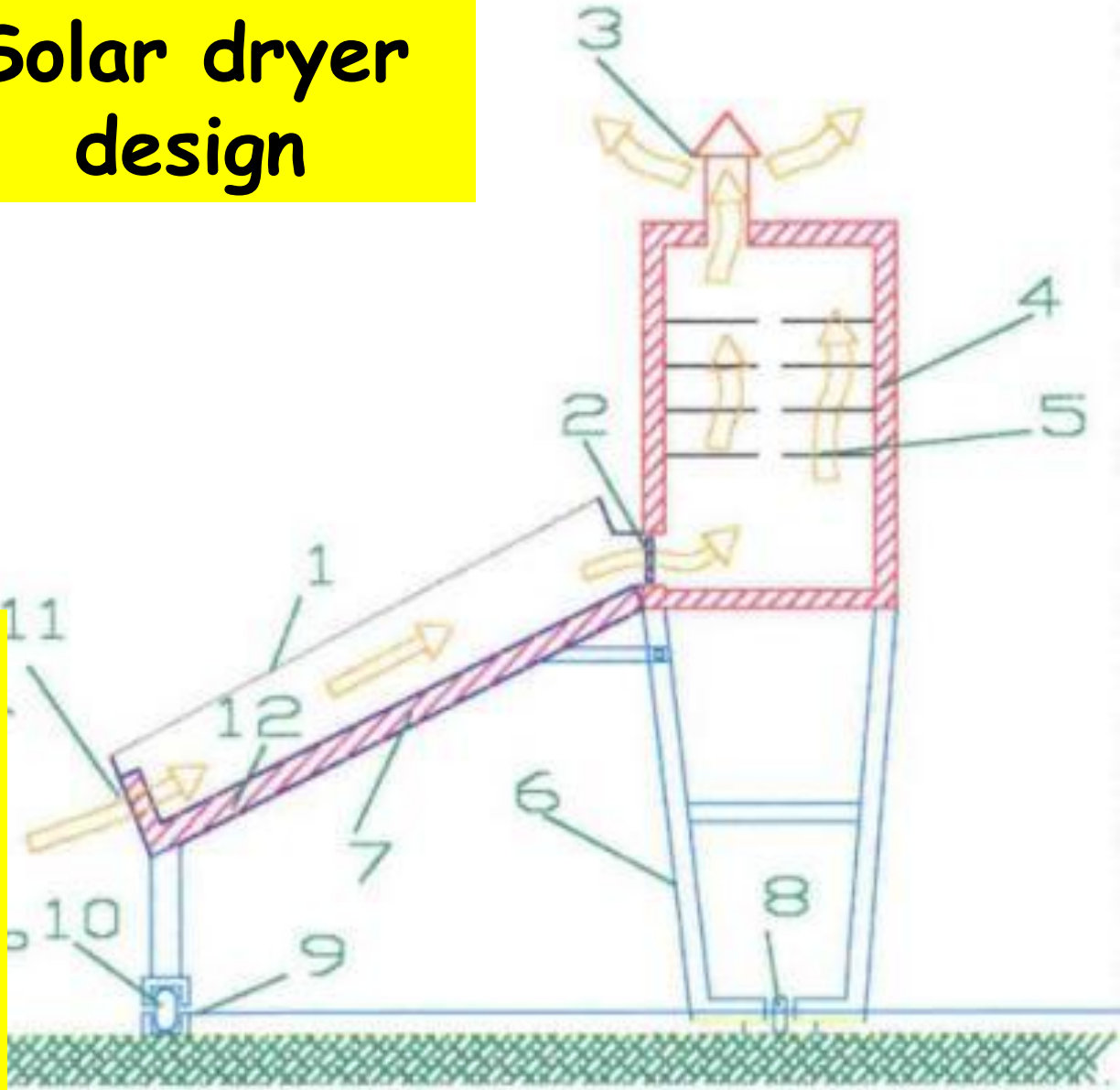
Cactus pear fruits

- Whole fruit or fruit pieces (solar drying)
- Pulp as fruit leathers or bars (solar or artificial drying)

Young cladodes ("nopalitos") and mature cladodes (2-3 years)

Solar dryer for rural areas

Solar dryer design



Components

1. Solar collector
2. Filters
3. Air out
4. 7. Aisle
5. Trials
6. 8. 9. 10. Iron structure
11. Air in
12. Receptor

Dehydrated cactus pear pulp

Cactus pear pulp to make fruit leathers, i.e. blended with apple pulp…

CACTUS PEAR/APPLE LEATHER

CHARACTERISTICS	PURPLE CACTUS PEAR	GREEN CACTUS PEAR	ORANGE CACTUS PEAR
SOLUBLE SOLIDS (°Brix)	76.9 ± 0.28	84.0 ± 0.0	76.9 ± 1.13
ACIDITY (% citric acid	1.4 ± 0.06	1.4 ± 0.01	1.5 ± 0.01
SS/ACIDITY	55.0 ± 2.24	58.0 ± 0.56	50.7 ± 0.27
MOISTURE (%)	10.4 ± 0.04	9.7 ± 0.78	11.5 ± 0.09

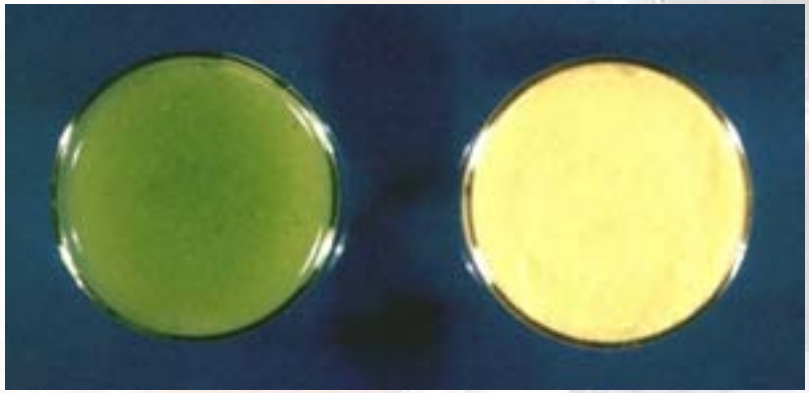
Thin layers pulp dehydrated in an oven

Lab oven with trays

aw =0.568-0.632

Fruit leathers (fruit sheets) and "fruit bars" are made with this technology

Cactus pear/quince sheets



100%CP 75%CP/25%Q 50%CP/50%Q

Commercial bars

Label of this products

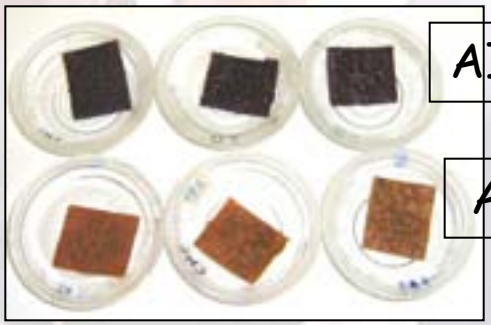
Benefits include:

- ✓100 % real fruit
- ✓Only 100 calories
- ✓Healthy and convenient
- ✓No sugar added
- ✓Gluten free
- ✓Lactose free
- ✓Kosher
- ✓Not sticky

Cactus pear/apple/flaxseeds bars *

Parameter	Assay I (orange cactus pear)		
	T1	T2	T3
Polyphenols GAE (ppm)	1445,3 a	1365,0 a	1640,1 b
Parameter	Ensayo II (purple cactus pear)		
	T1	T2	T3
Polifenoles GAE (ppm)	1404,7 a	1438,0 b	1846,0 b

T1 T2 T3



75% Purple Cp/25%Apple; T3: sucrose+flaxseeds

*Unpublished data

Cladodes drying

"Nopal" powder or cladodes powder

Cactus pads 2-3 years

Cactus pads powder

Dietary fiber in nopal powder (2-3 years old cladodes)

Type of fiber	(g/100g)	cv (%)
Insoluble fiber	28,5	5,6
Soluble fiber	14,5	13,1
Total dietary fiber	43,0	6,2

Less content TDF in young cladodes (close to 20%) (Gallardo *et al.*, 1997)

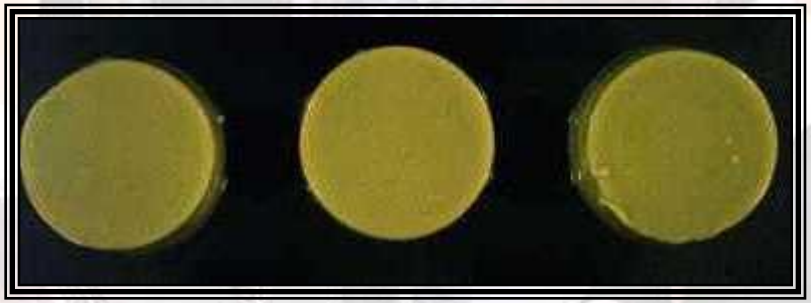
Foods in which the addition of nopal powder was tested

Vegetables cream or soup

Biscuits

Foods in which the addition of nopal flour was tested

Flans (desserts)



Water melon taste

Banana taste

16% 18% 20%

Addition levels

- 15-18% nopal flour (blended with other ingredients)
- Greater levels of addition produces negative changes in color, aroma and mucilaginous texture in some products
- Better results: in dried or solid products than in liquids foods
- **A beverage (with pineapple pulp) is being developed in our Department**

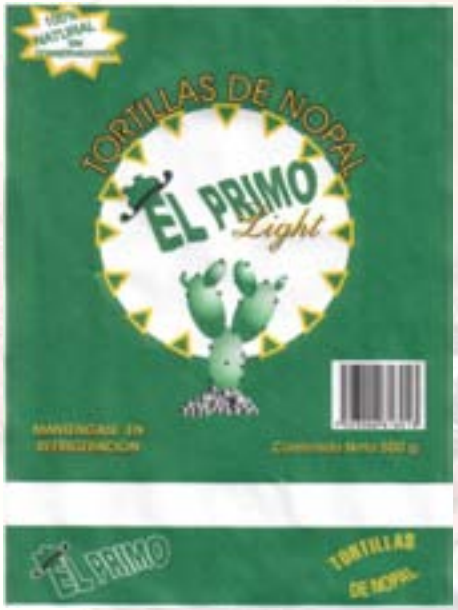
Nopal powders problems??

A **purified nopal powder** with less herbaceous aroma and less mucilage content was recently developed in our Dept.

This research is not yet published

The first results show that the addition of nopal powder (blended with wheat flour) could be greater than 15% to prepare good biscuits

A newly food prepared in Mexico are the typical "tortillas" with nopalitos added



Teresa Arellanos, Mexico (2005)

Prepared with fresh nopalitos

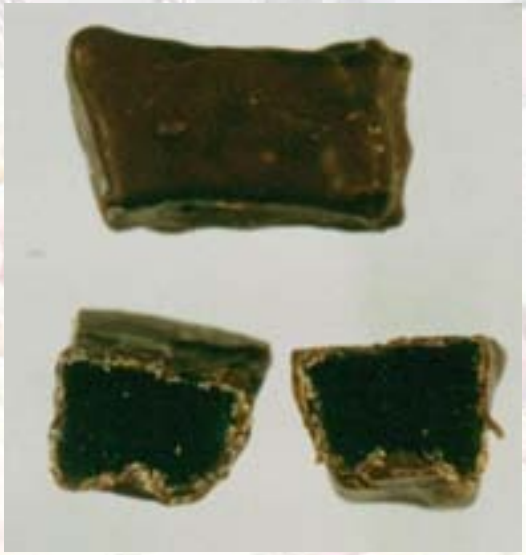
Osmotic dehydration

Candied or crystallized products from cactus pear fruit and from cladodes ("nopales")

Crystallized fruit (with peel)

Immersion in sucrose or glucose syrups (with increasing concentrations) and a final drying in an oven

Candied Cladodes



Candied cladodes covered with bitter or sweet chocolate

Evaporation

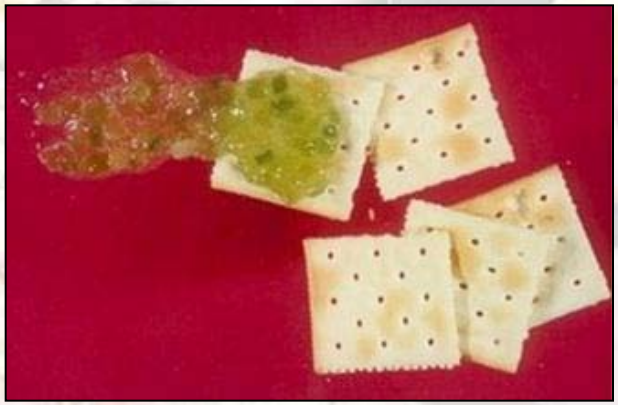
- Marmalades
- Syrups
- Concentrates juices

Cactus pear and cladodes

Marmalade

Ingredients:
Cladodes (cut), lemon peel, lemon juice and sugar

Nopal marmalade

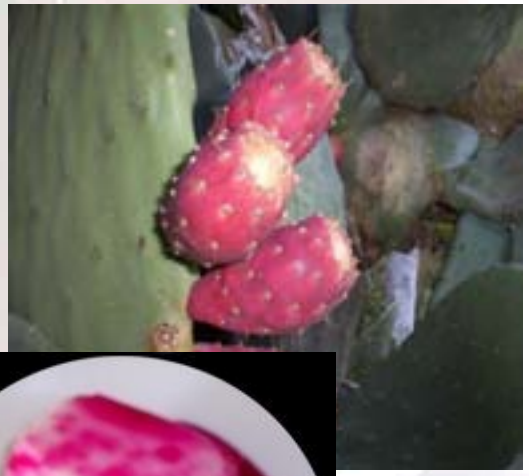


Commercial cactus pear marmalades, syrups and concentrates juices

Concentrated juices

Pilot plant

Developed in our Department in collaboration with the Faculty of Pharmacy



Toppings from colored cactus pear for desserts

(Morales *et al.*, 2008)

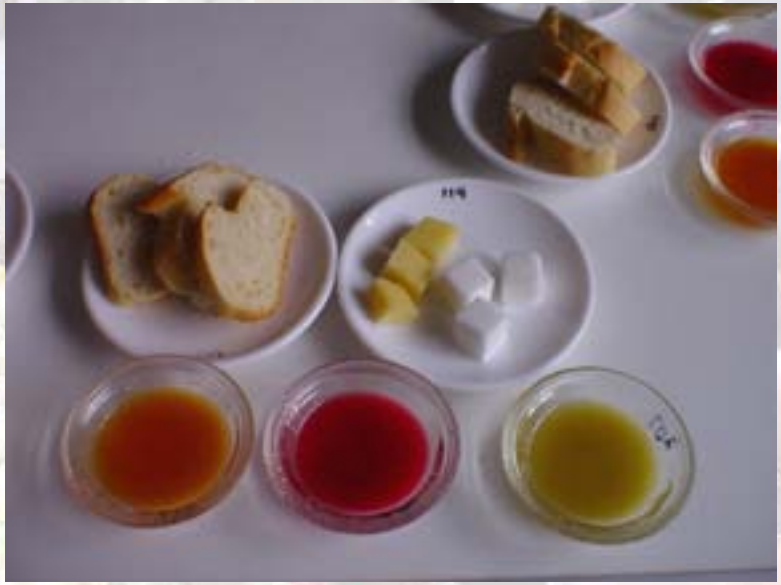
Bioactive Compounds in coloured cactus pear toppings

Bioactive Compounds	Purple cactus pear topping	Orange cactus pear topping
Carotenoids (μg/g)	0.186 ± 0.001	0.021 ± 0.001
Total phenolics totales (mg/L GAE)	350.50 ± 15.25	131.48 ± 5.72
Betalains	81.06 ±1.83	63.80 ± 1.86
Betacyanines as betanine (mg/Kg)	66.09 ± 1.03	0.92± 0.00
Bethaxantins as indicaxantin (mg/Kg)	14.97±1.53	62.88 ± 1.86

Developed in our Department

Balsamic type vinegar from colored cactus pear

(Prieto *et al.*, 2008)



Vinegar from purple cactus pear: the best sensory evaluated

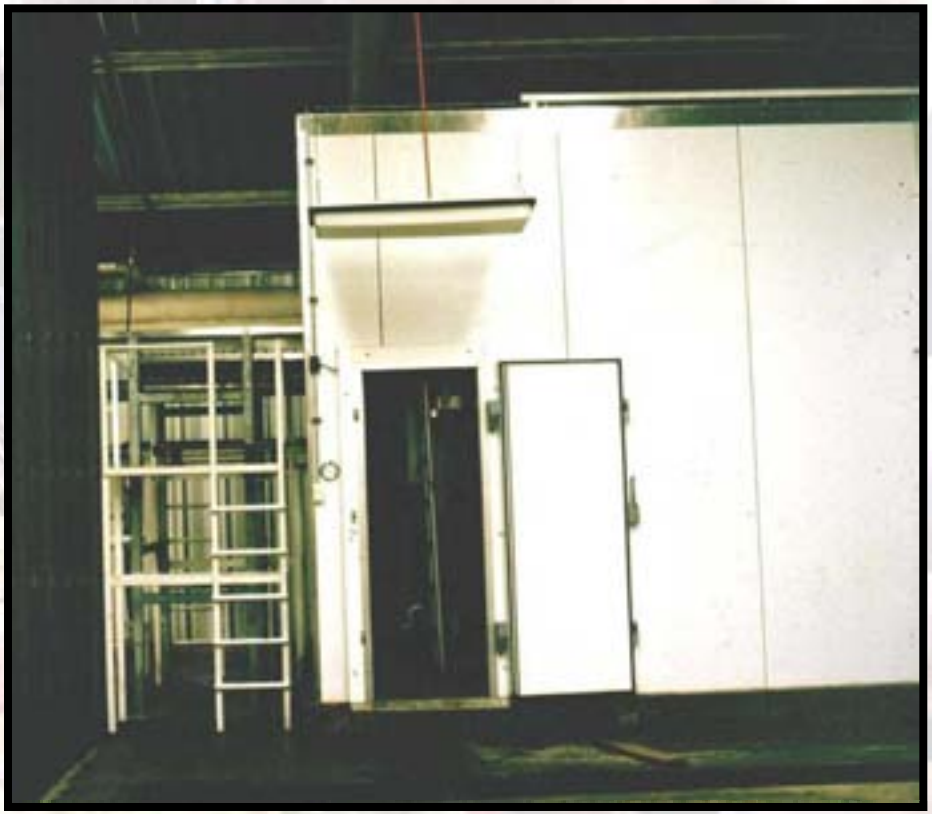
Freezing

- Reduction of a_w: control of microorganisms
- Cold: control of undesirable reactions and microorganism growth

To preserve the aroma, color and taste characteristics

Frozen cactus pear fruits: half and slices with and without peel (1988)

IQF system
(cold air at -40°C)



Main problems: Mucilaginous drip and texture loss in all cases, in spite of using so low temperature

Better: Freezing pulp (as a block in a chamber at -18°C) could be used to prepare ice-cream, juices, nectars, etc

Thermal treatments in foods

Cactus pear (juices) and "nopalitos" (pickled, brined)

- pH > 4,5
- Acidity
- % soluble solids

Other *Opuntia (O. macrohyza, O. xoconostle)* with low pH have advantages to be processed

Cactus pear juices

Peeling technologies

A group of the Hohenheim University (Germany) has tested some equipment (mills, finisher, decanters) to remove the peel and to obtain cactus pear juices

(Moßhammer *et al.*, 2005)

Cactus pear juices

Hydraulic press

Samples

Plate heat exchanger

"Nopalitos" in brine and pickled "nopalitos"

Nopalitos production in Hermosillo, Sonora, México
(A. Rodríguez)

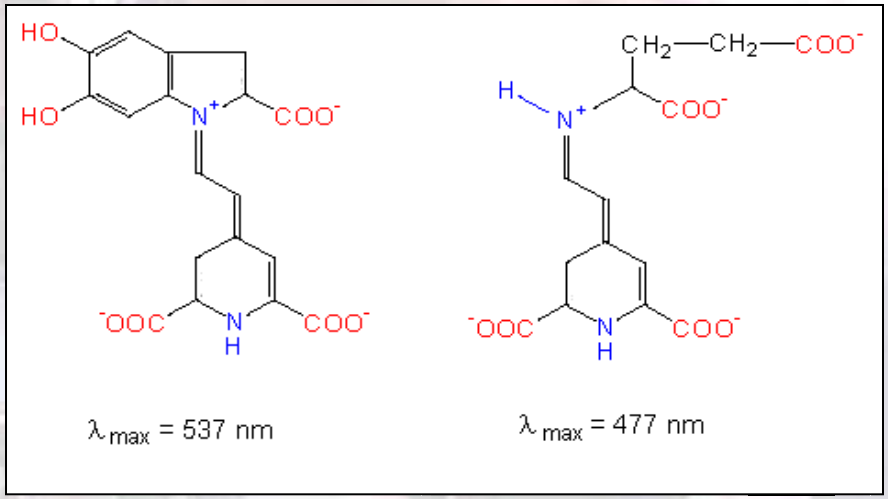
Food additives from *Opuntia*

Cactus pear fruit and cladodes

- Colorants
- Thickenning agents

Pigments to color foods

Betalains



Betacianine **Betaxantine**

Trends go from artificial dyes towards natural colorants

Makes cactus pear a promising source of water-soluble betalains

Betalains from Opuntia

Natural betalains from *Opuntia* could replace artificial colorants used in foods such as: amaranth (E-123); Ponceau 4 R (E-124); erythrosine (E-127),allura red (E-129), etc.

With no need of a new classification because is the same compound of red beet (E-162) but without earth-flavor and high nitrate concentration.



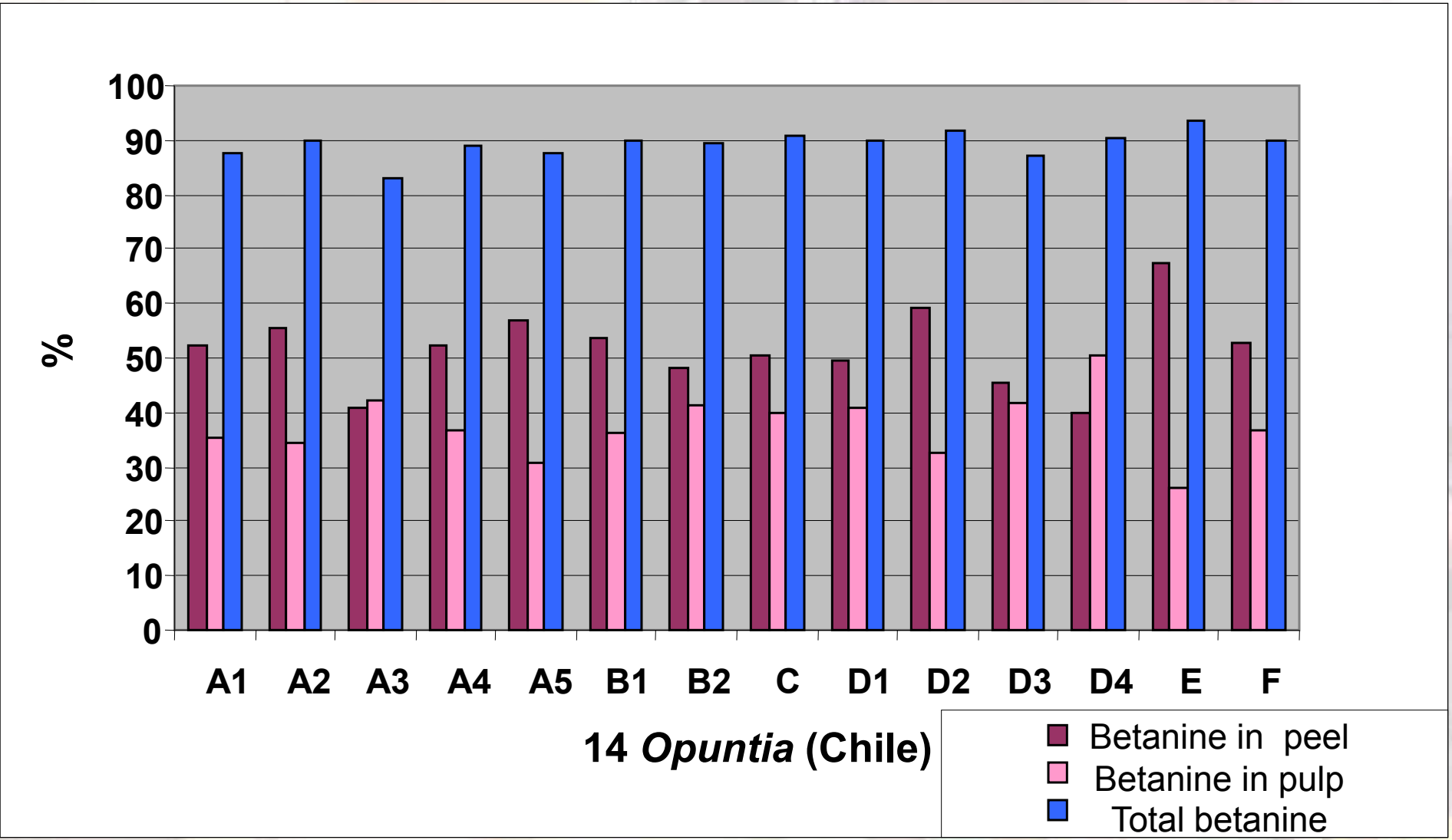









Betanine percentage in peel, pulp and whole cactus pear fruits (mg100g^{-1}f.m.)



Purple cactus pear colorant

Purple cactus pear colorant (whole fruit)

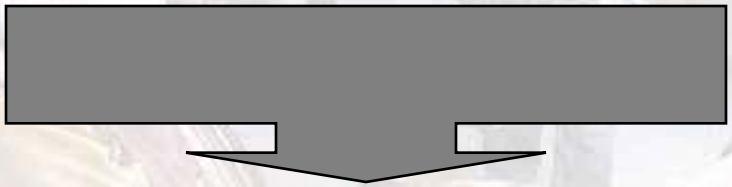
Characteristics	Average±SD
Soluble solids (°Brix)	65.3 ± 0.057
pH	4.7 ± 0.0
Acidity (% citric acid)	0.5 ± 0.037
Betanine (mg/100g)	123.0 ± 0.057
Color	
L*	17.5 ± 0.152
a*	3.9 ± 0.057
b*	2.1 ± 0.057
C*	4.4 ± 0.070
h°	28.3 ± 1.40

Cactus pear colorant: different water concentration

Red or purple

Betalains Stability

- pH : 4.0 - 5.0
- Thermal Treatments: 80°C, 10 min



The purple color remained stable and no Maillard reaction occured

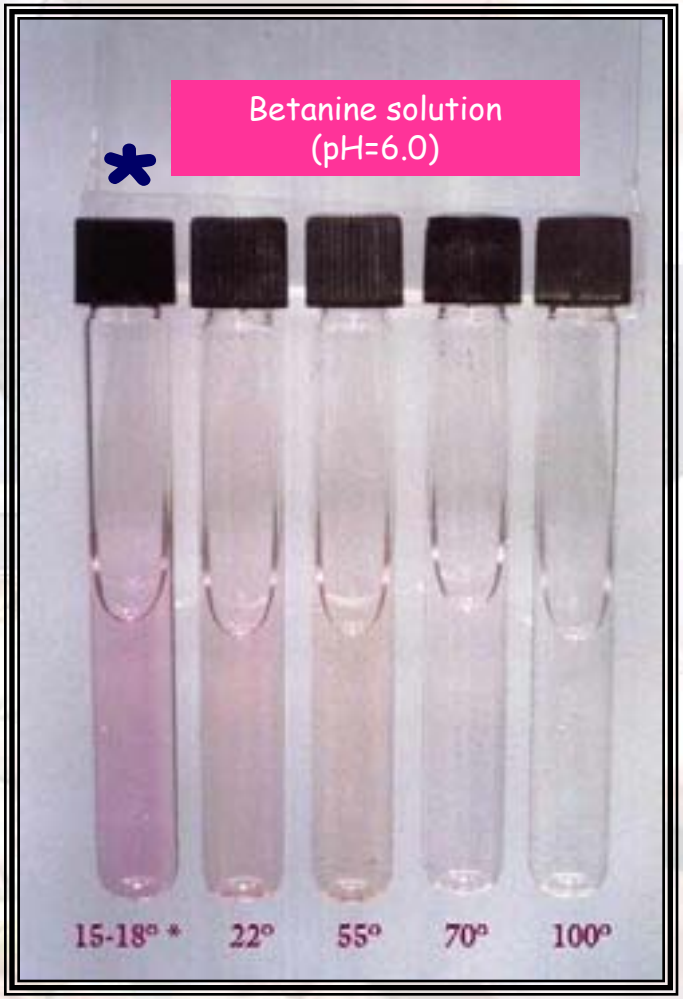
Source: Sáenz et al. (1997); Moßhammer *et al.* (2005).

In red beet there many papers published

Betalains Stability

Higher temperature and pH, reduce the pigment stability (heating x 5min)

(Extract 2%)

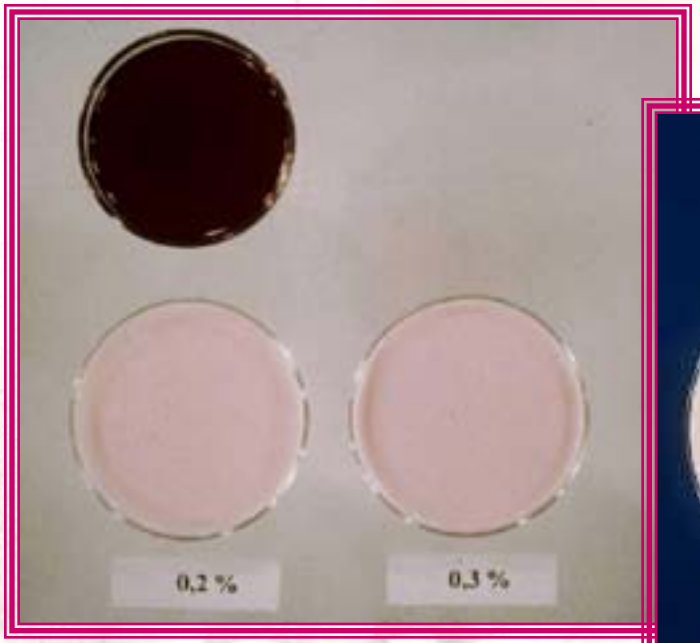


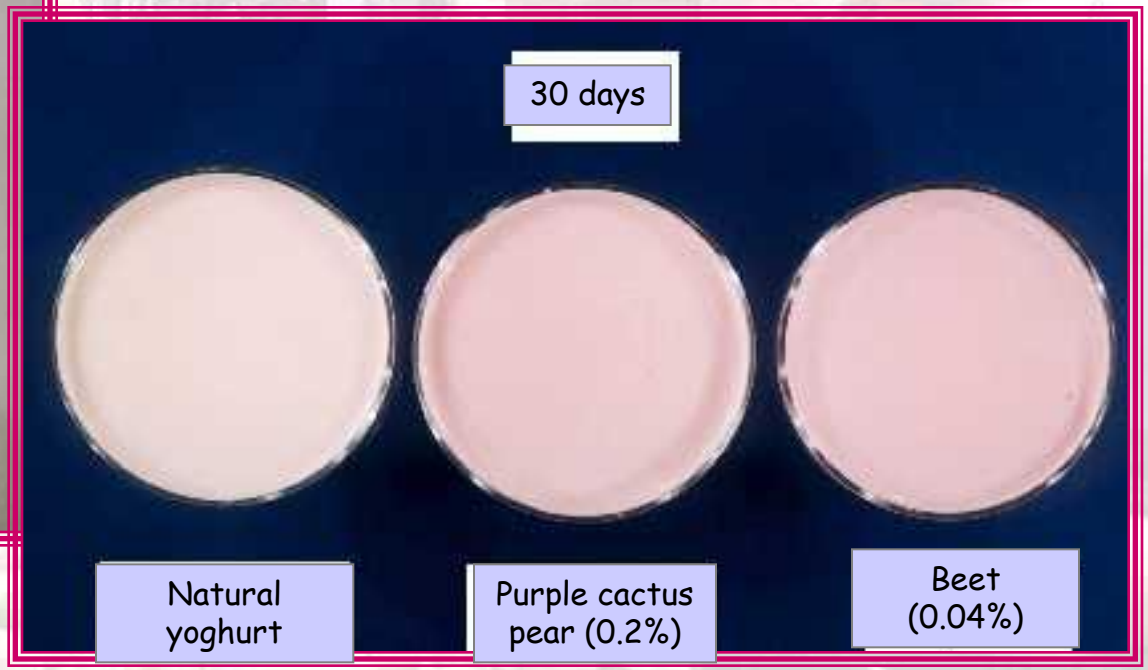
* Before the treatment

Colorant uses in a beverage model

Beverage storage in refrigeration (5-6°C)

Uses in yoghurt





In a commercial beet colorant, the betanine is 5 times than in the cactus pear colorant from cactus pear cultivated in Chile

Betalains as a functional component

Antioxidant activity of betalains is a *plus* for the use of cactus pear as a colorant

Butera *et al.*, 2002 ; Galati et al., 2003; Kuti, 2004; Tesoriere *et al.*, 2005; Stintzing et al., 2005; Morales *et al.*, 2008…

A powder colorant was recently developed by our group in collaboration with the Faculty of Pharmacy

Microencapsulated pigments from purple cactus pear

Mohammer et al., 2006 (*O. ficus-indica* cv Gialla);
Díaz Sanchez et al., 2006 (*O. strepthacantha*);
Sáenz et al., 2009 (*O. ficus-indica*, purple)

Microencapsulated pigments from purple cactus pear

Spray dryer

Pilot equipment

Dr. Paz Robert

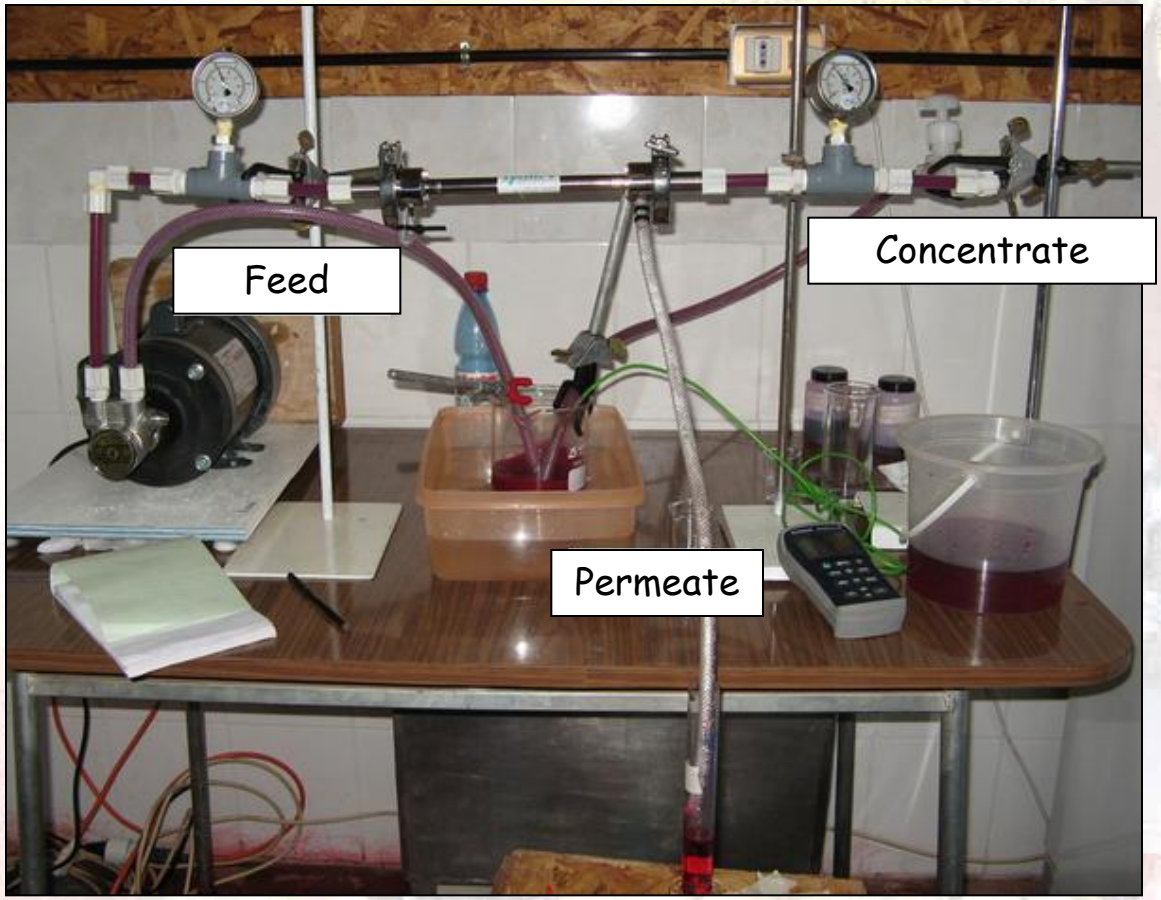
U. de Chile

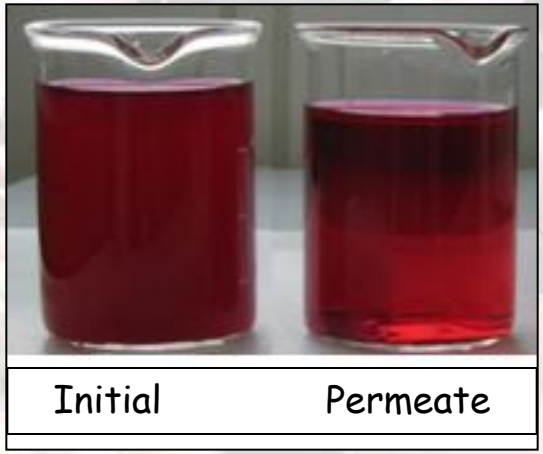
Researches recently beginning by our group in collaboration with the Faculty of Pharmacy (U. Chile) and PUCV

Betanine separation by membrane technologies

Microencapsulation

Microfiltration module





Lab processing

Dr. Beatriz Cancino

PUCV-Chile

Inicial	Concentrate	Permeate	Water

Purple cactus pear microfiltration

Thickenning agents

Mucilage

Is part of the dietary fiber

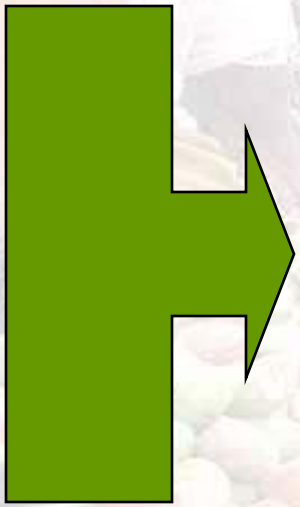
- Absorb and storage large amounts of water
- Form viscous or gelatinous coloids

Mucilage extraction from cladodes previous water maceration

* Water extraction and precipitation with ethanol
* Water extraction and liophylization
* Low yield (close to 1%)
* Changes in some properties (solubility)

Estructure suggested for the fruit mucilage

Shows a backbone of a rhamnogalacturonan-type polysaccharide



Arabinose
Galactose
Rhamnose
Xylose

Galacturonic acid

Potential uses for nopal mucilage

- To increase food viscosity (beverages, flans, desserts)
- To stabilize food foams
- To substitute fats and link aroma
- To protect the gastric mucus
- Other different to foods: to clarify water; as paint adhesive; to improve the water soil infiltration, etc

CMC can be replaced by nopal mucilage in fruit nectars to produce viscosity

Dose = 0.09% mucilage powder

Yolk egg foam stabilizer

Ingredients: yolk egg, sucrose syrup (65° Brix) and nopal hydrocolloid (0.5 and 0.8% p/v).

Foam Stability: syneresis and volume reduction. **Stability:** increase with nopal mucilage addition.

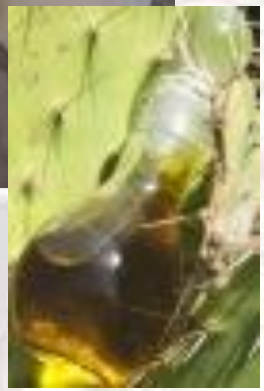
Cactus pear liqueurs

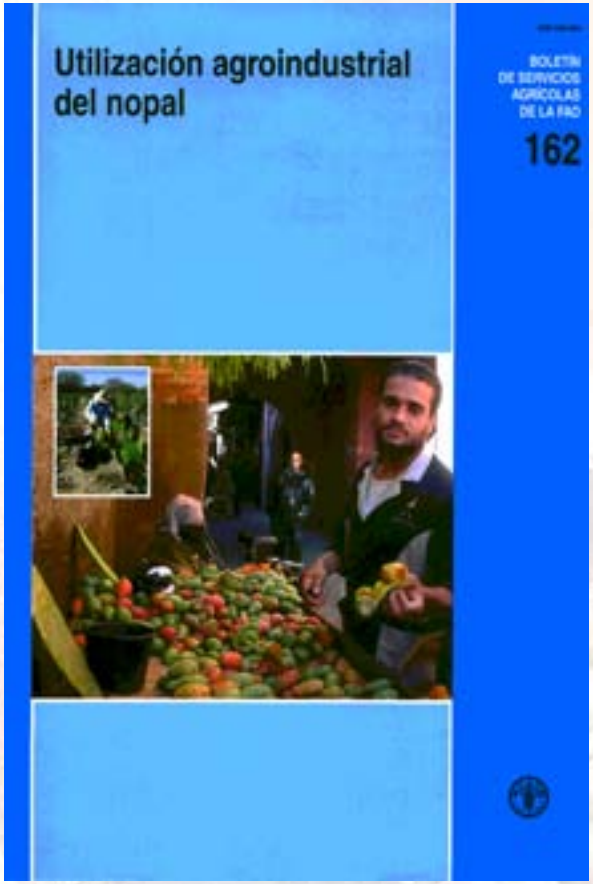
From
O. joconostle

From Italy and México

Some products from the market

http://www.andyboy.com/products/prickly





The book cover others topics such as the use of cactus pads for biofuel and carminic acid production and shows also the cactus development in several countries…

I want to thanks specially some researchers of our group:
Ing. Agr. Elena Sepúlveda
Ing. Agr. M. Sc. Carmen Prieto

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Sandra Tapia
Maylin Yoong
Cristina Vergara

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Dra. Paz Robert
Dr. Jorge Chávez
Quim. Farm. Nalda Romero

and from the Pontificia Universidad Católica de Valparaíso
Dra. Beatriz Cancino

Without their valuable contribution these results would not have become

Many technologies and different products under the sun