A glance about the industrial possibilities of cactus pear

Un coup d’œil 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 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
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

por Carmen Sáenz
Autora principal

y

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y Alimentaria (AGST) con la colaboración
de la Red Internacional de Cooperación Técnica
del Nopal (FAO-CACTUSNET)

ORGANIZACIÓN DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACIÓN
Roma, 2006
The aim of the book is to give details of several technologies that can be used 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)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Green*</th>
<th>Purple**</th>
<th>Orange***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>83.8</td>
<td>85.98</td>
<td>85.1</td>
</tr>
<tr>
<td>Protein</td>
<td>0.82</td>
<td>0.38</td>
<td>0.82</td>
</tr>
<tr>
<td>Fat</td>
<td>0.09</td>
<td>0.02</td>
<td>---</td>
</tr>
<tr>
<td>Fiber</td>
<td>0.23</td>
<td>0.05</td>
<td>---</td>
</tr>
<tr>
<td>Ash</td>
<td>0.44</td>
<td>0.32</td>
<td>0.26</td>
</tr>
<tr>
<td>Total sugars</td>
<td>14.06</td>
<td>13.25</td>
<td>14.8</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>20.33</td>
<td>20.0</td>
<td>24.1</td>
</tr>
<tr>
<td>β-carotene</td>
<td>0.53</td>
<td>---</td>
<td>2.28</td>
</tr>
<tr>
<td>Betalain (Betanine)</td>
<td>---</td>
<td>100</td>
<td>---</td>
</tr>
</tbody>
</table>

*Sepúlveda and Saéz (1990); **Sáenz, Sepúlveda and Moreno (1995); *** Sepúlveda and Sáez, (1999)
## Cladodes: chemical composition (% dry matter)

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Ash (%)</th>
<th>Crude fiber (%)</th>
<th>NNE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.4</td>
<td>1.29</td>
<td>18.2</td>
<td>12.0</td>
<td>63.1</td>
</tr>
<tr>
<td>2</td>
<td>4.2</td>
<td>1.40</td>
<td>13.2</td>
<td>14.5</td>
<td>66.7</td>
</tr>
<tr>
<td>3</td>
<td>3.7</td>
<td>1.33</td>
<td>14.2</td>
<td>17.0</td>
<td>63.7</td>
</tr>
<tr>
<td>4</td>
<td>2.5</td>
<td>1.67</td>
<td>14.4</td>
<td>17.5</td>
<td>63.9</td>
</tr>
</tbody>
</table>

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
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

Refrigeration (4-6°C) for 7-14 days

Market in Mexico
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

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>PURPLE CACTUS PEAR</th>
<th>GREEN CACTUS PEAR</th>
<th>ORANGE CACTUS PEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLUBLE SOLIDS (°Brix)</td>
<td>76.9 ± 0.28</td>
<td>84.0 ± 0.0</td>
<td>76.9 ± 1.13</td>
</tr>
<tr>
<td>ACIDITY (% citric acid)</td>
<td>1.4 ± 0.06</td>
<td>1.4 ± 0.01</td>
<td>1.5 ± 0.01</td>
</tr>
<tr>
<td>SS/ACIDITY</td>
<td>55.0 ± 2.24</td>
<td>58.0 ± 0.56</td>
<td>50.7 ± 0.27</td>
</tr>
<tr>
<td>MOISTURE (%)</td>
<td>10.4 ± 0.04</td>
<td>9.7 ± 0.78</td>
<td>11.5 ± 0.09</td>
</tr>
</tbody>
</table>
Fruit leathers (fruit sheets) and "fruit bars" are made with this technology.

Lab oven with trays

Thin layers pulp dehydrated in an oven

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

\[aw = 0.568-0.632\]
Cactus pear/quince sheets

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 *

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Assay I (orange cactus pear)</th>
<th>Assay II (purple cactus pear)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td>Polyphenols GAE (ppm)</td>
<td>1445.3 a</td>
<td>1365.0 a</td>
</tr>
</tbody>
</table>

*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)

<table>
<thead>
<tr>
<th>Type of fiber</th>
<th>(g/100g)</th>
<th>cv (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insoluble fiber</td>
<td>28.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Soluble fiber</td>
<td>14.5</td>
<td>13.1</td>
</tr>
<tr>
<td>Total dietary fiber</td>
<td>43.0</td>
<td>6.2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Control</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
</tr>
</thead>
</table>

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
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. Prepared with fresh nopalitos.

Teresa Arellanos, Mexico (2005)
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
Ingredients:
Cladodes (cut), lemon peel, lemon juice and sugar

Marmalade

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

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

- pH > 4.5
- Acidity
- % soluble solids

Cactus pear (juices) and “nopalitos” (pickled, brined)

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*

- **Colorants**
- **Thickening agents**

*Cactus pear fruit* and *cladodes*
Pigments to color foods

Betalains

Trends go from artificial dyes towards natural colorants

Makes cactus pear a promising source of water-soluble betalains
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 it 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⁻¹f.m.)
Purple cactus pear colorant
## Purple cactus pear colorant (whole fruit)

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

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

In red beet there are 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)

| Storage (days) |
| 0 | 20 | 40 | 50 |
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. streptheacantha*);
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

Microencapsulaton
Lab processing
Dr. Beatriz Cancino
PUCV-Chile
<table>
<thead>
<tr>
<th>Inicial</th>
<th>Concentrate</th>
<th>Permeate</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purple cactus pear microfiltration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

**Ingredients:**
- Yolk egg,
- Sucrose syrup (65° Brix)
- Nopal hydrocolloid (0.5 and 0.8% p/v)

**Foam Stability:**
- Syneresis and volume reduction.

**Stability:**
- Increase with nopal mucilage addition.

Dose = 0.09% mucilage powder

**Yolk egg foam stabilizer**
Cactus pear liqueurs

From Italy and México

From *O. joconostle*
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

My undergraduated and Magister and Ph. D. students:
Milagros Morales
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 are involved in this process. Thanks!