Overall Dragon Fruit Production and Global Marketing

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Presentation

1. World-wide production
2. Taxonomy in transition
3. Dragon fruit – the Future Market Expansion
   a. Needs
   b. Flavour – sweetness
   c. Postharvest handling

Recognized - Yosef Mizrahi, 2015
Countries Growing Hylocereus

Gaps?

https://cactus-epiphytes.eu/z_page_fruit_dragon_californie_01.html
Production

- **Vietnam** ~50,000 ha, producing ~1 million metric tons (MT) valued at US$ 895.70 million (2016). 22-35 MT/ha/year
- **PR China** expanding possibly exceeds 40,000 ha. Guangxi
- **Indonesia** started in 2000, now reported to be 4,300 ha.
- **Malaysia** had 1,641 ha in production in 2013 and produced of 11,000 MT with acreage increasing.
- **Thailand** In 2013 acreage reported ~1,000 ha, 6,451 kg/ha.
- **Philippines**, the area planted increased from 182 hectares (ha) in 2012 to 450 ha in 2018, producing 1,463 metric tons.
- **United States** production limited to Florida, California and Hawaii. Acreage is increasing. California to 150 ha, Florida 160 ha and ~80 ha in Hawaii.
Production & Trade

- Production data for most new and expanding tropical fruit is rarely available.
- Available evidence from individual countries suggests the Dragon fruit production is expanding.
- Expanding production in many countries including: Vietnam, China, Mexico, Colombia, Nicaragua, Ecuador, Thailand, Malaysia, Indonesia, Australia and United States.
- Dragon fruit is the fifth most imported tropical fruit from Asia exported to China. China imported 533 MT in 2017. Mostly white fleshefruit from Vietnam
- US consumers mainly Asian and Latin Americans, sales until now mainly in specialty stores and at farmers markets.
**Taxonomy - Hylocereus and Selenicereus**

- Night-blooming climbing cacti of the genera *Hylocereus* (Berger) Br. & R. and *Selenicereus* (Berger) Br. & R.
- Members of the Cactaceae subfamily Cactoideae, tribe Hylocereeae (Br. & R.)
- Genus *Hylocereus* ~16 species dispersed Central America and Northern South America.
- *Selenicereus* spp. comprises ~20 species distributed through tropical America and the Caribbean region.

Hylocereus spp. and Selenicereus spp.

What is a species?

What criteria do you use to group species into a genus?
### Species Classification Based - Stem Habit, Skin and Pulp Colour.

<table>
<thead>
<tr>
<th>Vine Cactus</th>
<th>Fruit Skin</th>
<th>Fruit Flesh</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hylocereus undatus</em></td>
<td>Red</td>
<td>White</td>
</tr>
<tr>
<td><em>Hylocereus undatus</em></td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td><em>Hylocereus triangularis</em></td>
<td>Yellow</td>
<td>White</td>
</tr>
<tr>
<td><em>Hylocereus costaricensis</em></td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td><em>Hylocereus ocamponis</em></td>
<td>Yellow</td>
<td>Red</td>
</tr>
<tr>
<td><em>Hylocereus polyrhizus</em></td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td><em>Selenicereus megalanthus</em> syn. <em>H. monacanthus</em></td>
<td>Yellow</td>
<td>White</td>
</tr>
</tbody>
</table>

Crane and Balerdi (2004); Mizrahi and Nerd (1999); Tel-Zur et al. (2004a/b).
Comparison of *Selenicereus* spp. and *Hylocereus* clones

<table>
<thead>
<tr>
<th><strong>Selenicereus – yellow</strong></th>
<th><strong>Red Hylocereus clones</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Four or more ribbed shoots</td>
<td>Three-ribbed shoots</td>
</tr>
<tr>
<td>Spiny or hairy fruit</td>
<td>No spines on fruit though non-commercial species do have spines</td>
</tr>
<tr>
<td>Small fruit bracts</td>
<td>Large fruit bracts</td>
</tr>
<tr>
<td>Weak vegetative production</td>
<td>Strong vegetative production</td>
</tr>
<tr>
<td>Tetraploid, self-compatible</td>
<td>Diploid only 10% self-compatible</td>
</tr>
<tr>
<td>Fruit small to medium in size</td>
<td>Fruit large</td>
</tr>
<tr>
<td>Low number of large seed in fruit, many seeds are aborted</td>
<td>High number of small seeds in fruit</td>
</tr>
<tr>
<td>Parenchyma &amp; chlorenchyma are mixed as one layer.</td>
<td>Parenchyma &amp; chlorenchyma are separate layers</td>
</tr>
</tbody>
</table>
Taxonomic Key

Pericarpel and fruit with small or inconspicuous bracts and spiny areoles

- Bracts usually 5-8(10) ribbed: *Selenicereus*
- Bracts usually 3-ribbed or angled: *Salmodyckia*
- Bracts 2-winged: *Cryptocereus*

Pericarpel and fruit with large ±deltoid bracts, obscuring the usually spineless areoles

*Hylocereus*

https://herbaria.plants.ox.ac.uk/bol/plants400/Profiles/GH/Hylocereus

(Hunt, 2017)
Britton & Rose (1920) relied heavily on three characters to separate the Caribbean species — color of the flower hairs, flower bud shape, and petal margins. These characters do not appear to be able to resolve species relationships. Are the above diagnostic?
Fruit of
- Three diploid *Hylocereus* spp.,
- *H. megalanthus* possibly a cross
- Two homoploid
- Two interploid species hybrids

All at the same magnification. Tel-Zur et al., 2004.
What is a species?

- At least 20 proposed species concepts depending upon expertise and type of organism studied (Naomi 2010).
- Concepts include: biological, ecological, phylogenetic
- Organized into primary, theoretical and operational.
- Need to avoid confusion of species concept and species delimitation. Reproductive incompatibilities during geographical isolation is less central (Coyne and Orr, 2004, Speciation)
- Morphological differences lead to current focus on DNA barcodes
- Plants differ in that hybridization is often a trigger for speciation. Much less common in animals.
- **Current focus** – evolutionary lineages – common ancestor - Monophyletic
NATURAL PEACH, 4000 B.C.

- 64% EDIBLE FLESH
- TASTES 'EARTHY', 'SWEET', 'SOUR' AND SLIGHTLY 'SALTY'
- 36% STONE
- 25 MM
- WAXY SKIN

ARTIFICIAL PEACH, 2014

- 90% EDIBLE FLESH
- 3.8% Reduction in Relative Fruite Size
- 10% STONE
- 100 MM
- 64 Times Larger

- SOFT, EDIBLE SKIN

3 KNOWN VARIETIES

ONLY FOUND IN CHINA

- 71.0% WATER
- 8.1% SUGARS
- 20.9% OTHER

- 88.9% WATER
- 27% Juicier
- 8.4% SUGARS
- 4% Sweeter
- 1.7% OTHER
- 63% more Potassium
- 46% more Calcium
- 42% more Zinc
- 3x less Protein

67-Fold Increase

- 200 VARIETIES
- Grown in 13 Countries

Annual Production: 14 Million Tonnes

JAMESKENNEDYMONASH.WORDPRESS.COM
# Fruit Morphology

- Fruit shape & size.
- Change in transcription factor expression & target

<table>
<thead>
<tr>
<th>QTL/gene</th>
<th>Allelic variation</th>
<th>Protein</th>
<th>Process affected</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>fw2.2</td>
<td>Promoter-Regulatory</td>
<td>A cell number regulator (CNR) family protein</td>
<td>Cell division/fruit size</td>
<td>Tomato eggplant Physalis</td>
</tr>
<tr>
<td>fw3.2 ovate</td>
<td>Promoter-regulatory</td>
<td>A cytochrome P450 protein</td>
<td>Cell division/fruit size</td>
<td>Tomato pepper</td>
</tr>
<tr>
<td></td>
<td>Premature stop</td>
<td>Ovate family proteins</td>
<td>Cell division/fruit size</td>
<td>Tomato eggplant pepper</td>
</tr>
<tr>
<td>sun</td>
<td>Transposon insertion-regulatory</td>
<td>A member of the IQD family of calmodulin-binding proteins</td>
<td>Cell division/fruit shape</td>
<td>Tomato eggplant</td>
</tr>
<tr>
<td>fas</td>
<td>Intron -regulatory</td>
<td>A YABBY-like transcription factor</td>
<td>Cell division/locule number/shape and size</td>
<td>Tomato</td>
</tr>
<tr>
<td>lc</td>
<td>SNPs in downstream-regulatory</td>
<td>A putative ortholog of WUSCHEL</td>
<td>Cell division/locule number/shape and size</td>
<td>Tomato</td>
</tr>
<tr>
<td>POS1</td>
<td>Intron-regulatory</td>
<td>A transcription factors with two CRF-AP2 domains</td>
<td>Cell expansion/fruit size</td>
<td>Physalis</td>
</tr>
</tbody>
</table>

Li et al., 2015, Front. Pl. Sci. 6, 248
Fruit Growth and Shape

- Capsella vs Arabidopsis both in Brassicaceae
- INDEHISCENT gene (IND) transcription factor involved in formation of dehiscence zone and newer data showing it is involved in morphology

![Diagram showing comparison between Capsella and Arabidopsis with IND expression and morphology differences.](Image)

Ferrandiz, 2019. Current Biology 29, R337
## Dragon Fruit - Dominance relationships and traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Dominance relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spines</td>
<td>Spines dominant over spineless</td>
</tr>
<tr>
<td>Scale length (cm)</td>
<td>Co-dominance</td>
</tr>
<tr>
<td>Fruit weight - Size</td>
<td>Co-dominance</td>
</tr>
<tr>
<td>Peel colour</td>
<td>Red dominant over purple (or co-dominant)</td>
</tr>
<tr>
<td></td>
<td>Yellow dominant over red (or co-dominant)</td>
</tr>
<tr>
<td></td>
<td>Purple dominant over yellow</td>
</tr>
<tr>
<td>Flesh colour</td>
<td>Purple dominant over white (or co-dominant)</td>
</tr>
<tr>
<td></td>
<td>Red dominant over white (or co-dominant)</td>
</tr>
<tr>
<td></td>
<td>Purple dominant over red (or co-dominant)</td>
</tr>
</tbody>
</table>

Tel-Zur et al., 2004
Criteria for Dragon Fruit

- Are ridges on stems - a useful criteria? Is it fasciation – mutation?
- Are the presences or absence of spines a useful criteria?
- Are the size of the bracts on the fruit relevant?
- Is fruit size important in defining a species?
- Is the colour of shoots, fruit skin or flesh useful criteria?
Criteria for Dragon Fruit

- Confusion as to what is the correct species name?
- Easiest approach is to refer to your species as *Hylocereus* spp. or *Selenicereus* spp. and describe it’s features.
- New data and the previous descriptions has lead to a new reclassification for these two genera
- Similar to what happened with tomatoes
Proposed Reclassification

- Recent molecular studies (plastid & nuclear DNA) support the conclusion that *Hylocereus* falls under *Selenicereus*

- Implication - a single common ancestor to the species in these former two genera (Plume et al., 2013; Korotkova et al., 2017).

- Morphological and anatomical comparisons reach a similar conclusion (Gomez-Hinostrosa et al., 2014).

- This reclassification removes some of the previous confusion about the overlapping characteristics of the many named species in these two genera.
Proposed Reclassification Result

- *Selenicereus* is regarded as having priority over *Hylocereus* though from an economic perspective *Hylocereus* has an international market and is relevant to CITES and trade (Korotkova et al., 2017).

- *Hylocereus* species specific epithet is retained. Species number declined from 17 to 8.

<table>
<thead>
<tr>
<th>Old name</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hylocereus undatus</em> (Haworth) Britton &amp; Rose</td>
<td><em>Selenicereus undatus</em> (Haworth) D.R. Hunt</td>
</tr>
<tr>
<td><em>Hylocereus guatemalensis</em> (Eichlam ex Weingart) Britton &amp; Rose,</td>
<td><em>Selenicereus guatemalensis</em> (Eichlam ex Weingart) D.R. Hunt</td>
</tr>
</tbody>
</table>
Dragon Fruit - Future

- Consumer desire
  - Freshness
  - Naturalness
  - Minimal processing

- To science, naturalness does not mean a food is less risky, healthier or tastier.

- To consumer, naturalness is positive food attribute, based upon how a food is grown, how it is produced and properties of the final product.

- How does Dragon Fruit measure up to these criteria?

Roman et al., 2017. Trends Food Sci Tech
Wholesaler and Retailer Needs
- Consistency in supply
- Consistency in quality
- Safety
- Price

How do we meet consumer desires and marketing requirement?
Dragon Fruit – Future Quality

- **Taste – sweetness**
  - Are we meeting consumer’s desires sweet having >10 to 12% TSS

- **Postharvest handling**
  - What is the quality of the fruit at the market?
## TSS versus Sugar Analysis

<table>
<thead>
<tr>
<th>Species</th>
<th>TSS</th>
<th>Sucrose g/kg</th>
<th>Glucose g/kg</th>
<th>Fructose g/kg</th>
<th>Total g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selenocereus spp. “Cebra”</td>
<td>7.1</td>
<td>ND</td>
<td>54.0</td>
<td>7.0</td>
<td>61.0</td>
</tr>
<tr>
<td>Selenocereus spp. “Lisa”</td>
<td>10.7</td>
<td>ND</td>
<td>46.0</td>
<td>4.0</td>
<td>50.0</td>
</tr>
<tr>
<td>S. polyrizus</td>
<td>10.7</td>
<td>ND</td>
<td>55.4</td>
<td>19.2</td>
<td>74.6</td>
</tr>
<tr>
<td>S. costaricensis, “Cebra”, Red flesh</td>
<td>10.9</td>
<td>ND</td>
<td>53.5</td>
<td>41.1</td>
<td>94.6</td>
</tr>
<tr>
<td>S. costaricensis, “Rosa”, Red flesh</td>
<td>11.8</td>
<td>ND</td>
<td>52.8</td>
<td>40.8</td>
<td>93.6</td>
</tr>
<tr>
<td>S. polyrizus x S. undatus, Light pink flesh</td>
<td>12.2</td>
<td>ND</td>
<td>58.8</td>
<td>45.5</td>
<td>99.9</td>
</tr>
<tr>
<td>S. undatus, “Mexicana”, White flesh</td>
<td>13.3</td>
<td>ND</td>
<td>70.1</td>
<td>48.2</td>
<td>118.3</td>
</tr>
<tr>
<td>S. undatus, White flesh</td>
<td>18.1</td>
<td>&lt;3%</td>
<td>68</td>
<td>51</td>
<td>119</td>
</tr>
<tr>
<td>S. undatus, White flesh</td>
<td>18.3</td>
<td>5.4</td>
<td>104.3</td>
<td>64.9</td>
<td>174.6</td>
</tr>
<tr>
<td>S. undatus, Red flesh</td>
<td>13.5</td>
<td>4.2</td>
<td>68.1</td>
<td>49.9</td>
<td>122.3</td>
</tr>
</tbody>
</table>
### Relative sweetness of sugars

(Moskowitz, 1970)

<table>
<thead>
<tr>
<th>Component</th>
<th>Relative Sweetness to Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>1.0</td>
</tr>
<tr>
<td>Fructose</td>
<td>0.85-1.0</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.56</td>
</tr>
<tr>
<td>Maltose</td>
<td>0.35</td>
</tr>
</tbody>
</table>
## TSS Limitations

Refractive index of common substances.

<table>
<thead>
<tr>
<th>Component</th>
<th>Refractive Index @ 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1.0003</td>
</tr>
<tr>
<td>Water</td>
<td>1.3300</td>
</tr>
<tr>
<td>Sucrose 25%</td>
<td>1.3723</td>
</tr>
<tr>
<td>Fructose</td>
<td>1.3574</td>
</tr>
<tr>
<td>Glucose 10%</td>
<td>1.3477</td>
</tr>
<tr>
<td>Ascorbic acid 1%</td>
<td>1.3350</td>
</tr>
<tr>
<td>Citric acid 10%</td>
<td>1.3450</td>
</tr>
<tr>
<td>Ethanol</td>
<td>1.3610</td>
</tr>
<tr>
<td>Apple pectin 0.5%</td>
<td>1.3304</td>
</tr>
<tr>
<td>Gelatin 25%</td>
<td>1.6180</td>
</tr>
</tbody>
</table>

Dragon fruit – 38-47% water soluble pectin in cell wall
Sugar Analysis of Dragon Fruit

- TSS detects organic and amino acids, and pectin.
- Only a few reports of sucrose in dragon fruit.
- Sucrose, total amino acids, & potassium 56, 21, and 9%, respectively, of the osmolality of the *Opuntia ficus-indica* phloem exudate (Wang & Nobel, 1995).

**Why did Wu and Chen (1997) find sucrose?**

- Tissue frozen before extraction with 90% ethanol
- Amount of sucrose found proportional to invertase activity, 2x to 3x higher acid invertase than neutral invertase.
- Suggested glucose and fructose from starch breakdown, Is starch being accumulated in this non-climacteric fruit? Cell wall pectin?? Amylase detected with soluble starch
Postharvest Problems

1. Mechanical Injury
2. Dehydration
   - Loss of skin gloss
   - Shrivelning
3. Food Safety
Different Markets – Different Requirements

9 Health Benefits of Dragon Fruit

- Rich in Fiber & Protein
- Rich in Vitamins & Minerals
- Loaded with Antioxidants
- Boosts Immune System
- Protects the Heart
- Good for Skin
- Contains Healthy Fats
- Helps in Digestion
- Benefits Diabetics
Where can we Improve?

Care in selecting fruit to be harvested and moved to the packing area
Where can we improve?

Grading and handlining critical?
What do you cull?
Where can we Improve?

- Care to avoid mechanical injury: abrasion, impact and compression.
- Do we have the biological data on the thresholds for injury? Are we exceeding those limits?
Where can we Improve?
Where can we Improve?

- In preparing our fruit for market does the packing protect the product from injury?
- Does the packaging limit dehydration?
- Does the packaging and handling meet criteria for avoiding cross-contamination and food safety?
Goal – Market a high-quality fruit in recognizable cartons

Keys

- Maturity at harvest to meet market needs
- Avoid mechanical injury
- Store and ship at recommended temperature, cool as soon as possible.
- Ensure all steps meet “Layer of Protection” for food safety
Acknowledgements

Faculty Collaborators
Peter Follet, Marisa Wall, Ming Li Wang, Ray Ming, Qingyi Yu
Richard Manshardt, Michael Kantar, Jensen Uyeda

Laboratory
Nancy Jung Chen
Kana Murai
Gail Uruu
Thank you.

Questions?

Research supported by USDA NIFA Hatch Funds and Special Federal Funds for Tropical Fruit Research from USDA-ARS