# Adding Value to Almond Co-Products


## William Orts – Research Leader, Bioproducts

USDA


16 June 2016

# Our USDA Research Mission:

**Add value to agricultural products to help the rural economy**

**Agricultural Research Service**

# USDA Western Regional Research Center

**Albany, California**

~450 people

~50 in Biofuels/ & Bioproducts

Known for biotechnology, especially crop biotech.

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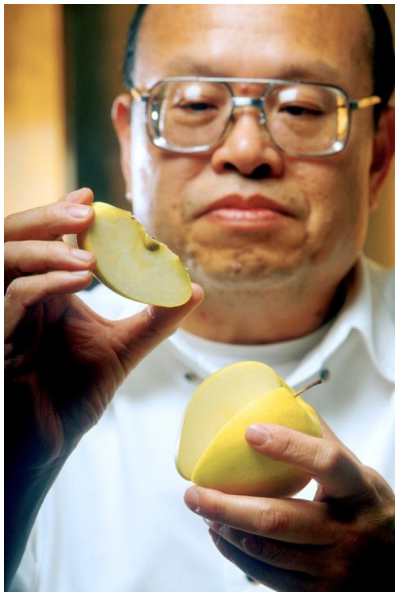
# Packaged Fruit Slices



Mantrose-Haeuser Co., Inc.

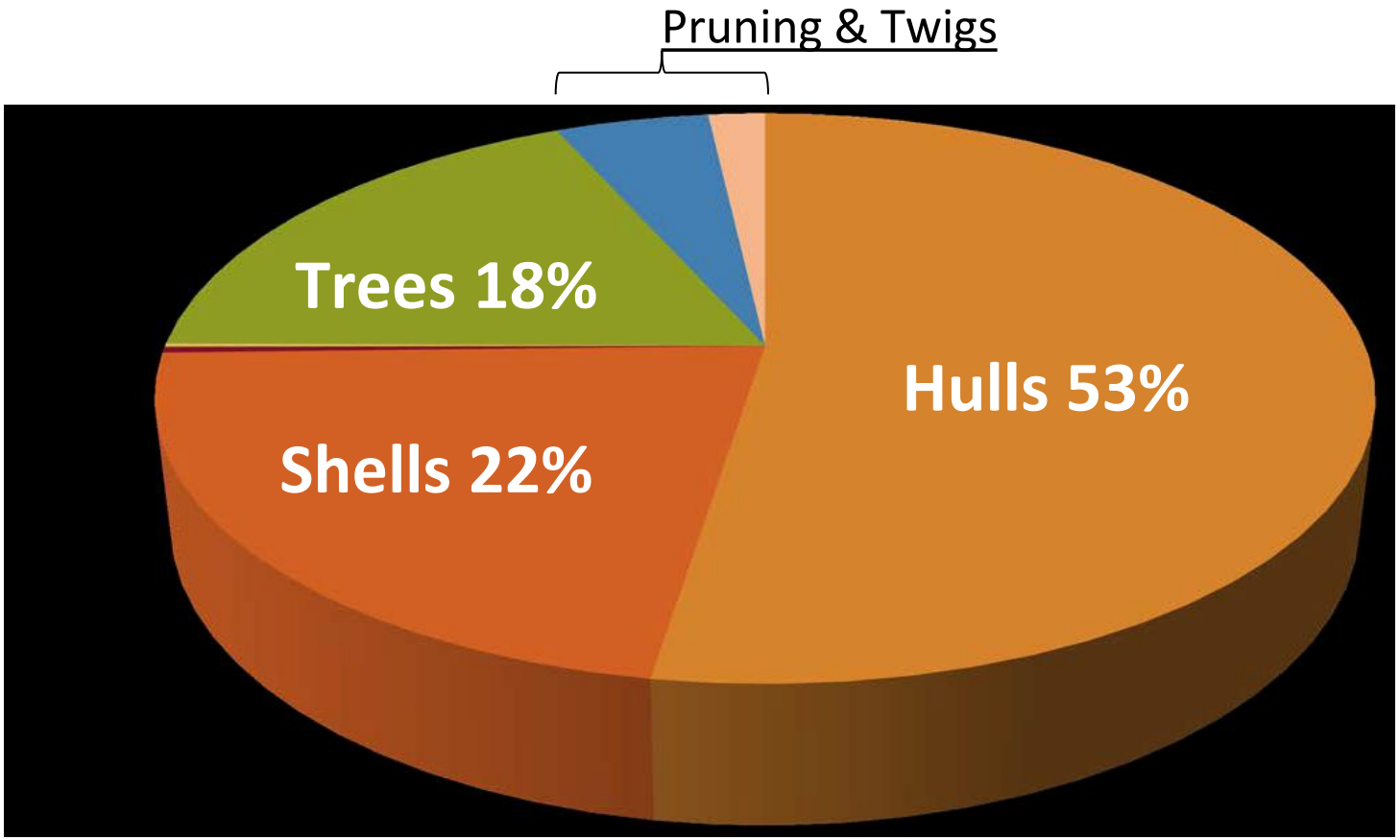


**McDonald's sells 65 million lbs/yr of apples in the U.S.**

USDA continues to collect royalties

# Almond Co-Products

## Almond Biomass ⇔ 2.4 million Tons/yr




SOURCE: Guangwei Huang, CA Almond Board, 2015 data, dry mass basis

california almonds

# Biomass from Shellers/Hullers

| | Wet Mass (MT) | Dry Mass (MT) |
|---|---|---|
| Hulls | 1,416,413 | 1,235,112 |
| Shells | 538,174 | 520,414 |
| Twigs | 66,972 | 42,192 |
| Totals | 2,021,558 | 1,797,718 |

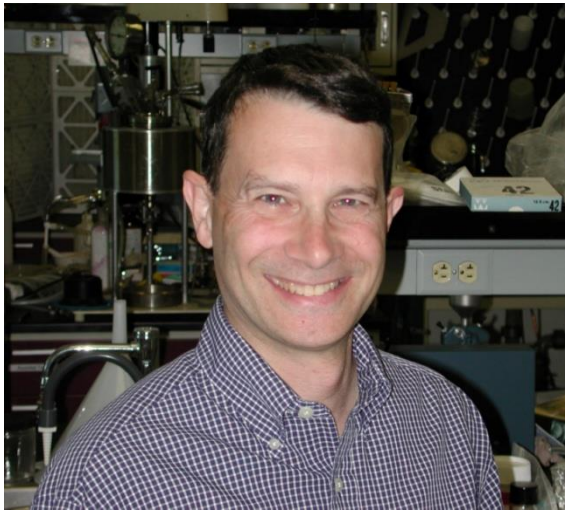
SOURCE: Guangwei Huang, CA Almond Board, 2015 data, dry mass basis

california almonds

# Ethanol Production from Hull Sugars?

**Kelley Covello**

Offeman, R.D., Holtman, K.M., Covello, K.M., Orts, W.J. Almond hulls as a biofuels feedstock: Variations in carbohydrates by variety and location in California. *Industrial Crops & Products* 54: 109-114, 2014.



**Rick Offeman**

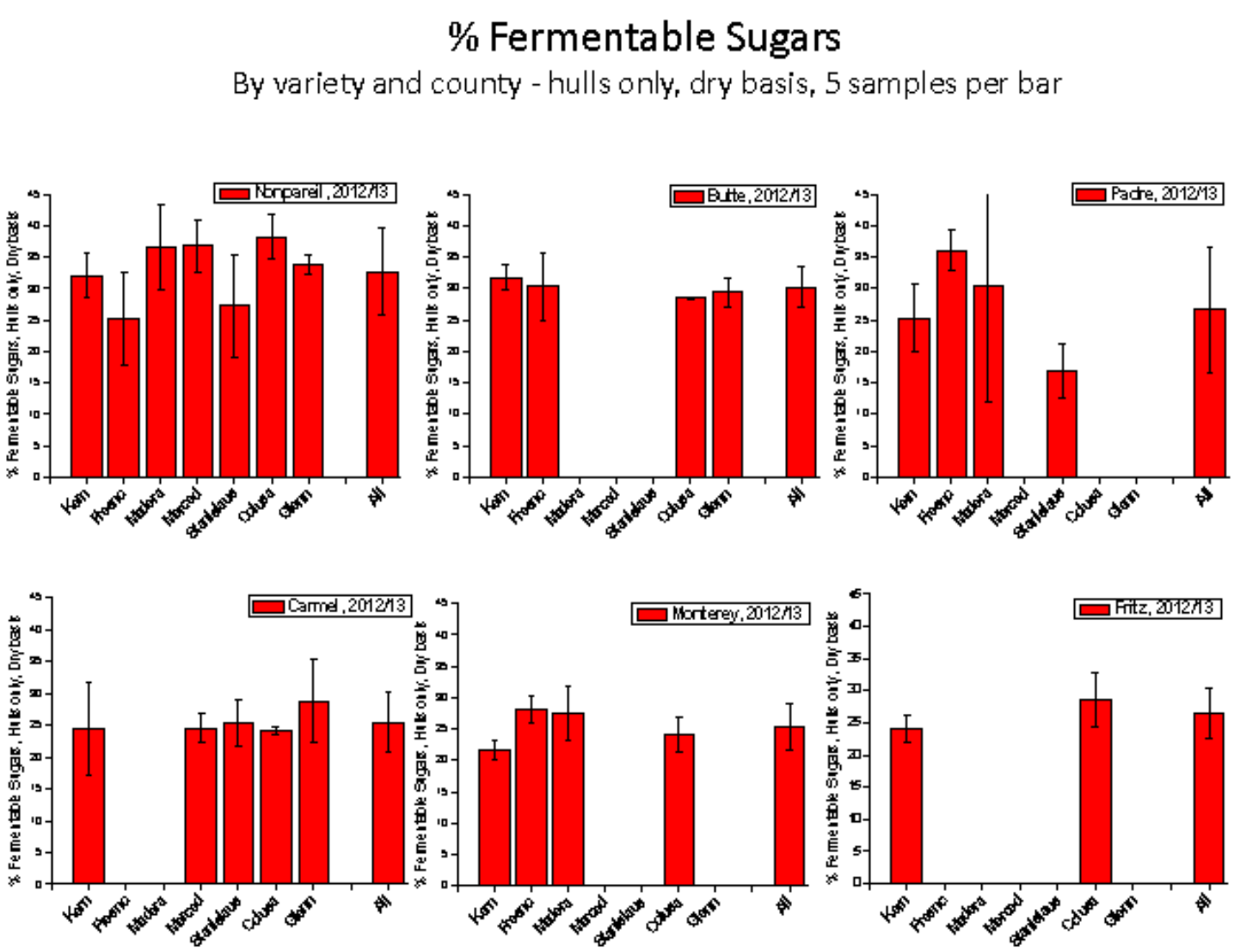
**Kevin Holtman**


★ Locations of hulling plants providing samples from 2012/13 season

# Sugars in Almond Hulls

| | % Sucrose | % Glucose | % Fructose | % Fermentable sugars | % Xylose | % Inositol | % Sorbitol | % Total sugars |
|---|---|---|---|---|---|---|---|---|
| **Non-Pareil** | 3.84 | 17.61 | 15.04 | 36.49 | 1.03 | 2.36 | 4.37 | 44.24 |
| **Butte/ Padre** | 0.38 | 12.87 | 12.55 | 25.80 | 0.77 | 0.99 | 2.84 | 30.40 |
| **Cali-fornia** | 0.14 | 6.79 | 3.53 | 10.46 | 0.64 | 1.89 | 1.76 | 14.75 |

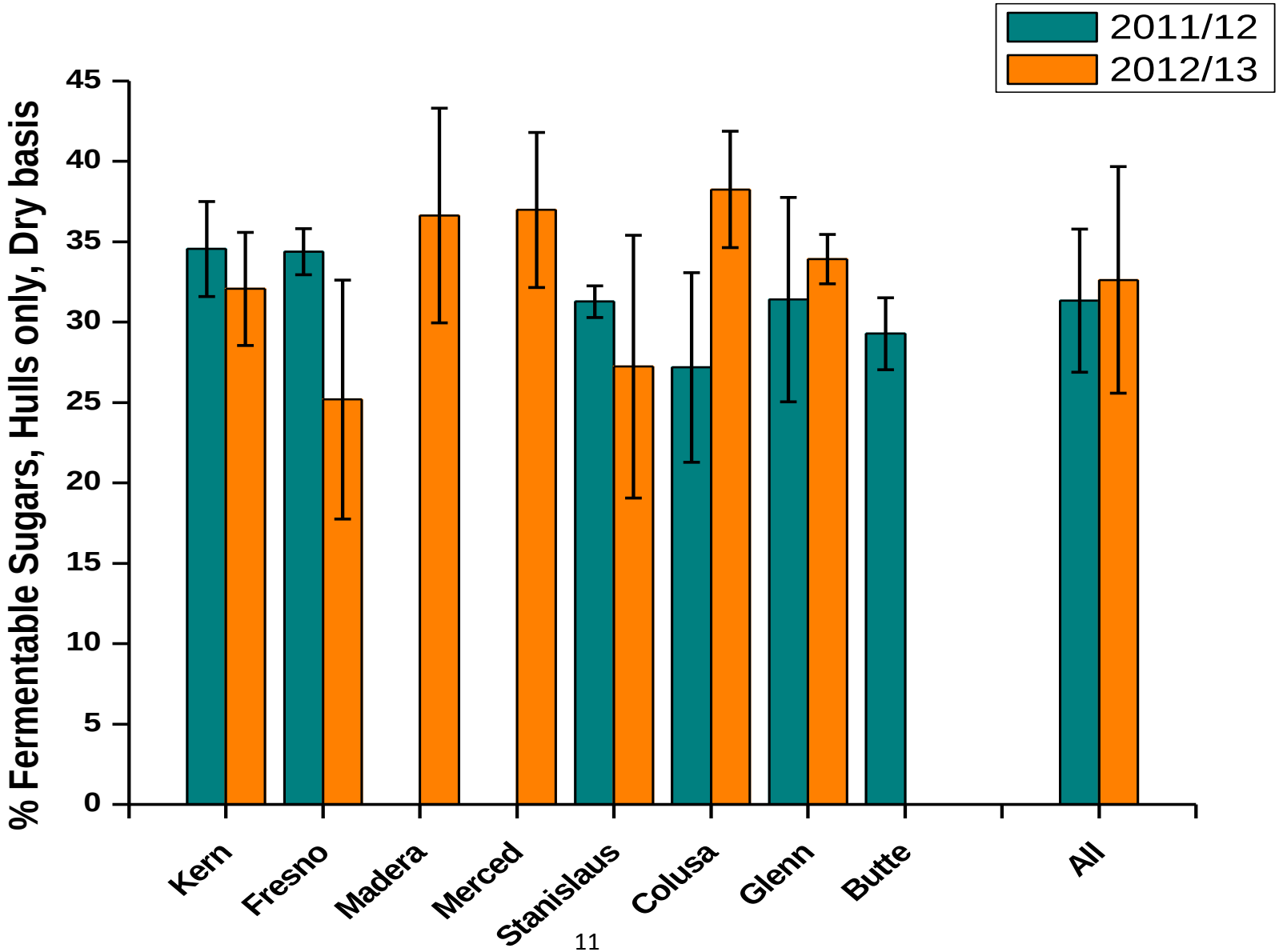
# Almond Hull Sugars




SOURCE: Offeman, Holtman *et al. (2014)* Ind. Crops & Prod. 54:109-114

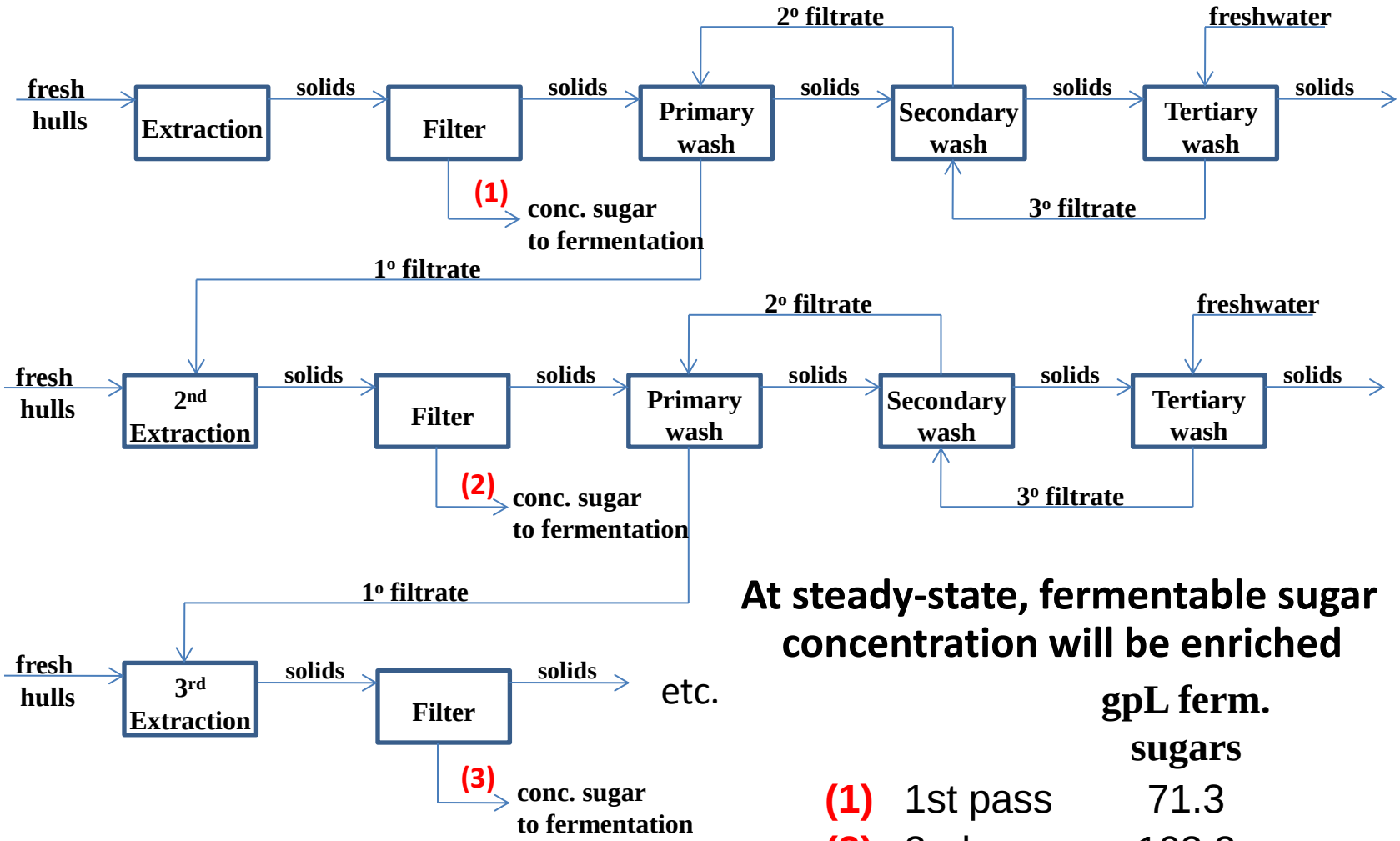
# Nonpareil, 2011/12 Season vs. 2012/13 Season

% Fermentable Sugars, Dry Basis (ave 5 samples each county)



# Extracting Sugar From Hulls

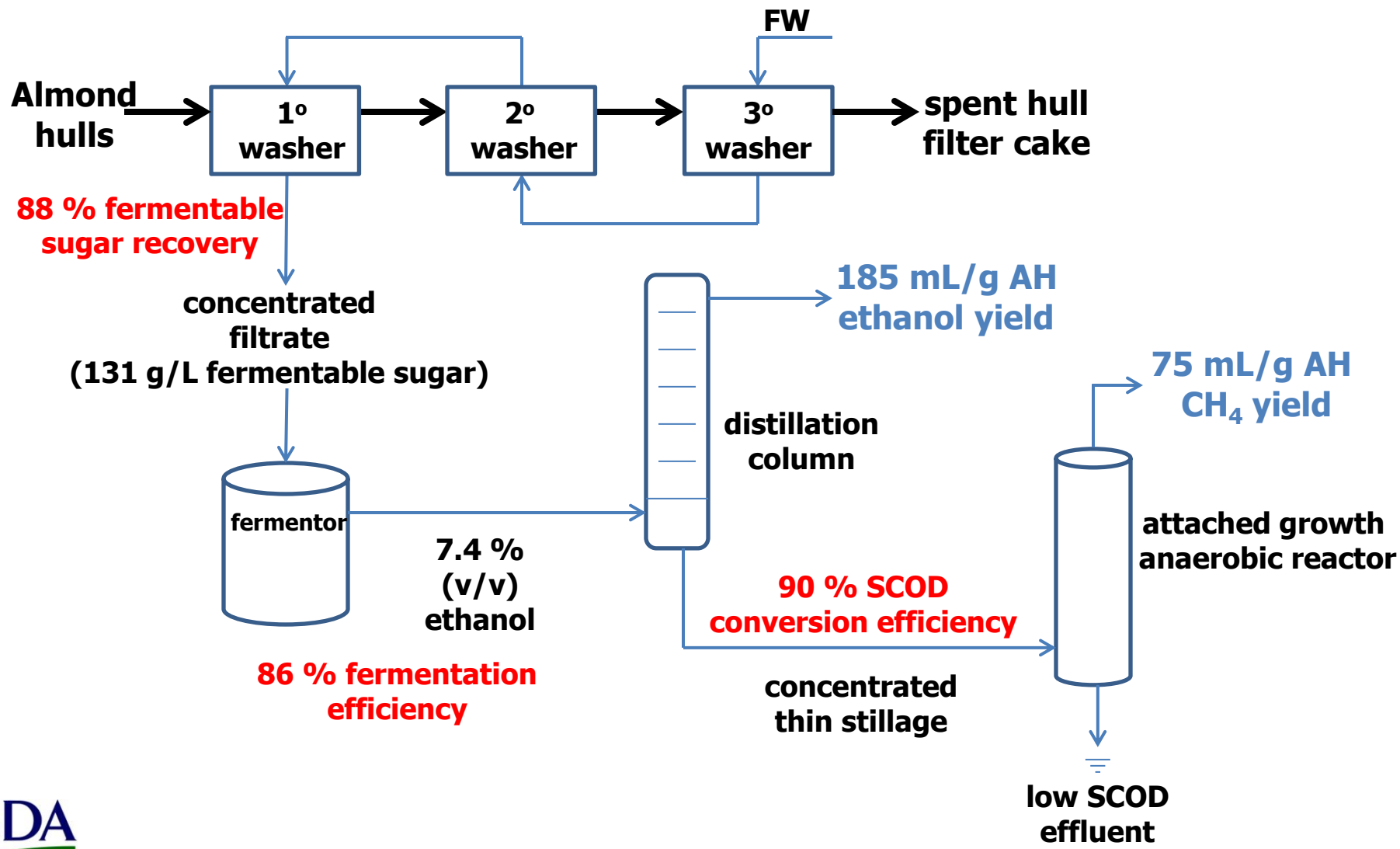
## -Countercurrent extraction




**At steady-state, fermentable sugar concentration will be enriched**

| | | gpL ferm. sugars |
|---|---|---|
| (1) | 1st pass | 71.3 |
| (2) | 2nd pass | 103.2 |
| (3) | 3rd pass | 121.6 |

# Integrated Ethanol Plant



# Ethanol Production from Hull Sugars?

| Raw Feed | $/ton | % sugar | Sugar (lbs) | Ethanol (gal) | $/gal Ethanol |
|---|---|---|---|---|---|
| Corn kernels | 132 | | 1286 | 95 | 1.38 |
| Sugar beets | 39 | 18.5 | 370 | 27 | 1.42 |
| Molasses (feed) | 180 | 79.5 | 1590 | 118 | 1.52 |
| Sugar cane | 39 | 14 | 280 | 21 | 1.88 |
| **Almond hulls** | **150** | **31** | **624** | **40** | **3.83** |

# Almond Hulls vs. Sugar Beet Cossettes

Almond Hulls
30 % fermentable sugar

Beet Cossette
15 % fermentable sugar

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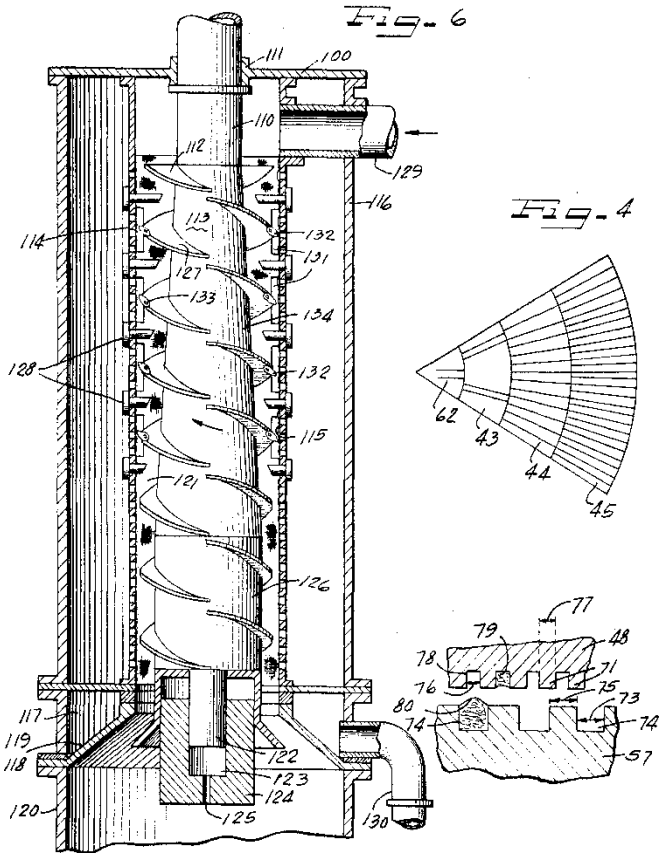
# Sugar Beet Extraction ⇔ Hull Extraction?

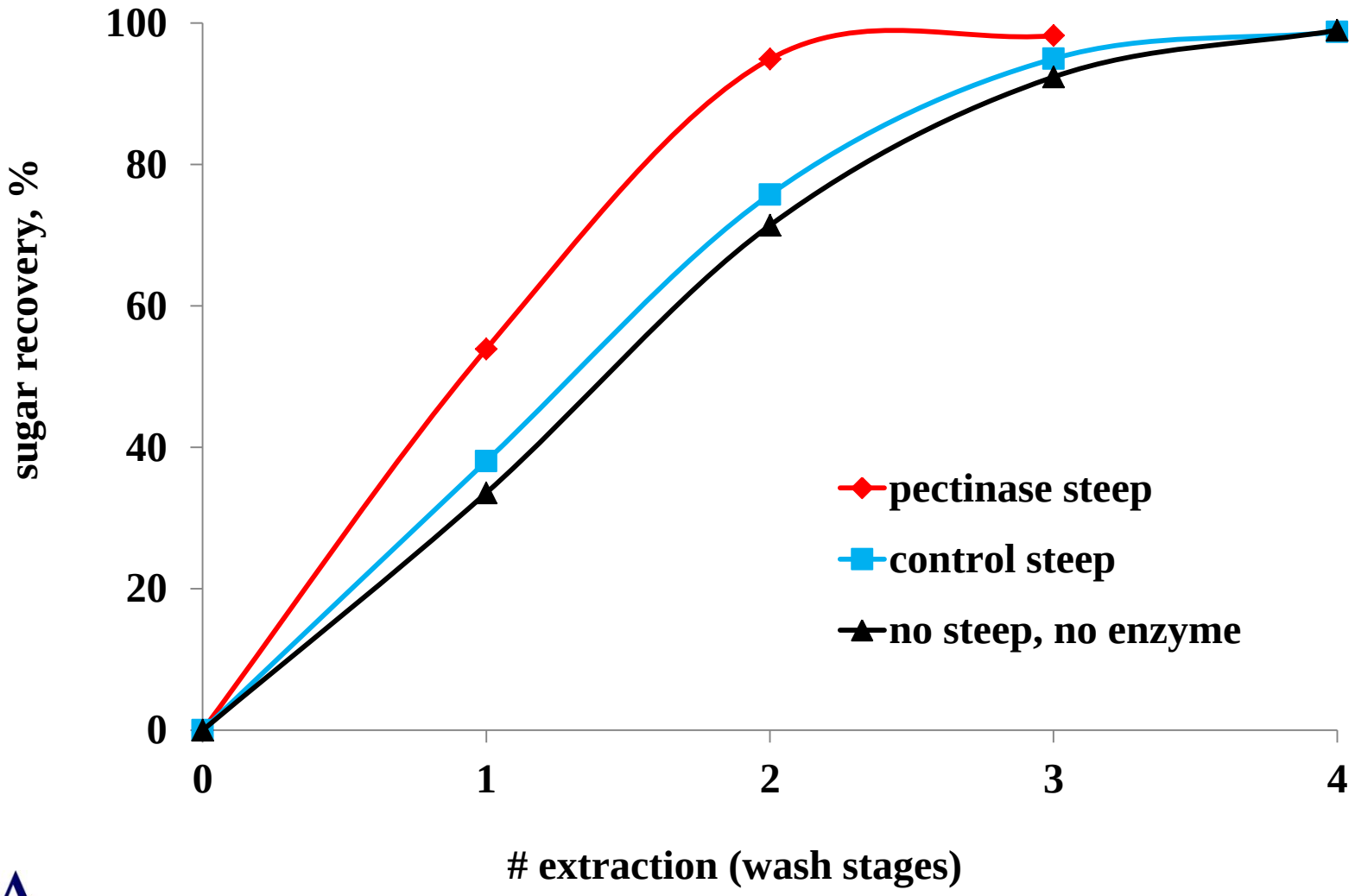
cossette mixer

diffusion tower




From US Patent # 3,477,873

# Comparison of Extraction Approaches

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# Processing Hulls to Sugars

- ONE IDEA: Make a concentrated sugar syrup
  - Countercurrent extraction with hot water
  - Concentrate syrup with multiple effect evaporators
- ETHANOL?
  - Ship to existing ethanol plant to co-feed with corn
- FOOD OR FEED SYRUP:  ????

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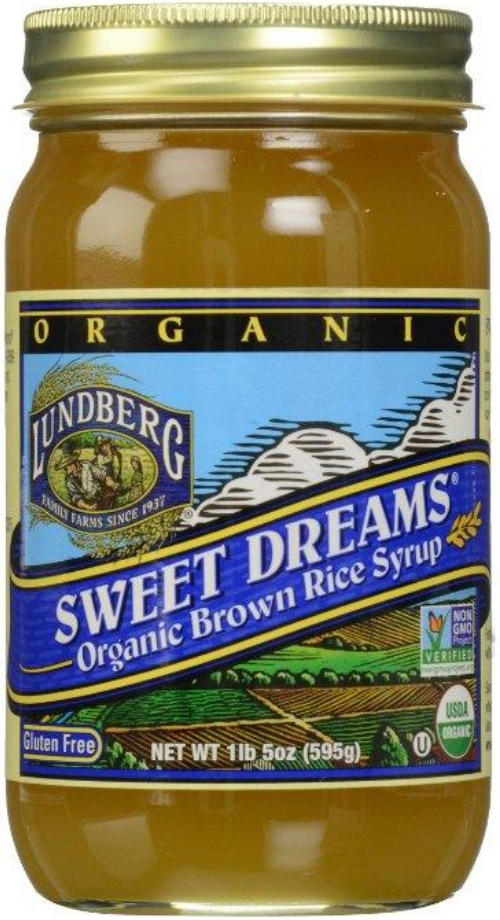
# Comparison of Extraction Approaches








PHOTOS: AP, NUTRAVISTA.COM

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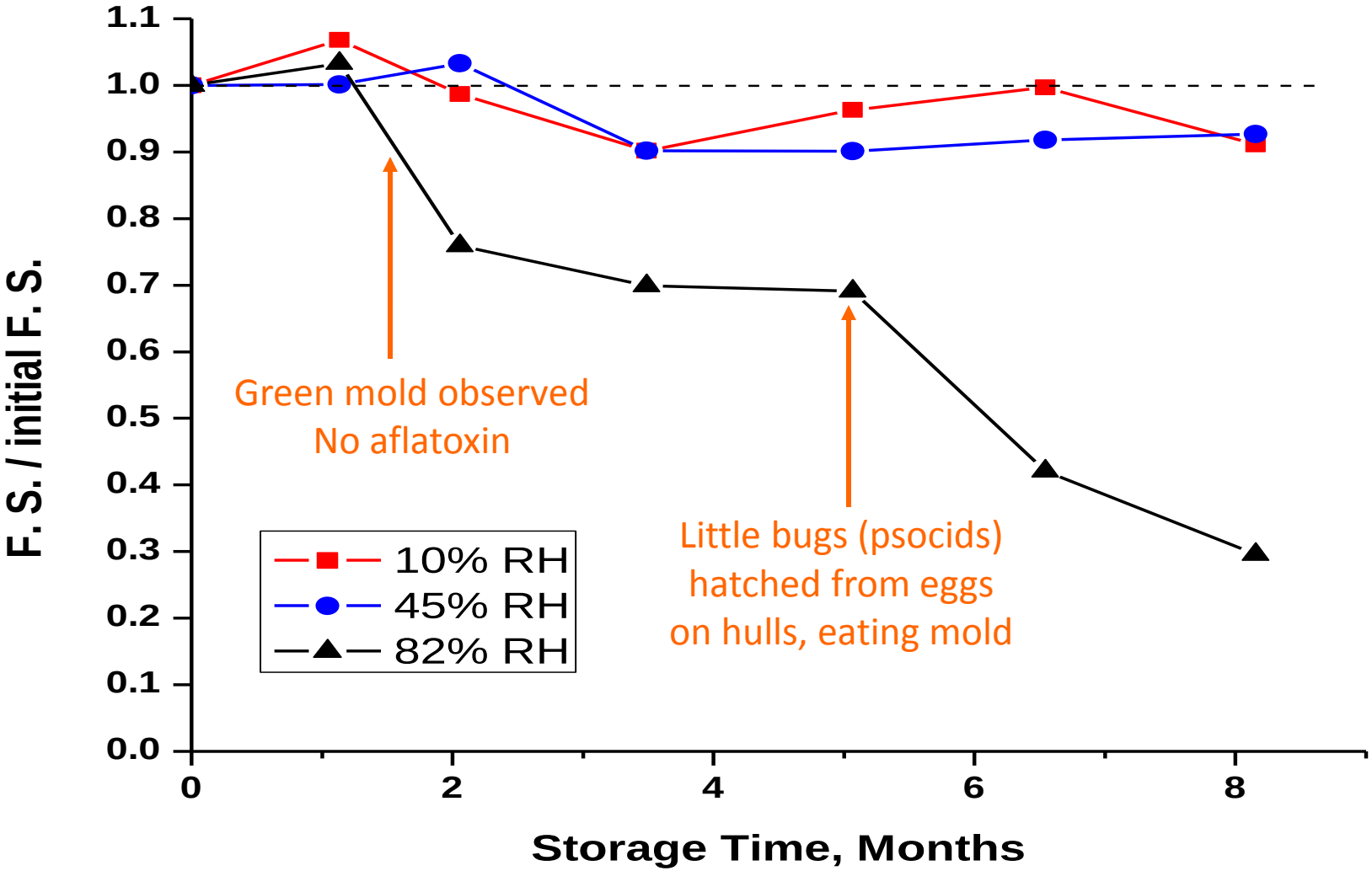
# Nonpareil Lab Storage Tests

Normalized to starting concentrations

Each point average of 3 samples (North State, Cortina, Central hulls)



# Spent Hulls ⇔ Uses?

**Key issue: Not practical to ferment hulls directly**

- Hulls absorb 4-8 times weight of water
  - Highest stirrable slurry is ~15% hulls in water.

Water: 90% 80% 70% 60% 50%

# Possible Outlets for Spent Hulls

## Characteristics

- High in cellulose, lignin, hemicellulose; no sugars
- Milled to < 8 mesh, and full of water **(~93% moisture!)**

## Cattle feed

- Feed value of dry spent hulls low (UC Davis analysis)
- As wet spent hulls, no monetary value
- Cost to dry the wet spent hulls too high: ~$150/ton

## Anaerobic digestion to biogas

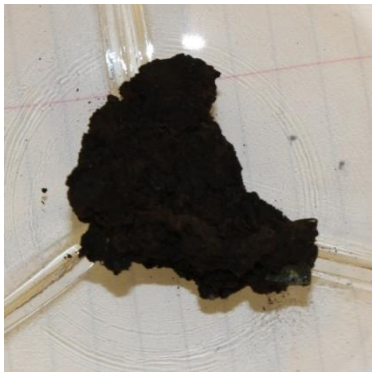
- Compressed natural gas (CNG) for local use
- BMP ~150 mL $CH_4$/T spent hulls
- ~50% methane, balance carbon dioxide. Upgrading needed

## Boiler fuel or gasification for heat/power

- Same drying issue

## Hydrothermal carbonization????

- Process suited specifically for high moisture wastes
- Produces biochar material



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# Almond Co-Products

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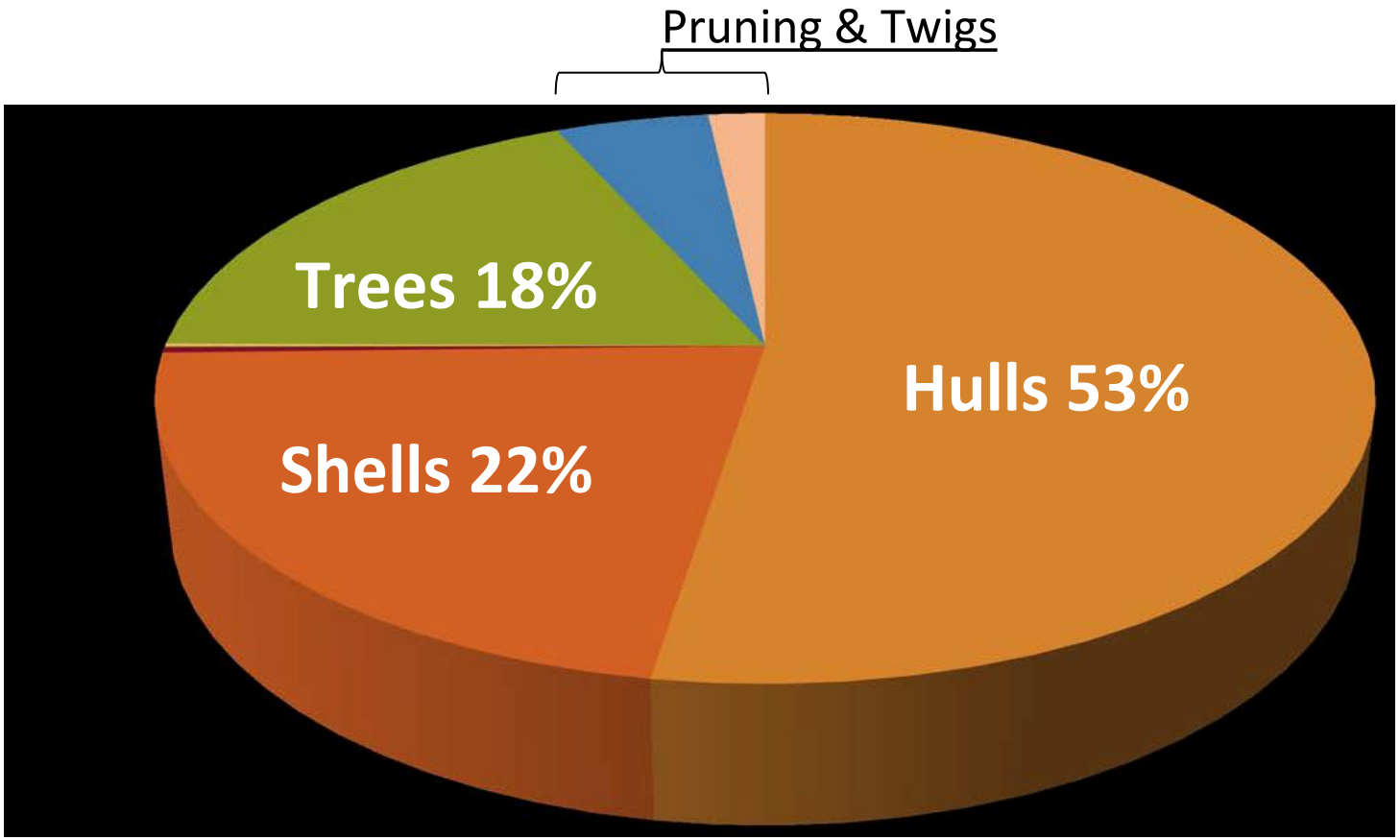


SOURCE: Guangwei Huang, CA Almond Board, 2015 data, dry mass basis

california almonds

# Almond Shell Characterization

## Previous work at USDA

| Fraction | Average (g/kg) | Std dev. |
|---|---|---|
| Ash | 34 | 0.07 |
| Hot water extractives (100°C) | 105 | 0.35 |
| Klason lignin | 237 | 0.53 |
| Glucan | 228 | 0.48 |
| Xylan | 329 | 0.45 |
| Galactan | 45 | 0.04 |
| Others | 24 | 0.05 |
| Mass balance | 1002 | 0.11 |

*Gong, D.C.; Holtman, K.M.; Franqui-Espiet, D.; Orts, W.J.; Zhao, R. *Biomass and Bioenergy* 35 (10): 4435-4441 (2011).

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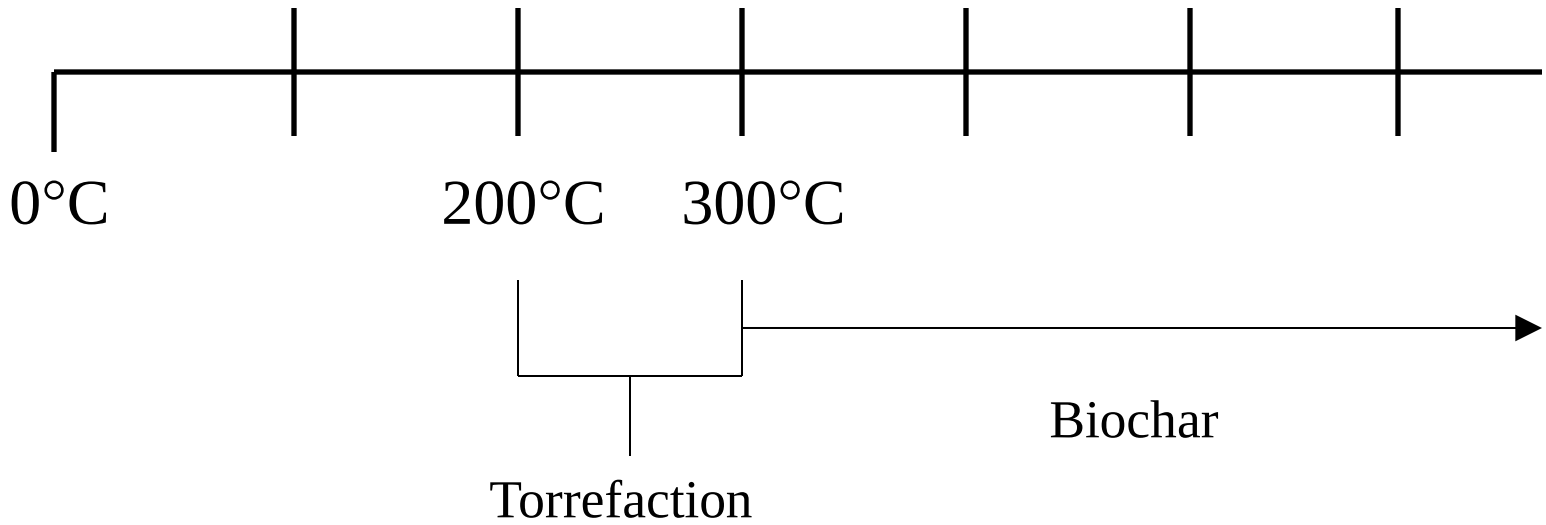
# Torrefaction ⇔ "Burning" in Limited Oxygen



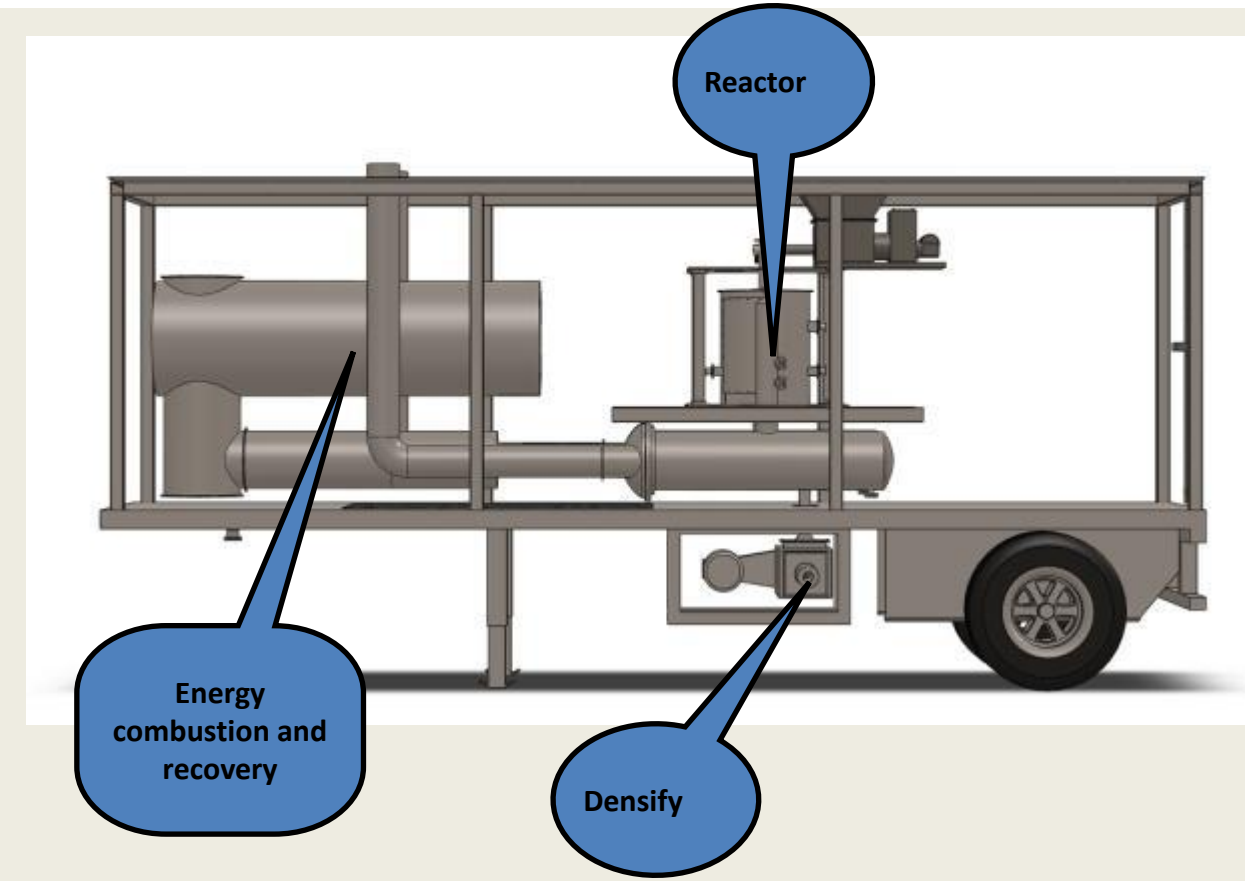

- **Torrefaction: 200°C to 300°C under inert atmosphere**
- **Removes moisture and volatiles → stable to microbial attack**
- **Densify torrefied biomass → cheaper to transport**
- **Energy value ~ low rank coal**

# Torrefaction: Conversion of Biomass to "Biocoal"

Built a portable 8 tons/day unit to produce BioCoal on location.

The 28' unit is mounted on an 18-wheel trailer

Almond hullers processing plant, Los Banos, CA



# RENEWABLE FUEL TECHNOLOGIES

http://renewablefueltech.wordpress.com/

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# Torrefied Almond Shells

230°C

260°C

290°C

60 min 80 min 100 min

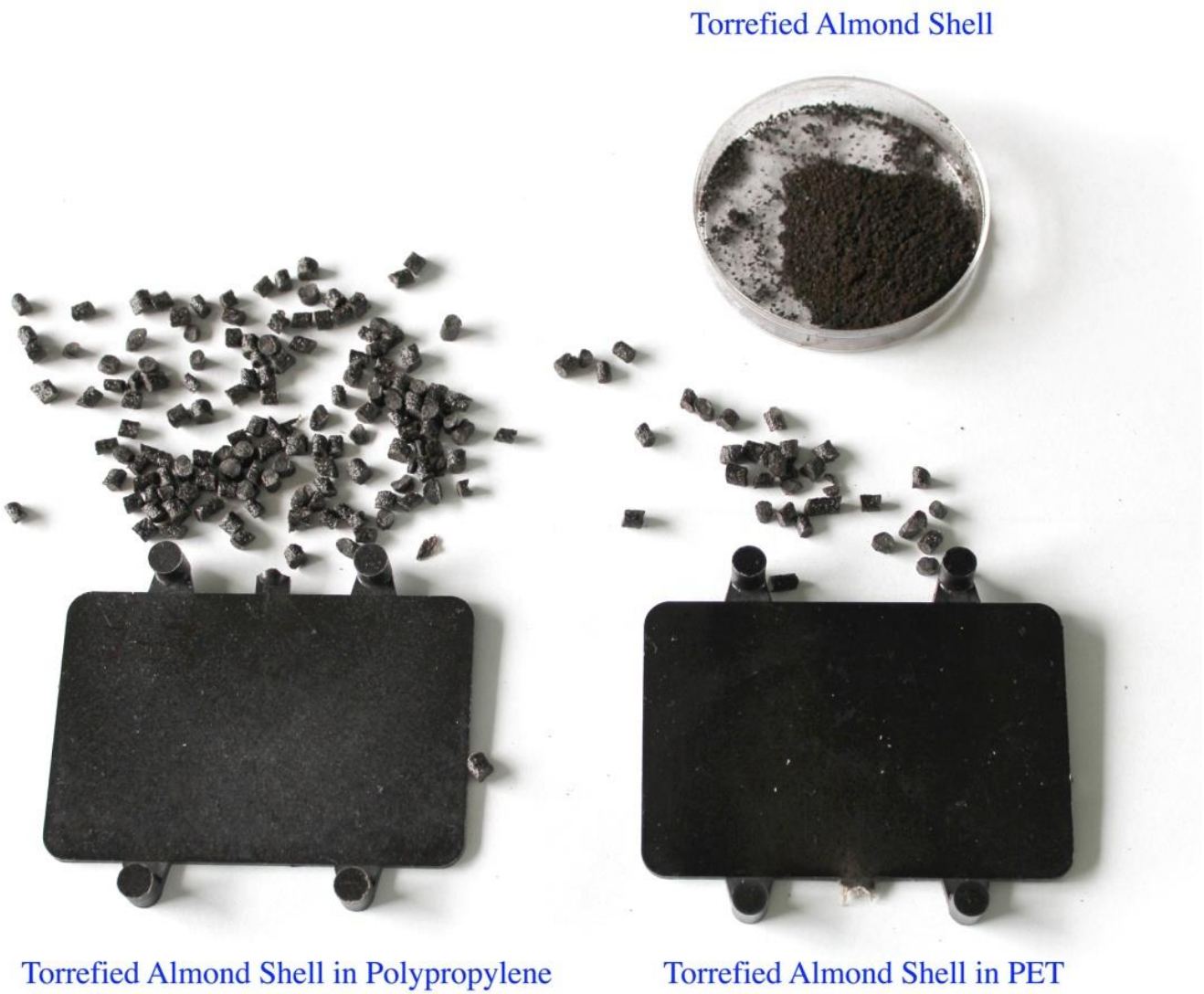
# Making plastic parts with almond shell additives

**Torrefied biomass:**

**Almond shells at 280°C**
**Wood at 280°C**
**Almond shells at 300°C**

**Polymer: Polypropylene**

# Torrefied Biomass-Polymer Composites

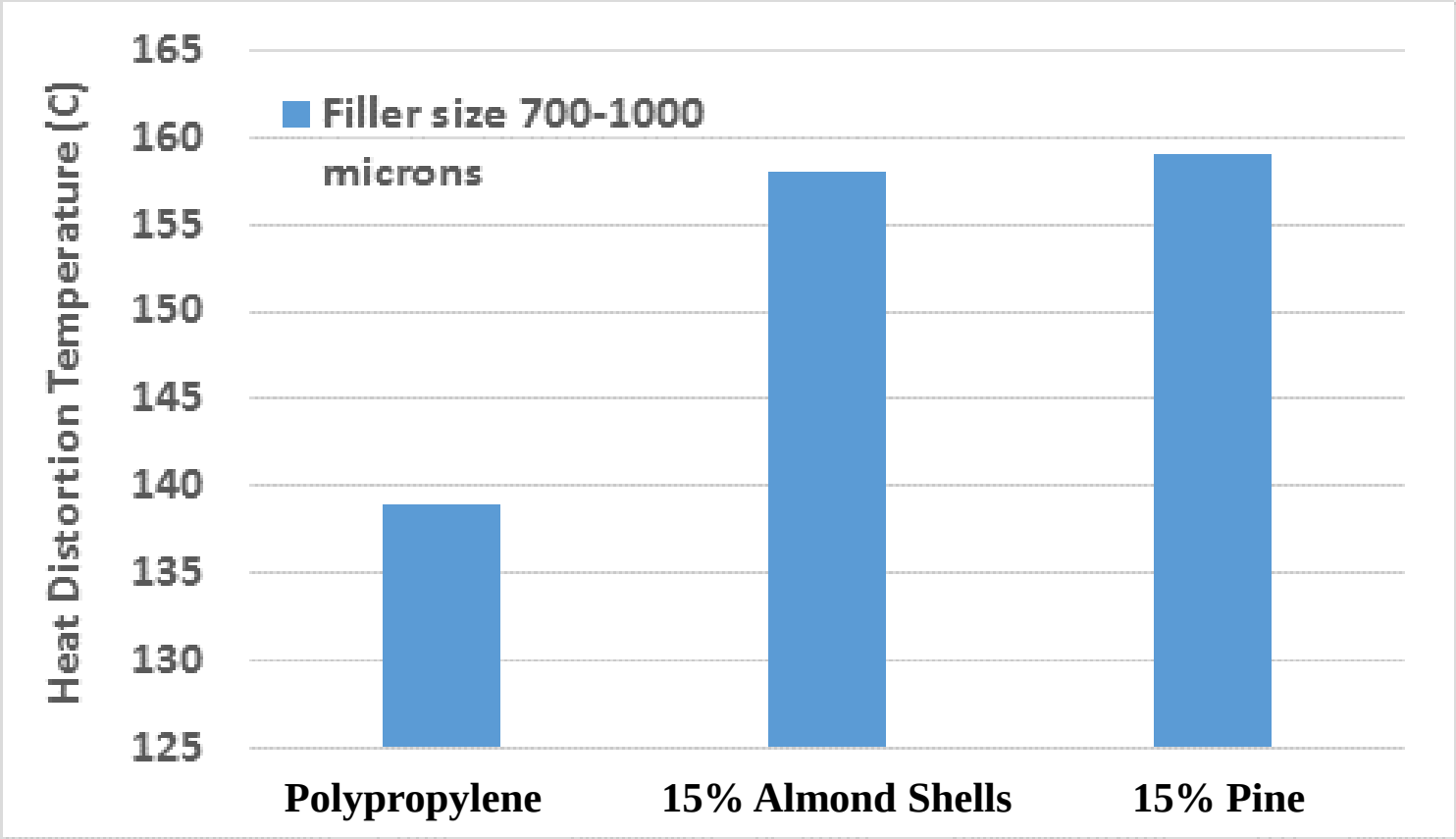



– Alternative to wood-polymer composites

# Heat Distortion Temperature

## a.k.a. ⇔ the softening point

Temperature at which material deforms under specific load



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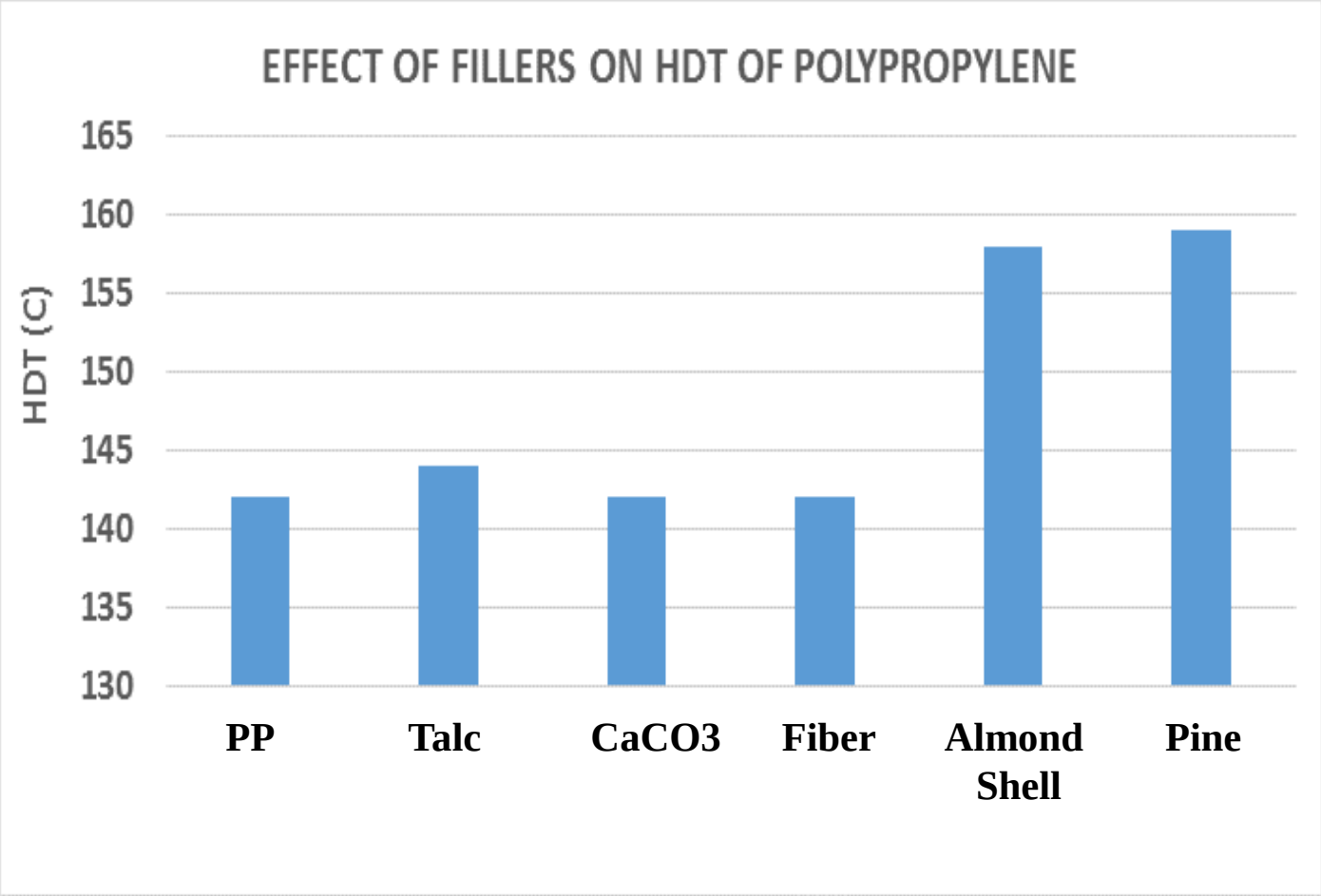

# Torrefied Biomass in Plastics

F-D-S Manufacturing Co.
Since 1950


The New York Times

# Making Tires From a Desert Shrub Found in the U.S.

**By DIANE CARDWELL** AUG. 18, 2015

**USDA researchers are partnering with tire companies to provide a domestic source of rubber to make US-produced rubber tires.**


**Colleen McMahan**


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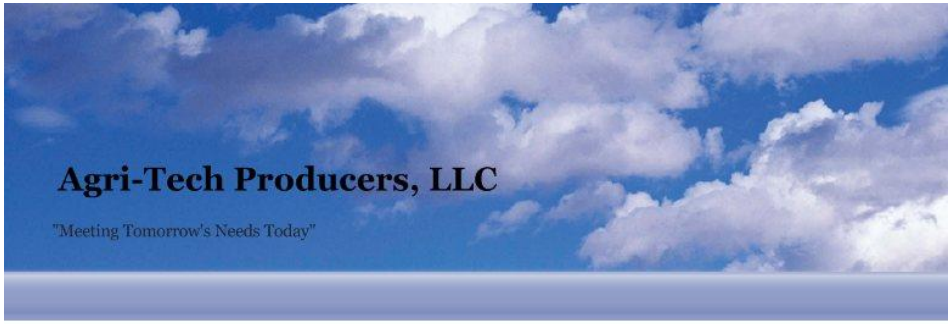
# Partnerships: Industrial Cooperators

# Glucaric acid production

**<u>Method Products uses "green" solvents</u>**

- **glucaric acid**
- **gluconic acid,**
- **cellobionic acid, etc….**

Why not make them from almond hull sugar?

# Next Steps….

- Work to isolate sugars from hulls for ????
  - Feed? Ethanol? Food?
  - Explore synergies with sugar beet
- Find new uses for spent hulls.
- Explore new uses for torrefied shells,
  - Plastics
  - Rubber tires!
- Take advantage of the fact that the hulls and shells are aggregated, in California…..

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# Acknowledgements


- **California Department of Food and Agriculture (Grant # SCB11021)**
- **RPAC Almonds for donating almond shells**



**Oils and Rubber**

- Colleen McMahan
- Grace Chen
- Ken Lin
- Tom McKeon

**Biofuels**

- Kevin Holtman
- Charles Lee
- Kurt Wagschal
- Dominic Wong

**Bioproducts**

- Greg Glenn
- Bor-Sen Chiou
- De Wood
- A player to be named later

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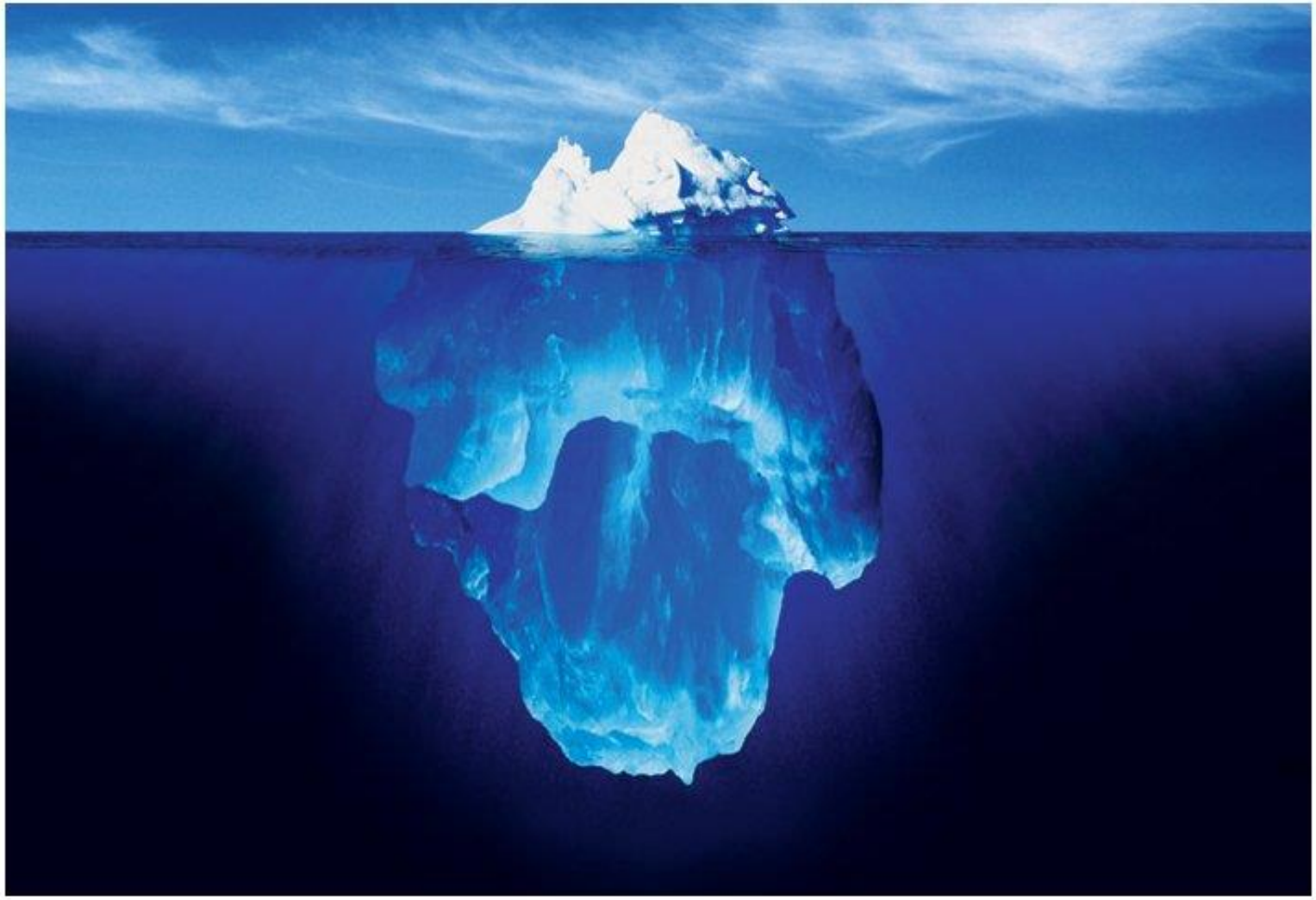
# Partnerships



# Biogas Capacity: An ongoing story……..

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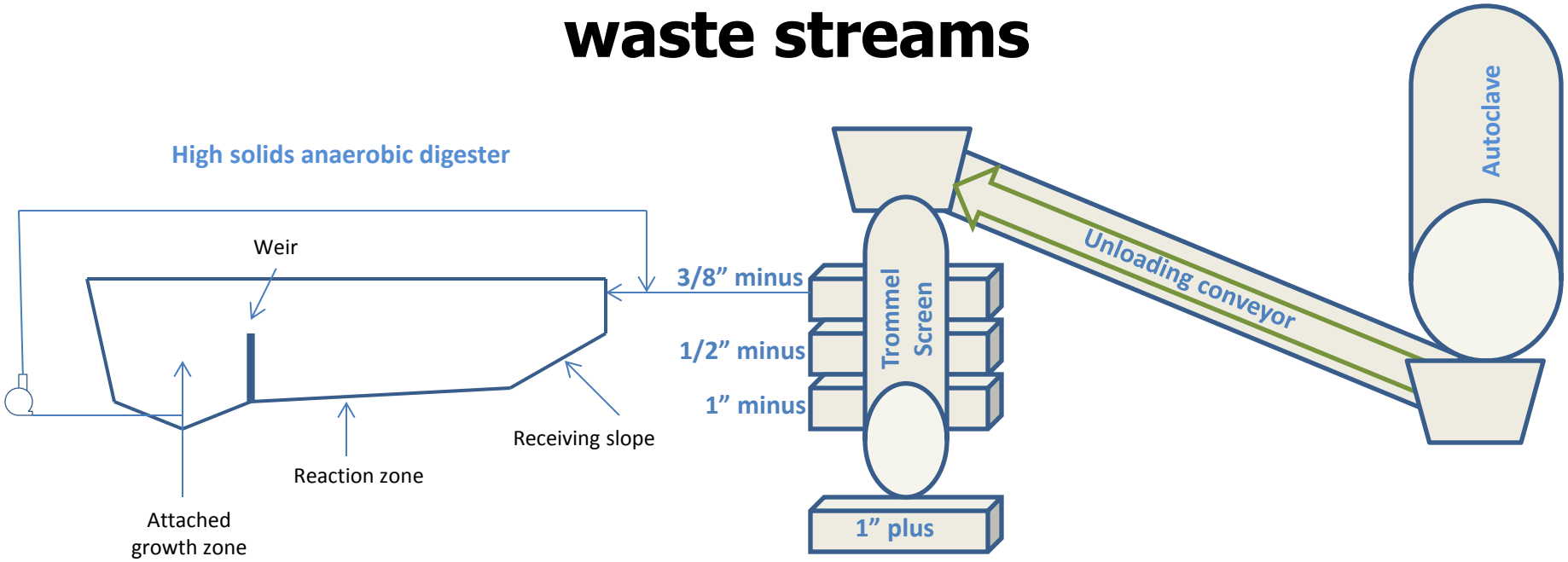
CR

SALINAS VALLEY SOLID WASTE AUTHORITY
*Promoting the Environmental Health of the Salinas Valley*

Reduce Recycle Reuse

jbei Joint BioEnergy Institute

# USDA AD system schematic for lignocellulosic waste streams




SALINAS VALLEY SOLID WASTE AUTHORITY
*Promoting the Environmental Health of the Salinas Valley*
Reduce Recycle Reuse



Kevin Holtman - USDA

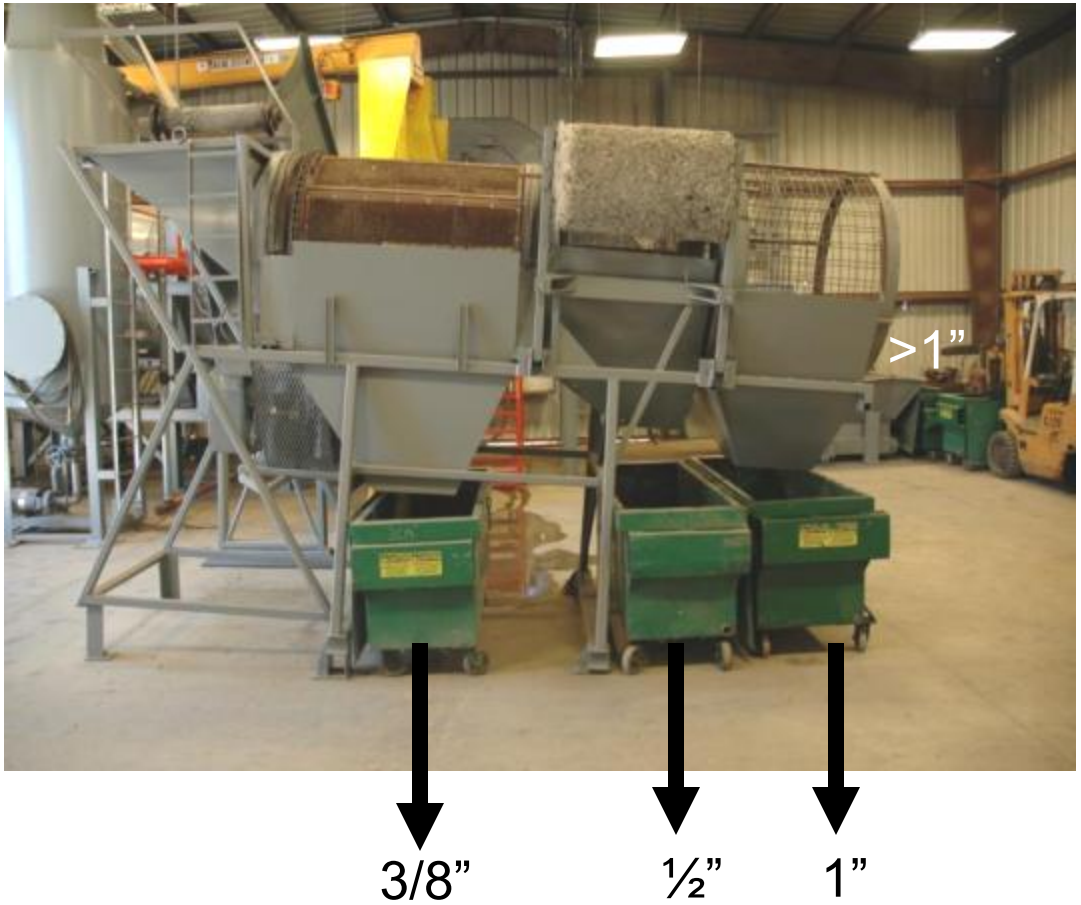
# Salinas Crazy Horse Landfill

# Conveyor loading MSW to autoclave

# MSW in the autoclave prior to treatment

# MSW after steam treatment

# Post-Autoclave MSW Sorting



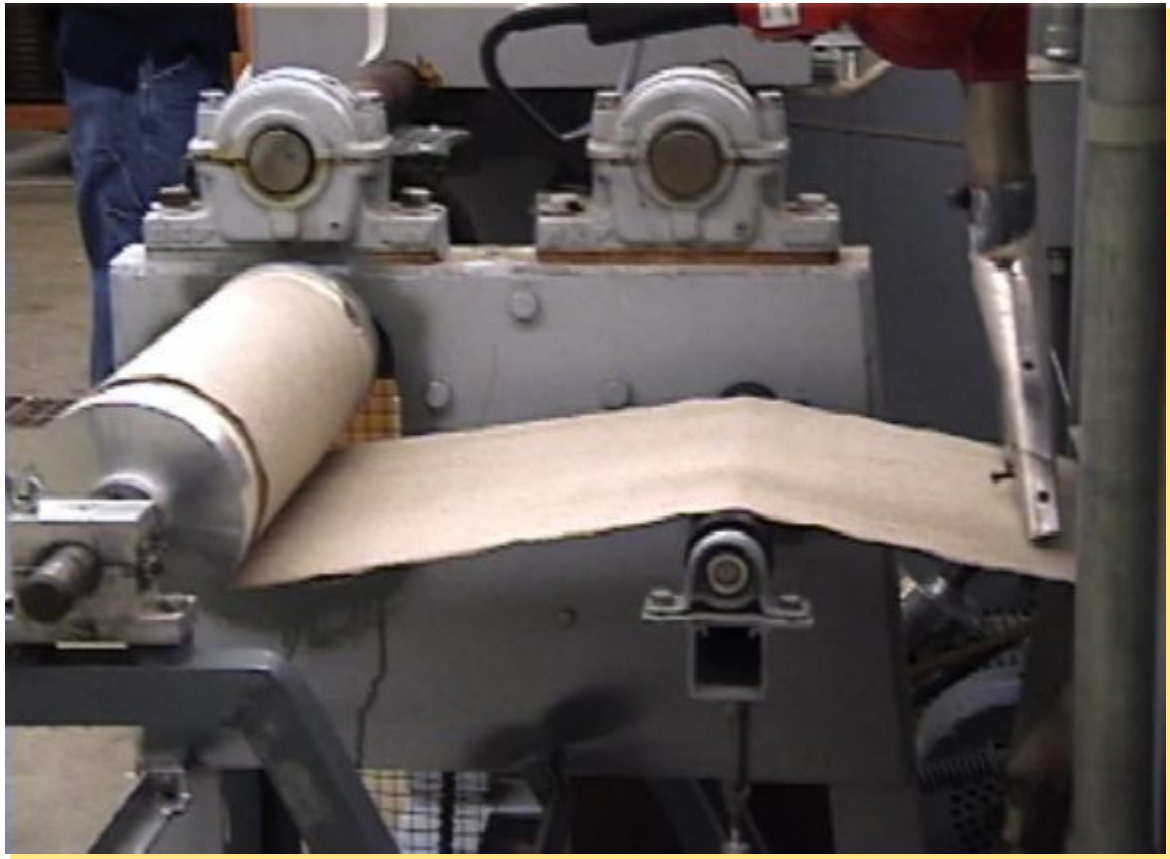

**Trommel Screen Side View**

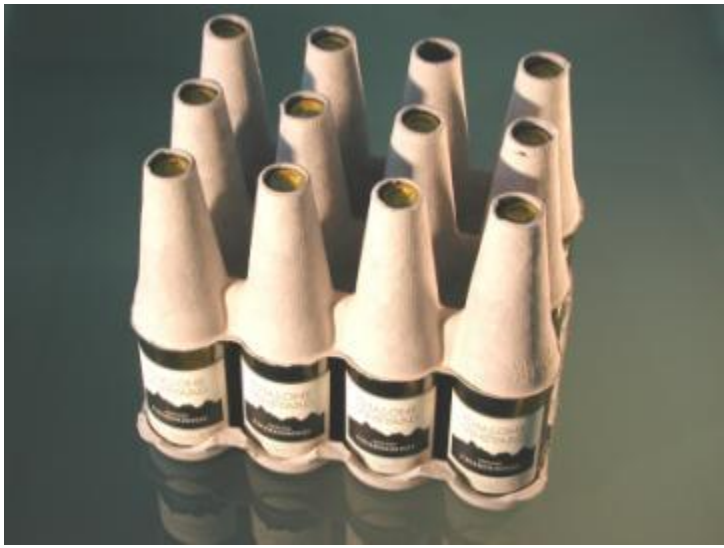
**Trommel Screen Front View**

# MSW fiber < 3/8”

# Cellulose Recovery from Autoclaved MSW

Processed paper from recovered fiber





# Grow Plastics Technology in Packaging

## Better

Equivalent/Superior Strength

Thermally Stable

## Greener

100% Bio Based

Up to 80% $CO_2$ Reductions from Materials

## Lower Cost


Beat Solid Plastics on Price by up to 40%

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