Water-free Electrostatic Processing of Plant Proteins

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Electrostatic Phenomena Observed Since Ancient Times
  ▪ Documented as Early as 600 BC
  ▪ Amber charged with Animal Fur would Attract Small, Light Objects

Today Electrostatic Separation is used in Minerals Processing and Recycling
What is Electrostatic Separation?

Tribo-charging (Contact Charging)

- Particles charge by contacting each other, or a third surface.
- Positive (+) or Negative (-) depends on difference in electron affinity (work function of material).
- Does not depend on conductivity, so useful for mixtures of non-conductors.
What is Electrostatic Separation?

- Pelgrom 2015; Wang 2016
  - ES Separation of pea and lupin
  - Benchtop parallel plate ES separator used
  - Very small scale (5-25 grams per experiment)
  - Samples collected off of electrodes
  - Enrichment of lupin flour from feed protein content of 30 – 35% feed to a product of 60% protein
- Small Samples - Not Continuous

*Benchtop Scale Parallel Plate ES Separator*
Electrostatic Separation of Oilseeds

- Electrostatic Separation of Oilseed Meals is a Recent Topic of Research Interest
- Sunflower Oil Cake (SOC) was milled and then separated using electrostatic methods. Protein increased by +18% absolute (30% to 48% wb).
- Rapeseed Oil Cake (ROC) increased from 31% protein (dry basis) to 51% protein (db) in multiple pass testwork.
- Testwork was performed on bench-scale separation device on a non-continuous basis.
- Not suitable for processing large quantities.

High Rate Continuous ES Separator

Benefits:

- Completely Dry
  - No Water or Chemicals
- High Processing Rate
  - 10-20 Tph for Feed & Food
- Continuous Operation
- Low Operating Cost
  - 2-4 kWhr / ton
- Compact Foot Print
- Simple to Run and Maintain
Proven Processing Technology

- **Mineral Separators:**
  - Canada 1 Unit
  - India 1 Unit
  - Europe 1 Unit
  - United States 1 Unit
Mineral Separators: 4 Units

- **Fly Ash Separators:**
  - United States 12 Units
  - United Kingdom 4 Units
  - Canada 1 Unit
  - Poland 2 Units
  - Philippines 1 Unit
  - South Korea 2 Units
  - Japan 1 Unit
Fly Ash Separators: 23 Units

- Experience in Wide Variety of Fine Powders:
  - Food & Feed
  - Minerals
  - Fly Ash

- Commercially Proven Processing Technology

- More than 25 Units Around the World
STET Separator

- Entirely Dry Process – No Water or Chemicals
- Tribo-charging by Intense Particle-Particle Collisions within the Device
- High Feed Rate (10 – 20 tons / hour for Food & Feed)
- Low Energy Consumption 2-4 kWh / ton
- Designed for Processing Combustible Dusts
Schematic of the Separator

- Small gap and vigorous agitation
- High electric field strength with moderate applied voltage (typ. 8-20 kV)
- High efficiency multi-stage separation through charging/recharging & internal recycle
Efficient Separation in a Single Pass

- Small gap and vigorous agitation
- High electric field strength with moderate applied voltage (typ. 8-20 kV)
- High efficiency multi-stage separation through charging/recharging & internal recycle

- Low residence times: ~1 sec
- Large particle size range: <1µm to ~1000 µm
- High Capacity: 10 – 20 TPH*

* For F & F materials
Process Testing Capability

STET Technical Center – Needham MA USA

Bench-Scale Separator

Pilot-Scale Separator

Benchtop Separator

Electrode Length 3.7 meters (12 Feet)

Pilot Separator

Electrode Length 6.1 meters (20 Feet)
Application - Sunflower Meal

- Two (2) Ton Solvent Extracted Sunflower Meal Purchased from Customer in USA
- Sample was Milled with Air Classified Mill and Hammer Mill

- Milled at 2 Particle Sizes:
  - 70 Micron ($d_{50}$)
  - 25 Micron ($d_{50}$)

- Tested in STET Pilot Plant
Sunflower Meal Results

Pilot-Scale Single Pass Results (70 um feed)

<table>
<thead>
<tr>
<th></th>
<th>Feed</th>
<th>E1</th>
<th>E2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass yield</td>
<td>-</td>
<td>46%</td>
<td>54%</td>
</tr>
<tr>
<td>Moisture</td>
<td>8.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (% DB)</td>
<td>40%</td>
<td>29%</td>
<td>52%</td>
</tr>
<tr>
<td>Oil</td>
<td>0.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fiber</td>
<td>33.0%</td>
<td>51.8%</td>
<td>22.9%</td>
</tr>
</tbody>
</table>

+11% (Absolute) Protein Increase
1 Pass

+17% (Absolute) Protein Increase
2 Pass

Feed Meal
40% Protein

Fiber Rich
29% Protein

Protein Rich
52% Protein
Application - Canola Meal

- STET Processed Sample of Defatted Canola Meal from Canadian source.
- Sample was Milled at California Pellet Mill (CPM Roskamp).
- Ground Samples Processed in STET Pilot Plant.
Canola Meal Results

Feed particle size distribution

One Pass: +7-8% Absolute Increase in Protein Content from Feed to Product

Further Optimization work on Feed Preparation underway
Oilseed Meal Process Overview

- **Simplified Process Flow Diagram**

- **Existing Meal**
  - Meal Taken As-Is
  - From Crush Plant

- **Grinding**
  - Ground to Fine Powder
  - For Fiber Liberation

- **STET Separation**
  - Processed with STET
  - Electrostatic Separator

- **Pelletizing**
  - Meal is Pelletized
  - For Economic Transport
Maximizing the Value of Oilseed Meal

Canola

Sunflower

Extraction

Defatted Meal

Milling

Oil

Value Added

Cattle have Lower Protein Requirement, Higher Fiber

Cattle Feed

Poultry and Fish need High Protein, Low Fiber

Poultry Feed

Fish Feed

Protein Concentration

Fiber Rich

Protein Rich
## Other Applications for Electrostatic Separation

<table>
<thead>
<tr>
<th>Feed Crop</th>
<th>Separation</th>
<th>Reported in Literature by others</th>
<th>STET Experience?</th>
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</thead>
<tbody>
<tr>
<td>Pea flour/concentrate</td>
<td>Protein from Fiber &amp; Starch</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Corn DDGS</td>
<td>Protein / Fiber</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lupin flour</td>
<td>Protein / Fiber</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fava Bean concentrate</td>
<td>Protein from Fiber &amp; Starch</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Chia flour</td>
<td>Protein / Fiber</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Fish meal</td>
<td>Protein / Ash</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Beef Bone meal</td>
<td>Protein / Ash</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>Bran / Starch</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Oat bran</td>
<td>Fiber / Starch</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Soy flour</td>
<td>Protein / Fiber</td>
<td>Yes</td>
<td>Yes</td>
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## Sustainability Benefits

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<th>Resource Optimization</th>
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<tr>
<td>✓ Increase value of low-grade Meals</td>
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<td>✓ Displace other costly feed ingredients</td>
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<tr>
<th>Maintain Protein Functionality</th>
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<tr>
<td>✓ No Drying</td>
</tr>
<tr>
<td>✓ No chemical additives</td>
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<tr>
<th>Environmentally Friendly</th>
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<tr>
<td>✓ No water / no wastewater</td>
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<td>✓ Low Energy 2-4 kWh/ton</td>
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| Small physical footprint |

## Additional Features

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<thead>
<tr>
<th>Commercially Proven for Minerals and Recycling</th>
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<th>High processing rate</th>
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<th>Separates wide range of particle sizes</th>
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<th>Ease of Operation</th>
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<tbody>
<tr>
<td>✓ Rapid start-up and shut-down</td>
</tr>
<tr>
<td>✓ Rapid response to feed variability</td>
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<tr>
<td>✓ Amenable to automation</td>
</tr>
<tr>
<td>✓ Produce several grades of product easily</td>
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Thank You!
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