Defatted Algal Co-products

Biofuels Co-products Workshop
Hosted by the Aquatic Feeds & Nutrition Dept.
Oceanic Institute

1 December 2011

F. C. Thomas Allnutt
Research & Development
• Introduce Phycal
• Our process & funding
• Pilot Plant (it’s coming)
• Products
• Co-products
• What’s next?
About Phycal

- Founded 2006
- Subpilot Facility and R&D in Ohio
- Algal Biotechnology Lab in Missouri
- Projects and support from:
  - DOE (National Energy Technology Lab - NETL)
  - NSF (SBIR/STTR)
  - DOD (Air Force Research Lab - AFRL)
- Recently selected for $51.5 million in funding from DOE for our pilot algae farm in central Oahu, Hawai’i
- Pilot farm operational in Hawai’i in 2012-2015.
Pilot Farm on Oahu, HI

- 120,000 gpy
- 34 acres
- DOE, HIH2, Investor Funded, Ulupono Initiative
- Produce:
  - Biocrude for HECO
  - Renewable Jet Fuel
  - Renewable Diesel
  - Co-Products
- EA, FONSI & NEPA
- Completed November
- Operational 2012
Commercialization Path

• Pilot farm 2012-2015
  – 120,000 gallons per year
  – Fuel and co-product qualification

• Demonstration farm 2015-2018
  – 3 million gallons per year
  – Demonstrate economics at scale

• Commercial farm 2018 onwards
  – 50 million gallons per year
  – Competitive without an operating subsidy
Products
Co-products

Phycal is a Renewable Energy Commodity Producer

- Energy will be the product, not the co-product
- Optimize production system for oil; then take available co-products

Co-product Markets and Prices

- Target large commodity markets (e.g. animal feed, high oleic acid product), not niche markets
- Co-product pricing is complex, effort currently being supported by scaled production, protein digestibility index (PDCAAS) results, and feed industry consultants.
- PDCAAS - Protein Digestibility Corrected Amino Acid Score is a method of evaluating the protein quality based on both the amino acids requirements of humans and their ability to digest it

Current Status

- Currently completing analyses of material our lipids, biomass
- Decisions about co-products made in the context of our production cost model (e.g., more co-product volume could reduce co-gen)
- In-progress now; we include only what we have done so far
Phycal 1st Generation Process

- CO₂
- Reclaimed Water
- Sunlight
- Nutrients

Ponds

H₂O

Dewater

Heteroboost™

Aqueous Extraction & Purification

Sugars

Biocrude

Refined Biocrude

Upgrade

Co-products

Residuals

Digestion

Methane

Hydrogen

Power

HECO

CO₂ Reclaimed Water Sunlight Nutrients

Ponds H₂O Dewater Heteroboost™ Aqueous Extraction & Purification Sugars Biocrude Refined Biocrude Upgrade Co-products Residuals Digestion Methane Hydrogen Power HECO
Co-Products (Work In Process)

• **Algal Delipidated Biomass** - >10% protein, residual lipids and remainder carbohydrate (predominately glucomannans)

• **Algal Protein Concentrate** – On protein digestibility index (PDCASS) similar to pea protein

• **Crude Oleic Acid** – High oleic acid cut

• **Pigments** – Under development, primarily lutein

Other synergistic co-products (Phycal Sugar & Phycal Fuel)

• **Leaf meal** ~27% protein with digestibility index of 0.76

• **Fiber Meal**

• **Cassava Protein Concentrate** ~75% protein with digestibility index of 0.37
## Phycal Oil Composition

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>C#: Dbl. Bonds</th>
<th>Relative Basis %</th>
<th>Sample Basis %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristic</td>
<td>14:0</td>
<td>0.66</td>
<td>0.62</td>
</tr>
<tr>
<td>Palmitic</td>
<td>16:0</td>
<td>9.58</td>
<td><strong>9.10</strong></td>
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<tr>
<td>Palmitoleic</td>
<td>16:1</td>
<td>0.36</td>
<td>0.34</td>
</tr>
<tr>
<td>Heptadecanoic</td>
<td>17:0</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Heptadecenoic</td>
<td>17:1</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Stearic</td>
<td>18:0</td>
<td>3.71</td>
<td>3.52</td>
</tr>
<tr>
<td>Oleic</td>
<td>18:1ω9</td>
<td><strong>68.64</strong></td>
<td><strong>65.19</strong></td>
</tr>
<tr>
<td>Linoleic</td>
<td>18:2ω6</td>
<td>14.91</td>
<td><strong>14.16</strong></td>
</tr>
<tr>
<td>Linolenic</td>
<td>18:3ω3</td>
<td>1.05</td>
<td>1.00</td>
</tr>
<tr>
<td>Arachidic</td>
<td>20:0</td>
<td>0.38</td>
<td>0.36</td>
</tr>
<tr>
<td>Eicosanoic</td>
<td>20:1ω11</td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>Eicosanoic</td>
<td>20:1ω9</td>
<td>0.19</td>
<td>0.18</td>
</tr>
<tr>
<td>Behenic</td>
<td>22:0</td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>Other</td>
<td>n/a</td>
<td>0.12</td>
<td>0.11</td>
</tr>
</tbody>
</table>

|                  |              | 100.00          | 94.98          |
|                  | Total % ω3   | 1.05            | 1.00           |
|                  | Total % ω6   | 14.91           | 14.16          |

- Not making long-chain, poly-unsaturated fatty acids (PUFAs)
# LEA Amino Acid Profile

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>mg aa/ g protein</th>
<th>PDCASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td>22</td>
<td>n/d</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>46</td>
<td>1.65</td>
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<tr>
<td>Leucine</td>
<td>96</td>
<td>1.46</td>
</tr>
<tr>
<td>Lysine</td>
<td>58</td>
<td>1.00</td>
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<tr>
<td>Met + Cys</td>
<td>24</td>
<td>0.95</td>
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<tr>
<td>Phe + Tyr</td>
<td>73</td>
<td>1.15</td>
</tr>
<tr>
<td>Threonine</td>
<td>55</td>
<td>1.63</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>18</td>
<td>1.68</td>
</tr>
<tr>
<td>Valine</td>
<td>71</td>
<td>2.04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>442</strong></td>
<td><strong>0.82</strong></td>
</tr>
</tbody>
</table>

PDCASS = digestibility score vs. requirement for preschoolers. Chickpea is 0.78 and Soybean 0.91
Looking Ahead

• Break ground in 2012 (Q1)

• Prepare to be surprised

• Continue development programs in technologies, co-products & crops

• Open Innovation – we want to work with anyone who can help us develop these co-products for their industry
Thank You!

Tom.Allnutt@phycal.com
www.phycal.com
(440)460-2478
(443) 878-4957