Value Added Co-product from *Jatropha*
Biodiesel Production Process

Rakshit K. Devappa
1. Introduction: *Jatropha*
2. Seed cake/kernel meal: Nutritional value
3. Detoxification: Current status
4. Approaches to improvise detoxification
**Jatropha curcas**

- **Origin:** Central American countries

- **Common names:** physic nut, pig nut, purging nut etc.

- **Distribution and habitat:**
  - Dry regions of tropics
  - Rainfall: 11.8" – 39.4"
  - Altitude: 0-500 m
  - Annual temp. (Avg): 65 °F

- **Botanical features**
  - Euphorbiaceae family
  - Small tree or shrub
  - When cut exudes white latex
  - Grows to 9 -16 feet
  - Yield (5-7 mt/h)

**Multipurpose uses**
Future *Jatropha* Production

Production of seeds

~28 billion pounds

*Considering (28% oil)*

Production of oil

7.84 billion gallons

*Considering*

- 248 gallons oil/acre
- *Cultivation* -31.63 million acres

Source: GEXSI market study on Jatropha (2008)

Production of:

(a) Defatted kernel meal

7.4 billion pounds

*Considering:*

- 63:37 = Kernel:shell
- 58% oil in kernel

(b) Defatted Seed cake

20.16 billion pounds

*Considering:*

- 28% oil recovery from seeds
Jatropha curcas Processing

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
# How Good is *Jatropha* as Fish Feed?

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Market share (%)</th>
<th>Energy (MJ/kg DM)</th>
<th>Protein (%)</th>
<th>Fibre (NDF %)</th>
<th>Antinutritional factors</th>
<th>Detoxification treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean meal</td>
<td>70</td>
<td>12</td>
<td>50 -53</td>
<td>6</td>
<td>Trypsin inhibitor, phytic acid, lectins, bitter taste, oligosacharides</td>
<td>Heat treatment and solvent extraction</td>
</tr>
<tr>
<td>Rapeseed Meal</td>
<td>12</td>
<td>12</td>
<td>39</td>
<td>12-14</td>
<td>Glucosinolates</td>
<td>Controlled feeding studies</td>
</tr>
<tr>
<td>Sunflower meal</td>
<td>6</td>
<td>9.5</td>
<td>37</td>
<td>15</td>
<td>Chlorogenic acid</td>
<td>Washing</td>
</tr>
<tr>
<td>Cotton meal</td>
<td>6</td>
<td>11.5</td>
<td>40</td>
<td>15</td>
<td>Gossypol</td>
<td>Controlled feeding levels, breeding, solvent extraction</td>
</tr>
<tr>
<td>Jatropha kernel meal</td>
<td>0</td>
<td>18</td>
<td>55-64</td>
<td>10</td>
<td>Phorbol esters, curcin, trypsin inhibitor, lectin, saponin, phytate</td>
<td>Chemical and solvent</td>
</tr>
</tbody>
</table>

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
### Chemical Composition of Toxic and Nontoxic Defatted *Jatropha curcas* Kernels

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Variety (<em>Jatropha Curcas</em>)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Toxic</td>
<td>Nontoxic</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>56-65</td>
<td>63.8</td>
</tr>
<tr>
<td>Lipid (%)</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>9.6</td>
<td>9.8</td>
</tr>
<tr>
<td>Gross energy (MJ/kg)</td>
<td>18.2</td>
<td>18</td>
</tr>
<tr>
<td>Neutral Detergent Fibre (%)</td>
<td>9.0</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany

Non toxic *Jatropha platyphyllla* seeds

Toxic *Jatropha curcas* seeds
# Quality of Amino Acid Profile (g/100 g protein)

<table>
<thead>
<tr>
<th>Amino acids</th>
<th>Cape Verde genotype</th>
<th>Nontoxic Mexican genotype</th>
<th>Protein Isolate</th>
<th>Soybean</th>
<th>Essential amino acid requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fish</td>
</tr>
<tr>
<td>Lysine</td>
<td>4.28</td>
<td>3.4</td>
<td>3</td>
<td>6.08</td>
<td>4.1-6.1</td>
</tr>
<tr>
<td>Leucine</td>
<td>6.94</td>
<td>7.5</td>
<td>7.08</td>
<td>7.72</td>
<td>2.8-5.3</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>4.53</td>
<td>4.85</td>
<td>4.47</td>
<td>4.62</td>
<td>2.0-4.0</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.91</td>
<td>1.76</td>
<td>1.66</td>
<td>1.22</td>
<td>2.2-6.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cystine</td>
<td>2.24</td>
<td>1.58</td>
<td>1.34</td>
<td>1.70</td>
<td>5.0-6.5</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>4.34</td>
<td>4.89</td>
<td>5.42</td>
<td>4.84</td>
<td>5.0-6.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>2.99</td>
<td>3.78</td>
<td>3.2</td>
<td>3.39</td>
<td>-</td>
</tr>
<tr>
<td>Valine</td>
<td>5.19</td>
<td>5.3</td>
<td>5.18</td>
<td>4.59</td>
<td>2.3-4.0</td>
</tr>
<tr>
<td>Histidine</td>
<td>3.3</td>
<td>3.08</td>
<td>3.51</td>
<td>2.50</td>
<td>1.3-2.1</td>
</tr>
<tr>
<td>Threonine</td>
<td>3.96</td>
<td>3.59</td>
<td>3.56</td>
<td>3.76</td>
<td>2.0-4.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> requirement varies depending on the amount of cystine in the diet

<sup>b</sup> requirement varies depending upon the amount of tyrosine in the diet

<sup>#</sup> in the absence of cystine

<sup>*</sup> in the absence of tyrosine

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
Antinutrient/toxic Constituents Present in Toxic and Nontoxic Defatted *Jatropha curcas* Kernel meal*

<table>
<thead>
<tr>
<th>Component</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Toxic</td>
</tr>
<tr>
<td>Phorbol ester (PEs; mg/g)</td>
<td>3.00</td>
</tr>
<tr>
<td>Total phenols (% tannic acid equivalent)</td>
<td>0.36</td>
</tr>
<tr>
<td>Tannins (% tannic acid equivalent)</td>
<td>0.04</td>
</tr>
<tr>
<td>Phytates (% dry matter)</td>
<td>9.40</td>
</tr>
<tr>
<td>Saponins (% diosgenin equivalent)</td>
<td>2.60</td>
</tr>
<tr>
<td>Trypsin inhibitor (mg trypsin inhibited per g sample)</td>
<td>21.30</td>
</tr>
<tr>
<td>Lectins (1/mg of meal that produced haemagglutination per ml of assay medium)</td>
<td>102</td>
</tr>
</tbody>
</table>

*Expressed on dry matter basis

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
Toxicity of *Jatropha* Seeds

**Mice:** LD$_{50}$ 27 mg/kg Bd. wt.
**Goat and sheep:** 0.05 g/kg/day in diet
**Chicks:** 0.1% seed in diet
**Molluscs:** 3 ppm of ethanol extract
**Fish:** 15 ppm PEs in diet
**Pig:** 0.8 mg/g PEs in diet
**Humans:** No authenticated studies

- 6 types of phorbol esters.
- Heat stable, Tumour promoters
- After pressing: 70% of PEs in oil + 30% of PEs in seed cake
- Quantification: HPLC method, LCMS

*Source: Haas et al., 2002; Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany*
Detoxification of *Jatropha* Cake/Kernel Meal

**Criteria:**

1. **Favourable:** Process should be fast, cost effective, phorbol esters (PEs) should be reduced to undetectable level in HPLC, exhibit no toxicity in bioassays and in animal trials.

2. **Not favourable:** time consuming, PEs reduced below or level similar to nontoxic genotypes of Jatropha containing PEs.

**Current detoxification methods to remove PEs**

1. **Solvent** – effective, time consuming
2. **Chemical** – effective, bit harsh on the amino acid profile
3. **Enzymatic** – promising but not completely effective
4. **Microbial** - time consuming, potentially effective
## Effect of Detoxification on *Jatropha* Cake/Kernel Meal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Untreated Jatropha kernel meal</th>
<th>Treated Jatropha Kernel meal</th>
<th>Soy bean meal</th>
<th>FAO**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (% DM basis)</td>
<td>64.0</td>
<td>63.0</td>
<td>50-53</td>
<td></td>
</tr>
<tr>
<td>Amino acid (g/16 g N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methionine</td>
<td>1.84</td>
<td>1.55</td>
<td>1.22</td>
<td>2.50</td>
</tr>
<tr>
<td>Cystine</td>
<td>1.51</td>
<td>1.36</td>
<td>1.70</td>
<td></td>
</tr>
<tr>
<td>Lysine</td>
<td>3.60</td>
<td>3.36</td>
<td>6.10</td>
<td>5.80</td>
</tr>
<tr>
<td>Protein digestibility % (pepsin + pancreatin)</td>
<td>95.2</td>
<td>85.8</td>
<td>91-95</td>
<td></td>
</tr>
</tbody>
</table>


**Ref. Protein for growing child

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
Is Detoxified* * Jatropha Kernel Meal Fit for Aqua Feed

Upto 50% protein replacement in fishmeal based diet (lysine + phytase added) growth performance equivalent to control.

MGR: Metabolic growth rate

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
Histopathology in Fish (*Cyprinus carpio*)

NO significant changes observed when fed on detoxified *Jatropha kernel meal* when compared to Fish meal based diet.

- Palatability
- Nutrient digestibility and digestive enzymes
- Growth
- Energy metabolism
- Growth hormone and IGF encoding genes
- Clinical markers enzymes
- Gut morphology
- No toxicity in - liver, kidney, intestine, stomach, heart
- No toxicity - serum biochemical characteristics: glucose and cholesterol levels, haemoglobin, haematocrit and triglyceride

Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany

Detoxified* *Jatropha* Meal in Animal Feed

**Poultry:** (10% and 20% in maize + soybean meal based diet)
- Digestibility of AA from DJKM in young turkeys is very high in comparison with data from other feeds

**Pig:** (25 and 50% replacement of soybean iso-nitrogenous diet)
- No histopathological or serum biochemical parameters were altered
- Detoxified Jatropha meal could replace up to 50% of soybean meal protein with no significant change in growth and feed conversion ratio.


Source: H.P.S. Makkar and K. Becker, University of Hohenheim, Stuttgart, Germany
Summary

- Jatropha kernel meal/seed cake is rich in protein.
- Kernel meal/seed cake contain phorbol esters as toxic constituent.
- Kernel meal/seed cake can be detoxified.
- Detoxified meal has a high acceptability when fed to animals (fish, poultry and pig).
- Inclusion of detoxified meal did not affect the growth and health of fish.
Acknowledgements

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Mr. Lee Jakeway
Ms. Kelly King
Information Sources

1. University of Hohenheim website: https://jatropha.uni-hohenheim.de/
2. Vikas Kumar, PhD thesis submitted to the University of Hohenheim (2010).