Jatropha meal, a promising plant protein source in aquafeed development

Vikas Kumar¹, Olesia Gavryliuk², Amit Kumar Sinha¹, Debhanu Barman*³, Eef De Clercq¹, Apu Das⁴ and Sagar C. Mandal⁵

Jatropha curcas (L.) (physic nut) is a multipurpose, drought resistant shrub or small tree that normally reaches a height of 3-5 m, but can reach a height of 8-10 m under favorable conditions (Figures 1, 2 and 3). It is found throughout the tropics and subtropics. It is a hardy plant, thriving on degraded land and requiring limited amounts of nutrients and water. Its seeds have been extensively investigated as a source of oil. The Jatropha kernel meal is obtained after the oil is extracted. The seed kernel contains about 60 percent oil that can be converted into biodiesel fuel of high quality upon trans-esterification and used as a substitute for diesel fuel (Makkar et al. 2007). The kernel meal obtained after oil extraction is an excellent source of nutrients, containing 58 to 65 percent crude protein (Kumar et al. 2010a). Furthermore, the levels of essential amino acids (EAA), except lysine, are higher in Jatropha kernel meal than soybean meals (Kumar et al. 2010a). However, the presence of high levels of antinutrients (Makkar et al. 2008) and major toxic components (Makkar et al. 1997) restrict their use in fish feed. Subsequently, besides being a source of oil, J. curcas also provides a meal that serves as a highly nutritious and economic protein supplement in animal feed, provided the toxins are removed (Becker and Makkar 1998). Jatropha plant can yield up to 5 t seeds per year from one ha of plantation, which can produce approximately 1 t of kernel meal rich in protein (Makkar and Becker 1997). This means that there is a possibility of producing enough Jatropha kernel meal to meet the growing demand from aquaculture.

Constraints in Using Jatropha Kernel Meal

Toxic and non-toxic genotypes of J. curcas have been reported in cultivation practices (Makkar and Becker 2009). The nontoxic genotype exists only in Mexico, while the toxic genotype is prevalent throughout the rest of the world. The use of Jatropha meals prepared from the toxic genotype in animal nutrition is limited because of the presence of antinutritional components and toxic factors (Table 1). The major antinutrients are trypsin inhibitors, lectin, and phytate. The main toxic factor present is phorbol esters (PEs), which are highly toxic to animals. The levels of trypsin inhibitor and lectin are similar to those in soybean meal and the level of phytate (9.4 percent) is approximately three times greater than in soybean meal. The kernel has greater crude protein, 22-28 percent and oil content of 54-58 percent (Makkar et al. 1998). Furthermore, it was shown that the force feeding of Jatropha meal containing PEs displayed toxicity in mice (Li et al. 2010), rats and goats (Goel et al. 2007). Similar results have also been reported in fish (Becker and Makkar 1998). The major organs affected were intestines, liver and kidney.

On the other hand, nontoxic J. curcas kernels are also rich in oil (55-58 percent) and protein (26-29 percent) (Makkar and Becker 2009). The nontoxic genotype does not have phorbol esters but contains the trypsin inhibitors, lectin and phytate, at the same levels as the meal from the toxic genotype. However, the nutritional value of meal obtained from the nontoxic genotype, after heat treatment, is very high as evaluated in fish (carp) and rats (Makkar and Becker 1999). Thereby, it could be an excellent protein-rich ingredient in feeds of ruminant and monogastric animals, including fish. However, removal of toxins to a safe level is, therefore, necessary before Jatropha meal can be used as animal feed.

Chemical Composition of Jatropha Meal

The content of crude protein (CP), lipid, ash, neutral detergent fiber (NDF), total sugar and starch in Jatropha kernel meal are similar for the two genotypes (Table 2, Makkar
The crude protein content of Jatropha meal is greater than soybean meal, but similar to fishmeal (Table 2). The amino acid composition of the toxic and non-toxic Jatropha meal and soybean meal is shown in Table 3. The levels of essential amino acids, except lysine, are greater in Jatropha kernel meal than soybean meal and castor bean meal (Makkar et al. 1998, Kumar et al. 2010a).

### Detoxification Methods for Jatropha Meal

In the past two decades, several studies have been carried out for the complete detoxification of Jatropha kernel meals. Ionizing radiation treatment could serve as a possible processing method for inactivation of certain antinutrients and...
Table 3. Amino acid composition (g kg⁻¹) of Jatropha kernel meal (J-Toxic and J-nontoxic), detoxified Jatropha kernel meal (DJKM) soybean meal and fish meal

<table>
<thead>
<tr>
<th>Amino acids</th>
<th>J-Toxic</th>
<th>J-Non-toxic</th>
<th>DJKM</th>
<th>Soybean meal</th>
<th>Fish meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>73.7</td>
<td>80.6</td>
<td>69.7</td>
<td>44.5</td>
<td>35.3</td>
</tr>
<tr>
<td>Histidine</td>
<td>20.6</td>
<td>19.2</td>
<td>21.7</td>
<td>15.6</td>
<td>17.7</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>28.1</td>
<td>30.0</td>
<td>26.7</td>
<td>28.8</td>
<td>22.8</td>
</tr>
<tr>
<td>Leucine</td>
<td>43.2</td>
<td>46.2</td>
<td>46.7</td>
<td>48.2</td>
<td>41.6</td>
</tr>
<tr>
<td>Lysine</td>
<td>26.1</td>
<td>21.1</td>
<td>23.3</td>
<td>38.0</td>
<td>40.9</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>27.2</td>
<td>30.2</td>
<td>30.4</td>
<td>30.2</td>
<td>21.8</td>
</tr>
<tr>
<td>Methionine</td>
<td>11.9</td>
<td>11.0</td>
<td>10.6</td>
<td>7.6</td>
<td>16.0</td>
</tr>
<tr>
<td>Threonine</td>
<td>24.4</td>
<td>22.3</td>
<td>22.0</td>
<td>23.5</td>
<td>23.0</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>8.2</td>
<td>ND</td>
<td>7.1</td>
<td>7.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Valine</td>
<td>32.3</td>
<td>33.5</td>
<td>31.6</td>
<td>28.6</td>
<td>29.3</td>
</tr>
<tr>
<td>Cystine</td>
<td>14.0</td>
<td>9.8</td>
<td>2.3</td>
<td>10.6</td>
<td>4.3</td>
</tr>
<tr>
<td>Alanine</td>
<td>32.5</td>
<td>30.8</td>
<td>29.4</td>
<td>26.4</td>
<td>43.3</td>
</tr>
<tr>
<td>Asparginine</td>
<td>59.3</td>
<td>62.0</td>
<td>68.7</td>
<td>70.6</td>
<td>60.5</td>
</tr>
<tr>
<td>Glycine</td>
<td>30.7</td>
<td>28.8</td>
<td>31.5</td>
<td>25.0</td>
<td>59.8</td>
</tr>
<tr>
<td>Glutamine</td>
<td>91.7</td>
<td>99.4</td>
<td>112.1</td>
<td>105.6</td>
<td>79.4</td>
</tr>
<tr>
<td>Proline</td>
<td>31.0</td>
<td>23.7</td>
<td>32.2</td>
<td>30.3</td>
<td>36.9</td>
</tr>
<tr>
<td>Serine</td>
<td>30.0</td>
<td>30.1</td>
<td>30.6</td>
<td>35.4</td>
<td>25.5</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>18.6</td>
<td>23.6</td>
<td>18.8</td>
<td>21.1</td>
<td>14.8</td>
</tr>
</tbody>
</table>

Makkar and Becker 2009 and Kumar et al. 2010a *ND: Not detected

toxic components, such as PEs, phytates, saponins and lectins (Siddhuraju et al. 2002). Heat labile antinutrients, protease inhibitors and lectins are easy to inactivate by moist heating (Aderibigbe et al. 1997, Aregheore et al. 2003). But, it is not possible to destroy PEs by heat treatment because they are heat stable and can withstand roasting a temperature as high as 160 °C for 30 min. However, it is possible to reduce their concentration in the meal by chemical treatments, which are not feasible economically (Aregheore et al. 2003). Furthermore, Martinez-Herrera et al. (2006) studied the effect of various treatments, such as hydrothermal processing techniques, solvent extraction, solvent extraction plus treatment with NaHCO₃ and ionizing radiation to inactivate the antinutritional factors in Jatropha kernel meal of both toxic and nontoxic varieties from different regions of Mexico; but, unfortunately, were unable to remove PEs from Jatropha kernel meal. Recently, a method for detoxification of Jatropha kernel meal has been developed (Makkar et al. 2008). This detoxification method is based on extraction of PEs using organic solvents and inactivation of trypsin inhibitors and lectin by heat treatment.

Role of Detoxified Jatropha Kernel Meal (DJKM) in Aquafeed

Aquaculture is growing rapidly at an average rate of 8.9 percent per year, compared with only 1.2 percent for capture fisheries and 2.8 percent for terrestrial farmed meat production systems (FAO 2007). Fishmeal is still a preferred protein source for fish diets corresponding to its high protein quality to meet the intensification of aquaculture systems (NRC 1993). However, because of the high cost and limited availability in many countries (Naylor et al. 2000), the replacement of fishmeal by plant protein sources is of great interest. Detoxified Jatropha kernel meal (DJKM) is a novel and highly nutritious plant protein source. Except for lysine, the level of EAA contents in DJKM was either greaterer or comparable to fishmeal and soybean meal (Kumar et al. 2010a; Table 3), indicating that the material can be used as excellent fishmeal and soybean replacer in fish and shrimp diets.

Up to 50 percent of fish meal could be replaced by DJKM in common carp (Cyprinus carpio L.), rainbow trout (Oncorhynchus mykiss) and whiteleg shrimp (Litopenaeus vannamei) without influencing the growth rate and nutrient utilization (feed conversion ratio and protein efficiency ratio) (Kumar et al. 2010a,b; Harter et al. 2010, Harter et al. 2010). Growth performance and nutrient utilization of shrimp groups fed DJKM at 50 percent replacement of fishmeal protein were better than that of the fishmeal fed group (Table 4). The higher growth response of the DJKM fed

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Table 4. An overview of the result of replacing fishmeal with Jatropha-based feed ingredients in fish and shrimp diets

<table>
<thead>
<tr>
<th>Jatropha-based ingredient</th>
<th>Species</th>
<th>Inclusion level in diet (%)</th>
<th>CP in diet (%)</th>
<th>Experimental period (weeks)</th>
<th>Fishmeal protein replaced in diet (%)</th>
<th>Biological effects</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detoxified jatropha kernel meal (DJKM)</td>
<td>Common carp (Cyprinus carpio L.)</td>
<td>24 and 36</td>
<td>38</td>
<td>8</td>
<td>50 and 75</td>
<td>At up to 50% replacement level growth performance and nutrient utilization were similar to those in control; &gt;50% replacement level decreased performance. Inclusion of DJKM in the diets did not change blood metabolite, ion and enzyme levels. Also no adverse histopathological changes were observed.</td>
<td>Kumar et al., 2010b, Kumar et al. 2011a</td>
</tr>
<tr>
<td>DJKM</td>
<td>Common carp</td>
<td>25 and 31</td>
<td>38</td>
<td>16</td>
<td>50 and 62.5</td>
<td>No significant difference in growth rate among the groups.</td>
<td>Kumar, 2011</td>
</tr>
<tr>
<td>DJKM</td>
<td>Rainbow trout (Onchorhyncus mykiss)</td>
<td>34 and 43</td>
<td>45</td>
<td>12</td>
<td>50 and 62.5</td>
<td>Growth rate and feed efficiency or 50% replacement group were similar to those for control; 62.5% replacement significantly depressed these parameters.</td>
<td>Kumar et al. 2011b</td>
</tr>
<tr>
<td>DJKM</td>
<td>White leg shrimp (Litopenaeus vannamei)</td>
<td>12.5 and 25</td>
<td>35</td>
<td>8</td>
<td>25 and 50</td>
<td>Shrimp on DJKM-based diet grew better than control; nutrient deposition in the body was similar; hypcholesterolaemic effect observed in fish fed DJKM-based diet.</td>
<td>Harter et al. 2011</td>
</tr>
<tr>
<td>Detoxified jatropha protein isolate (DJPI)</td>
<td>Common carp</td>
<td>20 and 30</td>
<td>38</td>
<td>12</td>
<td>50 and 75</td>
<td>Growth performance, nutrient utilization and digestive enzyme activity were similar to those in control, and improved protein utilization in DJPI-fed group. Blood parameters were in the normal range. Also no adverse histopathological changes were observed</td>
<td></td>
</tr>
<tr>
<td>Heated Jatropha platyphylla kernel meal (H-JPKM)</td>
<td>Nile tilapia (Oreoichromis niloticus L.)</td>
<td>20 and 25</td>
<td>36</td>
<td>12</td>
<td>50 and 62.5</td>
<td>No differences in growth rate, feed utilization, oxygen consumption and average metabolic rate among the H-JPKM diets and control.</td>
<td>Makkar et al. 2011, Akinleye et al. 2011</td>
</tr>
</tbody>
</table>

A study was conducted to verify the biochemical, haematological and histological responses of adding DJKM to common carp and rainbow trout diets (Kumar et al. 2010b, d). Blood parameters, such as RBC and WBC counts, hemoglobin and hematocrit concentrations, blood protein (albumin and globulin), blood ions (calcium, phosphorus, potassium and sodium), total bilirubin and total blood urea nitrogen were in the optimum range. There were no histo-

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Conclusions

*Jatropha curcas* is a biofuel plant and its seeds are rich in oil and protein. Jatropha seed cake and kernel meal, a by-product of Jatropha biodiesel manufacture, is rich in protein and can be used in aquafeeds. However, it must be detoxified before incorporation into fish and shrimp diets because of the presence of anti-nutritional and toxic components. Detoxified Jatropha kernel meal can be used as one of the promising fish meal replacers in the diets of common carp, rainbow trout and whiteleg shrimp. It can replace 50 percent of fishmeal protein without sacrificing the growth performance, nutrient utilization and health of fish and shrimp. These studies enlarge the number of plant protein sources that can be used in aquafeeds, and opens new market opportunities for the use of a new feed resource. Additional studies with DJKM-based diets on a larger scale and under commercial pond conditions are warranted.

Notes

1. Laboratory for Ecophysiology, Biochemistry and Toxicology, University of Antwerp, Belgium.
2. Department of Plant Physiology and Ecology, Faculty of Biology, Taras Shevchenko National University of Kiev, Volodymyrs'ka Street 60, 01030 Kiev, Ukraine.
3. Center for Aquaculture Research & Development, St. Xavier's Vocational Training Center, Don Bosco, Bishramganj, Tripura, India.
4. Corresponding author: debtanu08@gmail.com, Mobile: +919856423177
5. Central Institute of Fisheries Education (Deemed University), Mumbai, India
6. College of Fisheries, Central Agricultural University, Lembucherra, Tripura-799210, India

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Australasian Aquaculture Award winners announced

The inaugural Australasian Aquaculture Awards, sponsored by the Global Aquaculture Alliance Best Aquaculture Practices (GAA-BAP) certification program at Australasian Aquaculture 2012, recognized individuals and businesses that apply innovative and sustainable practices that will have lasting impacts on Australasian aquaculture over the next 10 years.

Presented on 2 May by BAP Vice President of Development Peter Redmond, during the “Articulture” event at Australasian Aquaculture Conference in Melbourne, Australia, the awards rewarded aquaculture excellence in several categories.

Tassal Operations Pty. Ltd. won the Aquaculture Production Award. The largest vertically integrated Atlantic Salmon producer in Australia, Tassal provides fish predominantly for the regional market. With sustainability at the core of all operations, it consulted varied stakeholders in preparing its first annual sustainability report – the first released by an Australian aquaculture company.

Tassal’s Environment and Sustainability team is focused on addressing environmental and social issues, and “what we learn we share,” by being, amongst other things, active in the Tasmania Salmon Growers Association. Tassal were awarded an AUD 25,000 grant to develop an e-learning program and mentoring opportunities for students interested in aquaculture as a career and they have a clear strategy for workforce development.

The Fish Oil Replacement in Australian Aquafeed project won the Aquaculture Science Research Award. Project work by Prof. Chris Carter (University of Tasmania), Dr. David Francis (Australian Institute of Marine Science), Dr. Peter Nichols (CSIRO Food Futures Flagship) and Dr. Giovanni

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