

Comparative evaluation of toxic and non-toxic Jatropha genotypes



Harinder Makkar

University of Hohenheim



Variation in seed numbers per fruit from toxic and non-toxic *Jatropha curcas*

| Non-toxic variety | Percentage of fruits with: | | | |
|----------------------|----------------------------|---------|---------|---------|
| | 1 seed | 2 seeds | 3 seeds | 4 seeds |
| Shrub 1 | 12,0 | 26.5 | 55.5 | 6.0 |
| Shrub 2 | 8.0 | 19.1 | 64.9 | 8.1 |
| Shrub 3 | 4.4 | 24.5 | 54.5 | 16.6 |
| Average | 8.1 | 23.4 | 58.3 | 10.2 |
| Toxic-variety | | | | |
| Shrub 1 | 13.7 | 27.5 | 53.6 | 5.2 |
| Shrub 2 | 14.4 | 22.4 | 56.8 | 6.4 |
| Shrub 3 | 15.8 | 27.3 | 45.6 | 11.3 |
| Average | 14.6 | 25.8 | 52.0 | 7.6 |

Variation in physical parameters of seeds and in oil content of seeds and kernels from toxic and non-toxic *Jatropha curcas* (n = 60; 20 from 1 tree)

| Toxic variety | | | | | | | Kernel protein (%) |
|-------------------------|---------------|----------------|-----------------|---------------------|----------------|--------------|--------------------|
| Average of fruits with: | Seed mass (g) | Shell mass (g) | Kernel mass (g) | Shell/Seed Mass (%) | Oil Kernel (%) | Oil Seed (%) | |
| 1 seed | 0,77 | 0,29 | 0,47 | 37,7 | 56,5 | 34,8 | 27.1 |
| 2 seeds | 0,78 | 0,30 | 0,49 | 38,5 | 57,2 | 36,0 | 26.3 |
| 3 seeds | 0,80 | 0,31 | 0,49 | 38,7 | 57,4 | 35,3 | 26.6 |
| 4 seeds | 0,77 | 0,29 | 0,48 | 37,7 | 56,9 | 35,5 | 26.8 |
| Average | 0,78 | 0,30 | 0,48 | 38,0 | 57,0 | 35,4 | 26.7 |
| Non-toxic variety | | | | | | | Kernel protein (%) |
| Average of fruits with: | Seed mass (g) | Shell mass (g) | Kernel mass (g) | Shell/Seed Mass (%) | Oil Kernel (%) | Oil Seed (%) | |
| 1 seed | 0,73 | 0,27 | 0,46 | 37,0 | 55,5 | 35,3 | 28.5 |
| 2 seeds | 0,73 | 0,26 | 0,47 | 35,6 | 57,6 | 37,0 | 26.9 |
| 3 seeds | 0,72 | 0,26 | 0,47 | 36,1 | 57,5 | 37,1 | 26.9 |
| 4 seeds | 0,72 | 0,25 | 0,45 | 34,8 | 56,2 | 36,1 | 26.4 |
| Average | 0,72 | 0,26 | 0,46 | 35,9 | 56,7 | 36,4 | 27.2 |

Composition of seed meal from toxic and non-toxic *Jatropha curcas*

| | Toxic variety | Non-toxic variety |
|-----------------------------|---------------|-------------------|
| Crude protein (%) | 56.4 | 63.8 |
| Lipid (%) | 1.5 | 1.0 |
| Ash (%) | 9.6 | 9.8 |
| Gross energy (MJ/kg) | 18.2 | 18.0 |
| Neutral Detergent Fibre (%) | 9.0 | 9.1 |

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Chemical composition of capsules and shell of *Jatropha curcas*

| Constituents (% DM) | Toxic variety | | Non-toxic variety | |
|-------------------------------------|---------------|-------|-------------------|-------|
| | Capsule husk | Shell | Capsule husk | Shell |
| Crude protein | 6.4* | 4.3 | - | 4.4 |
| Lipid | 0.6* | 0.7 | - | 0.5 |
| Ash | 17.9* | 6.0 | - | 2.8 |
| Neutral detergent fibre (NDF) | 65.9** | 83.9 | - | 89.4 |
| Acid detergent fibre (ADF) | 61.3** | 74.6 | - | 78.3 |
| Acid detergent lignin | 14.4** | 45.1 | - | 45.6 |
| Gross energy (MJ Kg ⁻¹) | 14.5* | 19.3 | - | 19.5 |

* from the hot desert of Egypt

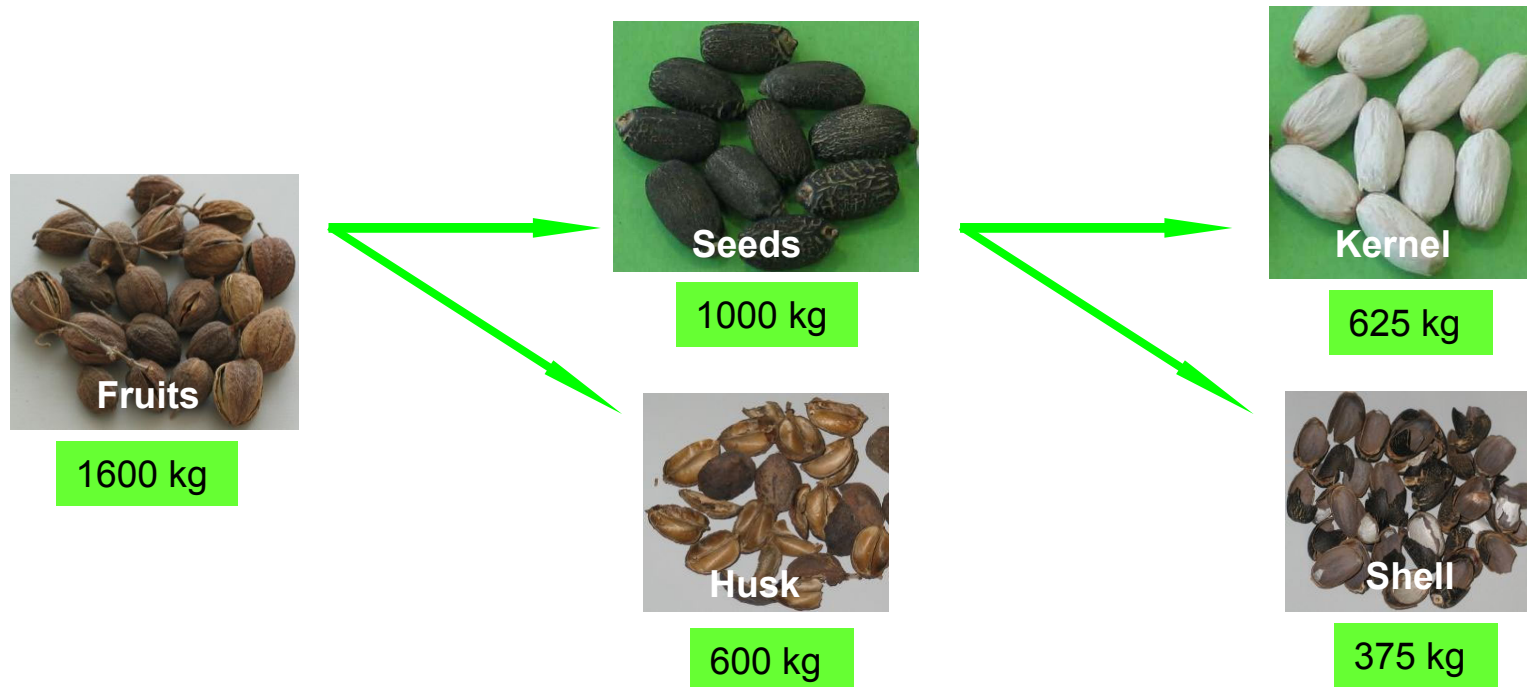
** from Ife, Nigeria

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Potentially useful fractions of Jatropha



Capsule sheath: Mulch, fuel briquettes (14.5 MJ/kg)

Seed shell: high energy content (18MJ/kg), ideal for process energy down the line, production of briquettes for sale

Potential products

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Non-toxic similar to the toxic one except for the phorbol esters

Important antinutrients in Jatropha seed meal (dry matter basis)

| Component | Toxic | Non-toxic |
|---|-------------|-------------------|
| Phorbolesters (mg/g kernel) | 2.79 | ND to 0.11 |
| Total phenols (% tannic acid equivalent) | 0.36 | 0.22 |
| Tannins (% tannic acid equivalent) | 0.04 | 0.02 |
| Phytates (% dry matter) | 9.40 | 8.90 |
| Saponins (% diosgenin equivalent) | 2.60 | 3.40 |
| Trypsin inhibitor (mg trypsin inhibited per g sample) | 21.3 | 26.5 |
| Lectins (1/mg of meal that produced haemagglutination per ml of assay medium) | 102 | 51 |

ND: not detected

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Essential aminoacid composition (g/16gN) of Jatropha seed meal compared to soybean and FAO child ref. protein

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| Aminoacids | Toxic | Non-toxic | Soybean meal | FAO (ref protein) |
|---------------|-------|-----------|--------------|-------------------|
| Methionine | 1.91 | 1.76 | 1.22 | } 2.50 |
| Cystine | 2.24 | 1.58 | 1.70 | |
| Valine | 5.19 | 5.30 | 4.59 | 3.50 |
| Isoleucine | 4.53 | 4.85 | 4.62 | 2.80 |
| Leucine | 6.94 | 7.50 | 7.72 | 6.60 |
| Phenylalanine | 4.34 | 4.89 | 4.84 | |
| Tyrosine | 2.99 | 3.78 | 3.39 | 6.30 |
| Histidine | 3.30 | 3.08 | 2.50 | 1.90 |
| Lysine | 4.28 | 3.40 | 6.08 | 5.80 |
| Arginine | 11.8 | 12.9 | 7.13 | |
| Threonine | 3.96 | 3.59 | 3.76 | 3.40 |
| Tryptophan | 1.31 | - | 1.24 | 1.10 |

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Nutritional parameters of Jatropha seed meals compared to soybean meal

| | Toxic | Non-toxic | Soybean meal |
|--|-------|-----------|--------------|
| Digestible organic matter (%) | 78 | 77.3 | 87.9 |
| Metabolizable energy (MJ kg ⁻¹ DM) | 10.9 | 10.7 | 13.3 |
| 24 h in vitro rumen degradable nitrogen (% of total N) | 43.3 | 28.9 | 80.9 |

- ❖ The current plantation efforts exclusively use the toxic provenance
 - ❖ Higher productivity outside Mexico
 - ❖ Higher tolerance to diseases

The seed cake from the toxic *Jatropha*– current uses

- Bio fertilizer cum bio pesticide
 - Contains 5.7–6.5% N, 2.6–3.0% P₂O₅, 0.9–1.0% K₂O, 0.6–0.7% CaO and 1.3–1.4% MgO
 - The phorbol esters contained acts as a pesticide against harmful soil organisms
 - Literature suggests that the phorbol esters are completely destroyed after 6 days – validation required
 - The limited quantity of the seed cake produced currently enjoys high demand for this purpose in some Indian states
- As a substrate for production of biogas
- Use as direct fuel in power generators

The seed kernel meal – potential as animal feed ingredient

Average gross chemical composition of Jatropha kernel meal

| Crude Protein % | Lipid % | Ash % | Gross energy (MJ/kg) | Neutral detergent fibre % |
|-----------------|---------|-------|----------------------|---------------------------|
| 60-63 | < 1.0 | 10 | 18.0 | 9 |

- Every kilo of oil extracted yields about
 - 0.75 kilo of seed meal if kernels are solvent extracted
- Soybean meal with 45% crude protein content has an international market price 300US\$/ton for use as animal feed
- Based on crude protein content the Jatropha meal could have a price to the order of 430 US\$/ton if detoxified

The seed meal from the toxic Jatropha contains a variety of antinutrients and one toxic substance – the phorbol esters: it needs to be detoxified before use as animal feed ingredient

Jatropha – seed cake

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Raw meal of the non-toxic *Jatropha* not suitable as such

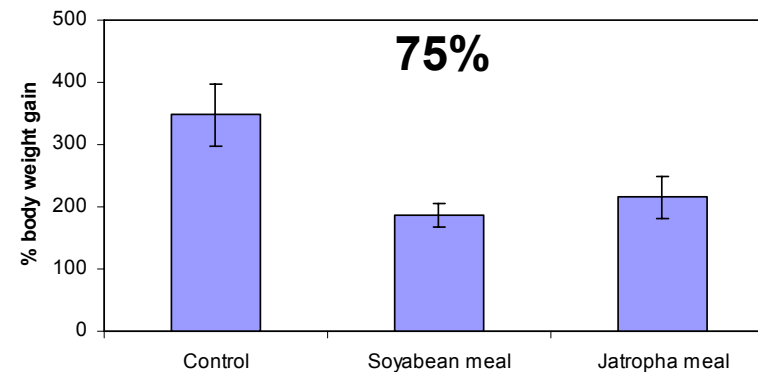
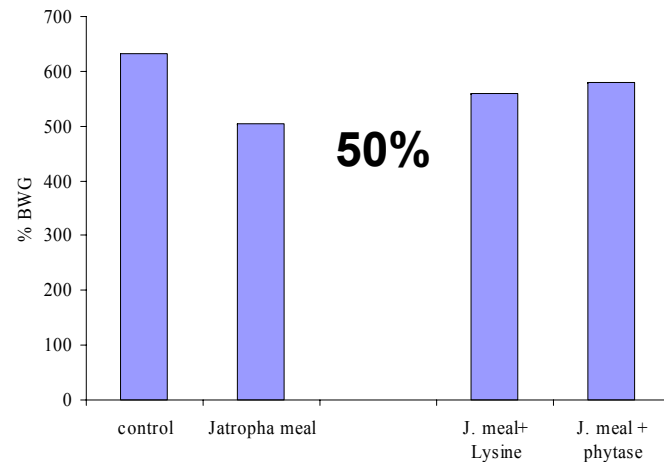
- Lower growth noticed in fish and rats
- Chemical and physical processing required to remove the secondary compounds (and increase protein digestibility?)

Treatments devised

- moist heating at 120°C helped remove trypsin inhibitors and lectins
- addition of microbial phytase (500 FTU) resulted in mitigation of adverse effects of phytate

The potential of seed kernel meal as fish feed ingredient established using treated meal from the non-toxic provenance

Percentage body weight gain of a common culture fish (carp) fed experimental diets containing 50 or 75% of protein supply from Jatropha meal or soybean meal for 8 weeks



The threshold level at which phorbol esters caused adverse effects was 15 ppm (15 µg/g) in the diet

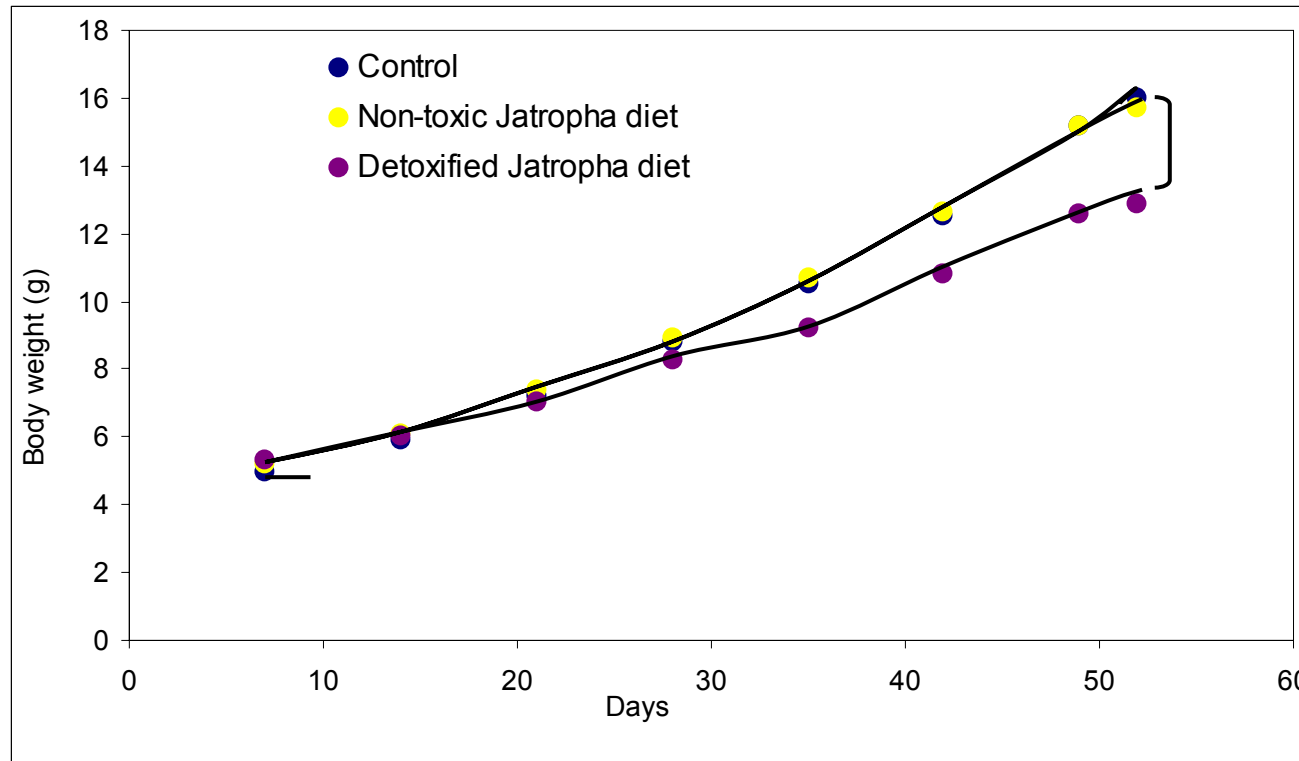
Even rumen bacteria were unable to break down phorbol esters in the seed meal

Phorbol ester (PE) content of residues from Jatropha seed cake or meal (with and without shell) after 24 h in buffered rumen liquor

| Sample | PE content (mg/g) before incubation | PE content (mg/g) after incubation |
|--|-------------------------------------|------------------------------------|
| Jatropha meal (defatted) | 1.67 ± 00 | 1.69 ± 0.08 |
| Jatropha seed cake with shell and oil residues | 0.63 ± 00 | 0.55 ± 0.06 |
| Jatropha seed cake with shell, defatted | 0.58 ± 00 | 0.40 ± 0.08 |

Hence the meal without removal of phorbol esters cannot be used as feed ingredient for ruminants

Detoxification of seed meal successfully achieved at laboratory scale



The detoxification method is scalable and can be integrated with oil extraction

Validation of upscaling and nutritional quality through long term field tests required

Body weight development of common carp fed diets containing 75% Jatropha meal compared to control

Jatropha – seed cake

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Some of our ongoing studies

- Jatropha toxins in the biodiesel production chain
- Distribution of phorbol esters in different parts of Jatropha plant
- Preparation and use of Jatropha protein concentrate
- Long-term feeding studies using detoxified seed meal
- Upscaling of the Jatropha seed meal detoxification process
- Development of efficient de-shelling technology
- Optimization of screw press technology for extraction of oil from kernels and kernels containing different amounts of shells
- Development of a cooking stove for use with Jatropha oil
- Development of small scale combustion systems (furnace) for using shells as energy source
- Economic evaluation of the detoxification process, and its accounting in the overall economic assessment of *Jatropha*-based small and large scale oil production systems
- Socio-economic evaluation of Jatropha cultivation and use

Future Research Needs

SHORT TERM

- Generation of value-added products in the process of biodiesel production from Jatropha oil, in particular detoxification of seed meal and isolation of phorbol esters
- Evaluation of existing genotypes (both toxic and non-toxic) under different environmental conditions and selection of genotypes for different conditions (focus: degraded lands)
- Optimization of agronomic practices (at least 1 ton oil/ha/year)
- Optimization of mechanical harvesting of Jatropha seeds
- Optimization of tissue-culture procedure and establishment of protocols for genetic transformation

Future Research Needs

MEDIUM TO LONG TERM

- Genetic improvement of Jatropha through conventional, mutation, and/or molecular breeding
 - Cold/Frost resistance
 - High oil yield and change of fatty acid composition
 - Early maturity and seed productivity
 - High efficiency of water and nitrogen use
- Fate of Jatropha toxins in the biodiesel production chain and in the environment and their impact on human health and environment
- Integration of Jatropha with leguminous food-feed crops and its socio-economic impact

Future Research Needs

- Development of criteria for certification of seeds
- Evaluation of sustainability of Jatropha as an energy source (life cycle analysis)
- Models for quantification of the tradable emission credits, both through sequestration of CO₂ in plant biomass and through the use of the CO₂ neutral bio-diesel produced
- Socio-economic analysis of Jatropha cultivation and use

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Prof. Dr. Harinder Makkar

Project Leader: BMBF-MOST Jatropha Project

Institute for Animal Production in the Tropics and Subtropics (480b)

University of Hohenheim, Stuttgart

E-mail: makkar@uni-hohenheim.de

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