Comparative evaluation of *Jatropha curcas* L. seed meals obtained by different methods of defatting on toxic, antinutritional and nutritive factors

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Abstract Different methods of defatting have a great impact on toxic, antinutritional and nutritive factors in the oilseed meals. In order to find the most suitable methods of defatting for *Jatropha curcas* seed meals, the *Jatropha curcas* L. seed meals, defatted by Soxhlet extraction and screw-press were characterized for their toxic, anti-nutritional and nutrient factors in this study. The toxins (phorbolsters, 3.1 and 2.9 mg/g) and some anti-nutritional factors (saponins, 2.9 and 2.6%; phytates, 11.1 and 11.6%) in meals obtained by the two defatting methods were present at high concentrations. However, the trypsin inhibitors activity (TIA) and lectin (2.7 mg/g and 1.5 mg/ml) in the screw-pressed meal were significantly lower, due to the high temperature (120 °C) used in this defatting process. From nutritional side, the values of crude protein (CP), buffer-soluble nitrogen, non-protein nitrogen, pepsin insoluble nitrogen, in vitro protein digestibility (IVPD), as well as essential amino acid index (EAAI), biological value (BV), nutritional index (NI) and protein-digestibility-corrected amino acid score (PDCAAS) of the meal obtained by Soxhlet extraction were better than the screw-pressed meal. However, taking practical application into account, from detoxification side, screw-pressed meal is better for detoxification.

Keywords *Jatropha curcas* · Nutrients · Toxin · Anti-nutrients

Introduction

With the development of world economy and rapid growth of population, there is an increasing in demand for protein

consumption. However, animal proteins are expensive and not available, especially in the developing countries. Therefore, the search for alternatives, cheap and good-quality protein sources has become particularly important.

Jatropha curcas is a small tree or shrub distributed in the subtropical and tropical regions of the world. It is stress tolerant, drought resistant, grows in semi-arid, marginal lands, as well as does not compete with conventional food or feed crops for land and water, which makes it as an ideal choice to make use of vast presently underutilized land resources (Heller 1996). In tropical countries such as India and China, it is well-known as an oilseed, a live hedge and used for prevention of soil erosion (Ye et al. 2009).

According to the statistics obtained from the International *Jatropha curcas* Organization, in 2017 there will be around 330000 km² of land cultivated worldwide producing 160 Mt of seeds and the total project can annually produce 53Mt of *Jatropha curcas* seed meal, which contains 50–62% protein (Makkar and Becker 2009; de Oliveira et al. 2009; Sirisomboon et al. 2007; Siang 2009). This indicates huge protein source supply in future from the field of the *Jatropha curcas* based biodiesel industry.

Until now, studies of *Jatropha curcas* seed have been focused on how to make the seed oil convert into biodiesel (Sirisomboon et al. 2007; Berchmans and Hirata 2008), how to isolate and purify the biological toxin of phorbolsters (PEs) from seed (Gaudani et al. 2009; Pramanik 2003) and how to produce activated carbon from the seed shell (Makkar and Becker 2009). But rational utilization of this feedstocks and taking advantage of protein present in *Jatropha curcas* seed could represent significant progress in developing countries. In order to obtain good-quality protein sources, the defatting method is the first key step. Because different defatting methods have a great impact on the residue toxins and the nutritional value in the oilseed meals. However, choosing what kind of defatting method for *Jatropha curcas* is still developed.

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For this aim, the objective of this study was to demonstrate and evaluate the effect of defatting methods on the toxic and anti-nutritional factors of *Jatropha curcas* L. seed meal. It is hoped that this information obtained from our paper will be helpful for developing alternatives, cheap and good-quality protein sources and possible extended human consumption from toxic, non-edible waste.

Materials and methods

Materials

Jatropha curcas L. seeds were collected from wild trees (mature, approx. age 5 years) existing in places around Si Chuan Province, China. These were transported to the lab and stored in airtight bags in dark, cool and dry place until further use. Phorbol-12-myristate-13-acetate, standard phytic acid, diosgenin, and tannic acid were obtained from Sigma Chemical Co. (St. Louis, MO). All other chemical solvents used were of analytical grade and purchased from sinopharm chemical reagent factory (Co., Ltd, P. R. China).

Preparation of samples

Jatropha curcas L. seeds were dehulled and ground. And the dehulled and ground seeds were named as ground kernel.

Soxhlet extracted meal (SEM) The ground kernel was defatted by Soxhlet extraction using petroleum ether at 50 °C for 8 h, and then air-dried at room temperature and stored in a separate plastic container at 4 °C until analysis.

Screw-pressed meal (SPM) The ground kernel was defatted using a screw-press (HD-80, Jinan Ward Machinery Factory, Jinan, China) at 120 °C, and then air-dried at room temperature and stored in a separate plastic container at 4 °C until analysis.

Proximate composition analysis

Moisture content was determined by drying samples to constant weight at 105 °C. Crude protein content was determined by Kjeldahl analysis. Lipid content was determined by Soxhlet extraction analysis. Ash content was determined by burning samples to constant weight at 550 °C. For determination of neutral detergent fiber (NDF), samples are boiled in a solution containing sodium lauryl sulphate for removing the detergent extracts lipids, sugars, organic acids and other water soluble components as well as pectin, non-protein nitrogen compounds. NDF % is the weight of the residue expressed as a percentage of the original sample.

For determination of acid detergent fiber (ADF), samples are boiled in a solution containing an acidified quaternary detergent for removing the cell soluble, hemicellulose and soluble minerals leaving a residue of cellulose, lignin, and heat damaged protein and a portion of cell wall protein and minerals. ADF is determined gravimetrically as the residue remaining after extraction (Helrich 1990). Gross energy (GE) was estimated by an adiabatic bomb calorimeter (IKA C7000) using benzoic acid as a standard (Sehgal et al. 2011).

Determination of toxin and antinutritional components

Determination of total phenolics

Total phenolics were extracted and determined by spectrophotometric methods described by Loganayaki (Loganayaki et al. 2011).

Determination of trypsin inhibitor activity (TIA), phytic acid and saponin contents

TIA was determined according to Liu (Liu and Markakis 1989) with some modifications. The sample was suspended in 0.01 M NaOH and stirred. After centrifuged 5 min at 14 000 g, 0.1 ml of the alkaline extract was mixed with 1.6 ml Tris-HCl (0.05 M, pH 8.2) containing 0.02 M CaCl₂, with 0.1 ml of trypsin 2 solution plus 0.1 ml of *N*α-benzoyl-L-arginine *p*-nitroanilide solution (10 mg/ml in dimethyl sulfoxide). The mixture was incubated for 45 min at 37 °C and then 0.2 ml 30% acetic acid solution was added. The absorbance was measured at 410 nm. The amount of TIA was calculated from a calibration curve using soybean trypsin inhibitor.

The phytic acid content was determined by a colorimetric procedure described by Vaintraub (Vaintraub and Lapteva 1988). Suitable aliquots were diluted with distilled water to make 3 ml and then used for the assay. Results are expressed as g /100 g phytic acid, using standard phytic acid. Total saponin content was determined using a spectrophotometric method, described by Hiai (Hiai et al. 1976). The concentration of saponins was read off from a standard curve of different concentrations of diosgenin in 80% aqueous methanol and expressed as diosgenin equivalents.

Determination of phytohemagglutinating activity

The lectin content was conducted by hemagglutination assay (Gordon and Marquardt 1974) in round-bottomed wells of microtitre plates using 1% (v/v) trypsinised cattle blood erythrocytes (Wuxi disease prevention and control center, Wuxi, China) suspension in phosphate buffered saline (PBS) (10 mM, pH 7.0). The hemagglutination activity was defined as the minimum amount of the kernel material (in mg per ml of the assay medium), which produced agglutination. The minimum

amount was the material per ml of the assay medium in the highest dilution that was positive for agglutination. One hemagglutinating unit (HU) was defined as the least amount of material per ml in the last dilution giving positive agglutination.

Determination of phorbolsters (PEs) by HPLC

About 2 g of each sample were weighed and subsequently extracted with methanol as described by Adolf (Adolf et al. 1984). The PEs content was determined by HPLC (Agilent Technologies, Santa Clara, CA). The analytical column was a reverse phase C18 (LiChrospher100, endcapped 5 μ m) 250 $\times$ 4 mm I.D. column protected with a guard column containing the same material as the main column according to the procedure outlined by Makkar, Aderibigbe et al. (Makkar et al. 1998a). Two mobile phases were used. A is 0.175% phosphoric acid solution and B is acetonitrile. The gradient elution was: 0–20 min (A, 40–25%; B, 60–75%), 20–30 min (A, 25–0%; B, 60–75%), 30–40 min (A, 0–0%; B, 100–100%). The separation was performed at room temperature (22 $^{\circ}$ C) and the flow rate was 1.3 ml/min. The four PE peaks appearing between 26 and 31 min were identified at 280 nm. The results were expressed as equivalent to a standard (phorbol-12-myristate-13-acetate), which appeared between 34 and 36 min.

Nutritional quality evaluation

Determination of in vitro protein digestibility (IVPD)

The IVPD of samples were measured using a multi-enzyme technique and protein digestibility of the sample was calculated using the following regression equation: $Y = 234.84 - 22.56(X)$, where $Y = \%$ protein digestibility and $X = \text{pH}$ of protein suspension after 20 min of digestion with the enzyme solution (Satterlee et al. 1979).

Determination of buffer-soluble nitrogen, non-protein nitrogen and pepsin insoluble nitrogen

Samples (5 g) were homogenized in 100 ml of phosphate buffer (0.05 M, pH 7.0) using an ultra-turrax at 10 000 $\times$ g for 20 min (4 $\times$ 5 min) and then filtered. 10 ml of the filtrate was mixed with 10 ml of 20% trichloroacetic acid (TCA), refrigerated overnight and centrifuged (3000 $\times$ g, 10 min) to collect the supernatant. Aliquots (10 ml) of the supernatant were analyzed for non-protein nitrogen using the Kjeldahl analysis. Total soluble nitrogen was determined (using Kjeldahl analysis) using 10 ml aliquots of the filtrate after homogenization. Results were expressed as g CP per 100 g dry matter (DM). The conversion factor we used was 6.25. Pepsin insoluble nitrogen was determined as described in Makkar and Becker (Makkar and Becker 1997).

Amino acid analysis

The amino acid composition was determined using an amino acid analyzer with a Hypersil ODS C18 (4 $\times$ 125 mm) column (Agilent Technologies, Santa Clara, CA) after hydrolyzing the samples with 6 M HCl at 100 $^{\circ}$ C for 22 h (Ogunbusola et al. 2010). Two mobile phases were used here. A is 500 mL 1.6% sodium acetate solution mixed with 90 μ L triethylamine, adjust pH to 7.2 with 2% acetic acid, then 2.9 mL tetrahydrofuran was added. B is 0.8% sodium acetate solution (adjust pH to 7.2 with 2% acetic acid), then added 200 mL acetonitrile and 200 mL methanol.

Determination of chemical score

Chemical score means amino acid score and was calculated using the following formula (Makkar et al. 1998b):

$$\frac{\text{g essential amino acid in test protein}}{\text{g total essential amino acid in test protein}} \times \frac{\text{g total essential amino acid in egg protein}}{\text{g essential amino acid in egg protein}}$$

Determination of essential amino acid index (EAAI) and biological value (BV)

EAAI was calculated according to the method of Oser (Oser 1951) and BV was calculated by using the formula of Ogunbusola (Ogunbusola et al. 2010).

$$BV = 1.09(EAAI) - 11.7$$

Determination of nutritional index (NI)

NI was calculated using formula of Obulesu M (Obulesu 2006).

$$NI = \frac{EAAI \times \% \text{ protein}}{100}$$

Determination of protein digestibility corrected amino acid score (PDCAAS)

PDCAAS was calculated using the following formula (Schaafsma 2005).

$$PDCAAS = \frac{\text{Amount of amino acid in test protein}}{\text{Amount of amino acid in reference protein}} \times \text{Digestibility of test protein}$$

Statistical analysis

All the experiments except the compositions of amino acid were conducted at least three times and the results were expressed as means±standard deviations. Analysis of variance was performed and means comparisons were carried out by Fisher's protected least significant difference ($p<0.05$). Data were analyzed by using statistical software (SPSS, 13.0).

Results and discussion

Proximate composition

The proximate compositions of meals (SPM, SEM and soybean meal (SM)) are shown in Table 1. The CP content of SEM was 58.6%, which was higher than SPM and SM (45.3% and 45.7%). The ash contents (10.3% and 10.4%) in SPM and SEM in our report were higher than that in SM (6.4%), while the contents of NDF (9.1% and 9.2%) and ADF (7.9% and 7.8%) were lower than that in SM (17.2% NDF and 12.2% ADF) (Makkar et al. 1998a), which were similar to the previous reported results (Aderibigbe et al. 1997). NDF and ADF are important indicators of nutritional value for feed. The lower the content of NDF is, the higher degree of NDF can be used. ADF is difficult for animals to digest, and the higher content will lead to the lower digestibility. The GE (48.0 MJ/kg) in SPM was higher than that in SEM (19.0 MJ/kg) and SM (19.4 MJ/kg), due to higher content of oil in SEM (comparison of 16.1% and 2.5%, 1.8%) (Aderibigbe et al. 1997). The requirement of a variety of nutrients is based on GE, which is the most important nutrient factor in the feed and also is the biggest gap in

resources. The above results indicated that SEM and SPM contained a very good nutrient profile, comparable to SM.

Toxin and anti-nutritional components

Nutritional value of most oilseed meal (cake) is limited by the presence of numerous naturally compounds which interfere with nutrient digestion and absorption. The *Jatropha curcas* L. seed meal is no exception. The quantities of different toxic and anti-nutritional components detected in SPM, SEM and SM were presented in Table 2. PEs is known to activate protein kinase C, which can activate a cascade of signal transduction reactions causing tumor promotion. The contents of PEs in SPM and SEM were very high (3.1 mg/g and 2.9 mg/g). Abud-aguye et al. (Abdu-Aguye et al. 1986) had reported that feeding mice with PEs as low as 1 mg/kg of body weight caused death. It is not clear whether the high levels of PEs in *Jatropha curcas* L. seeds from SiChuan province of China are caused by genetic or environmental factors.

TIA and Lectin generally considered being toxic factors in *Jatropha curcas* L. seeds. TIA can combine with trypsin and chymotrypsin in small intestinal fluid to produce an inactive complex, deplete and degrade the trypsin, which results in declining the capacity of protein digestion, absorption and utilization. At the same time, trypsin inhibitors combined with trypsin, reducing the number of trypsin in small intestinal fluid (Singh 1988). Lectin is a major component formed in long-term evolution of plants, which can resist pests and animals and have strong anti-nutritional effect to animals. The key anti-nutritional effect of Lectin is specifically binding to small intestine. This specifically bind results in: (i) the normal structure of the small intestine is damaged, which can decrease the absorption and utilization of nutrients, inhibit intestinal cell growth and differentiation and lead to the emergence of pathological diarrhea; (ii) Lectin enter into the circulatory system followed by destruction of the digestive organs, leading to systemic reactions (Singh 1988). The TIA and lectin were significantly lower (2.7 mg/g and 1.5 mg/ml) in the SPM, due to the high temperature (120 °C) used in this defatting process, and similar to that in the SM. This indicated that the process of screw-press had significant ($p<0.05$) effect on TIA and lectin.

The content of phytate in SPM and SEM were 11.1% and 11.6%, which were higher than that in the SM (1.5%). The high level of phytate present in *Jatropha curcas* L. seed meal might decrease the bioavailability of minerals (especially Ca^{2+} and Fe^{2+}). Phytates have also been implicated in decreasing protein digestibility by forming complexes and also by interacting with enzymes such as trypsin and pepsin (Aregheore et al. 1998). The values obtained in this study were very close to those reported by Singh et al. (Singh 1988).

Table 1 Effect of defatting method on proximate compositions (%) and gross energy (MJ/Kg)

	Samples		
	SEM	SPM	Soybean meal (SM) (Vasconcelos et al. 1997)
Crude protein	58.6±0.8 ^a	45.3±1.2 ^b	45.7
Lipid	2.5±0.1 ^b	16.1±0.3 ^a	1.8
Crude ash	10.3±0.2 ^a	10.4±0.5 ^a	6.4
Crude fiber	5.00±0.6 ^a	5.5±0.3 ^a	5.01
Neutral detergent fiber	9.1±0.2 ^a	9.2±0.4 ^a	17.2
Acid detergent fiber	7.9±0.1 ^a	7.8±0.6 ^a	12.2
Gross energy	19.0±0.8 ^b	48.0±1.5 ^a	19.4

All values are means±standard deviation ($n=3$). Values followed by different letters are significant difference ($p<0.05$)

SEM soxhelt extracted meal; SPM screw-pressed meal; SM soybean meal

Table 2 Effect of defatting method on toxin and antinutrients

	Samples			
	SEM	SPM	Non-toxic meal (Makkar and Becker 2009)	SM (Vasconcelos et al. 1997)
Total phorbolsters ¹ (mg/g)	3.1±0.2 ^a	2.9±0.2 ^a	ND	ND
Trypsin inhibitor activity (mg/g)	27.3±0.1 ^a	2.7±0 ^b	26.54	3.9
Lectin activity (mg/g) ²	38.8±1.2 ^a	1.5±0.1 ^b	51–100	0.32
Saponins (g/100 g) ³	2.9±0.1 ^a	2.6±0.1 ^b	3.40	4.7
Total phenolics (g/100 g) ⁴	0.36±0.01 ^a	0.31±0.01 ^a	0.22	NA
Phytic acid (%)	11.1±0.2 ^a	11.6±0.6 ^a	8.9	1.5

All values are means±standard deviation ($n=3$). Values followed by different letters are significant difference ($p<0.05$)

SEM soxhelt extracted meal; SPM screw-pressed meal; SM soybean meal

ND no detectable; NA no analysis

¹ Equivalent to phorbol-12-myristate 13-acetate

² Minimum amount of the sample required to show the agglutination in 1 ml of final assay medium

³ Diosgenin equivalents

⁴ Tannic acid equivalents

Only negligible amounts of total phenols were found in SPM and SEM (0.31%–0.36%, results shown in Table 2).

Saponins from some plants produce adverse effects whereas those from others confer beneficial effects. Reddy (Reddy and Pierson 1994) had reported that saponins are not destroyed by cooking. The contents of saponin in SPM and SEM were 2.9 and 2.6 g/100 g respectively, which were lower than that reported for SM (4.7 g/100 g; Makkar et al. 1998a).

In this study, we found the *Jatropha curcas* L. seeds from China contained high levels of anti-nutritional factors (such as TIA, lectin and phytate) and high level of toxin (PEs), which are likely to provide resistance to the pest and helpful for surviving and yielding seeds under adverse conditions. These results showed that different defatting methods have different effects on the toxic and anti-nutritional factors, especially heat-labile toxic, such as TIA and lectin. Taking practical application into account, screw-pressed meal, which is low in toxin, especially in TIA and lectin, is better for detoxification.

Nutritional quality evaluation

Table 3 showed the content of the buffer-soluble nitrogen, non-protein nitrogen, pepsin insoluble nitrogen and IVPD in defatted meals, which were important to evaluate if the meals can be utilized efficiently by animals. The buffer-soluble nitrogen and non-protein nitrogen were 7.2 and 6.0 CP/100 g, 4.3 and 9.5 g CP/100 g dry matter respectively. The data of buffer-soluble nitrogen and non-protein nitrogen in SEM were lower than that in SPM. Because the SPM suffered from high temperature, which may cause its protein denatured. But only 4.3%~9.5% of the total nitrogen in

SPM and SEM was non-protein nitrogen, suggesting the presence of a high level 90% of true protein, comparable to that in jojoba (21–30%), soybean (2.9–7.8%), sunflower (5.0%) and rapeseed (6.9%)(Wolf et al. 1994), respectively. The values of IVPD in the SEM and SPM were 79.7% and 72.8% respectively, which were lower than those reported in soybean (80.6%), faba beans (83.1%) and lentils (82.5%) (Elvin-Lewis 1988). This low digestibility may be that because the high content of TIA, lectin and phytate present in the *Jatropha curcas* meals and the protein had been denatured.

The amino acid composition in SPM, SEM and SM was shown in Table 4. In general, glutamic acid, arginine, aspartic acid and leucine were all abundant, similar to conventional oilseed proteins. In addition, a comparison between the amino acid composition of

Table 3 Effect of defatting method on buffer-soluble nitrogen, non-protein nitrogen, pepsin insoluble nitrogen and in vitro protein digestibilities (g CP/100 g DM)

	Samples		
	SEM	SPM	Non-toxic meal (Makkar and Becker 2009)
In vitro protein digestibility	79.7±0.3 ^a	72.8±1.2 ^b	80.6
Pepsin insoluble nitrogen	4.2±0.1 ^b	9.1±0 ^a	3.5
Buffer-soluble nitrogen	7.2±0.6 ^a	6.0±0.7 ^b	7.9
No-protein nitrogen	4.3±0 ^b	9.5±1.1 ^a	5.0

All values are means±standard deviation ($n=3$). Values followed by different letters are significant difference ($p<0.05$)

SEM soxhelt extracted meal; SPM screw-pressed meal

SPM, SEM and SM (Table 4) revealed an almost similar pattern for all essential amino acids except lysine and sulphur-amino acids. The levels of essential amino acids in SEM, except lysine, cysteine and phenylalanine, were higher than that of the FAO/WHO reference protein for a five year old child on a dry matter basis. This data indicates that S-S bonds would be absent in the structure of *Jatropha curcas* meal proteins.

Results for nutritional indices of the SPM, SEM and SM were given in Table 5. Evaluation of the nutritional value of protein must be based on the content and composition of amino acids, in particular the content and composition ratio of essential amino acids, which is an important factor to determine the nutritional value of protein. The values of nutritional indices of SEM were higher than that of SPM, but lower that of SM. Data showed that different defatting ways can affect the nutritional quality of protein.

Table 4 Effect of defatting method on amino acid compositions (g/100 g of protein)

Amino acid	Samples			
	SEM	SPM	SM (Vasconcelos et al. 1997)	FAO/WHO (ref.protein) ^a
Essential				
Cystine	1.01	0.57	1.64	2.50 ^b
Methionine	1.11	0.82	1.39	
Valine	4.98	5.61	4.72	3.50
Isoleucine	4.45	3.72	3.98	2.80
Leucine	6.97	8.94	7.61	6.60
Arginine	11.34	10.66	7.47	
Phenylalanine	4.52	5.10	5.76	6.30 ^c
Histidine	2.42	2.38	3.03	1.90
Lysine	3.48	2.99	6.84	5.80
threonine	3.62	2.71	3.85	3.40
Tyrosine	2.57	2.80	4.94	
Non-essential				
Aspartic acid	8.75	9.38	11.9	
Proline	5.94	5.75	5.10	
Serine	4.73	5.19	4.15	
Glutamic acid	16.07	11.39	18.6	
Glycine	4.42	5.01	3.93	
Alanine	4.76	6.16	4.19	

SEM soxhelt extracted meal; SPM screw-pressed meal; SM soybean meal

^a Reference pattern suggested for pro-school children (2–5 years old)

^b Methionine plus cystine

^c Phenylalanine plus Tyrosine

Table 5 Effect of defatting method on nutritional indices

	Samples		
	SEM	SPM	SM (Vasconcelos et al. 1997)
Essential amino acid index	72.4	68.0	80.87
Biological value	67.2	62.4	76.45
Nutritional index	42.5	30.8	34.96
Protein digestibility corrected amino acid score	0.55	0.51	0.68

SEM soxhelt extracted meal; SPM screw-pressed meal; SM soybean meal

Conclusion

Lack of dietary protein is often a limiting factor and the quality and quantity of protein in grain and other oilseed meal is inadequate. As can be seen from the results, it could be concluded that although the IVPD (79.7% and 72.8%) in *Jatropha curcas* meals were low, the contents of crude protein (58.6% and 45.3%), NDF (9.1% and 9.2%) and ADF (7.9% and 7.8%) were high. The pepsin insoluble nitrogen and buffer soluble nitrogen in the defatted meals were 4.2%, 9.1% and 7.2%, 6.0% of the total nitrogen, respectively. And about 90% of the protein was true protein. The nutritional indices (EAAI, BV, NI, and PDCAAS) were high. Therefore, full utilization of *Jatropha curcas* L. seed meal can not only turn waste into treasure, and to some extent, but also can alleviate the tight supply of dietary protein at the current status, which is important to open another door to feed resources.

Different defatting methods have different effects on the toxic and anti-nutritional factors. The TIA and lectin (2.7 mg/g and 1.5 mg/ml) were significantly lower in the screw-pressed meal, due to the high temperature (120 °C) used in this defatting process. Although different defatting method can inactive some anti-nutritional factors, however, the defatted meal also contained significant levels of toxin (PEs), detoxification ways is need to employ in removal of these factors. From nutritional side, the Soxhlet extracted meal was better than the screw-pressed meal. However, taking practical application into account, from detoxification side, screw-pressed meal is better for detoxification. The detoxification of *Jatropha curcas* meal is in progress in our laboratory.

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