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Original article

Evaluation of nutritional and antinutritional composition of meals of *Jatropha curcas* seeds/kernels obtained from four different agro-climatic areas of Ghana

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ABSTRACT

The research was conducted to evaluate the nutritional and antinutritional composition of defatted seeds and kernels of *Jatropha curcas* obtained from four different agro-climatic areas of Ghana with the aim of identifying an alternative source of plant protein that can be developed to supplement soyabean meal/fish meal. Jatropha curcas seeds were obtained from four different agro-climatic areas of Ghana: (1. Nyankpala, Northern Region, 2. Dambai, Volta Region, 3. WA, Upper West Region, 4. Techiman, Brong Ahafo Region). The seeds were processed in to seed meals and kernel meals for each Jatropha seed group. Large amount/percentage (77-79 %) of seed cake was produced from the mechanical defatted seeds. The seed meal samples differed in chemical composition. The dry matter content of the seed meal samples (1A, 2A, 3A, 4A) was between (92.27-94.37 %). The crude protein content of seed meals ranged between (27.33 - 29.61 %). The crude fibre was very high in the seed meal (21.46 - 24.72 %). Lipid, ash, and carbohydrates contents in seed meals were between (16.52 – 19.56 %), (7.15 – 9.01 %), and (12.16 – 19.35 %) respectively. on the other hand the kernel meals were very rich in crude protein (63.39 – 64.35 %) that did not differ significantly between the kernel meal samples (1B, 2B, 3B, 4B). Crude fibre was low in Jatropha kernel meals (5.55 – 8.25 %) and total ash was between (8.20 – 9.78 %). *Jatropha curcas* meals contained good amounts of phosphorus, potassium, calcium, and magnesium. Total nitrogen was also very high in the kernel meals (10.14 -10.30 %).

Jatropha seed/kernel meals contained crude phorbol esters (CPE), phytic acid, and tannins. The concentrations of these antinutrients in the seed meals were CPE (4.87-6.07 mg/g), phytic acid (8.11-9.82 % dry matter), and tannins (0.72-0.93 % tannic acid equivalent). The concentration of phorbol esters reduced by 39 -49 % in the kernel meals and ranged between (2.60 – 3.70 %). The phytic acid content in kernel meals was (6.56 – 7.46 %) while negligible amount of tannins were present in the kernel meals in the range of (0.03-0.07 %). The processing method (removal of shells) reduced tannins in kernel meals by 92-94 %). The kernel meals are therefore better source of protein for animals if detoxified completely.

1. Introduction

Generally, fish meal (FM) is utilized in poultry and fish feeds as the main source of dietary protein. In recent years, the increasing cost, decreasing availability in the market and poor quality of FM as well as the rapid expansion of poultry and aquaculture industries have stimulated several studies on its partial or complete substitution with alternative protein sources (Kaushik *et al*., 1995; Fournier *et al*., 2004; SOFIA, 2007). Protein ingredients to substitute for FM, either partially or completely include terrestrial plant meals and animal by-products readily available on the world markets (Samocha *et al*., 2004). Soybean meal (SBM) is currently the most commonly used plant protein source in livestock and fish feeds (Yue and Zhou, 2009). The over-dependence has caused the price of SBM to increase sharply (Azaza *et al*., 2009). The high cost of protein sources, their restricted availability and the unpredictability of their markets, increase the need for utilization of other inexpensive plant protein source which would be beneficial in reducing feed cost (Yue and Zhou, 2009). In this regard, Jatropha has been paid a special attention as various parts/products of the plant hold potential for use as animal feed and inclusion in medicinal preparations (Goel *et al*., 2007).

Jatropha curcas (L.) also known as 'Physic nut' is a multipurpose drought- resistant small industrial tree or shrub, widespread throughout the arid and semi-arid tropical and subtropical regions of the world (Heller, 1996; Wiesenhütter, 2003). The plant can yield up to 4 tons seed per year from one hectare of plantation, which can produce approximately 1 ton of kernel meal rich in protein (Makkar and Becker, 1997b). The seeds of the plant have been extensively investigated as a source of oil. The seed kernel contains about 60% oil that can be converted into biodiesel of high quality upon transesterification and used as a substitute for diesel fuel (Makkar *et al*., 2007a) as well as fuel for cooking and lighting (Ishii *et al*., 1987; Munch and Kiefer, 1989; Ouedraogo *et al*., 1991; Lutz, 1992). The Jatropha seed oil contains 21 % and 79 % saturated fatty acids and unsaturated fatty acids respectively (Raja *et al*., 2011). The seed cake left as a by-product after oil extraction from whole seed by screw press has approximately, 22 % crude protein and high content (500g/kg) indigestible shells (Makkar and Becker, 2009b). However, Jatropha kernel meal which is obtained after the kernel (seed without shells) is defatted has a high crude protein content of between 56.1- 64.4 % of which about 91 % is true protein (Makkar *et al*., 1998). The percentage of essential amino acids and mineral contents is comparable to those of other seed and press cakes used as a fodder (Trabi *et al.,* 1997). Hence, the Jatropha seed/kernel meal has a great potential to complement and substitute soybean meal as a protein source in livestock diets (Makkar and Becker, 1997b). *Jatropha curcas* seed meal was also reported to contain micro and macro minerals. The percentage nitrogen (N), phosphorus (P), and Potassium (K) in Jatropha seed meal was reported as 3.2-4.5 %, 1.4-2.1 %, and 1.2 -1.7 % respectively (Kumar and Sharma, 2008).The seed meal and oil from *Jatropha curcas* were however found toxic to mice (Adam, 1974; *Zayed et al*., 1998), calves, goats and sheep (Adam and Magzoub, 1975; Stirpe *et al*., 1976; Ahmed and Adams, 1979a, b; Joubert *et al*., 1984; Kronberg *et al*., 1993; Halaweish *et al.,* 2002), rats and fish (Liberalino *et al*., 1988; Makkar and Becker, 1999), chicken (Samia *et al*., 1992), and humans (Mampane *et al*., 1987). The toxicity of Jatropha was attributed to the antinutritional factors including trypsin inhibitor; lectin, phytate (Makkar *et al.,* 2008) and phorbol esters (Makkar and Becker, 1997a; Martinez-Herrera *et al*., 2006) in the seed and other parts of the plant which

restrict its use as animal feed. The heat-labile antinutrients, protease inhibitors and lectins are easy to inactivate by moist heating (Makkar and Becker, 2009). Phorbol esters (phorbol-12-myristate - 13- acetate) have been identified as the main toxic agent in Jatropha seeds (Makkar and Becker 1997a, 1997b; Liu *et al.,* 1997). The concentration of phorbol esters and other antinutrients in *the Jatropha curcas* seed and other parts of the plant depends on the genotype, soil and climatic conditions (Martinez-Herrera *et al*., 2006). These reasons therefore necessitated the need to investigate the chemical composition of *Jatropha curcas* seed/ kernel meals from different areas of Ghana with the aim to identify a suitable source of Jatropha meal and develop it to animal feed that can supplement the expensive soyabean meal.

2. Materials and methods

2.1. Collection of *Jatropha curcas* Seeds and Agro-climatic Conditions

Mature seeds of *Jatropha curcas* were obtained from the ripped fruits of locally grown *Jatropha curcas* plant from four different agro-climatic areas of Ghana in the month of December, 2011. The agro-climatic details of the different regions in Ghana, from where the *Jatropha curcas* seeds were collected, are as follows: (1) Nyankpala, Northern Region (Guinea savanna zone, Localization Lat. 09^{o} 25'N, Long. 00^{o} 58' W; Average temperature 28.3^{o}C; Annual rainfall 1043 mm; Average humidity 58 %); (2) Wa, Upper west region (Guinea Savanna/Sudan Savanna, Lat. 10^{o} 4' 0.00'N, Long. 2^{o} 30' 0.00'' W, Soil type is Lixisols, Annual rainfall 900 mm);); (3) Dambai ,Volta region (Transitional zone, location: Lat. 7° 40'N and 8° 15'N and Long. 0° 6'E and 0°20'E, Average temperature 27 ^{o}C, Annual rainfall 1,120 mm) and (4) Techiman, Brong Ahafo region (Transitional forest, Annual rainfall 1140 – 1270 mm, average temperature 24.5 ^{o}C). Soon after the harvesting of the fruits, the seeds were manually removed from the husk and stored in plastic containers at room temperature prior to further use.

2.2. Processing of *Jatropha curcas* seed and Kernel

The *Jatropha curcas* seeds collected from each of the four different areas were divided into two portions. The first portion of the seeds was cracked manually and the shells carefully removed to obtain the kernels. The second portion of the seeds was not cracked, intact seed. Equal weights (3kg) of seeds of each sample were taken and defatted separately using mechanical hydraulic press and the seed cake/meal collected. Equal weights of kernels of the four samples were also taken; ground and defatted separately in an automated Soxtec apparatus, using petroleum ether boiling at 60^{o}C. Both the seed meals and kernel meals were air-dried and stored separately in labeled polyester plastic containers at 2 ^{o}C in a refrigerator for later analysis.

2.3. Proximate composition

The dry matter (DM), crude protein, lipid, crude fiber, and ash content of *Jatropha curcas* seed meals and kernel meals were determined in accordance with the standard methods of AOAC (1990). Carbohydrates (Nitrogen free extracts) in samples were determined by difference. The analyses were conducted in triplicate and all reagents were of analytical grade.

2.4. Determination of phosphorus, potassium, calcium and magnesium

Total potassium concentration was determined using the flame photometer (JENWAY, PFP7 Flame photometer) whiles total phosphorus was determined using the Spectrophotometer (JENWAY, 730 Spectrophotomer). Atomic Absorption Spectrophotometer (Perkinelmer, AAnalyst 400) was use to determine Calcium and Magnesium concentrations.

2.5. Determination of crude phorbol ester

Phorbol esters in *Jatropha curcas* seed/kernel meals were extracted by the method described by Hass and Mittelbach (2000) and the vacuum dried phorbol ester rich fraction was weighed with an analytical scale to obtain the crude phorbol esters content of Jatropha seed/kernel meal samples. The crude phorbol ester concentration was expressed as mg/g of meal extracted.

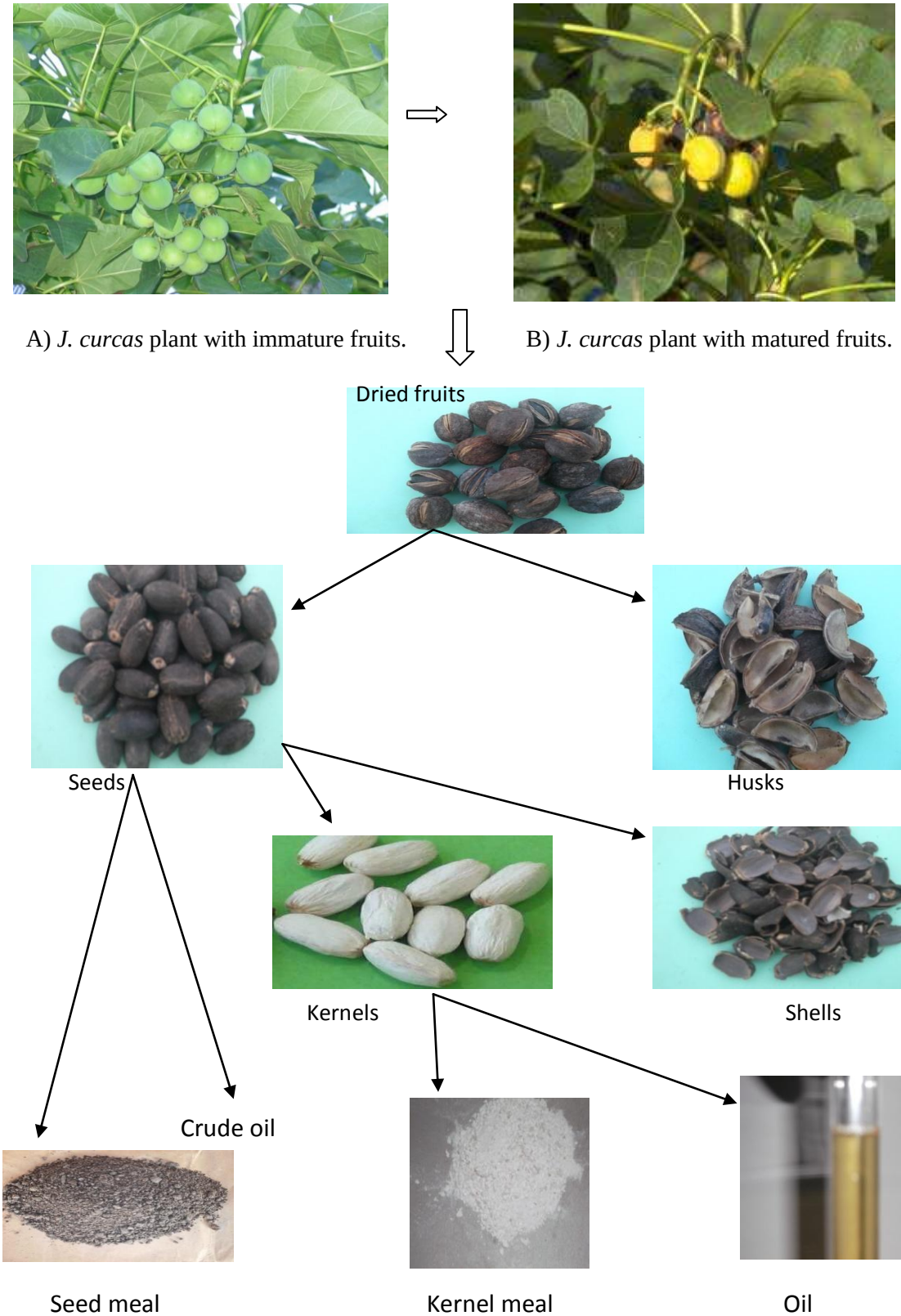

Plate 1. *Jatropha curcas*, fruit parts and products.

2.6. Tannins and phytic acid analysis

Tannins concentration was determined according to the titrimetric method described by the International Pharmacopoeia (2003) with some few modifications. The modifications made were: (1) the sample size was increased to 5 g (2) the mixture of the sample and distilled deionized water (dd H_2O) was shaken at 150 rpm for 15 minutes using mechanical shaker before allowing the mixture to stand at room temperature for 4 hours and then filtered. The shaken was to facilitate the rate at which tannins will dissolve. Phytic acid concentration was determined using the method of Young and Greaves (1940) as adopted by Lucas and Markakes (1975).

2.7. Statistical analysis

The data obtained from the study were analyzed using the General Linear Model (GLM) of the Analysis of Variance (ANOVA) of Minitab Statistical Package, Version 15 (Minitab, 2007). Where significant differences were found, the means were separated using Tukey Pair Wise comparison, at 5 % level of significance.

3. Result and Discussion

3.1. Proximate Composition

Three Kilogram (3 kg) each of *Jatropha curcas* seed samples 1(Nyankpala), 2(Dambai), 3(WA), and 4(Techiman) yielded Larger amounts of seed meals (2.31, 2.34, 2.37, and 2.34 kg representing 77, 78, 79, and 78 % respectively. these result was similar to the earlier finding of Achtena *et al*. (2008) that 4 kilograms of fresh Jatropha seeds can yield only about 1 kilogram of Jatropha oil and large amount (about 3 kg) of solid by-product left as Jatropha seed cake.

The chemical composition of Jatropha seed meal samples (1A, 2A, 3A, 4A) and kernel meal samples (1B, 2B, 3B, 4B) obtained from Jatropha seeds/kernels from four different agro-climatic areas of Ghana are shown in Table 1. Jatropha seed meal samples 1A (Nyankpala), 2A (Dambai), 3A (WA), and 4A (Techiman) varied in chemical composition. The dry matter (DM) content was significantly different ($p < 0.05$) among all the seed meal samples and ranged between (92.27 – 94.37 %). Crude protein (CP) content was also statistically different ($p < 0.05$) between the seed meal samples. Sample 1A recorded the highest CP content (29.61 %) while sample 3A had the lowest CP value (27.33 %). More also, the mechanically defatted Jatropha seeds contained significant amounts of lipid (16.52 – 19.56 %). The lipid content was statistically lower ($p < 0.05$) in sample 1 (16.52 %) and highest in sample 3A (19.56 %). The crude fibre (CF) contents of seed meals were significantly different among all the seed meal samples (1A, 2A, 3A, and 4A). The CF value measured was significantly higher in sample 3A (24.72 %) and 4A (23.81 %) than in samples 1A (21.46 %) and 2A (21.85 %). Ash content of Jatropha seed meals varied between 7.15 % in sample 3A and 9.01 % in sample 4A. The percentage carbohydrates in sample 1A (19.35 %) was statistically higher ($p < 0.05$) than values observed for samples 2A (16.25 %), 3A (14.50 %), and 4A (12.16 %). However, sample 3A and 4A had similar carbohydrates concentration ($p > 0.05$). The significant differences in proximate composition of Jatropha seed meals could be attributed to differences in the seed physical and chemical properties observed in our previous research which was further linked to differences in agro-climatic conditions of the areas where seeds were obtained from and perhaps variations in the genotype (Unpublished). It was observed in this current study that seed meal samples, WA (sample 3A) and Techiman (sample 4A) which recorded the lowest crude protein content, and highest lipid and crude fibre, the seeds from which the meals were obtained had the highest percentage shell of whole seed weight. These could be due to the fact that shells of *Jatropha curcas* is composed mainly of fibre with very little protein (Makkar *et al*., 1998) and also the thick shells covering the seed reduced the efficiency of oil been extracted from the kernel of the seed and therefore accounted for the high oil percentage retained in the seed meal samples. However, the CP content of all the seed meal samples were higher than the values observed in similar studies by Makkar and Becker (2009b); Saeta and Suntornsuk (2010). The lipid (ether extract) and ash content of seed meals samples were similar to the values reported by Saeta and Suntornsuk (2010). The crude fibre (CF) content of the seed meal samples were twice of the fibre content determined in other Jatropha seed meals (Saeta and Suntornsuk, 2010).

On the other hand, the Jatropha kernel meal samples (1B, 2B, 3B, 4B) have significantly similar ($p > 0.05$) dry matter and crude protein percentage. Jatropha kernel meals contained high amounts of CP that ranged between (64.3–64.35 %). However, the crude fibre and total ash contents of all the samples were statistically different ($p < 0.05$). The crude fibre, carbohydrates, and ash contents in kernel meals were 5.55 – 8.25 %, 15.02 – 15.54 %, and

8.20 – 9.78 % respectively. The chemical compositions of all the Jatropha kernel meals were similar to those reported by Makkar *et al*. (1997), (1998). Generally, the crude protein and crude fibre contents were extremely higher and lower respectively in all kernel meals than their respective seed meal samples. This could be attributed to differences in the processing of the two meal samples.

Table 1
Chemical composition (dry matter basis) of *Jatropha curcas* seed / Kernel meals obtained from Jatropha seeds from four different agro-climatic areas of Ghana.

Samples	Dry matter	Crude Protein	Ether extract	Crude fiber	Ash	Carbohydrates
1A	94.37^{a}	29.61^{a}	16.52^{d}	21.46^{c}	7.43^{c}	19.35^{a}
2A	92.65^{c}	28.82^{b}	17.21^{c}	21.85^{c}	8.52^{b}	16.25^{b}
3A	93.2^{b}	27.33^{d}	19.56^{a}	24.72^{a}	7.15^{d}	14.50^{c}
4A	92.27^{d}	28.65^{c}	18.65^{b}	23.81^{b}	9.01^{a}	12.16^{c}
P-value	0.001	0.004	0.001	0.001	0.001	0.001
1B	95.12	64.17	-	7.10^{b}	8.62^{bc}	15.21
2B	95.15	64.26	-	6.25^{c}	9.28^{ab}	15.38
3B	94.87	63.39	-	8.25^{a}	8.20^{c}	15.02
4B	95.19	64.35	-	5.55^{d}	9.78^{a}	15.54
P-value	0.333	0.065	-	0.001	0.027	0.742

Samples 1, 2, 3, and 4 represent *Jatropha curcas* seeds collected from Nyankpala, Dambai, WA, and Techiman respectively. A = raw seed meal (mechanically defatted); B = kernel meal (solvent extraction). Values within each column (seed meals & kernel meals) with no superscript in common are significantly different ($p < 0.05$).

3.2. Mineral composition

The percentage total nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) concentrations in *Jatropha curcas* seed meal and kernel meal samples are shown Figure 1 and 2 respectively. The concentration of total N, P, K, Ca, and Mg were significantly different ($p < 0.05$) among all the Jatropha seed meal samples. Total nitrogen content was significantly higher ($P < 0.05$) in sample 1A (4.74 %) followed by sample 2A (4.61 %) and 4A (4.59 %) and lower in sample 3A (4.38 %). The concentration of P and K, Ca and Mg in the seed meal samples ranged between 1.33- 3.80 %; 1.07 – 1.71 %; 0.54 – 0.87 %, and1.35 - 1.58 % dry matter respectively. On the other hand all the Jatropha kernel meal samples (1B, 2B, 3B, and 4B) contained total nitrogen in the range (10.14-10.30 %), phosphorus (1.29-3.55 %), potassium (0.87 -1.40 %), calcium (0.51-0.71 %), and magnesium (1.19-1.44 %) as shown in Figure2.

The differences in mineral concentrations among the Jatropha meal samples may be due to difference in soil conditions between the four different areas. The total nitrogen content of all Jatropha seed meal samples were similar to the values reported (Kumar and Sharma, 2008; El- Diwani *et al*., 2011). However, total nitrogen content observed in all the kernel meal samples (1B, 2B, 3B, 4B) were higher than the values published by Makkar and Becker (1997b); Kumar and Sharma (2008); El -Diwani *et al*., (2011). The P, Ca and Mg contents in Jatropha seed and kernel meal samples were very close to the values reported by Makkar and Becker (1997b). However, the concentration of potassium in seed meals were higher than the values measured by Makkar and Becker (1997b) but similar to those values recorded by Kumar and Sharma (2008); El Diwani *et al*. (2011). *Jatropha curcas* seed and kernel meals can be a source of macro-minerals in animals' diet formulation.

The concentrations of crude phorbol ester, tannins (tannic acid), and phytate (phytic acid) in *Jatropha curcas* seed meals and kernel meals are shown in Table 2. The CPE concentration in Jatropha seed meal samples ranged between (4.87 – 6.07 mg/g). The CPE content in sample 4A (6.07 mg/g) and sample 2A (5.88 mg/g) were statistically higher ($p < 0.05$) than sample 1A (4.87 mg/g) and 3A (5.14 mg/g). Similarly, phytic acid concentrations (dry matter basis) in Jatropha seed meals were significantly higher in sample 4A (9.82 %) and 2A (9.62 %) as compared to sample 1A (8.16 %) and 3A (8.11 %). The tannin concentration in Jatropha seed meals ranged between 0.72 - 0.93 (% tannic acid equivalent).

The CPE concentration in kernel meals (1B, 2B, 3B, 4B) ranged between 2.60 – 3.70 mg/g. The CPE concentration in samples 4B (3.70 mg/g) and 2B (3.52 mg/g) were significantly higher ($p < 0.05$) than samples 1B (2.92 mg/g) and 3B (2.60 mg/g). Similarly, phytic acid content differed significantly ($p < 0.05$) among the kernel meals.

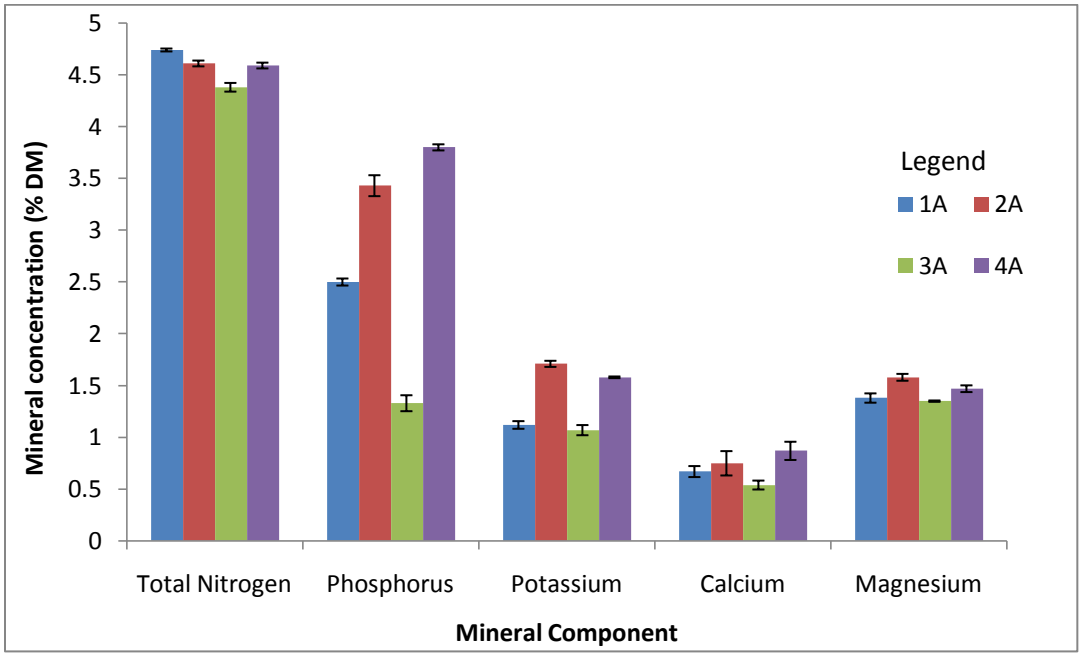

Fig. 1. Macro - Minerals compositions of defatted Jatropha seed samples. Sample 1A, 2A, 3A, and 4A represented seed meals obtained from *Jatropha curcas* seeds collected from Nyankpala, Dambai, WA, and Techiman of Ghana respectively. DM = Dry matter.

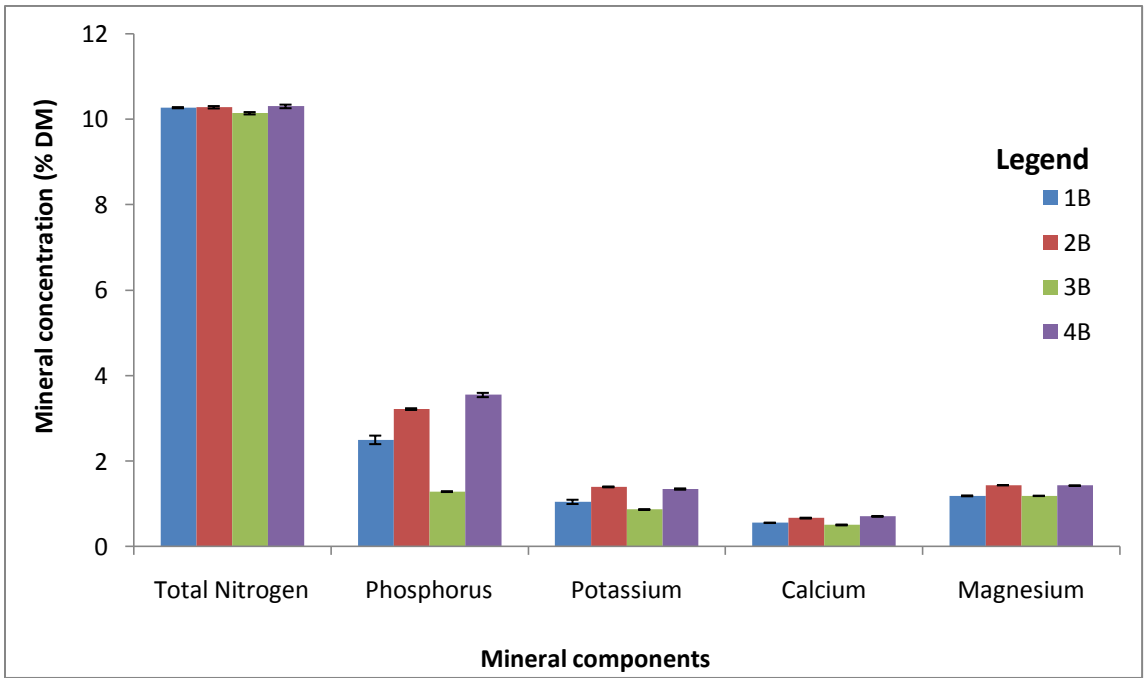

Fig. 2. Macro - Minerals compositions of defatted Jatropha kernels. Sample 1B, 2B, 3B, and 4B represented kernel meals obtained from *Jatropha curcas* seed kernels collected from Nyankpala, Dambai, WA, and Techiman of Ghana respectively. DM = Dry matter

Phytic acid was higher in sample 4B (7.46 %) and 2B (7.15 %) than Sample 1B (6.56 %) and 3B (6.65 %).Tannins content in kernel meals were negligible which ranged between 0.03 – 0.07 (% tannic acid equivalents). The antinutrients were higher seed meals and kernel meals of Jatropha samples from Techiman and Dambai than those samples from Nyankpala and WA. This could be due to differences in environmental conditions. The crude phorbol esters (CPE) concentrations recorded in Jatropha seed meals were extremely higher than the values reported for Jatropha seed meals from Zimbabwe and Nicaragua (Chivandi *et al*., 2004; Aregheore *et al*., 2003 respectively). The CPE concentrations in all the Jatropha kernel meal samples were closer to the values recorded in Jatropha kernel meals from Cape Verde, Nicaragua, Ife-Nigeria (Makkar *et al*., 1997) but higher than the phorbol ester concentrations determined in Jatropha meals from four provinces of Thailand: Chiang Mai, Satun, Phitsanulok, and Phrae (Saetae and Suntornsuk , 2010).The variation may be mainly due to differences in methods of analysis as well as differences in genotype and environmental factors. It should be noted that the values of phorbol ester concentrations reported in this study are crude values and not expressed as phorbol 12-myristate 13-acetate standard. More also crude phorbol ester concentration in the kernel meals reduced (39-49 %) as compared to the values observed in the seed meals. this reduction may be due to the high oil extracted from kernels leaving oil free kernel meals and since about 70 % of phorbol ester in Jatropha seed are present in the oil (Makkar *et al*., 2008). The tannins content in Jatropha seed meals were higher than while the concentration in kernel meals were similar to that reported by Makkar *et al*. (1998). The high tannic acid content found in the Jatropha seed meal samples could be as a result of shells incorporated in to the seed meal since the shells of Jatropha seed contain more tannin (Makkar *et al*., 1998). Tannins in kernel meals reduced drastically (92 - 96 %) as compared to tannin concentration in seed meals. Therefore removal of the shells from the seeds of Jatropha would help to reduce tannins concentration in the Jatropha seed meal. Further, the concentrations of phytate in all the Jatropha seed meals and kernel meals are within the range reported in other Jatropha seed meals (Makkar *et al*., 1997). The concentration of phytic acid in the kernel meals however decreased by (18 -27 %) as compared to the seed meal samples.

Table 2
Crude phorbol ester, tannic acid and phytic acid concentrations in *Jatropha curcas* seed and kernel meals from four different geographical areas of Ghana.

Sample	Crude PE (mg/g)	Tannins (% tannic acid equivalent)	Phytic acid (% DM)
1A	4.87^{b}	0.74^{c}	8.16^{c}
2A	5.88^{a}	0.83^{b}	9.62^{b}
3A	5.14^{b}	0.72^{c}	8.11^{c}
4A	6.07^{a}	0.93^{a}	9.82^{a}
P- value	0.001	0.011	0.001
1B	2.92^{b}	0.04^{b}	6.56^{c}
2B	3.52^{a}	0.06^{a}	7.15^{b}
3B	2.60^{b}	0.03^{b}	6.65^{c}
4B	3.70^{a}	0.07^{a}	7.46^{a}
P- value	0.001	0.045	0.001

Samples 1, 2, 3, and 4 are *Jatropha curcas* seeds collected from Nyankpala, Dambai, WA, and Techiman respectively. Samples with the letter A = raw seed meal (mechanically defatted); and B = kernel meal (solvent extraction). DM = Dry matter; PE = phorbol ester. Values within each column (seed meals & kernel meals) with no superscript in common are significantly different ($p < 0.05$).

4. Conclusion

The *Jatropha curcas* kernel meals contain high amount of crude protein that did not differ significantly between the various kernel meals. The crude fibre was also low in the kernel meals. However, the seed meals

contain very high crude fibre and lipid than other seed meals. The crude protein content was low in seed meals as compared with the kernel meals. The Jatropha meals also contained the macro-minerals phosphorus, potassium, calcium and magnesium. Phosphorus was much higher in the Jatropha seed/kernel meals. In general, the meals obtained from Jatropha seeds from Dambai and Techiman have higher mineral profile than those meals obtained from Nyankpala and WA. Apart from the good nutrition components of the Jatropha meal, antinutritional factors were present in the seed/kernel meal samples at different concentrations. The crude phorbol esters were higher in seed meals than the kernel meals. Phorbol ester being the main principal toxin in *Jatropha curcas* means that the meals may be toxic to animal when consumed. Phytic acid contents were high in seed meals than kernel meals. Phytic acid is not heat labile and its presences in an animal's diet can reduce availability of minerals to the animal when high levels of phytic acids are consumed. Tannins were negligibly low in the kernel meals than the seed meal samples and hence tannins may not necessary be a problem in Jatropha kernel meals. From the research conducted, it was clear that the kernel meals have better nutritional composition and low in antinutrients than the seed meals and could therefore be a better source of protein diet for animals if detoxified completely.

References

Achtena, W.M.J., Verchot, L., Frankenc,Y.J., Mathijsd, E., Singhe, V.P., Aertsa, R., Muys, B., 2008. Jatropha bio-diesel production and use. *Biomass and Bioenergy*, 32, 1063-1084.

Adam, S.E.I., 1974. Toxic effects of *Jatropha curcas* in mice. *Toxicology* 2, 67-76.

Adam, S.E.I., Magzoub, M., 1975. Toxicity of *Jatropha curcas* in goats. *Toxicology* 4, 347-354.

Ahmed, O.M., Adam, S.E.I., 1979a. Toxicity of *Jatropha curcas* in sheep and goats. *Research in Veterinary Science* 27, 89-96.

Ahmed, O.M., Adam, S.E.I., 1979b. Effects of *Jatropha curcas* on calves. *Veterinary Pathology* 16, 476-482.

AOAC, 1990. Official methods of analysis (15th ed.). Arlington, VA: Association of Official Analytical Chemists.

Aregheore, E.M., Becker, K., Makkar, H.P.S., 2003. Detoxification of a toxic variety of *Jatropha curcas* using heat and chemical treatments, and preliminary nutritional evaluation with rats. S. Pac. J. Nat. Sci. 21, 50-56.

Azaza, M.S., Wassim, K., Mensi, F., Abdelmouleh, A., Brini, B., Kraïem, M.M., 2009. Evaluation of faba beans (*Vicia faba L. Var. minuta*) as a replacement for soybean meal in practical diets of juvenile Nile tilapia Oreochromis niloticus. *Aquaculture 287, 174–179.*

Chivandi, E., Mtimuni, J.P., Read, J.S., Makuza, S.M., 2004. Effect of processing method on phorbol esters concentration, total phenolics, trypsin inhibitor activity and the proximate composition of the Zimbabwean Jatropha curcas provenance: A potential livestock feed. Pak. J. Biol. Sci. 7, 1001-1005.

El Diwani, G.I., El-Rafei S.A., Hawash, S.I., 2011. Ozone for Phorbol Esters Removal from Egyptian Jatropha Oil Seed Cake. Advances in Applied Science Research, 2011, 2 (4),221-232.

Fournier, V., Huelvan, C., Desbruyeres, E., 2004. Incorporation of a mixture of plant feedstuffs as substitute for fish meal in diets of juvenile turbot (Psetta maxima). Aquaculture 236, 451–465.

Goel, G., Makkar, H.P.S., Francis, G., Becker, K., 2007. Phorbol esters: structure, biological activity, and toxicity in animals. *International Journal of Toxicology* 26, 279-288.

Halaweish, F.T., Kronberg, S., Hubert, M.B., Rice, J.A., 2002. Toxic and aversive Diterpenes of *Euphorbia esula*. *J. Chem. Ecol.* 28,1599–1611.

Hass, W., Mittelbach, M., 2000. Detoxification experiments with the seed oil from *Jatropha curcas* L. Ind. Crop Prod. 12, 111-118.

Heller, J., 1996. Physic Nut: Jatropha curcas L. Promoting the Conservation and Use of Underutilized and Neglected Crops. I. Institute of Plant Genetics and Crop Plant Research, Gatersleben/ International Plant Genetic Resources Institute, Rome.

Ishii, Y., Takeuchi, R., Tokida, K., 1987. Transesterified curcas oil as a farm diesel engine fuel. In *proceedings of the International Symposium on Agriculture Mechanization and International Cooperation in a High Technology Era*. Pp 239. University of Tokyo, 3rd April.

International Pharmacopoeia, 2003. World Health Organization, 3rd ed., v.5, Geneva.

Joubert, P.H., Brown, M.M., Hay, I.T., Sebata, D.B., 1984. Acute poisoning with *Jatropha curcas* purging nut tree in children. *South African Medical Journal* 65, 729-730.

Kaushik, S.J., Cravedi, J.P., Lalles, J.P., Sumpter, J., Fauconneau, B., Laroche, M., 1995. Partial or total replacement of fish meal by soybean protein on growth, protein utilization, potential estrogenic or antigenic effects, cholesterolemia and flesh quality in rainbow trout, Oncorhynchus mykiss. *Aquaculture 133, 257–274.*

Kronberg, S.L., Muntifering, R.B., Ayers, E.L., Marlow, C.B., 1993. Cattle avoidance of leafy spurge: A case of conditioned aversion. *J. Range Manage* 46,364–366.

Kumar, V., Sharma, S., 2008. An evaluation of multipurpose oil seed crop for industrial uses (*Jatropha curcas* L.): A review. *Industrial Crops & Products*, 28, 1–10.

Liberalino, A.A.A., Bambirra, E.A., Moraes-Santos, T., Viera, E.C., 1988. Jatropha curcas L. seeds: Chemical analysis and toxicity. Braz. Arch. Biol. Technol. 31, 539–550.

Liu, S.Y., Sporer, F., Wink, M., Jourdane J., Henning, R., Li Y.L., Ruppel, A., 1997. Anthraquinones in *Rheum palmatum* and *Rumex dentatus* (Polygonaceae), and phorbol esters in *Jatropha curcas* (*Euphorbiaceae*) with molluscicidal activity against the schistosome vector snails *Oncomelania*, *Biomphalaria* and *Bulinus*. *Tropical Medicine and International Health* 2, 179-188.

Lucas, G.M., Markakes, P., 1975. Phytic acid and other phosphorus compounds of nevy bean (*Phaseolous vulgaris*). J. Agric., Food Chem., 23,13-15.

Lutz, A., 1992. Vegetable oil as fuel- an environmentally and socially compatible concept for Mali. GATE-Eschborn 4, pp. 38– 46.

Makkar, H.P.S., Aderibigbe, A.O., Becker, K., 1998. Comparative evaluation of non- toxic and toxic Jatropha curcas for chemical composition, digestibility, protein degradability and toxic factors. Food Chemistry, 62(2), 207-215.

Makkar, H.P.S., Becker, K., 1997a. Jatropha curcas toxicity: identification of toxic principle (s). In: Garland, T., Barr, A.C. (Eds.), Toxic Plants and Other Natural Toxicants. CAB International, New York, pp. 554–558.

Makkar, H.P.S., Becker, K., 1997b. Potential of *Jatropha curcas* Seed Meal as Protein Supplement in Livestock Feed, Constraints to its Utilisation and Possible Strategies to Overcome Constraints. Developed from the Symposium "Jatropha 97". 23–27 February 1997, Managua, Nicaragua. Biofuel and Industrial Products from J. curcas, pp. 190–205.

Makkar, H.P.S., Becker, K., 1999. Nutritional studies on rats and fish (carp Cyprinus carpio) fed diets containing unheated and heated *Jatropha curcas* meal of a non-toxic provenance. *Plant Foods Human Nutrition,* 53,183–192.

Makkar, H.P.S., Becker, K., 2009a. *Jatropha curcas,* a promising crop for the generation of biodiesel and value-added co-products. Eur. J. Lipid Sci. Technol. 111, 773– 787.

Makkar, H.P.S., Becker, K., 2009b. Challenges and Opportunities for Using Byproducts from the production of Biodiesel from Jatropha oil as Livestock Feed. Proceedings of Animal Nutrition Association World Conferences, 14-17 February 2009, New Delhi, India: 168- 170.

Makkar, H.P.S., Becker, K., Sporer, F., Wink, M., 1997. Studies on nutritive potential and toxic constituents of different provenances of *Jatropha curcas*. *Journal of Agriculture and Food Chemistry* 45, 3152-3157.

Makkar, H.P.S., Francis, G., Becker, K., 2007. Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems. Animal 1(9),1371–1391.

Makkar, H.P.S., Martinez-Herrera, J., Becker K., 2008. Variations in Seed Number per Fruit, Seed Physical Parameters and Contents of Oil, Protein and Phorbol Ester in Toxic and Non-Toxic Genotypes of *Jatropha curcas*, *Journal Plant Science*, 3(3), 260-265.

Mampane, K.J., Joubert, P. H., Hay, I.T., 1987. *Jatropha curcas*: use as a traditional Tswana medicine and its role as a cause of acute poisoning. *Phytotherapy Research* 1, 50-51.

Martinez-Herrera, J., Siddhuraju, P., George, F., Davilá-Ortíz, G., Becker, K., 2006. Chemical composition, toxic/anti-metabolic constituents and effects of different treatments on their levels in four provenances of *Jatropha curcas* L. from Mexico. *Food Chemistry* 96, 80-89.

Munch, E. and Kiefer, J., 1989. Purging nut (*Jatropha curcas* L.). Multi-use plant as a source of fuel in the future. Schriftenreihe der GTZ 209, 1-32.

Ouedraogo, M., Ayers, P.D., Linden, J.C., 199. Diesel engine performance tests using oil from Jatropha curcas L. Agricultural Mechanization in Asia, Africa and Latin America, 22: pp. 25-29.

Raja, A.S., Robinson, S.D.S., Lindon, R., Lee C., 2011. Biodiesel production from jatropha oil and its characterization. *Research Journal of Chemical Science*, Vol.1 (1), pp. 81-87.

Donlaporn, S., Suntornsuk, W., 2010. Antifungal Activities of Ethanolic Extract from Jatropha curcas Seed Cake. *Journal of Microbiology and Biotechnology* 20(2), 319–324.

Samia, M.A., Badwi, E.L., Mausa, H.M., Adam, S.E.I., 1992. Response of brown hisex chicks to low levels of *Jatropha curcas*, *Ricinus communis* or their mixture. *Veterinary and Human Toxicology* 34, 304-306.

Samocha, T.M., Davis, A.D., Soud, P.I., de Bault, K., 2004. Substitution of FM by co-extruded soybean poultry by-product meal in practical diets for the Pacific white shrimp, Litopenaeus vannamei. Aquaculture 231,197–203

SOFIA, 2007. The state of world fisheries and aquaculture 2006. FAO Fisheries and aquaculture Department, Rome, pp 1–180.

Stirpe, F., Pession-Brezzi, A., Lorenzoni, E., Strocchi, P., Montanaro, L. and Sperti, S., 1976. Studies on the proteins from the seeds of *Croton tiglium* and of *Jatropha curcas*. *Biochemical Journal* 156, 1-6.

Trabi, M., Gubitz, G.M., Steiner, W., Foidi, N., 1997. Toxicity of *Jatropha curcas* seeds. Biofuel and Industrial products from *Jatropha curcas*. Proceeding of a symposium held in Managua, Nicaragua, February 1997. Technical University of Graz, Uhlandgasse 8, A-8010 Graz, Austria.

Wiesenhütter, J., 2003. Use of the Physic Nut (*Jatropha curcas* L.) to Combat Desertification and Reduce Poverty. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

Young, S.M., Greaves, J.E., 1940. Influence of variety and treatment on phytic acid content of wheat. Food Res., 5,103-105.

Yue, Y., Zhou, Q., 2009. Effect of replacing soybean meal with cottonseed meal on growth, feed utilization, and hematological indexes for juvenile hybrid tilapia, Oreochromis niloticus, O. aureus. Aquaculture 284,185–189

Zayed, S.M., Farghaly, M., Taha, H., Gotta, H., Hecker, E., 1998. Dietary cancer risk conditional carcinogens in produce of livestock fed on species of spurge (Euphorbiaceae). I. Skin irritant and tumor-promoting ingenane-type diterpene esters in *E. peplus*, one of several herbaceous Euphorbia species contaminating fodder of livestock. *J. Cancer Res. Clin. Oncol.* 124,131–140.