World Journal of Agricultural Sciences 8 (1): 89-95, 2012
ISSN 1817-3047

Physical and Nutrient Characterisation of Raw and Processed Castor (*Ricinus communis* L.) Seeds in Nigeria

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Abstract: Castor bean *(Ricinus communis L.)* is an oilseed shrub of significant economic importance because of its several potential in industry and medicine. Castor seeds from four different locations in Nigeria were sampled and investigated for physical and chemical properties. The seeds size ranged from 0.08-0.9 g by weight and 0.8-1.9 cm by height. Since size is a continuous variation, the seeds were categorized into the small seeded variety (SSV) and the large seeded variety (LSY). More time and energy were expended in dehulling the SSV beside a considerable amount of kernel that were lost to the hull during processing. A tonne of castor seed generated about 53% of kernel for LSV compared to 49% kernel in SSV indicating a higher waste stream for SSV. The fibrous seed coat of 25% was obtained in LSV compared to 31% in SSV. The oil content ranged from 35-37% with higher oil yield in SSV. The energy values and the protein content showed numerical differences in the two seed types. Crude protein content of 26.7% and 24.6% and crude fat of 47.3% and 49.4% and gross energy values of 6.59 kcal/g and 6.89kcal/g were obtained for LSV and SSV respectively. The anti nutritional factors measured revealed that the lectin component of 4.7HU mg/ml obtained for LSV and 3.1HUmg/ml obtained for SSV was lower in LSV because more of the material was required to produce positive agglutination. Values of O.41% and 0.48% phytate and 0.94% and 0.79% oxalate were obtained in LSV and SSV respectively. Different processing methods were attempted on the seed meal samples to neutralize the antinutrients present in them. Lectin were better inactivated with extraction with lye water, pH 9.5 and moist heating at 100°C for 20 min. Phytate levels were slightly decreased by fermentation for 3-day. Handling and nutrient profile favoured LSV over SSV and may have higher preference in livestock feeding system when treated with lye.

Key words: Castor seeds · Varieties · Chemical constituents · Detoxification

INTRODUCTION

Castor bean (*Ricinus communis)* is an important drought-resistant shrub belonging to the Family *Euphorbiaceae*. It is native to the Ethiopian region of tropical Africa and has become naturalized in tropical and temperate regions throughout the world. The oil extracted from castor bean (*Ricinus communis L.*) already has a growing international market, assured by more than 700 uses, ranging from medicines and cosmetics to substituting petroleum in the manufacturing of biodiesel, plastics and lubricants [1,2]. The oil content can range from 35-52%, depending on the variety of seed and environment. The yield per hectare per year could reach up to 1000kg oil. The deoiled residue or castor bean cake contains toxins and allergens which remain behind in the residual meal after oil extraction. Ricin component of castor remain a serious impediment limiting the application of castor bean meal in animal diet [3]. The cake contained about 32-48% crude protein depending on levels of decortications and deoiling [4] and the whole seed contained 2.9-3.28kcal/kg true ME [5]. At best castor bean cake has popularly found application as fertilizer which is far below its potential. Despite the unhealthy toxins in the cake, when detoxified,

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they could make an important by-product that may be used as new generation feed stock considering its oil application in biodiesel production.

Recent research efforts have been directed to identify and evaluate certain novel legume seeds as alternative/additional protein source for the future world [6]. The exploitation and development of castor bean, as protein source for animals may offer a good scope to meet the increasing protein requirements at large, particularly in the developing countries. However, before recommending such non-conventional foodstuff, their compositional and nutritional properties should be thoroughly investigated. Chemical evaluation of the seeds and cake of castor grown in Nigeria could reveal the chemical compositions that may be useful for feed materials and those that could be improved upon or eliminated before use. Reports are available on the feeding value of castor bean cake [5,7,8], the information regarding the seed characteristics and anti-metabolic constituent appears to be meager. Hence, in the present study an attempt has been made to identify predominant castor varieties in Nigeria, determine the seed characteristic, nutrient and the anti nutritional components.

MATERIALS AND METHODS

Place and Seed Collection: Samples of matured dried castor fruits were collected from four major cities across the country (Akure, Ibadan, Bida and Ogbomoso) during dry season (harmattan) between December and February when the rainfall is at its minimum. Nigeria has a tropical climate with sharp regional variances depending on rainfall. Nigerian seasons are governed by the movement of the intertropical discontinuity, a zone where warm, moist air from the Atlantic converges with hot, dry and often dust-laden air from the Sahara known locally as the harmattan. Temperatures are high throughout the year, averaging from 25° to 28°C (77° to 82°F). About two kilogram each of the whole fruit was gathered for each type discovered through survey within the zones. The pods were air-dried which dehisced to release the seeds. The seeds were cleaned and sorted to remove broken ones and contaminant. It was stored in plastic containers.

Processing and Physical Properties: One hundred seeds were taken randomly from each sample type collected. Clean, dry seeds for each type were dehulled manually by breaking between two hard surfaces and the shaft was separated from the kernel. The shells were carefully removed and the weight, length and width of the kernels were recorded. The shaft and the hulls were packed separately and weighed on a sensitive balance to determine the percentage composition and to generate information on waste stream. Dehulled seed was crushed to increase surface area for better oil extraction and then pressed mechanically with hydraulic machine for an hour to facilitate better oil extraction. The cake obtained from the press was further ground, using a mechanical grinder and defatted in a Soxhlet apparatus, using petroleum ether (boiling point of 40-60°C), for 16 hr. The total crude oil was calculated from the two extractions.

Castor Bean Cake Treatment: Different portions of the castor bean cake were made to undergo different treatments such as lye, fermentation and hot water.

Lye Treatment: Lye water was prepared by passing clean water over gray ash in a barrel. The ash was collected from cassava processing plant, sieved to remove any pieces of charcoal then placed (without compaction) in a plastic container with holes plugged with sieve cloth at the base of the plastic. Hot water was poured on the ash and a brown liquid dripped at base of the container. This brown liquid represents the lye water used in this study. The pH of the lye water was determined by pH meter rule as 9.5. Castor bean cake was placed in muslin cloth and then soaked in the lye (1 part of the cake to 2parts of lye to completely submerge the cake) for 18 hours. It was drained and then sun-dried. Sundried product was then milled to produce Lye treated castor bean cake, LCB.

Fermentation: A portion of the cake was placed in a muslin clothing material, tied and placed in a plastic container, soaked in clean water completely for 3 days under air-tight condition. The water was drained on the 3rd day and the fermented product sun-dried. It was then milled to produce fermented castor bean cake, FCB.

Hot Water Treatment: Another portion of the castor bean cake was soaked in hot water at 100°C for 20 minutes, after which it was drained and dried. This represented hot water treated castor bean cake (HCBC) The fourth portion serve as the untreated castor bean cake.

Data Collection

Seed Selection: A total of 100 seeds for LSV and SSV from each zone were collected. Seeds from all the zones were mixed according to seed size (variety) and 100 seeds were randomly selected from each variety

Seed Weight: This was determined by a sensitive scale (1000g ± 0.1g). 100 seeds from each variety were counted and weighed in a plastic container. Each of the seed was also weighed separately and the average weight for each variety was determined.

Castor Fruit By-Products: The cotyledon or the kernel and two by-products, pods and seed coat were recovered from castor bean fruit. Pods, seed coat and cotyledon were packed separately in polytene bags, weighed and the weights were expressed as percentage composition of the whole fruit and whole seed

Oil Yield: This was determined by both mechanical extraction of the dehulled seed and the laboratory analysis of the defatted cake after mechanical expression the total content of the crude oil is addition of percentages of mechanically extracted oil and laboratory determined oil.

Chemical Evaluation

Proximate Analysis: Proximate composition of the castor bean meal was carried out according to the procedure of ……[9]. The crude protein was determined by the Kjeldahl method as described by ……. [9]. Crude protein value was estimated as 6.25 multiple of the nitrogen value. Crude fiber determination was carried out using the trichloroacetic acid (TCA) method. Ash and crude fat contents were obtained according to ….[9],while carbohydrate was calculated by difference.

Energy Values: Energy was determined using the bomb calorimeter. One gram of the feed sample was pelleted and oven-dried at 103°C for 24 hours. The samples were then re-weighed and bombed. Values of deflections obtained were used to calculate the gross energy of the diets.

Mineral Analysis: Phosphorus was determined by calorimetric means using the Vanadomolybdate [9].

The Antinutritinal: factors such as Lectin, oxalates, phytic acid, tannin etc were determined. The phytate content was determined based on the ability standard ferric chloride to precipitate phytate in dilute HCl extracts of the sample. The tannin content was determined using the method of….. [9]. Analysis of the lectin content was conducted by hemagglutination assay in round-bottomed wells of microtitre plates using 1% (v/v) trypsinised cattle blood erythrocytes suspension in saline phosphate buffer, pH 7.0 [10]. The hemagglutination activity was defined as the minimum amount of the kernel material (in mg per ml of the assay medium), which produced agglutination. One hemagglutinating unit (HU) was defined as the least amount of material per ml in the last dilution giving positive agglutination [11].

Statistical Analysis: The means of data obtained were compared using a X-square.

RESULTS

Castor Varieties and Traits: Based on seed size, two main varieties of dry dehiscent castor seed type were discovered within the study area. There were the large seeded variety major (LSV) and the small seeded variety minor (SSV) (Plate 1). Two seed coat colours were also predominant, the white speckle brown type was averagely bigger in size and predominates in southern part of the country while the brown specked black occurs both as large and small seed type and predominate in the northern part of the country. The largest seeded variety range from 0.4 -0.9g by weight, 1-1.5cm by width, 0.5-0.95 cm by thickness and 1.3- 2.05cm by height while the SSV ranged from 0.08-0.15g, 0.33-0.52cm, 0.3-0.45cm and 0.6-.95cm for the weight, width, thickness and height respectively. Large seeded variety exists in two colours, white and dark while the SSV exist mainly in dark colour as indicated in plate 1. Table 1 shows that the percentage of pod and hull vary in the two varieties of seed, 24.7% and 31% hulls were generated in LSV and SSV respectively. The kernel yield for LSV was 75.3%, while it is only 69% for SSV whereas the oil yield of 39.4% in SSV was higher than 37.2% obtained in LSV when pressed mechanically with a hydraulic machine.

Chemical Composition: The proximate composition, total soluble sugars, calcium, phosphorous, gross energy and some anti nutrients in the two varieties of castor bean seed in Nigeria are shown in Table 2. There was some variation from LSV - SSV in the contents of crude protein, CP, (24 - 26.3%); crude fibre CF (2.4 - 3.15) and lipid (47- 49.5%). The gross energy was about 6.6kcal/g in LSV and 6.8kcal in SSV. Among the antinutitional factors analyzed the lectin component (mg/ml of assay mixture

Table 1: Chemical constituents of two varieties of castor seed in Nigeria LSV-Large seeded variety, SSV- Small seeded variety, HU-Haemagglutinating unit (HU) amount of material per ml in the dilution giving positive agglutination

Parameter	LSV	SSV
Proximate composition, %		
Moisture	7.32	7.18
Crude protein	24.3	22.11
Crude fibre	2.41	3.15
Crude oil	47.18	48.56
Ash	3.26	3.89
NFE	15.19	15.11
Mineral content, %		
Ca	0.59	0.55
P	0.65	0.76
Gross energy (kcal/g)	6.69	6.87
Antinutritive factors,%		
*Lectin (Ricin) HU mg/ml	4.7	3.1
Oxalate (%)	0.41	0.49
Phytic acid (%)	0.94	0.79
Tannin (%)	0.35	0.37

*One hemagglutinating unit (HU) was defined as the amount of material per ml that give positive agglutination

Table 2: Physical characteristics of two main varieties castor seed in Nigeria.

Parameter	LSV	SSV
Whole fruit (g)	1.29 ±0.12	0.238±0.01
Whole seed (g)	0.68 ±0.1	0.116±0.02
Husk (g)	0.604±0.01	0.122±0.02
Testa (g)	0.168±0.002	0.036±0.003
Kernel (g)	0.515±0.01	0.08±0.01
Percentage seed	52.7±2.15	48.7±2.12
Percentage kernel	75.7±2.55	69.0±2.53
Husk: seed ratio	0.89±0.07	1.05±0.08
Coat: kernel ratio	0.33±0.01	0.45±0.01
Oil: cake ratio	0.33±0.01	0.37±0.01
Seed width, cm	1.30±0.17	0.45±0.03
Seed thickness, cm	0.74±0.09	0.40±0.05
Seed height, cm	1.75±0.09	0.85±0.03

LSV- Large seeded variety; SSV- Small seeded variety.

Table 3: Chemical profile of processed castor cake

Parameter	Untreated CBC	LCBC	FCBC	PCBC
Proximate composition, %				
Moisture	9.34	9.59	9.56	9.17
Crude protein	38.58	39.43	38.87	39.32
Crude fibre	3.46	2.53	3.92	3.45
Ether extract	11.15	9.79	10.53	10.88
Ash	5.87	6.11	5.92	5.36
NFE	32.60	31.74	32.56	31.54
Gross energy kcal/g	5.624	5.493	5.495	5.595
Mineral content, %				
Ca	0.62	0.54	0.55	0.47
P	0.34	0.45	0.37	0.41
Antinutritive factor, %				
Lectin, mg/ml	2.5	7.40	5.83	5.30
Tannin	0.25	0.23	0.32	0.20
Phytic acid	0.42	0.21	0.24	0.17
Oxalate	1.2	1.1	1.0	0.92
Cyanogenic glycoside mg/kg	33.45	27.00	30.0	26.17

(mg/ ml- of assay mixture which produced agglutination) of dehulled and defatted castor bean seed

Plate 1: The two types of castor bean seed (dry dehiscent type) in Nigeria

which produced agglutination) was considerably lower in LSV with 4.7mg/ml and about 3.1mg/ml in SSV. Others such as oxalate, phytate, tannin etc are comparable. The defatted meal contained higher crude protein of 39%, higher crude fibre of 3.46% and low gross energy of 6.2kcal/g but higher activities of lectin.

Effect of Treatment: The effect of different treatments on castor bean cake on chemical composition is shown in Table 3. Dry matter content of hot water treated castor bean appears to be slightly higher with about 0.5% than other treatments. Although there were numerical differences in crude protein content, ether extract and soluble carbohydrate, no particular trend was observed. Crude fibre was notably lower in fermented castor bean cake compare to other treatments. There was downward trend in gross energy composition of treated castor bean compared to untreated castor bean cake. Phosphorous content of lye treated castor bean cake was a bit higher followed by hot water treatment CBC but with lowest calcium. All the treatments employed in this study bring down the level of antinutrients in castor seed cake with varying degree of detoxification. Tannin and oxalate appear not to have been significantly affected by the treatments applied whereas over 50% of phytate were removed by all the treatments. The lectin levels fall drastically in lye treatment followed by fermentation and the least detoxification was achieved with hot water treatment.

DISCUSSION

Physical Properties of Castor Seed: Castor plant differs in many notable traits such as plant height(dwarf or tall), leaf shape and colour, stem colour(green, gray, purple, red), nature of pod (dehiscent or indehiscent), seed size (small or large), seed coat colour (white, brow, dark brown). There are a lot of hybrids that that have been developed for a specific trait such as oil yield, nature of pod (indehiscent type to reduce loss to splitting). In Nigeria, there are smooth indehiscent pod type and spiny dehiscent type which are widely distributed across the country. Since, no suitable machine has been reported for decorticating and dehulling castor fruit, it is economically viable to consider the dehiscent type over the indehiscent type because of the need for decortication. The spiny seed pod or capsule composed of three sections or carpels which split apart at maturity. Each section (carpel) contains a single seed and as the carpel dries and splits open, the seed is often ejected with considerable force.

Based on the seed size, a wide range of classification may ensue from all the samples collected. The seeds of the castor plants that grow in northern states of Nigeria have been classified into seven distinct varieties according to their sizes and colors [12]. Since size is a continuous variation, an attempt to identify all categories will definitely be cumbersome. Hence the two varieties, large seeded variety major (LSV) and small seeded variety minor SSV were recognized in this study and revealed that variation within each variety may be attributed to season of collection (Dry season, December - March and Rainy season, May-September), soil and possible cross breeding (not determined) during flowering. The small seeded variety usually grows wild and commonly found along road sides, river bank, residential area and waste land. The large seeded is traditionally cultivated in the eastern part of the country as backyard farming system where the seed is popularly used as food condiment called ogiri [13]. The toxicity of castor seed is a reason why most farmers do not grow the crop extensively. However, Castor oil has become the wave of the future biodiesel with several hundreds of uses ranging from lubrication, cosmetics, medicine and biodiesel production. This has been an impetus to a country like Nigeria such that Benue state government, received over two billion naira for castor oil seed production initiative in 2008.

The seeds were composed of about 25 per cent husk and 75 per cent kernel. The percentage of pod and husk vary in the two varieties of seed. Large seeded variety contained less of both pod and hull compared to SSV. Since LSV is about six times the size of the SSV, more husks are essentially generated than the kernel in small seed variety. It follows then that higher waste or by-products will be produced in seed processing of the small seeded variety. About 92% dehulling was achieved with LSV while it was only 83% for SSV. It is practically difficult to dehull the SSV; more time was wasted in dehulling it owing to its relatively smaller size beside a reasonable percentage of kernels that were lost with the hull during processing. Similarly, a higher waste stream generation was observed for SSV compared to LSV. In the choice of a material as a potential feed resource, waste stream composition has been a key determinant. For instance, one tonne of castor seed can generate about 530 kg of kernel for LSV when dehulled whereas about 490kg kernel of SSV can be recovered from the same quantity of seed. This has a serious implication on costs accrued from processing and transportation of the seed especially when large tonnage is considered commercially. Most reports on feeding of castor bean meal to livestock had actually voted for the LSV, reason for this may be adduced to its relatively easy handling and processing. Since high fibre content of undehulled castor seed constitute a serious nutritional impediment to the use of CBC in animal feeding, the large seeded variety will offer better overall value in livestock feeding due to its easy handling, lesser waste production and higher kernel yield.

Literature reports indicated that the oil content of the seed varies from 35 to 55 per cent of the weight of the seeds [14]. The values obtained from the present finding fall within the range of oil reported. The mechanical press with hydraulic could only remove about 70% of the available oil in the seed, further extraction with petroleum or ether will remove the residual oil.

Proximate Composition: Defatted seed had higher crude protein which is similar to that obtained from most conventional protein feed resource such as soybean meal and peanut meal. Treated castor cake had slightly higher crude protein of about 1%increase than the untreated castor cake. Crude fibre in SSV was higher which may be attributed to some difficulty encountered in complete separation of hull from the kernel and thereby added up to increase the fiber content of the product. The crude fibre content reported by earlier researcher was very high because the seeds were not dehulled. It is very imperative to dehull castor seed before applied to animal feed particularly in the monogastric feeding system. The highest fibre content will also influence the utilization of other nutrient by the animals. The crude oil was higher in SSV. Mechanical expelling in combination with press cake hexane extraction is an effective method to recover more than 99% of the oil present in seed [15]. No single mechanical method has been successfully used for the total extraction of castor oil leaving the cake with varying level of oil. Mechanical pressing will only remove about 70% of the oil present. It has also been suggested that castor bean cake should be properly deoiled before applied in livestock feed as high fat cake may reduce nutrient utilization [16]. The observation may be related to the purgative effect of the oil which prevented absorption of the nutrients in the intestine. Both calcium and phosphorous content of LSV were higher compared to their SSV counterpart and follow similar trend with only 0.1% difference between the two varieties in the country. The soluble carbohydrate was comparable and did not indicate any significant variation between the two varieties. The results of proximate position reveal that higher crude protein and lower fibre content of the LSV may favour its use as animal feed over the SSV. Higher oil content associated with the small seeds may be an attracting factor to oil based industry but when the overall value in tems of seed yield, waste stream handling and processing are considered, the. LSV may be favoured.

Anti Nutritional Factors: The lectin component, a more serious limiting factor in castor obviously showed that LSV produced lower activities of agglutination than the SSV. It is b elieved that animals are able to sense the ricin (lectin) in castor which prevented them from browsing it. An unintended but important observation about the two varieties was the fact that animals do browse on the LSV whereas they do not touch the SSV. As such LSV may be preferred to SSV since castor toxins remain a serious threat to the use of castor bean plant in most countries of the world. The amino acid profile has been described by….. [7]. Castor bean is particularly deficient in the sulphur containing amino acids. Threonine and methionine are the first limiting amino acids [17].

Effect of Treatment: The processing techniques affected the chemical profile of castor bean cake. There was a short fall in energy values of treated bean compared to untreated bean. Since all treatments are in a form washed with fluid, there are tendencies that parts of the nutrients were lost to the fluid particularly the soluble carbohydrate as reflected in the nitrogen free extract values of fermented product which also had the least gross energy. The crude protein of the defatted seed was reasonably high compare to many other oilseeds and match up with the conventional sources, soya bean meal and groundnut cake. Fermentation decreased the fibre content of the product and this may influence positively the bioavailability of other nutrients [18]. Decorticated and treated castor seed cake contains high values of phosphorus and calcium than the untreated full-fat seed and this revealed that castor bean cake contains sufficient of these nutrients to meet the nutritional requirements of farm animals.

All the treatment employed in this study reduced the level of antinutrients in castor seed cake with varying degree of detoxification. The antinutritional factors were better deactivated by lye treatment while the least detoxification was attained with heat treatment. Lectins are known to be heat labile. Higher agglutination observed in heat treatment may be due to: short duration of heating, presence of certain factors in castor meal which mimic the action of lectin (agglutination of erythrocytes) and that such factors are not heat labile or presence of lectins in the bound form in the untreated sample and possible liberation of these lectins by heat treatment [19,20].

Tannin and oxalate appear not to have been significantly affected by the treatments applied whereas over 50% of phytate were removed by all the treatments.

CONCLUSION

Castor bean seed offers a wide range of economic value particularly in tropical climate where the plants naturally thrive. Despite the apparent benefits, the ant metabolic component (ricin and fibre content) remained a serious impediment in cultivation and use of castor bean and its product in animal feed. Large seeded variety may offer better overall value (easy handling, higher yield, low fibre and lower antimetabolic substance) and may be preferred to the small seeded type in feeding of farm animals. Results have demonstrated that the seeds and cake contain high nutrients with potentials to meet the nutritional requirements of farm animals if given proper treatments and supplementation with the limiting amino acids. The use of lye water on castor cake proved efficient in detoxifying the cake and may be preferred to fermentation and perboiling. Further research is encouraged to remove any residual effect on farm animals.

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