

Full Length Research Paper

Nutritional quality of *Jatropha curcas* seeds and effect of some physical and chemical treatments on their anti-nutritional factors

Azza A. Abou-Arab* and Ferial M. Abu-Salem

Department of Food Technology, National Research Centre, Dokki, Cairo, Egypt.

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The physical characteristics of Egyptian *Jatropha curcas* seeds were studied. The average of whole seed mass, kernel weight, shell weight, percentage kernel mass of whole seeds and percentage shell mass of whole seeds were 0.69, 0.47, 0.22, 68.12 g and 31.88% respectively. Chemical composition proved that *J. curcas* seeds are a good source of protein (32.88%), oil (27.36%) and carbohydrates (30.11%). The seeds are rich in various micro-elements, that is Mn, Fe, and Zn which recorded 28.37, 0.38 and 47.13 mg/kg, respectively as well as macro-elements, that is, K, Ca, Na, Mg and P, which recorded 103.13, 34.21, 8.44, 109.89 and 185.17 mg/kg respectively. The seeds contain 52.59 mg/100 g, 25.58 mg/g, 39.95 mg/100 g and 1.51 g/100 g of phytic acid, trypsin inhibitor activity, total phenols and saponins, respectively. Therefore, it could be inferred that the seeds is nutritionally promising because of its high nutrient content and low antinutrient level. The effect of some physical treatments (soaking, germination and roasting) and some chemical treatments (NaHCO₃, ethanol extraction and NaOH) were successful inactivating the antinutrients.

Key words: *Jatropha curcas*, nutrient, anti-nutrient, mineral content, chemical composition.

INTRODUCTION

Jatropha curcas (physic nut or purging nut) the new cultivated and promising crop is convenient to adapt in Egypt for increasing the local planted production (MSEA, 2008). The primary use of *J. curcas* seeds in Egypt is for oil extraction which is a good alternative to biofuel, and has proven success used either independently or by mixing the diesel to operate farm machinery, household lighting, in Soap and Candles (El-Gamassy, 2008).

J. curcas is native to Central America and has become naturalized in many tropical and subtropical areas, including India, Africa, and North America. Originating in the Caribbean, *Jatropha* was spread as a valuable hedge plant to Africa and Asia by Portuguese traders (Fairless, 2007).

Growers of *Jatropha* are increasingly demanding seeds in Egypt for cultivation for the production of biofuel. In 2004 - 2005, the area planted with *J. curcas* was about 100 hectare, increased seven times to about 700 ha in

2007. The rate of increase is 175%, which is really very high (MSEA, 2008).

In Egypt were planted about 70 ha on wastewater treatment in Luxor, Ismailia, Suez and Giza. This is grown in hectare between 350 - 500 saplings, and seed production range between 1.5 - 12 tons per hectare or the yield per hectare is up to 5 tons seed given about 1.85 tons of oil in the year (El-Gamassy, 2008).

J. curcas a member of the *Euphorbiaceae* family is a multipurpose tree of significant economic importance because of its several industrial and medicinal uses (Makkar et al., 2008a). *Jatropha* bush and have multiple uses it well to produce outstanding biodiesel as fuel and due to fires without emissions that pollute the environment, so-called oil friend of the environments is also used for lighting and several other industrial purposes (El-Gamassy, 2008).

Jatropha grow throughout most of the tropics. It survives on poor stony soils and can be used to reclaim land (Munch and Kiefer, 1989). *Jatropha* plants start yielding from the second year of planting, but in limited quantity. If managed properly, it starts giving 4 - 5 kg of

*Corresponding author. E- mail: drazza_nrc@yahoo.com.

seed per tree production from the fifth year onwards and seed yield can be obtained up to 40 - 50 years from the day of planting (Kumar et al., 2003). The seed weights ranged from 0.53 - 0.86 g and the kernel contains 22 - 27% protein and 57 - 63% oil (Oladele and Oshodi, 2008). These limits indicating that *Jatropha* is a good nutritional value. The seed kernels are known to contain highly oil, which can be used as fuel directly or as a substitute to diesel in the transesterified form. The oil is also used for making candles, soap, lubricants and varnishes and is used for illumination. The seed cake can be a good protein source for humans as well as for livestock (Makkar et al., 2008a).

J. curcas seeds are highly toxic to a number of animal species due to the presence of some types of anti-nutritional components such as phytic acid, trypsin inhibitor, phenolic compounds and saponins at high amounts (Makkar et al., 2008b). So, the seed cake obtained from oil extraction didn't use in animal diet (Makkar et al., 2008b). The decreases in the levels of anti-nutritional factors to safe limits may be caused by thermal degradation, soaking in distilled water, germination, and extraction of methanol (Yasmin et al., 2008; Magdi, 2007; Ramakrishna et al., 2006; Aderibigbe et al., 1997).

The objective of the present study was to demonstrate the nutritional quality of Egyptian *J. curcas* seeds. Also, the effect of some processing methods on some antinutritional factors of *J. curcas* seeds will be study to decreasing the antinutritional factors to safe limits.

MATERIALS AND METHODS

Sample materials

Jatropha species (*Jatropha curcas* L.) were purchased from Luxor city, Luxor governorate, Egypt that harvested at April, 2009. The sample was cleaned manually to remove all foreign materials such as dust, dirt, small branches and immature seeds. The cleaned and graded seeds were de-hulled to gain access to a cream-coloured endosperm, which is the sample material. The sample materials were blended to powder (0.5 mm) form with a high-speed blender (Braun KMM 30 mill), type 3045, CombiMax (Germany). This was stored in an airtight polyethylene bags and kept in a refrigerator prior to analysis.

Chemicals and reagents

All chemicals and reagents were purchased from Sigma chemical Co. (St. Louis, Mo, USA). The used water was distilled using water distillation apparatus (D 4000).

Trypsin enzyme from bovine pancreas type III; 16.500 BAUF Umg⁻¹, was purchased from Sigma chemical Co. (St. Louis, Mo, USA).

Micro-elements, that is lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), cobalt (Co), zinc (Zn), manganese (Mn), copper (Cu), and iron (Fe) as well as macro-elements, i.e. potassium (K), calcium (Ca), phosphorus (P) and sodium (Na) were provided by (Merck, Darmstadt, Germany). The working standards were prepared from the individual stock solution (1000 mg/l).

Physical properties of *Jatropha* seeds

Thirty seeds of *Jatropha* were randomly taken and the average weight of the seeds was estimated. The seeds were cracked using a mechanical cracker, the shells were carefully removed, and the weights of the kernel were recorded. Further, the average shell weight was calculated from the total seed weight minus kernel weight of the respective seeds.

Effect of some physical and chemical treatments on the antinutrients of *J. curcas* seeds

Biological treatments

Soaking: Seeds were soaked in distilled water at ratio of 1:10 (w/v) at room temperatures ($25 \pm 2^\circ\text{C}$) for 12 h, then dried in a hot air oven at 40°C to a constant weight. The samples were milled in a Braun (KMM 30) mill to pass through a 0.5 mm sieve and stored in plastic bags until required for further analysis.

Germination: The seeds were germinated at room temperatures ($25 \pm 2^\circ\text{C}$) for 5 days by keeping them in trays lined with wet filter paper. The germinated seeds were dried in a hot air oven at 40°C to a constant weight. The samples were milled in a Braun (KMM 30) mill to pass through a 0.5 mm sieve and stored in plastic bags until required for further analysis.

Roasting: The seeds were generally roasted on trays at $160^\circ\text{C}/30$ min according to the method of (Yanez et al., 1986).

Chemical treatments

The whole seeds and kernel were divided and into five equal experiments (500 g of each). The first experiment not treated as control. The second experiment was treated with 0.07% NaHCO_3 solution in the ratio of 1:5 (w/v) and immediately autoclaved at 121°C for 25 min. The samples were dried in hot air oven at 40°C . Experiment three was extracted with 90% ethanol for 2 h. at room temperature ($25 \pm 2^\circ\text{C}$) with constant stirring. The sample to solvent ratio was 1:10 (w/v). The solvent was removed by filtration and the residue was dried in hot air oven at 40°C . The fourth experiment sample, after treatment similar to experiment (3) was air-dried, mixed with 0.07% NaHCO_3 solution in the ratio of 1:5 (w/v) and subjected to autoclaving at 121°C for 25 min and the residual was dried in hot air oven at 40°C . In experiment five, the seeds (300 g) were weight into 1000 ml beakers, followed by the addition 4% NaOH solution to form a paste. The paste was heat treated (autoclaving at 121°C for 25 min), then dried by hot air oven at 40°C . The dried paste was grounded using a simple laboratory mill to give the sample. Consequently, the grounded sample was washed with distilled water three times, prior to milling.

Sample preparation

The kernel and whole seeds were grounded, using a mechanical grinder (Braun KMM 30 mill), and defatted in soxhlet apparatus, using diethyl ether (boiling point of $40 - 60^\circ\text{C}$), for 16 h. The defatted seed was air dried at room temperature ($25 \pm 2^\circ\text{C}$) and stored in a separate plastic container at 4°C .

Analytical methods

All *J. curcas* samples (whole seeds, kernel and shell) were

Table 1. Physical characteristics of *J. curcas* seeds.

Item	Level (on dry weight basis) \pm SD
Whole seed of weight (g)	0.69 \pm 0.2
Kernel weight ((g)	0.47 \pm 0.3
Shell weight (g)	0.22 \pm 0.3
Kernel, % of whole seed	68.12 \pm 4.42
Shell, % of whole seed	31.88 \pm 1.91

*Mean of thirty seeds.

analyzed for moisture, crude protein, oil and ash contents according to the standard methods of AOAC (2000). The method of Pearson (1976) was used for the determination crude fiber. While total carbohydrates were determined by the phenolsulphoric acid method using glucose as standard (Dubois et al., 1956). Reducing sugars were estimated by 3,5-dinitrosalicylic acid (DNS) method using D (-) fructose (Mw = 180.16, Fluka) as standard (Miller, 1959) and non-reducing sugars were expressed as difference between total carbohydrates and reducing sugars. The values of these compounds are reported on dry weight basis (g/100 g dry solids).

Minerals

Mineral contents, that is copper (Cu), magnesium (Mg), manganese (Mn), iron (Fe), zinc (Zn), lead (Pb) and nickel (Ni) were determined according to the method of A.O.A.C (2000) using atomic absorption spectrophotometer, Perkin-Elmer 2380, manufacture (USA). The flame photometer was applied for macro-elements: potassium (K), calcium (Ca) and sodium (Na) determination according to the methods described by Pearson (1976). While Spectrophotometric method was used for determination of the phosphorus (P) content of the tested samples using ammonium molybdate as outlined in the AOAC (2000).

Determination of antinutritional components

Phytic acid: The determination of phytic acid was applied according to the method described by Mohamed et al. (1986) using chromogenic reagent. The color was measured at 830 nm against a blank. The results were calculated as mg phytic acid/100 g dry sample using standard phytic acid.

Trypsin inhibitor activity (TIA)

The determination of trypsin inhibitor activity was applied according to the method of Smith et al. (1980), except that the enzyme was added last, as suggested by Liu and Markakis (1989). Results are expressed as mg trypsin inhibited per g of dry sample.

Total phenolics

The extraction and determination of total phenolics were applied by spectrophotometric method described by Makkar et al. (1997). Total phenolics were quantified by the Folin-Ciocalteu reagent and results were expressed as tannic acid equivalents.

Total saponins content

The determinations of total saponins were applied using a

spectrophotometric method described by Hiai et al. (1989). The concentration of saponins were read off from a standard curve of different concentrations of diosgenin in 80% aqueous methanol and expressed as diosgenin equivalents.

Statistical analysis

The data were statistically analyzed by analysis of variance and least significant difference (L.S.D.) at 0.05 levels according to the method described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Physical properties of *J. curcas* seeds

Physical properties of *J. curcas* seeds were determined (Table 1). Data presented that average mass of whole thirty seeds was 0.69 g, and the average kernel weight was 0.47 g, as well as the shell average weights was 0.22 g. Data proved also, that the percentage kernel and shell mass to whole seeds were 68.12 and 31.88%, respectively. Similar results reported by Herrera et al. (2006). However, the values of the percentage kernel weights found in this study were larger than that detected by Makkar et al. (1998).

Chemical composition of raw *J. curcas*

Biochemical composition of the whole seeds, kernels and shells of untreated seeds (raw) of *J. curcas* are presented in Table 2. Data shows that whole seeds contains 5.58% moisture, 32.88% protein, 27.36% oil, 5.68% ash, 3.81% fiber and 30.11% total carbohydrates (reducing and non-reducing sugars). These values are very similar to those reported by Makkar et al. (1998). However, Akintayo (2004) reported lower value of protein (24.60%) and higher value of oil (47.25%) with moisture content 5.54%. On the other hand, Ogbobe and Akano (1993) reported that the seed of *Jatropha gossipifolia* contains crude oil, protein, fiber, and carbohydrates at levels 35.8, 13.40, 9.25 and 30.32% respectively.

Regarding to kernel seeds data indicate that oil was the mainly composed followed by protein with low ash, crude fiber and total carbohydrates (Table 2). Moisture content

Table 2. Chemical composition of whole, kernels and shells from raw seeds of *J. curcas*.

Components %	Values (on dry weight basis) \pm SD			LSD at 5 %
	Whole seeds	Kernel seeds	Shells	
Moisture	5.58 ^b \pm 0.02	4.46 ^c \pm 0.02	6.54 ^a \pm 0.03	6.21
Protein	32.88 ^a \pm 3.98	29.91 ^b \pm 4.28	4.32 ^c \pm 0.02	7.43
Oil	27.36 ^b \pm 3.98	47.18 ^a \pm 2.71	1.28 ^c \pm 0.01	7.21
Ash	5.68 ^b \pm 0.03	5.42 ^c \pm 2.0	6.21 ^a \pm 4.0	6.21
Fiber	3.81 ^b \pm 3.96	2.48 ^c \pm 3.0	83.50 ^a \pm 0.03	6.24
Reducing sugars	17.10 ^a \pm 0.04	12.62 ^b \pm 2.97	1.68 ^c \pm 4.0	0.07
Non-reducing sugars	13.01 ^a \pm 3.0	2.34 ^c \pm 0.05	2.89 ^b \pm 0.04	8.16
Total carbohydrates	30.11 ^a \pm 0.03	14.96 ^b \pm 3.98	4.57 ^c \pm 0.03	6.62

All values are means of triplicate determinations \pm standard deviation. Means within rows with different letters are significantly different ($P < 0.05$).

Table 3. Anti-nutritional factors of whole, kernels and shells from raw seeds of *J. curcas*.

Anti-nutritional factors	Values (on dry weight basis) \pm SD			LSD at 5%
	Whole seeds	Kernel seeds	Shells	
Phytic acid (mg/100 g)	52.59 ^b \pm 0.85	34.37 ^c \pm 0.25	61.10 ^a \pm 0.03	1.02
Trypsin inhibitor activity (TIA mg/g sample)	25.58 ^b \pm 2.82	33.26 ^a \pm 0.03	15.83 ^c \pm 3.98	6.50
Total phenols (mg/100 g)	39.95 ^c \pm 0.65	75.93 ^a \pm 4.14	43.91 ^b \pm 4.42	4.83
Saponins (g/100 g)	1.51 ^b \pm 0.02	2.63 ^a \pm 0.04	0.65 ^c \pm 0.03	6.21

All values are means of triplicate determinations \pm standard deviation. Means within rows with different letters are significantly different ($P < 0.05$).

was 4.46% is obviously lower than the 10% moisture content limit recommended for storage stability of flours (Makkar et al., 1998). These results are agreement with that reported by Herrera et al. (2006).

Table 2 proved that the shells of *J. curcas* seeds composed mainly of fiber with very little protein, oil and total carbohydrates, that indicating poorly nutritional value. However, the shells consider a good source of fuel as it has high gross energy. Moisture content of shells was 6.54% which the shell moisture content ($< 10\%$) could be partly responsible for the non deterioration of seeds over a long period (Makkar et al., 1998).

It could be concluded that significantly differences ($P < 0.05$) were detected between the whole seeds, kernel seeds and shells among the components of moisture, protein, oil, ash, fiber and carbohydrates contents.

Crude oil is the most abundant lipids found in nature. High value of oil (47.18%) was recorded with kernel of *J. curcas* seed. This oil content is much higher than the value recorded for other much seeds. The crude fiber is very high (83.50%) in *Jatropha* shells and lower in whole and kernel seeds. Fiber content is a significant component of the diet. It increases stool bulk and decreases the time that waste materials spend in the gastrointestinal tract. It is commonly used as an index of value in poultry and feeding stocks feeds (Eze and Ibe, 2005). Crude protein values of 32.88 and 29.91% observed for whole and kernel *J. curcas* seeds are

obviously much higher than most legumes and grains. Carbohydrate content (30.11%) of whole seeds of *J. curcas* detected is much higher than most grains. They are essential for the maintenance of plant and animal life and also provide raw materials for many industries.

Anti-nutritional factors of raw *J. curcas*:

The antinutrient (phytic acid, trypsin inhibitor, total phenols, and saponins) contents of the defatted whole *J. curcas*, kernel and shell seeds are shown in Table 3. In whole seeds, phytic acid (mg/100 g), trypsin inhibitor activity (mg/g), total phenols (mg/100 g) and saponins (g/100 g) were 52.59, 25.58, 39.95 and 1.51 respectively. In kernel seeds these factors were increased significantly ($P < 0.05$) except its content of phytic acid which decreased significantly. On the other hand, phytic acid and total phenols contents were increased significantly ($P < 0.05$) with shells compared with whole seeds. However, the other factors (TIA and saponins) were decreased significantly.

These results demonstrated the high levels of phytic acid in raw *J. curcas*. The phytate content of *Jatropha* seed varied according to the variety (Reddy and Pierson, 1994). In the present study significant differences ($P < 0.05$) were observed between the contents of phytic acid in whole seeds or kernel and shells. These indicate that

Table 4. Mineral contents of whole, kernels and shells from raw seeds of *J. curcas*.

Elements	Concentrations mg/kg (on dry weight basis) \pm SD			LSD at 5 %
	Whole seeds	Kernel seeds	Shell	
Micro elements				
Copper (Cu)	Nd	Nd	nd	-
Manganese (Mn)	28.37 ^a \pm 0.03	0.79 ^c \pm 0.03	12.91 ^b \pm 3.03	5.98
Iron (Fe)	0.38 ^c \pm 0.01	0.44 ^b \pm 0.01	7.31 ^a \pm 0.03	7.39
Zinc (Zn)	47.13 ^a \pm 0.03	42.13 ^b \pm 0.02	1.07 ^c \pm 0.01	7.43
Nickel (Ni)	Nd	Nd	nd	nd
Lead (Pb)	Nd	Nd	nd	nd
Macro elements				
Potassium (K)	103.13 ^b \pm 0.03	109.52 ^a \pm 4.42	34.24 ^c \pm 1.9	7.21
Calcium (Ca)	34.21 ^b \pm 4.47	51.41 ^a \pm 3.49	28.01 ^c \pm 0.52	0.60
Sodium (Na)	8.44 ^c \pm 3.0	8.83 ^b \pm 2.01	18.22 ^a \pm 3.95	6.18
Magnesium (Mg)	109.89 ^a \pm 0.03	102.29 ^b \pm 0.03	5.04 ^c \pm 0.03	7.21
Phosphorus (P)	185.17 ^a \pm 2.21	165.33 ^b \pm 1.0	2.59 ^c \pm 3.0	n.s

All values are means of triplicate determinations \pm standard deviation. Means within rows with different letters are significantly different ($P < 0.05$). nd: not detectable. ns: non-significant.

the consumption of *Jatropha* meal can decrease the bioavailability of minerals (Oladele and Oshodi, 2007); especially Ca and Zn. Phytates have also been implicated in decreasing protein digestibility by forming complexes and also by interacting with enzymes such as trypsin and pepsin (Reddy and Pierson, 1994).

Trypsin inhibitor activity (TIA) content is high in *J. curcas*. Highly significant differences ($P < 0.05$) in kernel seeds compared with whole seeds and shells were observed. Similar results obtained by Makkar et al. (1998) who reported that the trypsin inhibitor activity of *Jatropha* ranged between 18.4 - 26.85 mg/ g.

Regarding to total phenols, data showed that the highest significant differences ($P < 0.05$) was detected with kernel followed by shells and whole seeds. Phenolic compounds are commonly found in both edible and non-edible plants, and they have been reported to have multiple biological effects, including antioxidant activity (Kahkonen et al., 1999). The presence of phenolic compounds in injured plants may have an important effect on the oxidative stability and microbial safety (Hollman et al., 1996). Polyphenolic compounds are responsible for the colour of the seed-coat of certain legumes.

Saponins in *J. curcas* were lower than other anti-nutritional factors under study. However, significant differences was reported among whole seeds, kernel and shells and the highest significant differences ($P < 0.05$) detected with kernel followed by whole seeds and shells. Saponins, which are natural triterpene plant glycosides found in many plant species, have been of great interest recently because of their physiological activities

(Fenwick et al., 1991).

Minerals contents of *J. curcas*

Mineral contents of *Jatropha* samples (whole, kernel and shell seeds) are shown in Table 4. Results indicate that the highest mean level of micro elements in the whole seed and shell was manganese which recorded 28.37 and 12.91 mg/kg d.b, respectively. However, in whole seeds, the highest mean level (47.13 mg/kg d.b) was recorded with zinc. Regarding to iron in whole seeds, manganese and iron in kernel seeds as well as iron and zinc in shell samples were detected at lower levels. On the other hand, copper, nickel and lead were not detected in any of the analyzed samples. These results confirmed by statistical analysis which data proved that highly significant differences ($P < 0.05$) were observed with manganese in whole seeds, iron in shells and zinc in kernel seeds compared with other factors.

The contents of macro elements were varied in different samples. Kernel seeds were reached by potassium (109.52 mg/kg), calcium (51.41 mg/kg), magnesium (102.29 mg/kg) and phosphorus (165.33 mg/kg). Statistical analysis proved that highly significant differences ($P < 0.05$) were detected with kernel seeds with these elements compared with whole seeds and shell samples. However, the highest level of sodium (18.22 mg/kg) was detected in shell samples. On the other hand, moderate levels of K, Ca, Mg and P were observed in whole seeds. Beside, these elements were found at lower levels in shell samples except Na. Similar

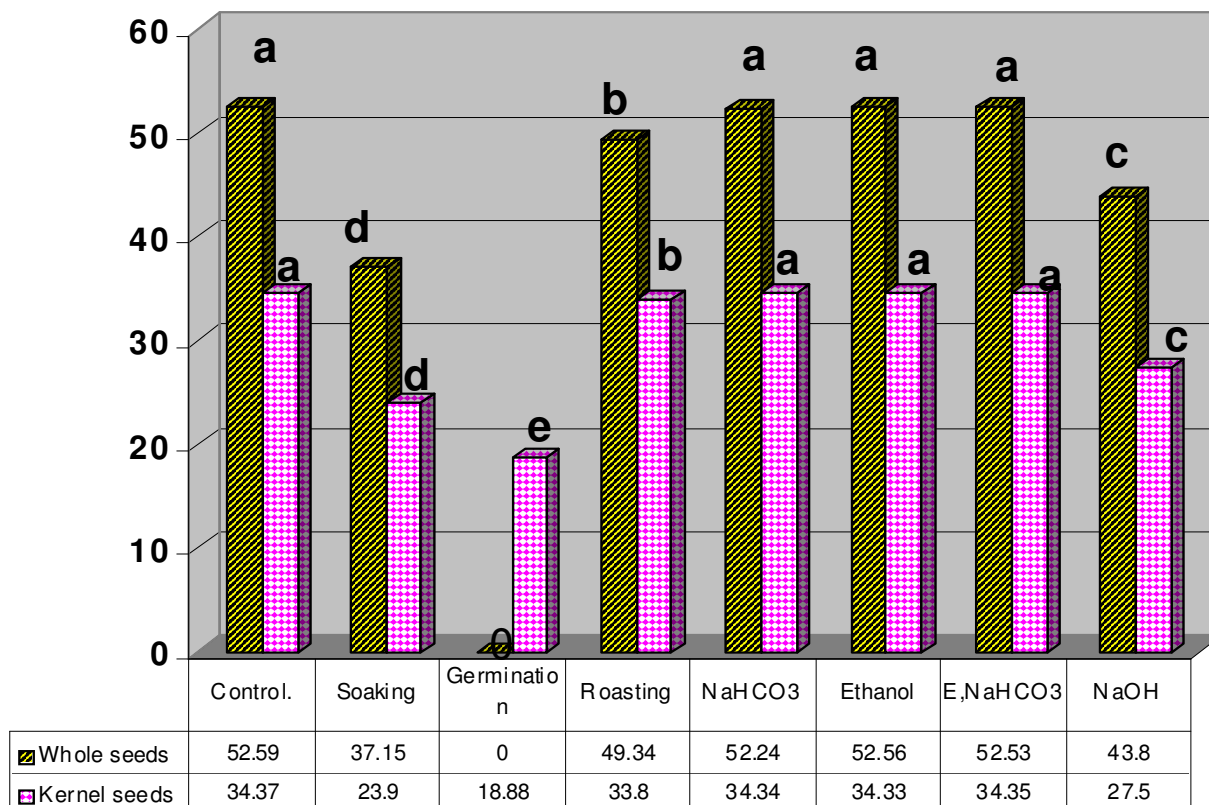


Figure 1. Phytic acid content (mg/100g on dry weight basis) of *J. curcas* seeds as affected by some biological and chemical treatments. Means within rows with different letters are significantly different ($P < 0.05$).

results obtained by Oladele and Oshodi (2007). The seeds could therefore be referred to as a good source of calcium, magnesium, potassium, phosphorus and zinc.

Effect of some biological and chemical treatments on the antinutrients of *J. curcas* seeds

Effect of different treatments on phytic acid content

Figure 1 shows the phytic acid content of *J. curcas* seeds after soaking in distilled water. Data showed that phytic acid content decreased significantly ($P < 0.05$) by 29.36 % and 30.46 % in whole and kernel seeds, respectively. This reduction may be attributed to leaching out of phytate ions into soaking water under the influence of concentration gradient, such losses may be taken as a function of changed permeability of seed coat (Duhan et al., 1989). These results are agreement with that reported by Ramakrishna et al. (2006).

Figure 1 show that the phytic acid content decreased significantly ($P < 0.05$) after soaking in distilled water with kernel seeds and the reduction was 45.07% due to leaching out of this compound in water. Similar results obtained by Yasmin et al. (2008).

Phytic acid content in defatted whole and kernel seeds as affected by roasting (Figure 1) slightly affected significantly ($P < 0.05$). These indicate that phytate constitutes a major heat-resistant antinutritive component in *Jatropha* meals. These results coincide with those obtained by Makkar et al. (1998).

Phytic acid content as affected by 0.07% NaHCO₃ followed by heat treatment using autoclave at 121 °C for 25 min (Figure 1) was not affected significantly ($P < 0.05$) in either whole or kernel seeds. These results agreement with those reported by Aderibigbe et al. (1997). The high level of phytate present in defatted *Jatropha* might decrease the bioavailability of minerals (especially Ca²⁺ and Fe²⁺). Phytates have also been implicated in decreasing protein digestibility by forming complexes and also by interacting with enzymes such as trypsin and pepsin (Reddy and Pierson, 1994).

Extraction of whole and kernel seed samples by 90% ethanol for 2 h at room temperature ($25 \pm 2^\circ\text{C}$) with constant stirring on phytic acid content (Figure 1) showed that the phytic acid level is not affected significantly ($P < 0.05$). These results are agreement with those reported by Makkar et al. (1997).

Extraction of whole and kernel seed samples by 90% ethanol for 2 h and treated by 0.07% NaHCO₃ and

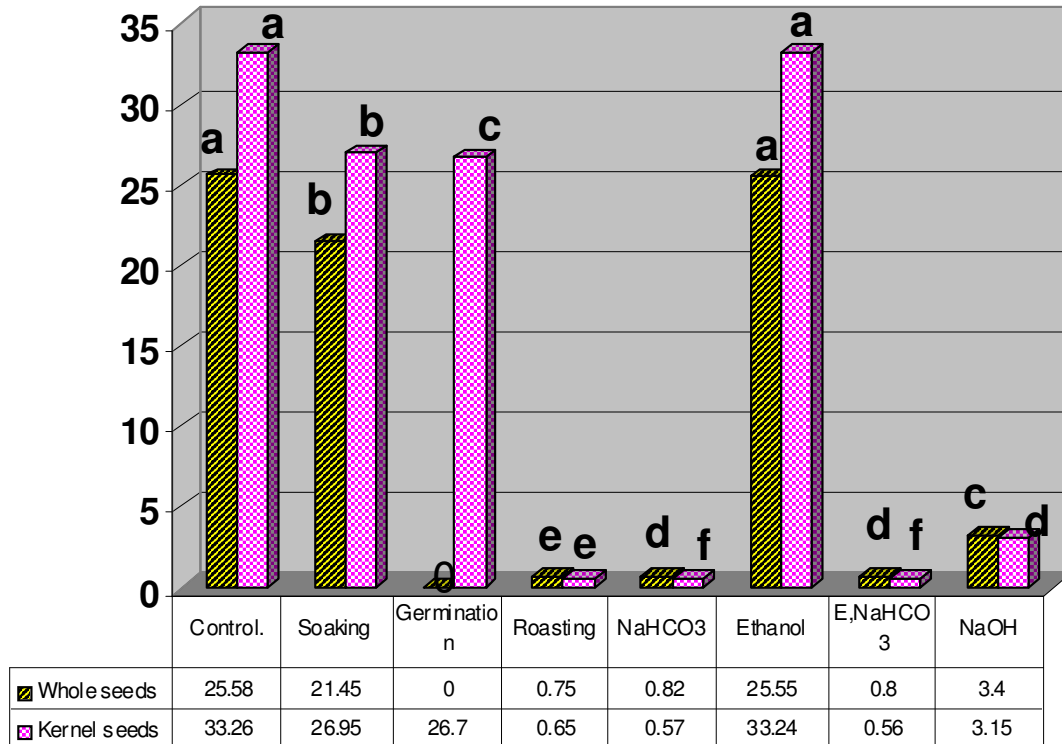


Figure 2. Trypsin inhibitor activity (mg/g on dry weight basis) of *J. curcas* seeds as affected by some biological and chemical treatments. Means within rows with different letters are significantly different ($P < 0.05$).

autoclaved at 121°C/25 min on phytic acid content (Figure 1) proved that the phytic acid level is not affected significantly ($P < 0.05$) of both whole and kernel seeds. The values obtained are very close to those reported by Makkar et al. (1997).

The effect of sodium hydroxide treatment followed by washing with distilled water decreased significantly ($P < 0.05$) the phytic acid content by about 16.71% and 19.99% of defatted whole and kernel seeds, respectively (Figure 1). These results are in agreement with those reported by Makkar and Becker (1997b).

Effect of different treatments on trypsin inhibitor activity (TIA)

The effect of soaking of *J. curcas* seeds in distilled water on inactivation trypsin inhibitor was studied and data summarized in Figure 2. From the results, it could be noticed that, trypsin inhibitor activity content was decreased significantly ($P < 0.05$) by 16.15 and 18.97% of defatted whole and kernel seed, respectively. This reduction may be attributed to leaching out of (TIA) as a result of soaking and also due to the known heat labile nature of trypsin inhibitors (Siddhuraju et al., 1996). However, the fact that not all TIA was removed shows that at least some of the trypsin inhibitors are heat-

resistant. These findings agree with that reported by Magdi (2007).

The effect of germination on inactivation of trypsin inhibitor activity (TIA) in *J. curcas* seeds (Figure 2) showed that (TIA) decreased significantly ($P < 0.05$) by 19.72% in *Jatropha* kernel seeds compared with control. These results are in agreement with those reported by Magdi (2007).

Data also showed that trypsin inhibitor activity of *Jatropha* seeds reduced significantly ($P < 0.05$) by 97.07 and 98.05% of defatted whole *Jatropha* seeds and kernel, respectively due to roasting effect (Figure 2). These results are in agreement with those reported by Makkar and Becker (1997a). On the other hand, roasting of *Dolichos lablab* bean reduced the amount of trypsin inhibitor activity, by 23.05% (Magdi, 2007).

The results given in Figure 2 shows also the effect of 0.07% NaHCO₃ treatment followed by autoclaved at 121°C for 25 min on inactivation of trypsin inhibitor activity. The results indicate that, trypsin inhibitor activity content of defatted whole *Jatropha* and kernel seeds were significantly decreased ($P < 0.05$) by 96.79 and 98.29% with whole and kernel seeds, respectively. These values were slightly better than those reported by Aderibigbe et al. (1997) who found that the autoclaving treatment employed inactivated the trypsin inhibitor levels by 83 - 99%. Autoclaving was the most effective as

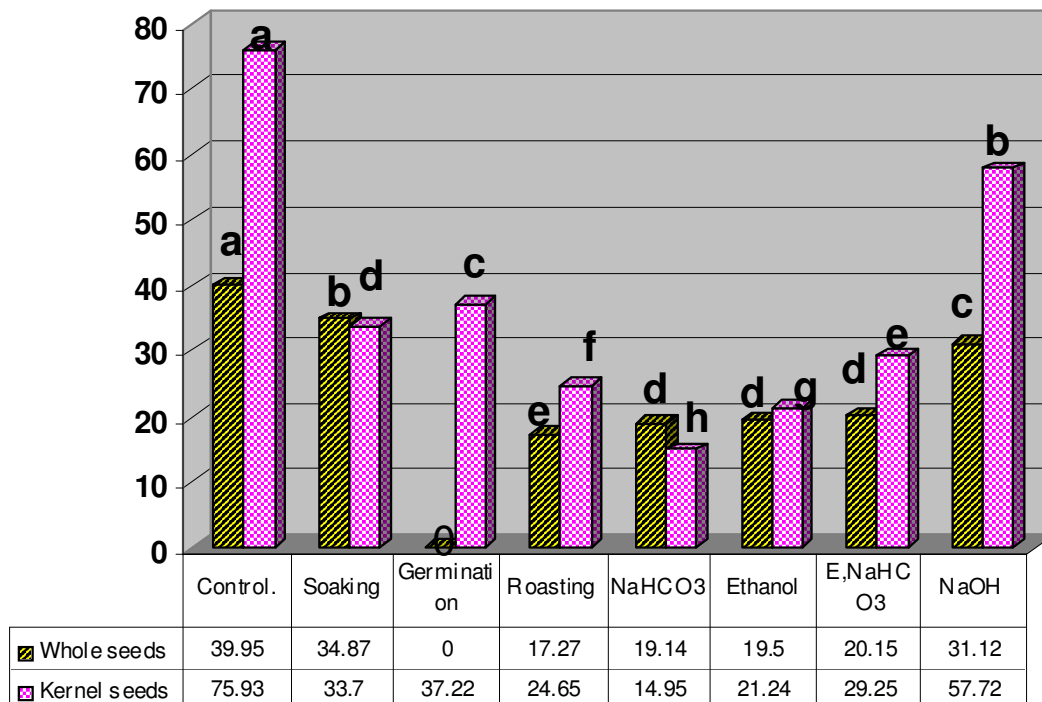


Figure 3. Total phenols (mg/100 g on dry weight basis) of *J. curcas* seeds as affected by some biological and chemical treatments. Means within rows with different letters are significantly different ($P < 0.05$).

trypsin inhibitors are not heat stable.

Trypsin inhibitors interfere with the physiological process of digestion through interference with the normal functioning of pancreatic proteolytic enzymes in non-ruminants, leading to severe growth depression (White et al., 1989). It is possible that the antinutrient effect of trypsin inhibitors is due to their direct interaction with pancreatic proteolytic enzymes and a corresponding reduction in the digestibility of the proteins of the diet (Hajos et al., 1995). Trypsin inhibitors are heat-labile and can be partially or completely denatured when exposed to elevated temperature. Jyothi and Sumathi (1995) reported that the extraction at both low and high temperatures with sodium bicarbonate was most effective in the case of trypsin inhibitors of common bean seeds.

The results given in Figure 2 shows the effect of extraction of whole and kernel seed by 90% ethanol for 2 h on inactivation of trypsin inhibitor activity. The results showed that, trypsin inhibitor activity content of defatted whole *Jatropha* and kernel seeds were not affected significantly ($P < 0.05$). These results are in agreement with those reported by Chivandi et al. (2005).

Extraction of whole and kernel seeds by ethanol 90% for 2 h followed by 0.07% NaHCO₃ and autoclaved at 121°C for 25 min decreased significantly ($P < 0.05$) trypsin inhibitors values by 96.87 and 98.32% of whole and kernel *Jatropha* seed, respectively (Figure 2). These values were slightly better than those reported by Aderibigbe et al. (1997) who found that the autoclaving

treatment employed inactivated the trypsin inhibitor levels by 83 - 99%. Autoclaving was the most effective as trypsin inhibitors are not heat stable. Trypsin inhibitors are heat-labile and can be partially or completely denatured when exposed to elevated temperature.

The effects of sodium hydroxide treatment followed by washing with distilled water on inactivation of trypsin inhibitor activity (Figure 2) showed that the trypsin inhibitor activity significantly decreased ($P < 0.05$) by about 86.71 and 90.53% of defatted whole and kernel seeds, respectively. Chemical treatments (NaOH) with heat treatment for detoxification of *Jatropha* seeds (121°C for 30 min) were most effective. This results agreement with that reported by (Makkar and Becker, 1997b).

Effect of different treatments on total phenols

Total phenols in *J. curcas* seeds were determined after soaking in distilled water for 12 h. at room temperature and data are presented in Figure 3. The results indicate that total phenols were decreased significantly ($P < 0.05$) with whole and kernel seeds, which recorded 12.72 and 55.62% respectively. This reduction was attributed to leaching out of phenols into soaking water. These results are in accordance with those reported by Majed et al. (2006).

Total phenols levels were significantly decreased ($P < 0.05$) with germination of kernel seed by 50.98% (Figure 3).

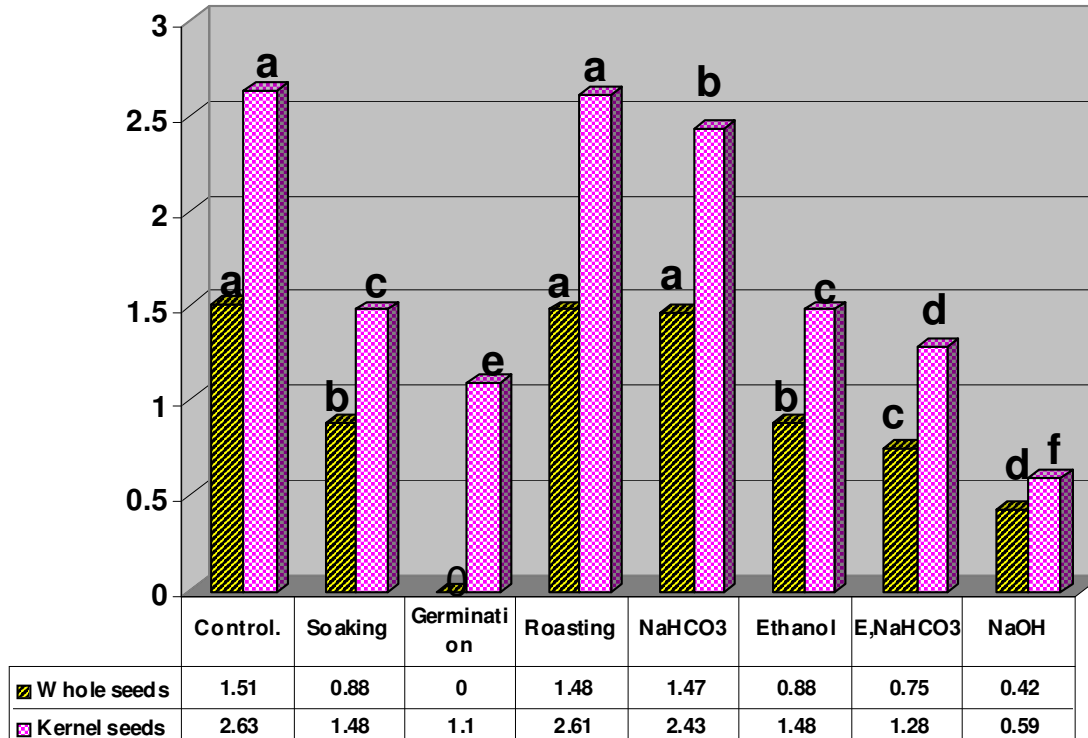


Figure 4. Saponin contents (g/100 g on dry weight basis) of *J. curcas* seeds as affected by some biological and chemical treatments.

Means within rows with different letters are significantly different ($P < 0.05$).

This reduction may be attributed to enzymatic hydrolysis of polyphenols by polyphenol oxidase. Similar results reported by Magdi (2007).

Total phenols of *J. curcas* seeds significantly reduced ($P < 0.05$) due to roasting at 160°C/30 min and the reduction was 56.77 and 67.54% of defatted whole and kernel seeds, respectively (Figure 3). These results are in agreement with those reported by Ibrahim et al. (2002).

The effect of 0.07 % NaHCO₃ treatment followed by autoclaved at 121°C for 25 min on reduction of total phenols in defatted *Jatropha* seeds (Figure 3) showed that, total phenols levels were affected significantly ($P < 0.05$) which reduced by 52.09 and 80.31% with whole and kernel seeds, respectively. Similar results obtained by Vijayakumari et al. (1995).

The extraction of *J. curcas* seeds by 90% ethanol for 2 h (Figure 3). showed that, total phenols levels are reduced significantly ($P < 0.05$) which recorded 51.19 and 72.03% with defatted whole and kernel seeds, respectively. This reduction of total phenols was probably due to extraction along with ethanol (Reddy and Pierson, 1994).

On the other hand, extraction of *J. curcas* seeds by 90% ethanol for 2 h followed by 0.07% NaHCO₃ and autoclaved at 121°C/25 min significantly reduced ($P < 0.05$) total phenol in defatted whole and kernel *Jatropha* seeds by 49.56 and 61.48%, respectively. Similar results reported by Vijayakumari et al. (1995).

The effect of sodium hydroxide (4% solution) treatment followed by washing with distilled water on total phenols significantly reduced ($P < 0.05$) by 22.10 and 23.98% with whole and kernel seeds, respectively (Figure 3). These results coincide with those detected by Stella et al. (1990).

Effect of different treatments on saponin contents

The effect of soaking defatted whole and kernel of *J. curcas* seeds in distilled water for 12 h. at room temperature ($25 \pm 2^\circ\text{C}$) on saponins contents were studied and data shown in Figure 4. It could be noticed that the saponin contents significantly reduced ($P < 0.05$) by 41.72 and 43.73% with whole and kernel seeds, respectively. This reduction could be due to leaching of saponins into the soak water. These results are in agreement with those detected by Bishnoi and Khetarpal (1994).

Germination of *J. curcas* seeds (kernel) and their effect on saponin contents caused a significant decrease ($P < 0.05$) in saponin content of defatted kernel seeds by 58.17% (Figure 4). Similar results reported by Duhan et al. (2001).

Saponin contents in defatted whole and kernel seeds did not affected significantly with roasting (160°C/30 min).

These results are in agreement with those reported by Makkar et al. (1998).

The same Figure 4 indicates the effect of NaHCO₃ treatment followed by autoclaved at 121 °C for 25 min on saponin contents in *J. curcas* seeds. It could be noticed that the treatment did not affect significantly on the saponin contents in whole or kernel seeds.

The extraction of *J. curcas* seeds by 90 % ethanol for 2 h caused significant decrease ($P < 0.05$) in saponin contents (Figure 4). The reduction in saponin content of defatted whole and kernel seeds of *Jatropha* were 41.72 and 43.73% with whole and kernel seeds, respectively. This reduction of saponin was probably due to extraction along with ethanol (Reddy and Pierson, 1994).

Extraction of *J. curcas* seeds by ethanol (90%) for 2 h and 0.07% NaHCO₃ as well as autoclaving at 121 °C/ 25 min on saponin contents was caused significantly decrease ($P < 0.05$) in saponin content by about 50.33 and 51.33% of defatted whole and kernel seeds, respectively. This reduction probably due to their extraction along with ethanol. Similar results obtained by Aderibigbe et al. (1997) who found that the alkali treatments of *Jatropha* kernel seeds were most effective in reducing the saponin content by 84.2%.

Saponin content as affected by sodium hydroxide treatment of *J. curcas* seeds followed by washing by distilled water (Figure 4) of whole and defatted kernel seeds was significantly reduced ($P < 0.05$) by 72.19 and 77.57% respectively. On the other hand, Makkar and Becker (1997b) reported that the alkali treatment (NaOH) with heat treatment (121 °C for 30 min) for detoxification was most effective in reducing the saponin content by 84.2%.

Conclusion

It could be concluded that *J. curcas* seeds are source of carbohydrate, protein, oil and minerals with tolerable antinutrient level. The seed of *J. curcas* which is currently underutilized/ unexplored in most regions of the world is nutritionally promising and could solve the problem of protein malnutrition which is a major public health problem in the developing world, where diets in these parts are predominantly starchy, the major food crops being roots and tubers. The effect of some physical treatments (soaking, germination and roasting) and some chemical treatments (NaHCO₃, ethanol extraction and NaOH) were successful inactivating the antinutrients (phytic acid, trypsin inhibitor activity, total phenols and saponins).

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