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Use of Physic Nut (*Jatropha curcas* L.) Seed Cake in Three Mixtures of Raw Materials for Compost Production

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Abstract

Seed cake of physic nut (*Jatropha curcas* L.) is a major by-product of the biodiesel extraction process. Study on biological conversion of *J. curcas* seed cake (JSC) into added value product (compost) was carried out. Three mixtures (JSC + date palm leaves + cattle manure), (JSC + date palm leaves + chicken manure) and (JSC + date palm leaves + banana leaves), each of 65 kg and with the same carbon to nitrogen ratio (25:1) were formulated and fermented to produce three types of compost named as cattle, chicken and banana compost. The finished composts were assessed for the chemical properties. Results showed germination index exceeded 80% in 60 days of decomposition. Banana compost gave the highest nitrogen (2.66%) and organic carbon (29.35%) compared to cattle and chicken compost nitrogen (2.38%) and organic carbon of 28.01 and 27.80%, respectively. Nutrients content in the finished composts were within the desired levels, with banana compost showed the highest values. Huge quantities of JSC will be expected if *J. curcas* plantation succeeded. Therefore, the current finding is of utmost importance in eliminating such by-product through co-composting with other organic wastes, and that the commercial production of compost will increase the efficiency and profitability of *J. curcas* and bio-fuel industry.

Keywords: Barbados nut, composting, bulking agent, date palm leaves, germination index.

Introduction

Physic nut, also called Barbados nut, purging nut or JCL (*Jatropha curcas* L.), of the plant family Euphorbiaceae, is a multipurpose large shrub or small tree, easy to establish and has the potential to produce non-edible (toxic) seeds with oil content which is renewable and environmentally safe biofuel (Kumar *et al*., 2010). Moreover, the plant is drought resistant, survives well in arid and semiarid regions and grows in all types of soils. Also, it can be used for conservation purposes and income generation. It helps to reclaim problematic lands, restore eroded areas and control erosion. Oil extraction process from *Jatropha* seed for biodiesel production generates substantial amount of seed cake. Mahanta *et al*. (2008) estimated that *Jatropha* plantation produce 1000 kg seed cake/ha of crop. Furthermore, Sharma *et al*. (2009) and Sinha *et al*. (2011) reported the efficiency of *Jatropha* seed cake as organic fertilizer due to its high content of nitrogen (3.2-4.4%), phosphorus (1.4-2.09%) and potassium (1.2 – 1.68%).

Composting is the aerobic decomposition of organic wastes by microorganisms under controlled conditions to produce biologically stable material (compost) which can be used to improve fertility and quality of soils. During composting microorganisms mineralize and metabolize organic carbon compounds, which produce carbon dioxide, ammonia, water vapor, organic acids and heat. To achieve best composting many factors need to be optimized, among which is the C/N ratio. Based on the requirements of microorganisms (30 part of carbon per one unit of nitrogen), adequate C/N ratio for composting is in the range of 25 - 35 (Bishop and Godfrey, 1983). Thus, low C/N ratio can be corrected by adding bulking agent to provide degradable organic carbon and raise the C/N of the composting mixture to an acceptable level.

In Sudan, there is a governmental program underway dedicated for plantation of *J. curcas* tree for biodiesel production. Seed cake of *Jatropha* is the major by-product of the biodiesel extraction process. However, as the biodiesel program reaches its maturity, a lot of seed cake will be produced. Under commercial production of *Jatropha*, disposal of such by-product is expected to create environmental problems unless being recycled in sustainable way. On the other hand, since most of cultivated soils in Sudan are low in organic matter content (< 1%), *Jatropha* plantation may utilize large quantities of nutrients (which will not be extracted with oil) and deplete soil fertility if it was not fertilized. Therefore, recycling of *Jatropha* seed cake back to the soil will contribute significantly in improving soil fertility so that substantial production of the crop can be achieved.

The scopes of the present investigation were to produce compost from co- composting of *J. curcas* seed cake with date palm leaves, added to cow dung, chicken manure or banana leaves, and to evaluate the produced compost in terms of nutritional value.

Materials and Methods

A composting experiment was carried out in 2014 at the "Environment, Natural Resources and Desertification Research Institute", Khartoum, using *J. curcas* seed cake (JSC) - as primary substrate and date palm leaves - as bulking agent (carbon source), mixed either with banana leaves, cow dung or chicken manure as raw materials. The five organic wastes were analyzed in the laboratory for determination of total nitrogen, organic carbon, macronutrients and micronutrients using standard methods, as explained below. Plant materials were shredded and three mixtures of the raw materials were prepared and named as listed below:

Mixture name	Composition of raw materials mixtures
Banana	JSC + date palm leaves + banana leaves
Cattle	JSC + date palm leaves + cattle dung
Chicken	JSC + date palm leaves + chicken manure

The mixtures contain same weight of JSC (15 kg). Different weights of the other four raw materials were used so that each one of the three piles gave approximately a total weight of 65kg and the same carbon to nitrogen ratio (1:25) to hasten the composting process. Each mixture was replicated thrice and filled individually in cemented trough ($1m^2$), then moistened by water to about 65% moisture content (W/V), mixed thoroughly, heaped in pile, covered with plastic cover and left for aerobic fermentation. During the co-composting process, the piles were periodically turned manually at different intervals for aeration and addition of water whenever required to maintain the moisture content at 65% approximately. Their temperatures were measured manually using a 60 cm stem dial thermometer at about 30cm depth in 3 locations of the piles, and the averages were recorded at intervals of 0 - 58 days. The composting period lasted for sixty days.

About 200 g of composted materials were drawn from three different locations of each pile at 0, 30 and 60 days. The samples of each pile were mixed individually to make composite samples. A representative sample was taken from each composite sample, air dried, ground to pass through 1.0 mm sieve and analyzed in the laboratory for determination of pH and electrical conductivity (EC) in compost: water suspension (1:5, W/V) using digital pH meter, total organic carbon by wet digestion (Walkley and Black, 1934), total nitrogen was estimated by semi micro Kjeldahl (AOAC, 1990), and available phosphorus content was determined by method of Chapman and Pratt (1961). Effect of compost maturity on seedling emergence was determined by measuring germination index (GI) of *Raphanus sativas* (radish) seeds as described by Zucconi *et al*. (1981). The seeds were placed on sterile filter paper in Petri dishes, soaked with 2 ml of compost: water (1:10) extract for 72 h in the dark at room temperature. Numbers of seeds germinated on the filter paper were recorded and roots lengths were measured. Seed germinated in distilled water served as the control. Germination index (GI) was expressed as:

$$\textbf{GI} = \frac{\textbf{Seed germination\% X root length of treatment}}{\textbf{Seed germination \% X root length of control}} \textbf{X100}$$

Statistical analysis

The collected data were analyzed using Gen Stat Release 10.3DE (PC/Windows 7). One way analysis of variance (ANOVA) was carried out based on a Randomized Complete Block design. Treatment means of significant differences were separated using the Least Significant Difference (LSD) procedure, at 0.05 level of significance.

Results and Discussion

Composition of raw materials used in the prepared compost showed wide variation in their nitrogen, phosphorous and C/N ratio contents (Table 1). The table indicated that JSC is a rich source of nitrogen (4.69%), compared to the other raw materials, but with a C/N ratio (9.48) lower than the adequate level for composting (25 – 35). Contrarily, date palm leaves exposed the lowest nitrogen content (0.42%) and the highest C/N ratio (110.45), therefore, they increased the C/N ratio in the substrate mixture to an acceptable level (25:1).

Table 1. Chemical composition of raw materials used for composting.

Parameters	**Substrate**				
	JSC	**Chicken manure**	**Cattle dung**	**Date palm leaves**	**Banana leaves**
Nitrogen (%)	4.69	4.34	2.24	0.42	1.96
Organic carbon (%)	44.44	43.69	36.23	46.39	47.58
C:N	9.48	10.07	16.17	110.45	24.27
Phosphorus (%)	1.34	0.11	0.68	0.14	0.28
Calcium (%)	0.20	0.22	0.11	0.26	0.10
Potassium(%)	0.18	0.11	0.07	0.07	0.34
Magnesium (%)	0.21	0.16	0.16	0.30	0.23
Sodium (%)	0.01	0.134	0.09	0.009	0.007
Cupper (mgkg^{-1})	10.30	19.45	10.4	4.0	2.85
Zinc (mgkg^{-1})	23.35	61.7	29.9	16.4	11.15
Iron (mgkg^{-1})	77.75	117.75	162.85	27.00	12.15
Manganese(mgkg^{-1})	10.60	26.2	14.0	7.15	25.7

JCS = *Jatropha curcas* seed cake.

Trend of temperature during composting was depicted in figure 1. The temperatures increased steadily during the first phase and reached the peak (55, 54 and 52°C) after 18 days in banana, cattle and chicken piles, respectively, showing rapid initiation of composting process. According to Bernal *et al*. (2009), during the first phase of the composting process the simple organic carbon compounds were easily mineralized and metabolized by the microorganisms, producing carbon dioxide, ammonia, water, organic acids and heat. The accumulation of such heat raises the temperature of the piles and the decomposition process implies the volume reduction of the wastes. However, the optimum temperature range for composting was reported by de Bertoldi *et al*. (1983) as 40 – 65°C, while Miller (1992) stated that temperature in the range 52 – 60°C is the most favorable one for decomposition. Thereafter, the temperature declined in all piles, as shown in figure 1. The rise and fall in temperature have been reported to correlate with the rise and fall of microbial activity (Tiquia *et al*., 1996), and the existence of microorganisms differ with the temperature of the composting pile (Manohara and Belagali, 2014). In the later stage, temperature in the different piles reached 34°C (more or less same as ambient air temperature) almost at the same time (54 days). Such a level of temperature remained constant even after addition of water and pile's turning. This result can be attributed to depletion of readily decomposed materials, which indicates stabilization of the composts. This observation was in line with that of Harada *et al*. (1981), who stated that maturity stage started when the temperature decreased to normal air daily temperature and remain constant with turning of the piles. Therefore, this parameter is considered as a good indicator for the end of the biodegradation phase where the compost maturity is achieved (Jimenez and Garcia, 1989). At this stage the three mixtures became brownish black in color, crumbly, with an earthy smell and non offensive odor, their volumes were reduced, and consequently, their original constituents were undifferentiated. The obtained results were in clear conformity with those of Diaz *et al*. (1993), who stated that the matured compost may be grayish-black or brownish-black in color, depending on whether tannins, melanin or other materials containing brown pigments were originally present. Also, Bernal *et al*. (2009) stated that composting causes substantial reduction in the volume of the raw materials and the resulting compost is physically and biochemically different from the original materials.

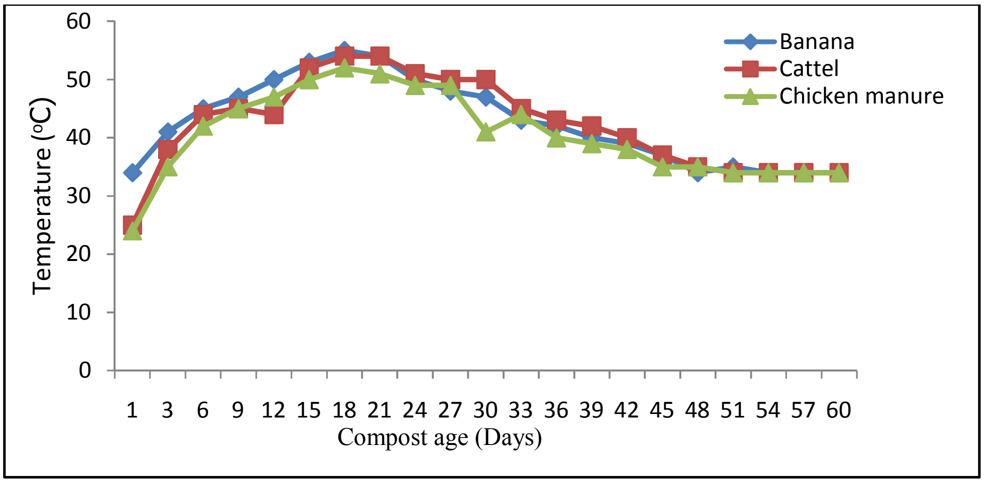

Figure 1. Temperature variation in the three mixtures of banana, cattle and chicken with seed cake of *Jatropha cucas* during composting time.

Results of produced composts (Table 2) revealed that the concentration of organic carbon in the three mixtures decreased throughout the composting process in all substrates mixtures from their initial values, with only significant difference ($p< 0.05$) between them after 30 days of composting, indicating a good level of degradation of organic materials. This degradation can be attributed to liberation of carbon dioxide during the composting process. Similarly, Parè *et al.* (1998) observed that the total organic carbon in animal manure and shredded paper decreased continuously during composting. After 30 days of composting the degradation rate of organic matter decreased gradually, this thought to be occurred as a result of reduction in available carbon sources and synthesis of new complex organic compounds. Results in table 2 also showed that the concentration of nitrogen increased throughout the composting process, and without significant difference between the three mixtures. This fact can be explained by the concentration effect caused by degradation of the labile organic carbon compounds which reduced the weight of composting mass. In this regard, Bernal *et al.* (1998) reported that the concentration of nitrogen usually increases during composting when volatile solid (organic matter) loss is greater than the loss of ammonia. Moreover, addition of materials rich in organic carbon (bulking agent) can reduce nitrogen losses during the composting of organic wastes with a high nitrogen concentration (Bernal *et al.*, 2009). The finding is in consistency with Morisaki *et al.* (1989), who reported that NH_3 binds tightly with the components of the bulking agent, and therefore, nitrogen loss will be reduced during composting. Barrington and Moreno (1995) stated that bulking agents have been used to conserve nitrogen as they usually possess high water and cation absorption properties. Thus, the decrease of organic carbon and increase in nitrogen resulted in a reduction of C/N ratio without significant difference between the three mixtures; and this agreed with the finding of Bernal *et al.* (1998) that C/N ratio of all organic wastes decreases during the composting process. The C/N ratios in the currently produced composts ranged between 11.03 - 11.77. In this regard, it is reported that C/N ratio below 20 is an indicative of acceptable maturity (Golueke, 1981), whereas C/N ratio < 15 or even lower is preferable for agricultural crop residues as plant cannot assimilates mineral nitrogen unless the C/N ratio is in the order of 10 – 15:1 (Edwards and Bohlen, 1996). Moreover, Bernal *et al.* (1998) stated a C/N ratio < 12 as an index of maturity.

Table 2. Chemical characteristics of the raw materials mixture at different intervals of composting.

Mixture characteristics	**Mixture age (days)**	**Mixture name**			**LSD**
		Chicken	**Cattle**	**Banana**	
Organic carbon (%)	0	47.41	45.38	45.28	14.96
	30	34.91	34.42	38.74	3.36
	60	27.80	28.01	29.35	14.55
Total nitrogen (%)	0	1.96	1.82	1.82	0.33
	30	2.66	2.38	2.10	0.63
	60	2.38`	2.38	2.66	0.50
C/N	0	24.19	24.93	24.88	7.78
	30	13.12	14.46	13.69	1.81
	60	11.68	11.77	11.03	1.18
Electrical Conductivity (dSm^{-1})	0	6.30	5.70	6.40	1.35
	30	5.40	5.30	6.70	1.29
	60	3.50	4.30	4.80	0.38
pH	0	5.58	5.68	5.92	1.60
	30	7.14	7.20	8.15	1.38
	60	6.96	6.87	7.76	1.41

The initial pH of the composting mixtures were in the range of 5.58 – 5.92, and it increased up to the range of 7.14 – 8.15 after 30 days of decomposition process (Table 2). According to Paredes *et al.* (2000) and Sharma *et al.* (2009), this increase may be due to the production of NH_4^+ during proteolysis, and when oxygen is not a limiting factor, organic acid production will be low but ammonia emission will be high, hence pH of compost rises. By the end of composting process, the pH decreased to the range of 6.87 – 7.76, with no significant differences between the three mixtures in the three stages. In this respect, de Bertoldi *et al.* (1983) and Miller (1992) stated that the optimum pH to support microbial activity during composting is 5.5 – 8.0. The pH of finished chicken and cattle compost were in the neutral range of 6.5 – 7.4 and of banana (7.76) was slightly alkaline after 60 days. These values were within the optimum range (6 -8) as indicated in literature (Negro *et al.*, 1999). The neutral pH is the most desired, because it ensures less volatilization of NH_3 and a balanced microbial population (Gaind *et al.*, 2009).

Electrical conductivity measures the amount of soluble salts in the compost sample, and its most desirable values ranged from 3 to 5 dSm^{-1}. Values lower than these indicate the lack of available minerals, whereas higher values inhibit the biological activities (Sharma *et al.*, 2009). However, EC of the three composting mixtures showed a decreasing trend with the progress of composting (Table 2), with almost significant differences between the three mixtures ($p < 0.05$) after 30 and 60 days from the start. The decrease in EC can be attributed to precipitation of salts and the production of ammonium. Although, the EC values (3.5 - 4.8 dSm^{-1}) of the obtained composts were within the optimum range suggested above by Sharma *et al.* (2009), the EC of cattle (4.3 dSm^{-1}) and banana (4.8 dSm^{-1}) compost were more than the value (4) suggested by Lasaridi, *et al.* (2006).

The attained results showed that during composting the concentration of macronutrients (potassium, calcium, magnesium and phosphorus) (Table 3), and micronutrients (iron, manganese, copper and zinc) (Table 4) were increased with significant differences between the three mixtures ($p < 0.05$) after 60 days of composting. Properly, this increase was due to losses of organic carbon, hydrogen and oxygen from the piles in form of carbon dioxide and water during composting, leaving these elements accumulated behind. This confirmed the finding of Kaushik and Garg (2004) that the degradation of organic matter during composting is reflected in the increase of phosphorus, potassium, calcium and magnesium. In this context, Tiquia and Tam (2002) reported that the increases in these elements correspond with decreases in organic carbon. The results also showed that the micronutrients concentrations in the produced composts were in the following order: iron > copper > zinc > manganese. Similar results were obtained by Manohara and Belagali (2014).

Seed germination index (GI) is commonly used to assess the phytotoxicity of compost, since it is a problem associated with immature composts. Table 5 shows that the GI of radish seed increased with the time of composting, scoring variable values for the different composting mixtures. They were in the range of 85.5 – 91.8%, which was above the threshold value of 50 – 60% stated by Gaind *et al.* (2009). According to Zucconi *et al.* (1981) a germination index below 50% characterizes immature compost, and that greater than 80% was phytotoxin free and considered as completely mature. In the produced compost banana mixture recorded the highest value of GI (91.80%) which is significantly ($p < 0.05$) different from the other two composts.

Table 3. Concentration of macronutrients (%) in the raw materials mixtures at different intervals of composting.

Mixture characteristics	Mixture age (days)	Mixture name			LSD
		Chicken	Cattle	Banana	
Sodium (%)	0	0.10	0.20	0.12	0.14
	30	0.12	0.16	0.14	0.05
	60	0.22	0.12	0.12	0.04
Potassium (%)	0	1.30	1.10	2.00	1.16
	30	1.70	1.60	2.70	1.21
	60	1.90	1.40	4.10	1.40
Calcium (%)	0	2.10	1.50	2.40	0.39
	30	2.40	2.40	3.00	0.33
	60	2.70	1.50	3.60	0.63
Magnesium (%)	0	1.32	1.32	2.28	0.34
	30	2.16	3.20	3.70	0.12
	60	3.56	2.48	3.64	0.46
Phosphorus (%)	0	0.64	0.54	0.54	0.05
	30	0.74	0.84	0.60	0.25
	60	0.96	0.90	1.02	0.10

Table 4. Concentration of micronutrients ($mgkg^{-1}$) in the raw materials mixtures at different intervals of composting.

Mixture charcteristics	Mixture age (days)	Mixture name			LSD
		Chicken	Cattle	Banana	
Iron (ppm)	0	57.55	90.70	44.30	11.77
	30	196.55	258.05	277.85	22.51
	60	193.95	295.90	220.30	4.01
Manganese (ppm)	0	17.20	13.40	37.05	10.01
	30	34.50	46.40	61.30	13.44
	60	54.00	43.65	85.65	2.96
Copper (ppm)	0	8.70	9.55	5.95	7.20
	30	14.15	11.80	10.95	8.82
	60	15.45	12.60	12.00	1.68
Zinc (ppm)	0	21.35	19.15	14.65	8.21
	30	24.45	31.65	34.30	3.09
	60	35.35	34.40	49.15	1.96

Table 5. Germination index (%) of the organic materials mixtures at different intervals of composting.

Mixture name	Germination index (%)	
	After 30 days	After 60 days
Chicken	44.03	87.20
Cattle	62.70	85.50
Banana	89.48	91.80
LSD	13.65	3.26

Conclusion

The produced composts contained nutrients essential for plant growth including trace elements; therefore, they can be utilized as sustainable organic fertilizers for *Jatropha curcas* trees. The nutritional benefit of *J. curcas* seed cake is best utilized in this manner as it cannot be used as animal feed due to its content of a toxic substance (phorbol ester). Such non edible seed cake with its rich nitrogen content can be used to improve nitrogen content of cellulosic wastes with high C/N ratio for producing valuable composts. Therefore, huge volume of *J. curcas* seed cake can be eliminated through co-composting with other organic wastes, and that the commercial usage of this by-product could increase the efficiency and profitability of the *Jatropha* crop and biofuel industry. Field trials are needed to assess the applicability and potentialities of the prepared composts as soil amendment.

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