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Jatropha Curcas L. Biomass Waste and Its Utilization

Sri Rizki Putri Primandari, A.K.M. Aminul Islam,
Zahira Yaakob and Swapan Chakrabarty

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<http://dx.doi.org/10.5772/intechopen.72803>

Abstract

Jatropha curcas L. is cultivated for its oil utilization as fuel feedstock. This main purpose is achieved with the biomass waste after oil extraction. The biomass wastes are leaf and stem from pruning, fruit hull, seed husk, and oily-cake. This paper discusses the utilization of the waste in order to achieve zero waste of *jatropha* and develop the *jatropha* utilizations. *Jatropha* waste is also utilized as fertilizer, briquettes, adsorbent, resin, and bioactive compost. It can also be utilized as feedstock for production of polymer composite, combustion for gasifier, biogas, liquid oil, and dye. These wide utilizations make *jatropha* very suitable for biofuel proposes.

Keywords: biomass, *Jatropha* cake, utilization, environment, waste management

1. Introduction

Jatropha curcas L. is one of growing interest in bioenergy resource. It belongs to the family Euphorbiaceae. It is perennial bush, easy to grow in tropical and subtropical regions, resistance to drought and produce crimson color flower (**Figure 1**). It is native to Mexico and Central America, but can be suitably cultivated in tropical and subtropical areas such as South East Asia. It is a small tree with height of about 6 m. *J. curcas* L. is planted principally as a hedge to prevent crop plant from the cattle, sheep and goats. Currently, *jatropha* is popularized as bioenergy plant due to high content of oil in the seeds. The oil from this crop is a promising alternative in biodiesel production. Utilization of *jatropha* oil as biodiesel feedstock is increasing as its oil is non-edible and does not compete with food crops. It helps the food security in biodiesel production. Some advantages using it as biodiesel resource are continuity resources (renewable) and ecofriendly energy.



Figure 1. *Jatropha curcas* L.

The oil can be converted to biodiesel through transesterification easily [1]. Utilization is associated with the biomass that is left behind after the oil extraction. Large number of waste impacts the environment. In this chapter, we present several ways of processing the waste to make it a valuable product.

2. The biomass waste of *Jatropha curcas* L. oil production

The waste biomass from oil production is shown in **Figure 2** below.

Waste biomass from *J. curcas* L. plantation and its oil production has nutrient and mineral content as presented in **Table 1**.

Although there are small amount of nutrients in leaves but these compounds are good for the soil fertility. When the plant sheds off its leaves, they decompose and their minerals go back

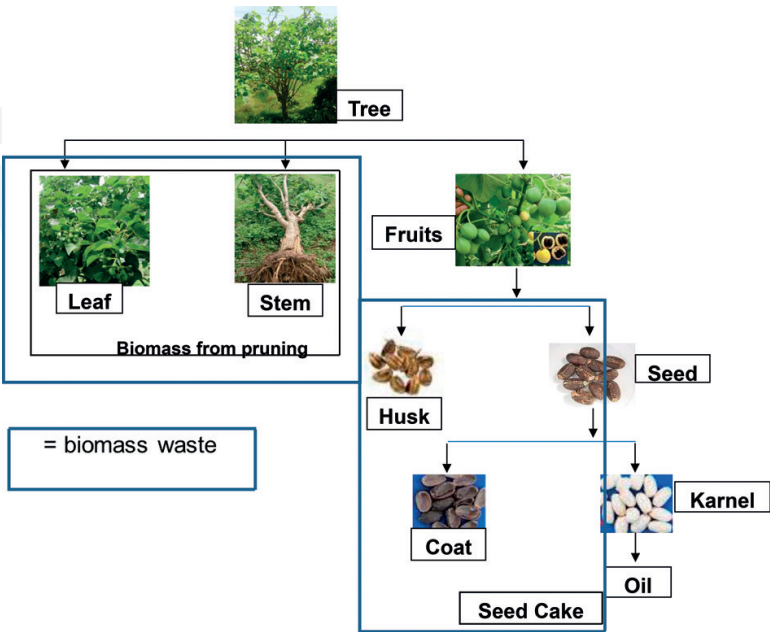


Figure 2. Biomass waste from *Jatropha curcas* L. oil production.

Nutrients	Leaf ^a	Wood ^b	Fruit			Seed cake ^b
			Hull ^b	Seed husk ^b	Kernel ^c	
N (%)	6.40	3.34	2.15	0.19	4.39	4.90
P (%)	0.34	0.09	0.05	0.01	1.10	0.90
K (%)	2.45	2.87	0.73	0.31	0.94	1.75
Ca (%)	1.40	0.30	0.44	0.28	0.34	0.31
Mg (%)	0.53	0.26	0.30	0.06	0.53	0.68
S (%)	0.19	0.12	0.10	0.01	0.21	0.24
Zn (ppm)	28	55	22	1	47	55
Fe (ppm)	168	99	40	8	73	772
Cu (ppm)	6	2	11	3	18	22
Mn (ppm)	117	605	25	13	28	85
B (ppm)	71	10	4	2	5	20
Na (ppm)	808	134	28	20	17	—

Refs: ^aPacheco et al. [2]; ^bSaturnino et al. [3]; ^cWan et al. [4].

Table 1. Nutrient composition of *Jatropha curcas* L. plant.

to the soil. The fruit hull constitutes 30% of the fruit. Calorific value of fruit hull is dependent on the humidity. With humidity 15%, the calorific value being considered is 11.1 MJ/kg [5]. Calorific value will increase with increase in its humidity.

Considering nutrients and minerals above (**Table 1**), waste biomass from *J. curcas* L. has its own peculiarity. *Jatropha* seed cake has proven as fertilizer [6]. Leaf has nutrient and mineral content higher than other parts especially seed cake, while stem also has potential nutrients and minerals too. Seed cake cannot be used as animal feed because it contains toxins such as phorbol ester curcasin and cursin [2].

The leaves, stems, fruit hull and seed oilcake could be used as potential fertilizer. *Jatropha* hull has very high ash content, around 13% [7] and ash will melt at temperature above 750°C. Gasifier operates around 900–1000°C. Hence, the hull is not suitable for being used as a fuel for gasifier. It creates melted ash that can deposit in the bed fluidization. However, the hull can be converted to biogas using biological conversion process.

Theoretically, the best use of press cake is for energy purposes first, and then as a fertilizer. Even when digested to obtain biogas for energy, the nutritional value remains intact. The presence of milky substance (sap) in the stem makes it hard to burn the stem without drying it first.

The largest biomass from *jatropha* is from seed cake, which is around 59.24%w of fruit (wet basis), fruit hull 22.05%w of fruit (wet basis), seed husk 27.16%w of fruit (wet basis) [8]. Around 95% oil can be extracted using chemical extraction, while only 85% can be obtained by mechanical extraction [9]. It means the seed cake still contains 5–15% oil. Considering the amount of energy in *jatropha* seed cake, it should first be utilized for energy purposes such

as biogas production and second purpose may be as a fertilizer. The seed cake of jatropha can be used as organic fertilizer because it still has nutrients and mineral needed by the plant. Jatropha seed cake could be used in combustion process but considering air emission produced by burning, its use as a fertilizer would be a better choice.

2.1. Jatropha as a fertilizer (green manure)

In this section, use of jatropha as a fertilizer or green manure has been presented. Green manure can reduce loss of nutrients from soil and give sustainable nutrient supply for long period as compared to chemical fertilizer. Chemical fertilizers can get solubilize in water and will drift together with water especially during the rainy seasons. Patolia et al. [10] reported after 2 years that N_{45} application could increase the dry matter compared to N_0 application. Ghosh et al. [6] also reported that dry matter of sandy loam soil could be increased upto 120% by adding 3 tons of seedcake/ha as manure. *J. curcas* L. seedcake contain 2% N, 1.2% P_2O_5 and 1.4% K_2O .

2.2. Biogas production

Biogas (methane) is produced by anaerobic digestion. Biogas has wide utilities as it can be applied directly for cooking, heating and stationary engine operation in dual fuel mode. The biogas is purified, compressed and stored in cylinder as CNG (Compressed Natural Gas) for automotive transport purposes, power generation as well as in agricultural unit operation.

Jatropha seed cake has good potential as biogas feedstock due to confer 60% higher biogas and also better calorific value than the cattle dung [11]. Chandra et al. [11] reported jatropha seed cakes have biogas generation potential in the range of 220–250 and 240–265 L/kg of cake respectively (under mesophilic temperature range of anaerobic digestion). C, H, and N composition was 48.8; 6.20 and 3.85% with C/N ratio of 12.70. The methane content of biogas derived from non-edible oil seed cakes has been found to range between 65 and 70% against 55% from the cattle dung. The best dilution ratio of cake is at 1:4 (cake:water) for *J. curcas* seed cakes. Production of biogas from *J. curcas* seed cakes is one of easy ways for waste management. It can also be used to fulfill energy need for rural areas. According to Kumar [12], in India ~2550 million cubic meters of biogas has been produced from 10.2 lakh metric tons of *J. curcas* seed cakes.

Visser and Adriaans [13] studied anaerobic digestion of *J. curcas* press cake. The cake was from cold pressing jatropha seed including the husk. Digestion was carried out at temperature 20°C, pressure 1 bar during 60 days. Jatropha cake that pressed with nozzle (aperture size of 7 mm) contain 33% hull produced a cumulative biogas yield of 0.95 m³/kg dry matter, with 85% carbon conversion. Gunaseelan [8] reported energy biomass from part of fresh *J. curcas*. The feedstocks were dried at 60°C before use and subsequently grained to become 2 mm mesh. Other parts of *J. curcas* plant as a biogas feedstock is presented in **Figure 3**.

Figure 3 suggests not only jatropha cake, but also all parts of the jatropha plant could be utilized for producing biogas (methane). The highest yield was achieved from seed kernel 0.969 L/g Volatile Solid added. If compared to the yield from de-oiled cake, which is just 0.23 L/g VS added, it shows oil has potential with 0.739 L/g Volatile Solid added.

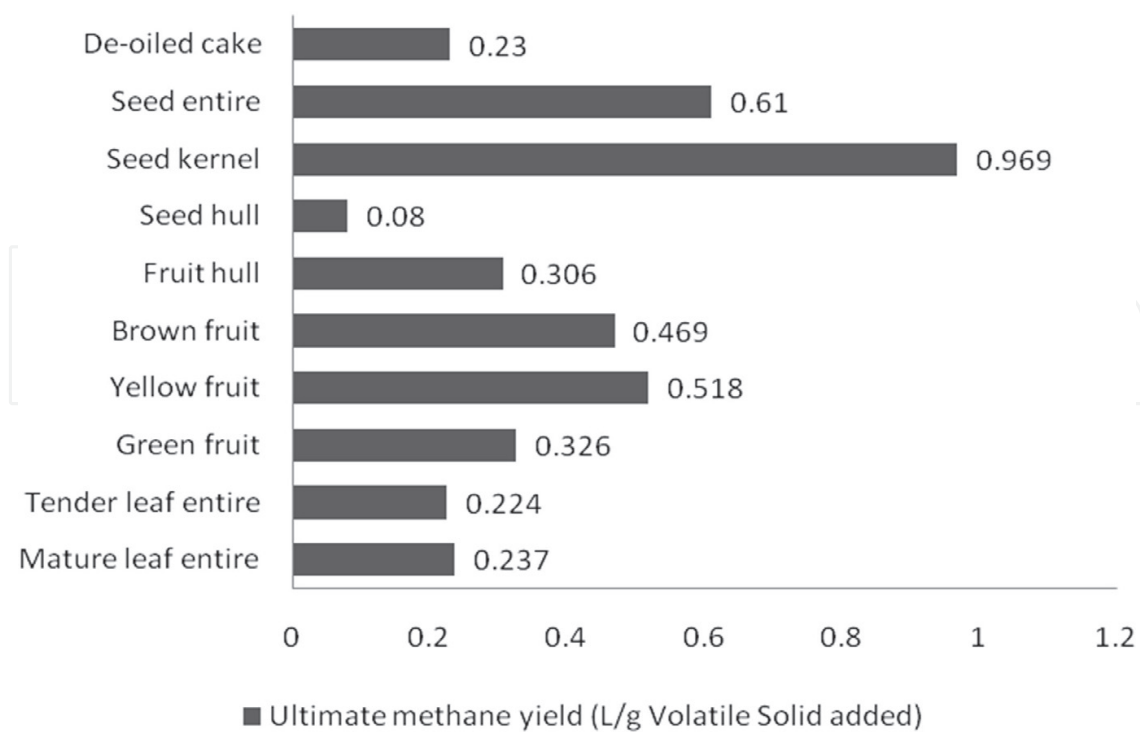


Figure 3. Production of methane from parts of *Jatropha curcas* L. [8].

2.3. Feedstock combustion for gasifier

Vyas and Singh [14] reported that jatropha seed husk could be used successfully as feedstock for open core down draft gasifier, although the gasifier has to be induced by 1 kg charcoal and 3.2 kg wood. Jatropha seed husk analysis contains 3.97% dry basis ash, 71.04% dry basis volatile matter and 24.99% dry basis fixed carbon. Gasifier was able to run on jatropha seed husk for 340 minute at 2 flow rates (4.5 and 5.5 m³/h) without any problems. Gasification efficiency of 68.31% was achieved at gas flow rate of 5.5 m³/h and biomass consumption rate of 2.2 kg/h. Gasification efficiency can possibly be increased 2.35% by increasing 1 m³/h of gas flow rate and by adding 0.4 kg/h biomass consumption rate.

2.4. Bioactive compost production

Bioactive compost can be produced from *J. curcas* hull. Sharma et al. [15] produced bioactive compost from jatropha hull biomass by using lingocellulolytic fungi. Bioactive compost is for increasing the added value compared to ordinary manure. Within 1 month, carbon to nitrogen (C/N) ratio of hull decreases from 66.93 to 12–16. From C/N ratio point of view, composting of jatropha hull in 1 month has indicated a better composition of bioactive compost. However, it takes nearly 4 months for complete compost maturation. After 4 months, phytotoxicity of compost can be reduced, thus compost will be ready to use. Bioactive compost from jatropha hull is alkaline, so it is suitable for acidic soil. It can balance the pH of the acidic soil.

2.5. Liquid oil from pyrolysis of jatropha cake

Pyrolysis is a thermal decomposition without oxygen that converts biomass into solid (charcoal), liquid (tar and other organics, such as acetic acid, acetone and methanol) and gaseous products (H_2 , CO_2 , CO). *J. curcas* seed cake is lignocellulosic biomass that consists of cellulose, hemicellulose and lignin contents. Lignocelluloses decompose at different temperatures. Hemicelluloses decompose at temperatures of 470–530 K. Meanwhile, cellulose decomposes at the temperature range between 510 and 620 K and lignin being the last component to pyrolyze at temperatures of 550–770 K [16]. Thus, pyrolysis of *J. curcas* seed cake is being carried out at elevated temperature [17]. The liquid oil as pyrolysis product has a reddish-brown color with an irritant odor [18].

J. curcas seed cake has empirical formula of $CH_{1.53}O_{0.4}N_{0.007}S_{0.0008}$ with H/C ratio 1.53. The gross energy value of seed cake was found to be 17.7 MJ/kg. Pyrolysis of seed cake can obtain maximum yield of oil (31.17% by wt) at 500°C [17]. Fast pyrolysis without catalyst (thermal pyrolysis) produced wide range of organic compounds. Purification needs to be addressed such as liquid–liquid extraction into aqueous and organic phases. This oil is considered as another source for biofuel. The sludge obtained after biogas can be used as fertilizer.

2.6. Briquettes

Briquetting can be used as one of the solution to handle the jatropha press cake. The seed cake still has energy content of around 25 MJ/kg [18]. Since the briquette produces a lot of smoke, it is better to use the product outdoors. It can be used indoors with proper ventilation [19]. The carbonized process should be maintained at average time 10 minutes per 5 kg in order to prevent cake from complete combustion. Complete combustion will produce ash instead of charcoal briquette. Cassava and corn starch were used as binders for bonding the carbonized cake. Pandey et al. [20] reported that using 10% binder (cassava and corn starch) for pressed cake produced good jatropha charcoal briquette. The briquette from jatropha seed cake has emission of CO and CO_2 are lower than briquette from wood. However, briquette from jatropha seed cake has much higher emissions of NO and NO_2 than wood pellet. It is because of the presence of residual oil and higher nitrogen content [20].

2.7. Dye productions

Dye can be produced from leaves, stem, bark, wax, and roots of jatropha plant [21–23]. The leaves and stem of jatropha produced brownish dye when boiled in water as an extraction process [20]. It is based on experience of Tharu tribes, Devipatan division. The dye has no irritative and/or toxic effect on skin. Bark contains tannins that produce purple color in dye production [22]. Meanwhile, combining wax and bark produced dark blue dyes. Roots of jatropha could produce yellow dye. The dye is used to dye domestic threads, ropes and clothes during ceremonial occasions [23].

2.8. Polymer composite production

Polymer composite has strong and stiff fibers in a matrix which is weaker and less stiff compared to fiber. The quality of polymer composite is determined by their characteristic properties

such as modulus of rupture (MOR), modulus of elasticity (MOE). The cake of jatropha and the shell were utilized for polymer composite production by Hrabě [24] and Raju [25]. Jatropha cakes were in two forms, *viz.*, continuous (as epoxy adhesive) and discontinuous phase (as reinforcing particles). The filler moisture was $4.59 \pm 0.22\%$ wet basis. Raju [25] produced polymer composite by using jatropha shell as reinforcement and reported that 20 wt% of shell has maximum MOR of 40.57 MPa and 60 wt% of shell as reinforcement has maximum MOE of 8.204 GPa.

2.9. Adsorbent

Adsorbent (activated carbon) was produced by using jatropha pods (hull). It is used as an adsorbent for the removal of reactive dye, Remazol Brilliant Blue R (RBBR) [26]. It adsorbed 24.5 g dye by using 0.1 g activated carbon from jatropha pods. Further, the adsorbent removed almost 245 g dye per g activated carbon. Another study [26] reported that the hull of jatropha produced active carbon that had the potential to remove heavy-metal ions, such as zinc and cadmium from waste water and dye (malachite green) and has shown a remarkable adsorption capacity. Its adsorption capacity can reach up to 11.89 mg/g for cadmium removal. Biosorption of Zinc (II) from waste water was also supported by Abidin et al. [27] by using aqueous solution of jatropha press cake (kernel part only). Abidin et al. [27] reported that ~40 mg/L Zinc (II) was removed from 1 L waste water by using 0.5 g jatropha press cake in about 100 minutes. It revealed that jatropha has potential for adsorbent production either in the form of activated carbon or deoiled-press cake itself without any prior treatment [27].

2.10. Resin

Resin is one of the essential chemical in polymer industries. One of resins, alkyd, is widely applied in coatings and paint industries. Usually, resin is produced by using palm oil and other edible oil such as rapeseed, coconut and soybean oil. However, utilization of edible oil affects food security. Thus, non-edible oil such as jatropha oil has potential for substituting the edible oil in resin production. The jatropha seed oil-based epoxy acrylate synthesized has a potential to be used in formulations for the pre-polymer resin for UV curable coating applications [28, 29]. Further, phenolic resin derived from jatropha seed-husk lignin is used as phenol substitute.

3. Conclusion

Jatropha curcas L. is a potential biofuel plant especially in tropical and subtropical land. It is resistant to environmental factors such as low nutrient and low moisture soil. All of the plant parts and also its waste have multipurpose uses to generate valuable commercialized product. Moreover, high non-edible oil content in jatropha seed makes this plant popular as a renewable resource for bioenergy and food security. Thus, this plant is considerable rising star for solution of better future in the energy security demand.

Author details

Sri Rizki Putri Primandari¹, A.K.M. Aminul Islam^{2*}, Zahira Yaakob³ and Swapan Chakrabarty²

*Address all correspondence to: aminuljkkp@yahoo.com

1 Politeknik Akademi Teknologi Industri Padang, Ministry of Industry, Padang, West Sumatera, Indonesia

2 Department of Genetics and Plant Breeding, Faculty of Agriculture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

3 Department of Chemical and Process Engineering, Faculty of Engineering and Built Environment, National University of Malaysia, Bangi, Selangor, Malaysia

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