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A case study on material balance in batch level production of bio diesel from *Jatropha curcas*

The demand for diesel, is projected to increase at an annual rate of 5.8% (Kumar *et al.*, 2003) and for other refined products will be at much higher rate. The energy demand for agricultural sector is mainly due to use of power sources like tractors, power tillers, combine harvesters, irrigation pumpsets and other power operated machinery. This shows increase in dependence of agriculture on petroleum based fuels. Hence, there is an urgent need to explose the opportunities for alternative fuel sources. It is estimated that one acre of Jatropha curcas plantation could produce oil sufficient to meet the energy requirement of a farm and the oil cake left out can be used as a fertilizer [Parivesh, 2005]. Extensive studies have been done on bio fuel crops production and process of extraction and conversion of jatropha bio diesel in isolation. However detailed investigation specifically on the complete process of extraction and conversion of jatropha biodiesel is very limited. Therefore, to investigate the use of bio diesel in farm engines for various operations, the present study investigating seed processing to bio fuel extraction from jatropha curcas was taken up. Sukumaran and Singh (1989) reported that the amount of oil removed in a pressing operation was influenced by applied pressure and pressing time. The pressure required to expel the oil is influenced by pre-treatments used. The moisture content of the seeds was observed to have a relatively greater effect on the oil point pressure. Mbeza *et al.* (2002) has conducted studies with Jatropha curcas on ram press. The best ratio of oil recovery was observed when 50 percent of seeds were hulled. Chauhan *et al.* (1998) conducted experiments to standardize the jatbopha oil methyl esterification process parameters. It was observed that raw jatropha oil at 60°C reaction temperature reacted at 6:1 oil to methanol motional molar ratio for 1 hour yielded maximum ester recovery. Peterson *et al.* (1983) reported that heating the seed to 75 to 120°C for 30 to 60 min increased the efficiency of extraction.

The *jatropha* seeds were procured and allowed to dry under ambient temperature until the moisture content was below six per cent. The physical characteristics of the seeds were measured. A mechanical screw press oil expeller having capacity of 100 Kg/hr was used for oil expulsion , which run by a 7.5 KW electrical motor.

The seeds were partially crushed in a seed crusher to get partially dehulled seeds for feeding in to expeller. The jatropha seeds were pre treated by steam heating. Which was generated in a wood fired boiler and introduced into the feed mixing chamber. The steam pressure maintained in mixing chamber was in the range of 2.5-3.5 kg/cm^2. The expelled oil contained large quantities of suspended particles which were separated by a filter press. To optimize the steam temperature for maximum oil extraction, three different steam temperatures were selected in the range of below 65 ^{0}C, 70-95 ^{0}C and above 95 ^{0}C and extraction efficiency noted.

The alkali-catalyzed transesterification method was adopted for conversion of raw *jatropha* oil into biodiesel and Sodium hydroxide was used as catalyst. Production of biodiesel was carried out in 250 litres per day capacity pilot biodiesel plant designed by Tamil Nadu Agricultural University. Esterification was done using methanol at 20 per cent with one per cent NaOH as catalyst. The optimum reaction temperature was maintained in the range of 58-60 ^{0}C and the reaction time was set for 2 hours. The quantity of water to raw biodiesel used in washing was 1:1. The setting time for settling of glycerol was 12 hours and the raw oil was washed with warm water at 45-50 ^{0}C. The comparison of physiochemical properties of the extracted raw jatropha oil and transesterified Bio diesel were measured as per the American Oil Chemist Society standards.

The *jatropha* seeds used in the study were bold and 100 seeds weighed 0.0747 kg and 16.6 mm in length, 11mm in width and 8.2 mm in breadth. The moisture content of seeds was brought down to 3.5 per cent by allowing the seeds to dry under storage. The oil content at 3.5 percent moisture content was 34.79 per cent (Table 1) and Seed hull was 38.40 per cent and kernel was 60.51 per cent (Fig.1). The kernel to hull ratio of the seed was 1:0.63. The complete flowchart with mass balance detailed is given in Fig. 2. Totally 590 kg of seeds were crushed during the process which yielded 118 litres (108 kg) of oil, 437 kg of cake and 35 kg of solid sediments. It was found that on an average 15.5 per cent of oil was left in the cake.

The total oil available in 590 kg of seeds was 205.26 litres , Out of which only 118 litres of oil was extracted in the mechanical oil expeller. These results are in agreement with the findings of

Table 1. Properties of Jatropha curcas seeds used for oil extraction

Seed Properties	%
Moisture content of seeds (w.b.)	3.50
Oil content	34.79
Weight of hull	38.80
Weight of kernel	61.20
Crushed seeds in feed	77.20
Uncrushed seeds in feed	22.80

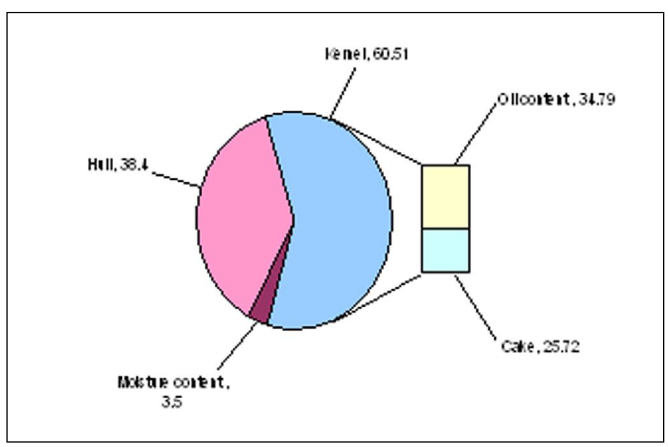

Fig. 1.Constituents of Jatropha seed

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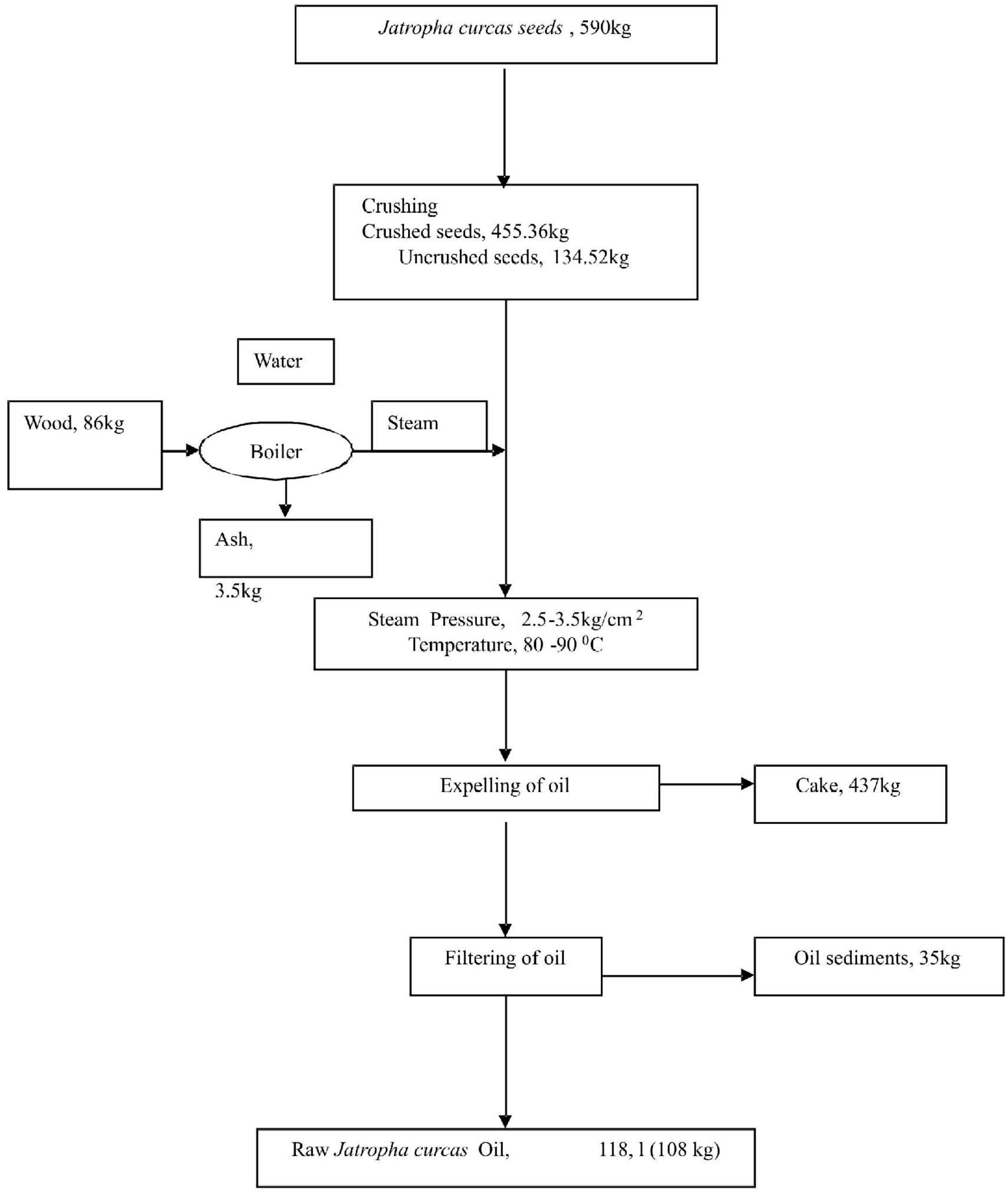

Fig 2. Mass balance flow chart diagram of *Jatropha curcas* oil extraction

Olayanju *et al.* (2006).The efficiency of mechanical extraction of oil was found to be 67 per cent, when the oil in the sediment (filter press cake was taken in to account).

The efficiency of the filter press was 78 per cent, Hence for the batch of 590 kg of seeds 14 per cent of oil is lost in filter cake, 33 per cent with the oil cake (from expeller) 52 per cent of the oil is obtained in the filtered form. It is inferred from the above results that in continuous operation of expeller, the cake from filter press can be fed gradually with the fresh feed to enhance efficiency of the process. It was reported by Ramesh and Sampathrajan (2008), that the feed temperature affects the extraction process. The influence of temperature on oil extraction was studied and the per cent oil extracted at different temperatures was presented in Table 2. From results of Table 2, it is inferred that the optimum temperature range for pre- heating the seeds for mechanical

Table 2. Effect of feed temperature on per cent oil retained in the cake

Temperature range	Per cent oil retained in the cake			Mean
	S1	S2	S3	
(> 95 ^{0}C)	15.82	14.65	14.88	15.11
(65-95 ^{0}C)	7.20	9.50	8.3	8.33
(< 65 ^{0}C)	16.75	15.48	16.11	16.41

Table 3. Biodiesel recovery from esterification process

Batch	Quantity of raw *jatropha* oil (lit)	Quantity of Methonal (lit)	Wt.of NaOH (kg)	Quantity of water for washing (lit)	Quantity of Esterified oil collected (lit) (without wash and heating)	Quantity of glycerol collected (kg)	Biodiesel recovery per cent
First	30	6	0.3	30	25.80	8.45	86
Second	30	6	0.3	30	27.00	8.00	90
Third	35	7	0.3	35	31.50	9.50	90

expelling is (65-95 ^{0}C). At feed temperature of 65-95 ^{0}C, the oil retained in the cake was 8.33 per cent and at temperature > 95 ^{0}C and < 65 ^{0}C the per cent of oil retained in the cake were more as compared to 65-95 ^{0}C. These findings are in agreement with that of Sivakumaran *et al.* (1985) and Peterson *et al*. (1983).

The esterification process was carried out in three batches. The results of the conversion process are given in Table 3. It was observed that on an average 0.887 litre of biodiesel and 0.268 kg of glycerol were obtained per litre of raw jatropha oil, resulting 88.7% biodiesel recovery. These results are in agreement with the findings of Chauhan *et al*. (1998). The physicochemical properties of raw Jatropha oil and esterified *jatropha* oil are presented in Table 4. The kinematic viscosity of raw jatropha oil was found to be 25.28 cSt, which was 6.5 times higher than esterified *jatropha* oil. The calorific value of raw *jatropha* oil was 33.42 MJ/kg and esterified oil was 36.53 MJ/kg. The specific gravity of raw *jatropha* oil was 0.91 g/cc and for esterified jatropha oil it was 0.873 g/cc. The flash point for raw jatropha oil was 188^{0}C and after transitarification it was reduces to 143°C, which was lower than value of 175°C reported by Kandapal and Mira (1995) and Foidl *et al*. (1996). This may be due to composition of the volatile fraction in oil. The Free fatty acid of esterified *jatropha* oil was 0.66 per cent and it was lower than that of raw jatropha oil (2.16 per cent). This may be due to neutralization of free fatty acid by excess amount of NaOH catalyst during esterification process. Acid value for raw jatropha oil was 4.37 and for esterified oil it reduced to 1.326.

A batch extraction and conversion process of bio diesel was carried out to simulate the farm level production from jatropha oil. The batch process was found to be efficient and could produce 118 liters of raw oil from 590 kg of seeds. The raw oil could be converted to bio diesel through esterification process at conversion efficiency of 88.7 per cent. The properties of estrified oils indicates that esterified jatropha biodiesl properties are nearer to standard diesel. This study has shown that small farm power sources like power tiller, tractor and small capacity diesel engines can be operate by locally produced bio diesel from batch processes.

Table 4. Physicochemical properties of raw Jatropha oil and esterified *Jatropha* oil

Properties	Raw jatropha oil	Jatropha biodiesel
Kinematic viscosity, cSt	25.28	3.84
Calorific value, K cla/kg	33.42	36.53
Specific gravity, g/cc	0.91	0.873
Flash point, ^{0}C	188	143
Fire point, ^{0}C	203	161
Pour point, ^{0}C	-1	-3.5
Could point, ^{0}C	5.5	3.5
Carbon residue, %	0.51	0.35
Free fatty acid, %	2.16	0.66
Acid value	4.378	1.326
Saphonification number	209.0	192.16

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