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Original Research Article

Processing of Jatropha Seed for Oil Extraction

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Keywords

Oil extraction, clearance, feed rate, moisture content, dimensions, density, porosity

A B S T R A C T

The physical properties of Jatropha seed were evaluated as a function of moisture content. Principle dimensions- length, breath, thickness, geometric mean diameter; weight of 1000 seeds, coefficient of friction, angle of repose, bulk density, true density and porosity were determined experimentally for *Jatropha carcus* kernels at four different levels of moisture contents (7.5, 12.12, 17.23, 32.7 % db.). Effect of moisture content, clearance and feed rate (machine parameters) on dependent parameters percent oil yield, oil extraction efficiency, residual oil content and oil cake yield were analyzed. It was observed that moisture content had significant on percent oil yield, oil and Residual oil content. In the moisture range from 7.5% to 32.7% db,, the length, breadth and thickness increased from 16.97, 11.04 and 8.0mm to 19.67, 12.79 and 10.58 mm respectively,. The 1000 seed weight, true density and bulk density increased from 605.20 g, 66..86 kg/m^3 and 300.70 kg/ m^3 to 824.60 g, 834.44 kg/m^3 and 396.63 kg/m^3 respectively. Maximum amount of Jatropha oil was recorded at 17.23% moisture (7, 5, 12.12, 17.23% & 32.7 %) 17.23% db. moisture content also gave the highest values for the physical properties. Maximum oil recovery was obtained at 17.23% db moisture content, 3mm clearance, 50kg/hr feed rates.

Introduction

India's rank is 6th in the world in terms of energy demand accounting for 3.5% of world, share energy demand in 2001. With a Gross Domestic Product (GDP) growth of 8%, the energy demand is expected to grow at 5.2 %. Diesel forms nearly 40% of the energy consumed in the form of oil. The current annual import bill of crude oil in terms of foreign exchange is around Rs. 60,400 crores. The ongoing economic expansion (6% GDP growth) would increase the demand of transportation fuel in short and medium term at high rates. However, there are non-edible species like Jatropha Curcas (Ratanjyot), Pongamia Pinnata (Karanja), Calophylluminophyllum (Nagchampa or Polanga), Mahua, and Caster which can be used for biodiesel production. Among these, Jatropha curcas has been recognized as the most promising. Apart from being used in the rural mechanized agricultural sector for irrigation, pumping and decentralized distributed power generation, biodiesel holds a great promise for use in transportation sector mainly because of its vast source potential and clean-burning features.

Since the physical properties of Jatropha seed are essential for the design of equipment for handling, processing and storing, it is necessary to determine the physical properties. The objective of this study is to investigate the moisture dependent physical properties such as size, bulk density, ture density, porosity, 1000 seed weight, terminal velocity, angle of repose and co-efficient of friction. The range of Moisture content was selected from 7.5% to 32.23% (db.) as the oil extraction process can be performed in this moisture range. There are various processes, which were suitable for edible oil extraction can be utilized for extracting oil from non-edible oil seeds. The processes are classified mainly as mechanically by using hydraulic press or simple screw press. The study was undertaken to optimize the seed and machine parameter for maximum oil yield.

Materials and Methods

For the present study, the Jatropha seed was obtained from the local market. The initial moisture content of the seed was found to be 7.5% db. The seeds were cleaned manually for foreign matter, broken and immature seeds. Sieve analysis of the seed showed that 59% and 40% of the seeds were retained by sieves having number BSS 12 and BSS 18 meshes respectively.

The moisture content of the seed was determined by the vacuum oven method (1, 2), set at 102^{o}C until a constant mass was obtained. To vary the moisture content of the sample, the predetermined quantity of cumin seed was dried down to the desired moisture content. To obtain higher moisture content, a predetermined quantity of water was added and the sample was packed in sealed moisture resistant flexible pouches. The sample was kept at 5^{o}C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the product. Before starting the experiment, the pouches were taken out of the refrigerator and allowed to warm up to the room temperature for 24 h. The pouches were opened just before determination of the seed properties.

Several researchers have described the size of the grains by measuring the length, breadth and thickness. To determine the average size of the Jatropha seed, one hundred seeds were randomly picked and their three principal dimensions as stated above were measured using a traveling microscope reading to an accuracy of ±0.01 mm.

The average bulk density of the Jatropha seed at three different levels was investigated using the standard test weight procedure by filling a container of 500 ml with the seed from a height of 150 mm at a constant rate and then weighing the content.

The average true density, as a function of moisture content was determined using the toluene displaced was found by immersing a weighed quantity of Jatropha seed in the toluene.

The porosity, as defined by Thompson and Isaac, that is, the space in the bulk grain which is not occupied by the grain was calculated from the following relationship (8).

$$\text{Porosity } (\Sigma) = \left(1 - \frac{\delta b}{\delta t}\right) \times 100$$

Where,

Σ = Porosity (%),
δb = B.D., kg/m^3,
δt = T.D., kg/m^3

The one thousand seed mass was measured by means of an electronic balance reading to

0.001 g. To determine emptying or dynamic angle of repose, glass wooden box 300 x 300 x 300 mm in size, having a removable front panel was used. The box was filled with the sample, then the front panel was quickly removed, allowing the seeds to flow and assume a natural slope (3, 4, 9, 10). The angle of repose was calculated from the measurement of the height of the free surface of the sample at the centre.

The static coefficient of friction of Jatropha seed was determined against four surface glass, wooden, G.I. sheet & sun mica respectively. A polyvinylchloride cylindrical pipe of 50 mm diameter and 50 mm height was placed on an adjustable tilting plate, faced with the surface, and filled with the seed sample. The cylinder was raised about 2 mm above the base of the bulk seed so as not to touch the surface. The structural surface with the cylinder resting on it was gradually raised with a screw device until the cylinder along with the sample just started to slide down and the angle of tilt was read from a graduated scale. The coefficient of friction was calculated from the following relationship.

$\mu = \tan \varphi$

Where,

μ, coefficient of friction and φ, angle of tilt.

All the experiments were replicated five times, unless stated otherwise. Average values of the properties are given in the following section.

Determination of Dependent Variables

Oil Yield (%)

Percent oil yield (POY) may be defined as the ratio of output weight of oil to input weight of oilseed/oil cake. Percent oil yield may be calculated as follows for each treatment combination experiment.

$$POY = \frac{\text{Wt. of oil}}{\text{Wt. of input seed}} \times 100$$

Oil Extraction Efficiency (%)

The oil extraction efficiency (OEE) was calculated on the basis of the percent oil yield obtained from each lot and the theoretical content of oil present in that oil seed. For the purpose of present study, the theoretical content of oilseed was taken as 35% for Jatropha curcas. The oil extraction efficiency may be calculated by following formula:

$$OEE\ (\%) = \frac{\text{Per cent oil yield}}{\text{Theoretical oil content (\%)}} \times 100$$

Results and Discussion

Seed dimensions, bulk and true density

The mean dimensions viz. length, breath and thickness of 100 randomly selected seeds were measured. Average values are shown in Table 1.The values of the bulk density for different moisture levels varied from 300.70 to 396.63 kg. Initially the bulk density increased from 300.70 to 396.63 kg/m^3 with an increase in moisture content from 7.5 to 32.72 % d.b. The initial increase of bulk density was probably owing to a greater increase in mass than volume but as the moisture content was increased beyond 9.5% db., the volumetric expansion of the seed and pore spaces became proportionally greater which resulted in a decrease in the bulk density. The true density of seed was found to increase linearly from 660.86 to 834.14 kg/m^3 with increase in moisture content from 7.5 to 32.72 % (db.). The increase in true density may be attributed to the possible higher weight increase of seed in comparison to its volume expansion on moisture gain.

Porosity

The porosity increased from 52.67 to 59.52 % when the moisture content changed from 7.5 to 32.72 % db. A comparison of porosity of Jatropha seed with those other agricultural materials related that the increase with moisture content was similar to that of other grains.

Thousand Seed weight

It increased linearly from 4.13 to 4.80 g when the moisture content changed from 7.52 to 32.72 % db.

Angle of repose

The experimental results for angle of repose with respect to moisture content are shown in Fig. 4.5. It was observed to increased linearly from 23.12 to 26.93^0 with increase in moisture content from 7.52 to 32.72% d.b. The value of angle of repose for Jatropha seed was considrably higher than those reported for other agricultural materials such as gram[4], pigeon-pea[3], oilbean seed[9] and pumpkin seed[5]. This is owing to the surface roughness of the seed imposing resistance to the seeds sliding on each other. The same reason, roughness of the seed surface may be responsible for the increasing trend of angle of repose at higher.

Coefficient of friction

The static coefficient of friction for Jatropha seed with respect to moisture content on four metal surfaces is presented in Fig. 4.6 (i) to (iv). It is observed that the static coefficient of friction is lowest against stainless steel. This may be owing to the smoother and polished surface of the stainless steel sheet compared with other sheet used.

The static coefficient of friction increased linearly with respect to moisture content for all four surfaces. It may be that at higher moisture contents, the seed became more rough and sliding characteristics are diminished, so that the static coefficent of friction increased.

Effect of Independent Parameters on per cent oil yield of Jatropha seeds

The effect of feed rate (FR), clearance (CL) and moisture content (MC) on per cent oil yield of Jatropha curcas was explained using regression equations. The regression equation explaining the effect of independent variables on percent oil yield (POY), at 50 kg/hr feed rate (fig.1) is given by

At 7.5 % M $POY_t = 31.45\ e^{-0.07C}$ ($R^2 = 0.96$)

At 12.12 % M $POY_t = 33.31\ e^{-0.07C}$ ($R^2 = 0.96$)

At 17.23 % M $POY_t = 39.06\ e^{-0.08C}$ ($R^2 = 0.97$)

Also, The regression equation for explaining the effect of variation in moisture content, clearance on per cent oil yield at 80 kg/hr feed rate (fig.2) is given by

At 7.5 % M $POY_t = 29.53\ e^{-0.06C}$ ($R^2 = 0.93$)

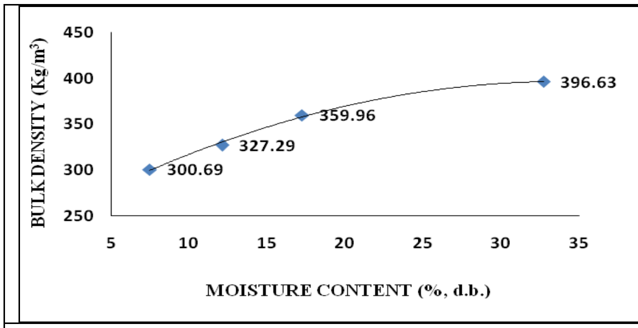
At 12.12 %M $POY_t = 32.97\ e^{-0.07C}$ ($R^2 = 0.93$)

At 17.23 % M $POY_t = 34.92\ e^{-0.06C}$ ($R^2 = 0.95$)

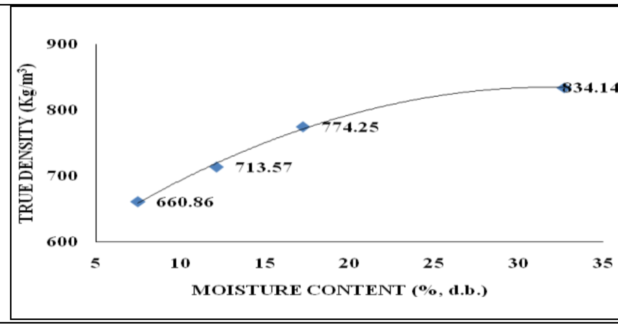
Table.1 Length breath, thickness size and sphericity of Jatropha seeds at Different moisture contents

Moisture content (%) (db.)	Length (a) (mm)	Breath (b) (mm)	Thickness (c) (mm)	Size (abc) 1/3 (mm)	Sphericity fraction
7.5	16.97	11.04	8.00	11.44	0.67
12.12	17.13	11.01	8.75	11.81	0.69
17.23	18.46	11.32	9.52	12.57	0.68
32.72	19.67	12.79	10.55	13.84	0.70

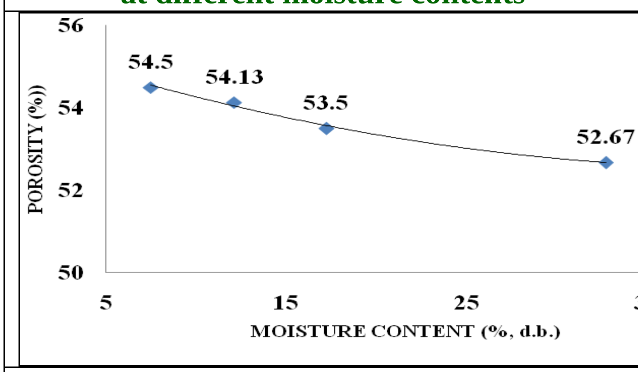
Fig.1 Variations in physical properties of Jatropha seed at different moisture contents



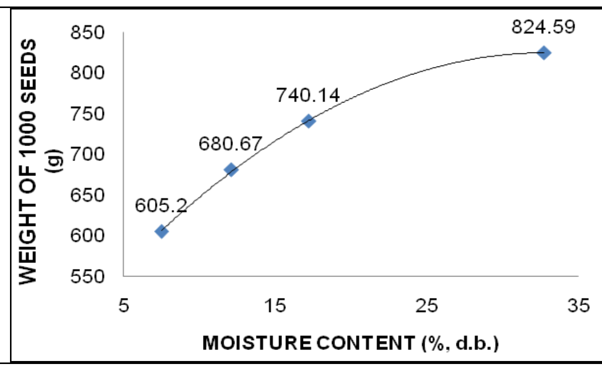
Variations in Bulk density of Jatropha seed at different moisture contents



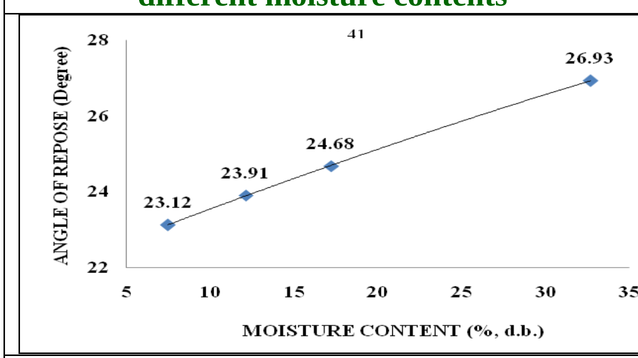
Variations in True density of Jatropha seed at different moisture contents



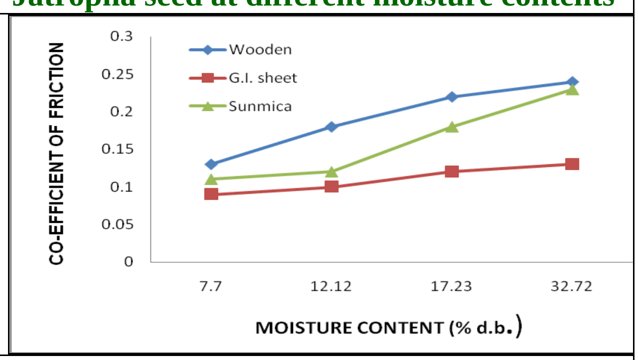
Variations in porosity of Jatropha seed at different moisture contents



Variations in weight of 1000 seeds of Jatropha seed at different moisture contents



Variations in angle of repose of Jatropha seed at different moisture contents



Variations in Co-efficient of friction of Jatropha seed at different moisture contents on different surfaces

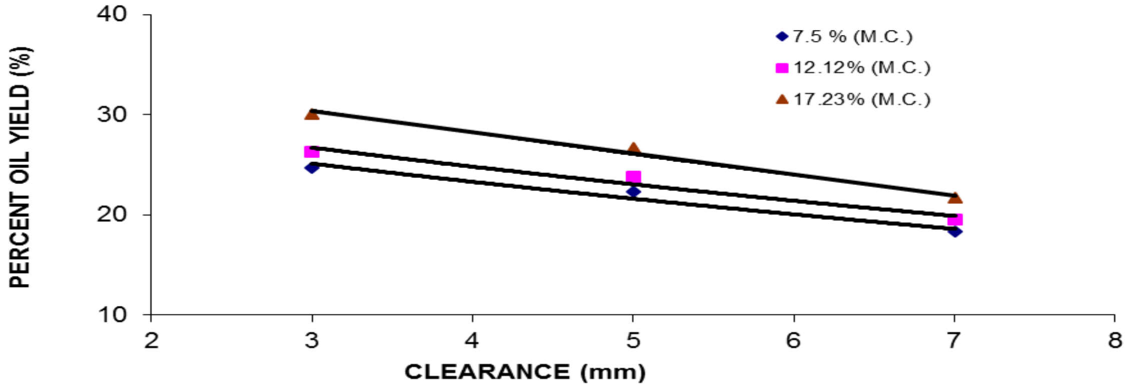


Fig-1. Graph showing the variation in percent oil yield of Jatropha seeds at different moisture content and clearance for 50kg/hr feedrate.

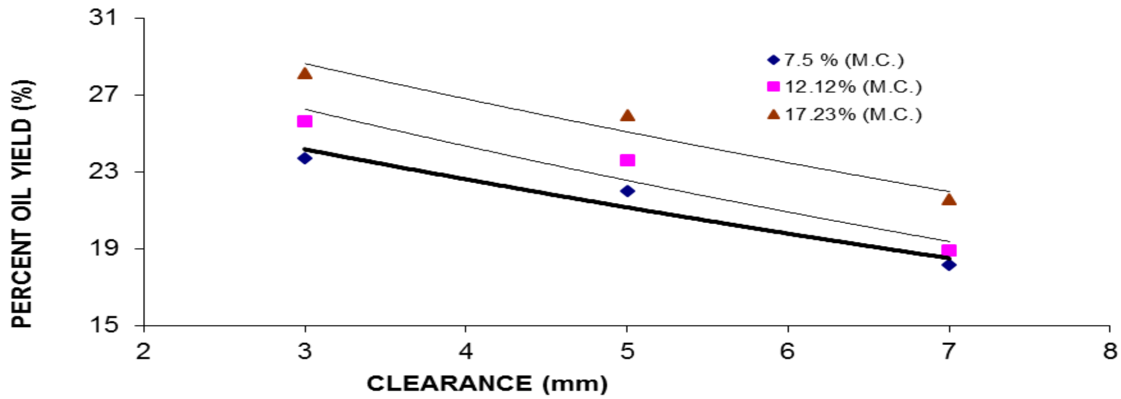


Fig-2. Graph showing the variation in percent oil yield of Jatropha seeds at different moisture content and clearance for 80kg/hr feedrate.

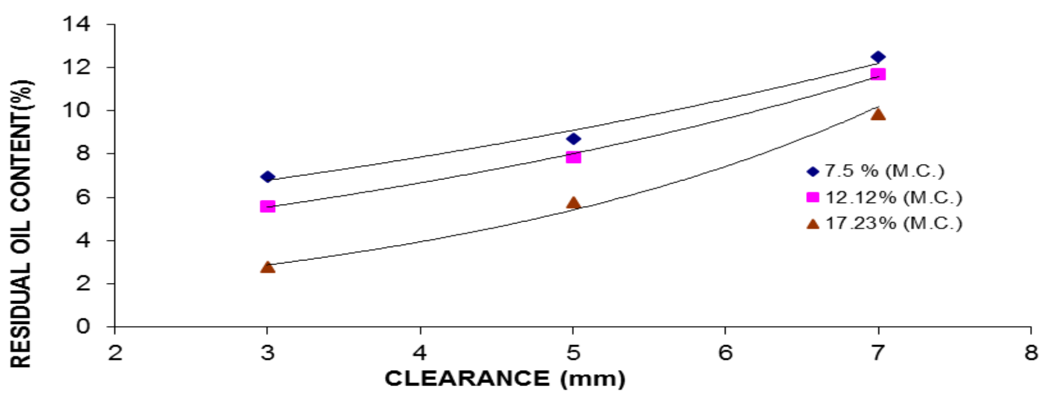


Fig-3. Graph showing the variation in Residual Oil Content of Jatropha seeds at different moisture content and clearance for 50kg/hr feedrate.

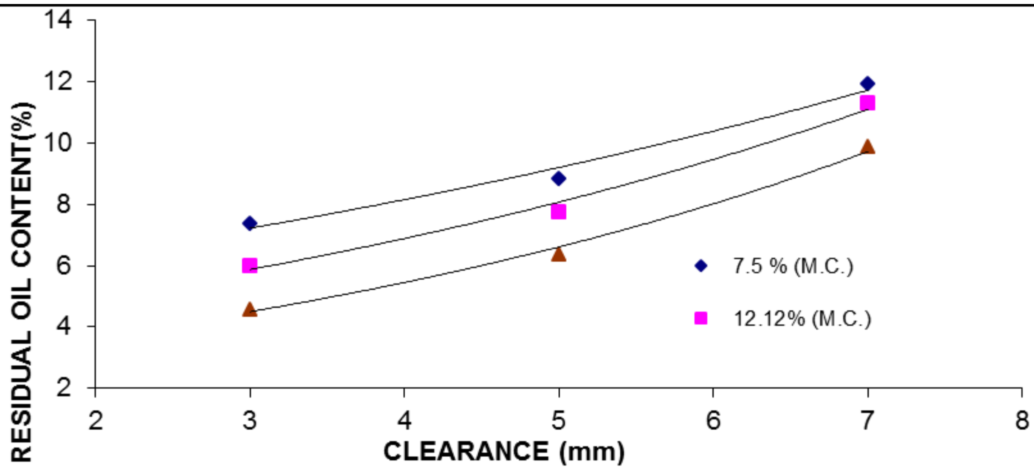


Fig-4. Graph showing the variation in Residual Oil Content of Jatropha seeds at different moisture content and clearance for 80kg/hr feedrate.

Data was statistically analyzed and ANOVA for effect of Independent variables on per cent oil yield confirmed that the clearance affected the per cent oil yield in a highly significant manner, whereas, the other two variables (moisture content and feed rate) significantly affected the per cent oil yield at 1% level of significance. The feed rate having lowest F-value had the least significant effect on per cent oil yield. It was seen that the overall variation in per cent oil yield was from 18.1 to 30.0 %. The minimum value of per cent oil yield i.e.18.1% was observed at 7.5 % moisture content, db. 7 mm clearance and 80 kg/h feed rate combination. However, the maximum value of per cent oil yield of 30.0% was observed at 17.23% moisture content, db., 3mm clearance and 50 kg/h feed rate combination.

The reason to above behavior can be explained to a limited extent. Pressure and heat generated in the expeller results in extraction of Jatropha oil from the seeds. The two parameters can be optimized if clearance of the barrel is changed accordingly. Large the clearance, lesser will be retention time of the seeds inside the expeller, lower will be the pressure and heat generated which results in lower per cent oil yield (first) value. Also, two low clearance results in reduced capacity of the expeller which may severely affect the cost economics of oil extraction process. Besides, it may also choke the barrel of the expeller.

The moisture content of Jatropha Oil seed is critically on important variables in oil expression/extraction. If moisture content is higher than optimal value, it results in slippage of materials in the expeller. The moisture content at which maximum per cent oil yield (first) is achieved at a set of condition clearance and feed rate and machine capacity and capably is recommended moisture content value for the oil extraction process.

Machine capacity is known by it feed rate. The capacity can be changed depending on

Economic of process
Oil seed type

Feed rate effects the retention time of oilseeds in the expeller directly. More the

FR, Lower will be retention time of seed, lower will be duration for extraction of pressure and heat on the seeds, lower will be oil yield.

Effect of Independent Parameters on residual oil content of Jatropha seeds

Oil extraction efficiency at is directly dependent on per cent oil yield (first) as it is a ratio of per cent oil yield (first) to theoretical oil content (taken as 35% for present study). The following regression equation explains the effect of variation in independent parameters on total oil extraction efficiency at 50 kg/h feed rate (fig.3) is given by

At 7.5 % M $OEE_t = 87.37\ e^{-0.07C}$ ($R^2 = 0.96$)

At 12.12 % M $OEE_t = 92.54\ e^{-0.07C}$ ($R^2 = 0.96$)

At 17.23 % M $OEE_t = 108.5\ e^{-0.08C}$ ($R^2 = 0.97$)

The regression equation for explaining the effect of variation in moisture content, clearance on oil extraction efficiency (total) at 80 kg/hr feed rate (fig.4) is given by

At 7.5 % M $OEE_t = 82.03\ e^{-0.06C}$ ($R^2 = 0.93$)

At 12.12 % M $OEE_t = 91.59\ e^{-0.07C}$ ($R^2 = 0.93$)

At 17.23 % M $OEE_t = 97.00\ e^{-0.06C}$ ($R^2 = 0.95$)

All the independent variables moisture content, feed rate and clearance had a significant effect on oil extraction efficiency at 1 % level of significant. It was seen that clearance had the maximum while feed rate had the least effect on oil extraction efficiency. The minimum of 50.3% oil extraction efficiency (total) was observed at 7.5 % moisture content (db.), 7 mm clearance and 80 kg/hr feed rate combination while the maximum oil extraction efficiency of 83.5% was observed at 17.23% moisture content (db.), 3 mm clearance and 50 kg/hr feed rate combination. Since oil extraction efficiency is directly dependent upon per cent oil yield so effect of feed rate, clearance and moisture content on oil extraction efficiency is similar to that of per cent oil yield.

Biodiesel production has been identified as an important sector to revive the economy of the country by the planning commission, Govt. of India. As biodiesel is obtained from non-edible oil seeds like Jatropha, its processing for oil extraction is an important step involved in biodiesel production. The Technologies for the steps are under optimization for maximizing the yield.

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