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**Research article**

# Physicochemical characterization of *Jatropha* oil seed and suitability as biodiesel feedstock

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**Abstract:** The physiocochemical properties of *Jatropha curcas* kernel oils were characterized as potential biodiesel, including oil yield per plant, seed oil content, kernel oil content, acid value, iodine value, saponification value and cetane number. Twenty-five accessions of *Jatropha curcas* were used for oil content measurement sranging from 21.14 to 40.66 %with a mean value of 32.85% and Kernels oil 48.59 to 60.45 % with a mean value of 56.28 %. The seed index ranged significantly from a seed weight of 45.45 to 64.45 g. Oil yields per plant ranged from 0.44 to 2.85 kg with a mean value of 1.70 kg per plant, respectively. To understand the properties of acid value, iodine value, saponification and cetane number, experimental physio-chemical studies were performed. Since these properties are critical for determining the current oil condition. The current study confirms that accession seeds performed higher than international saponification value, iodine value and cetane number standards may be an important source for meeting potential energy requirements.
**Keywords:** *Jatropha* - Oil content - Acid value - Iodine value - Saponification - Cetane number.

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## INTRODUCTION

*Jatropha curcas* L. is perennial shrub oil seed plant commonly called as physic nut belonging to the family Euphorbiaceae and comprises 172 species. It is a diploid plant species having chromosome 2n=22 and small genome size of 419 Mb (Carvalho *et al*. 2008, Sato *et al*. 2011). It is a native of tropical America and widely distributed in Centarl and South America, Africa, India and South-East Asia (Openshaw 2008). *Jatropha curcas* has been recognized as an important crop for biodiesel production which can reduce the greenhouse emission. *Jatropha curcas* has been traditionally cultivated by farmers as the source of non-edible oil used for soap production, as fence, to control soil erosion, coloring dye (Openshaw 2008). Moreover, *Jatropha curcas* seed cake, which is a waste byproduct of the biodiesel trans-esterification process, can be used for the manufacture of various supplies such as organic fertilizer, high-quality paper, energy pellets, cosmetics, embalming fluid, pipe joint cement and cough medicine (Sabandar *et al*. 2013, Maghuly *et al.* 2020).

The physiochemical properties of *Jatropha curcas* oil and its blending with diesel oil depend on the performance of engine and emissions character (Sunil *et al.* 2018, Verma *et al.* 2019). The higher number of cetane value increases the efficiency of combustion (Meena *et al.* 2018). The longer fatty acid chains and Cetane number of biodiesel depends on the feedstock used for production (Divya & Tyagi 2006). The physical and chemical properties of the fatty acid composition of *Jatropha curcas* oil plays an important role for the determination of biodiesel like cetane number and oxidation stability, etc. (Ramos *et al.* 2009). However, the process of transesterification used for the conversion of oil into fatty acid methyl esters is more comparable to biodiesel. Besides transesterification, some other biometrical and biochemical properties of *Jatropha curcas* oil is considered such as saponification value, iodine value, acid value and cetane number.


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In addition, the Government of India has announced the National Biofuels Policy in 2009 for the blending of Jatropha oil to achieve the goal of 20% blending of biofuels for both biodiesel and bioethenol by 2017 (Keerthika *et al.* 2015). *Jatropha curcas* deserves to be highlighted among the potential species for the production of biofuels, as its seed contain high oil content (36%) with the best quality (Souza *et al.* 2019) and the promising feedstock for commercial biodiesel production (Maghuly *et al.* 2020, Jonas *et al.* 2020). Oil from *Jatropha curcas* has strong oxidation stability, low viscosity and a low pour point, which makes its oil better tan soybean oil and palm oil (Peixoto *et al*. 2017).

These factors have contributed to the rapid expansion of cultivated area and the need for better Veterinary and livestock feed cultivars (Maghuly & Laimer 2013). The studies on the chemical properties of *Jatropha* oil preserve all these aspects. In MGCGV Chitrakoot Madhya Pradesh; the *Jatropha* seeds are evaluated for acid value, iodine value, saponification value and cetane number which indirectly affect the quality of the oil for the production of biodiesel.

## MATERIALS AND METHODS

A total of twenty-five accessions of *Jatropha curcas* seed samples were collected from Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. These accessions representing different eco-geographical and agro-climatic zone of Uttar Pradesh. For acid value, saponification value, iodine value and cetane value the best performing accession of *Jatropha curcas* have been estimated.

## RESULTS

Given its potential in the production of biodiesel, the screening of various accessions for the content of seed oil in order to identify superior genotypes/accessions was emphasized in order to derive maximum benefits from this miracle plant.

### *Seed oil content*

In various *Jatropha* accessions, seed oil content showed broad and significant variability from 21.14 to 40.66 % with a mean value of 32.85% (Fig. 1). Within the twenty-five *Jatropha* accession, the amplitude of 3.70% observed in oil content indicates a large scope for identifying high oil-bearing accessions for further improvement through quality breeding. Accession K18 was found to contain maximum seed oil which differed significantly with the rest of the accessions. K2, K10, K17, K18, K23, K24 and K25 were identified among the groups as high oil containing accessions. It should also be noted that seven out of a total twenty-five accessions contained higher values for oil content values than the mean value of 32.85.

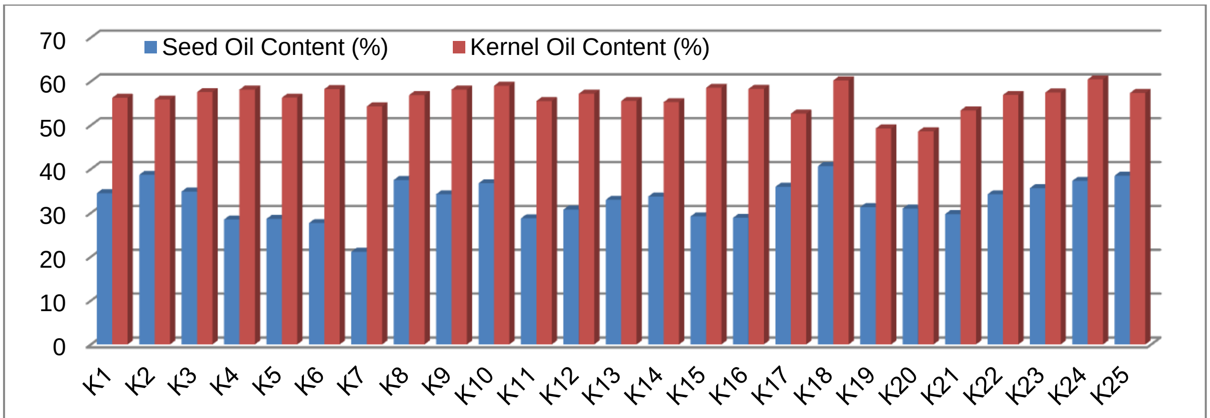


**Figure 1.** Status of seed and kernel oil content in different *Jatropha* accessions.

### *Kernel oil content*

On decortications, seeds of *Jatropha* yield up to 60–70% of kernels that are more concentrated sources of oil as compared to the corresponding seeds. In addition, kernels, compared to seeds, deliver better oil consistency. Kernels of different accessions of *Jatropha* were analyzed for oil content to determine oil levels, the results of which are recorded in table 1.

In terms of oil content, kernels of different *Jatropha* accessions registered a broad and substantial variability from 48.59 to 60.45 % with a mean value of 56.28%. The difference in the minimum and maximum values for the quality of kernel oil showed amplitude of 7.34%, which was greater than that observed for the *Jatropha* accession seed oil content. K24 was adjusted as maximum accession kernel oil-bearing, which varied significantly from the remainder of the accession protected by the current investigation. K4, K6, K9, K10, K15, K16, K23, K24 and K25 have been identified as high kernel oil containing accessions and may be used to grow high oil lines in the breeding programme. It was important to note that, relative to the mean value of 31.06%, 13 accessions showed higher kernel oil content. The mean value observed for the content of kernel oil content (31.06%) and seed oil content (22.57%) clearly showed 8.49% higher kernel oil levels compared to the corresponding seed samples.

**Table 1.** Range, mean values and best performing accessions of *Jatropha* in respect of seed and kernel oil content.

| Parameters | Range | Mean | Best Performing accessions |
|---|---|---|---|
| Seed Oil Content (%) | 21.14–40.66 | 32.85 | K2, K10, K17, K18, K23, K24, K25 |
| Kernel Oil Content (%) | 48.59–60.45 | 56.28 | K4, K6, K9, K10, K15, K16, K23, K24, K25 |

*Average oil content per seed*

Large variations in seed index from 45.45 to 64.45 g (mean 0.56 g/seed) showed very high and important variations in mean seed weight, which was measured in the range of 0.45 to 0.64 g/seed (Fig. 2; Table 2). Data on average oil content per seed, which showed wide and significant variability from 0.119 to 0.182 g/seed with a mean value of 0.150 seed, to assess the seed potential in harvesting oil. *Jatropha* accession K1, K4, K5, K9, K14 and K25 indicated higher oil content values per seed. The Values recorded by these six accessions were statistically significantly different from each other in terms of oil per seed.

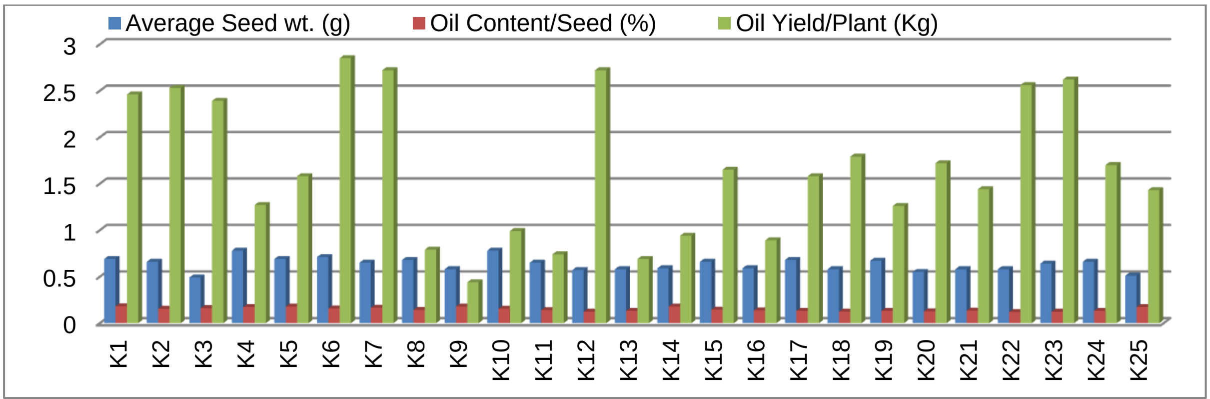


**Figure 2.** Relative performance of different *Jatropha* accessions in respect of average seed weight, oil content/seed and oil yield/plant.

**Table 2.** Range, mean values and best performing accessions of *Jatropha* in respect of average seed weight, oil content per seed and oil content per plant.

| Parameters | Range | Mean | Best Performing Accessions |
|---|---|---|---|
| Average Seed Wt. (g). | 0.490–0.780 | 0.63 | K1, K2, K4, K5, K6, K8, K10, K15, K17, K19, K24 |
| Oil Content /seed (%) | 0.119–0.182 | 1.50 | K1, K4, K5, K9, K14, K25 |
| Oil yield/ Plant (kg) | 0.440–2.850 | 1.70 | K1, K2, K3, K6, K7, K12, K22, K23 |

*Oil yield per plant*

Normally, the cultivation of *Jatropha* plants is not carried out on regular basis; the collection of data on the yield of *Jatropha* seed oil per hectare is therefore a difficult task at a realistic level. Seeds are typically collected from different locations and the oil yield per plant is measured based on the oil content (%) and the seed yield per plant.

Significantly variability in the oil yield per plant from 0.44 to 2.85 kg with a mean value of 1.70 kg per plant was observed in the different accessions. Accession K1, K2, K3, K6, K7, K12, K22 and K23 were also identified as high oil yielding accessions since they all had more than 2 kg per plant of oil yield. Variations in oil yield per plant were statistically important, providing good scope to identify particular plants with high oil yielding locations.

*Saponification value*

Oil samples collected from seeds of various *Jatropha* accessions showed a significant range between 168.28 to 224.40 with a mean value of 200.50, indicating very high amplitude (56.12) of variability. K3, K4, K5, K8, K10, K11, K14, K15 and K16 registered the maximum value for saponification. The two accessions, namely K24 and K25, have registered a minimum saponification value of 168.28.

*Iodine value*

Oil samples from different *Jatropha* accession showed significant variability from 100.00 to 120.50 with a mean value of 109.79 (Fig. 3; Table 3). The K12 accession registered the highest value of 120.50, which was closely followed by K1, K2, K3, K4, K5, K9, K11, K15, K16, K17, K19, K23 and K25. It was important to note that ten oil samples extracted from *Jatropha* accession seed oil showed lower iodine values than the mean value of 104.87 reported for the same one. Iodine values registered in the medium range from 100.00 to 108.40 for K6, K7, K8, K10, K12, K13, K14, K18, K20, K21, K22 and K24.The presence of high levels of unsaturated fatty acids in the oil suggests oil with a high Iodine content, which adversely affects oxidative stability of the oil. In addition, it can polymerize during its use in the engine as fuel due to the heat produced by the engine which can contribute to the formation of deposits, degrading the lubricating action of the oil, which can also create dense sludge in the engine sumps as the fuel flow down the side of the cylinder into the crankcase.

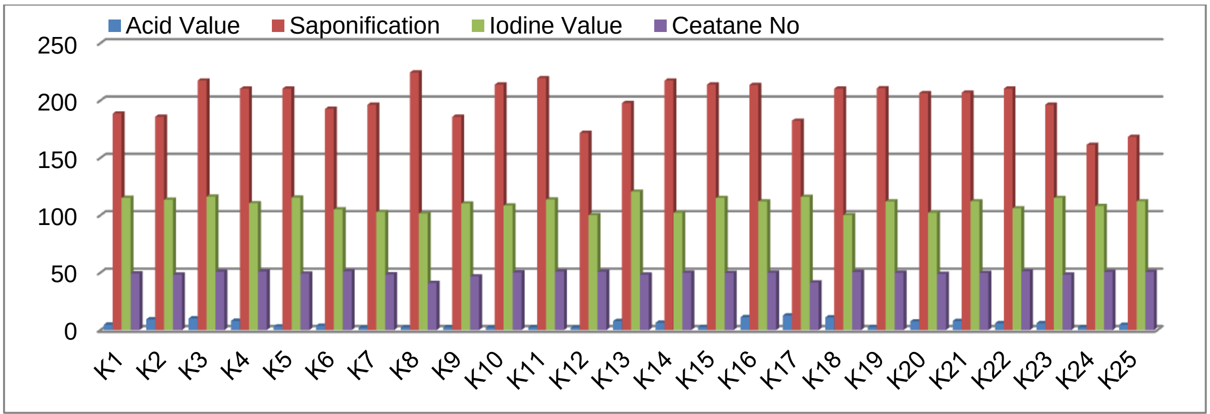


**Figure 3.** Relative performance of different *Jatropha* accessions in respect of acid value, saponification value, iodine value, cetane number.

**Table 3.** Range, mean values and best performing accessions of *Jatropha* in respect of acid value, saponification value, iodine value and cetane number.

| Parameters | Range | Mean | Best Performing accessions |
|---|---|---|---|
| Acid Value | 2.06–12.71 | 5.64 | K7, K10, K12 |
| Saponification Value | 168.28–224.40 | 200.50 | K3, K4, K5, K8, K10, K11, K14, K15, K16 |
| Iodine Value | 100.00–120.50 | 109.79 | K1, K2, K3, K4, K5, K9, K11, K15, K16, K17, K19, K23, K25 |
| Cetane Number | 40.95–51.16 | 49.08 | K4, K10, K11, K12, K14, K18, K24, K25 |

*Acid value*

A range of 2.06 to 12.71 with a mean value of 5.64 was suggested by the experimental finding of free fatty acids. The K7, K10 and K12accessions registered the lowest acid value of 2.06. Because lower acid values are desirable for better oil quality, accession K7, K8, K9, K10, K11, K12, K15, K19 and K24 have been identified as having lower acid values which may find better utility in the production of biodiesel. Among the high acid value containing accessions were K3, K16, K17 and K18. The variations reported for the acid value were statistically important, with variability amplitude of 10.65 providing scope for the identification of accessions suitable for the development of biodiesel.

*Cetane number*

Cetane number is one of the most critical indicators of the quality of diesel fuel as it tests the fuel's auto-ignition readiness when injected into the engine. Biodiesel is made from a variety of feedstock vegetable oils with a range of 45 to 67 different numbers of cetane. In the United States, however, values ranging from 42 to 45 for cetane numbers were recommended for diesel fuel. To determine the variability in the number of cetane oil samples obtained from the *Jatropha* accession collected from different locations and to classify appropriate *Jatropha* accessions for the development of biodiesel, the number of different *Jatropha* seed oil cetane samples was calculated. The number of different accessions of cetane *Jatropha* showed large and substantial variability from 40.95–51.16, indicating a mean of 49.08.

The maximum value of 51.16 (K6) closely followed by accessions K4, K10, K11, K12, K14, K18, K24, K25. Seed oil extracted from up to 7 accessions was found to have a higher cetane value compared to the mean (48.65) observed for cetane.

## DISCUSSION

The physicochemical properties of biodiesel rely on avariety of factors, such as the composition of the fatty acid in the raw feedstock, the chain length of the fatty acid, the degree of saturation and the branching. Other consideration includes the manufacturing technique and operating conditions for the synthesis of biodiesel (Reddy *et al.* 2018).

Biodiesel content can also vary due to impurities caused by unreacted feedstock glycerides, fractional non-fatty acids or runway reactions during the transesterification process (Knothe *et al.* 2005). A longer fatty acid chain usually improves the synthesis of biodiesel products with a higher number of cetane, resulting in lower toxic NOx emissions (Knothe *et al.* 2003). The fatty acid composition determines the extent of higher compositional saturation, resulting in a higher degree of saturation and viscosity (Ayetor *et al.* 2015, Mehandi *et al.* 2015).

The fatty acid composition has a significant affect on the fuel properties of biodiesel (Hamzah *et al.* 2020). Usually high compositions of detrimental free fatty acids (FFA) include non-edible oils such as *Jatropha*, which decreases biodiesel yields. Similarly, the high fatty acid content hampers the direct conversion of the oil into biodiesel because the high FFAs facilitate the formation of soap, which can hamper product separation during or after transesterification.

Before the conversion of *Jatropha* oil into biodiesel, it is important to know acid number first because it can affect the amount of biodiesel product. The maximum acceptable acid number in a system using an alkaline catalyst is less than 2.5% (Santoso *et al.* 2018). Experimental results on free fatty acids indicated a range of 2.06 to 12.71 with a mean value of 5.64. The lowest acid value of 2.06 was recorded by accession K7, K10 and K12.

The principal indicator of fuel quality, especially ignition and combustion in diesel engines, is the cetane number. A high cetane number usually implies a lower ignition delay period, *i.e.* the time interval from the fuel injection to the ignition initialization in the combustion chamber. Usually, the parameter ensure good fuel combustion efficiency, cold start and engine output, along with low white smoke formation and emissions (Ramos *et al.* 2009, Mehandi *et al.* 2018).

The cetane number depends on the composition of the fuel which internally depends on the type of feedstock used for fuel purposes. Since biodiesel is made from a variety of feedstock vegetable oils, their cetane numbers vary from 45 to 67. However, in the United States, the values for diesel fuel were set from 42 to 45 for that number. The cetane number of different *Jatropha* accessions showed a large and substantial variability from 40.95–51.16, indicating a mean of 49.08. The maximum value of 51.16 (K6) closely followed by accessions K4, K10, K11, K12, K14, K18, K24, K25 respectively.

Iodine value, a calculation of the average amount of unsaturation present in fats and oil, has used to calculate the different physical and chemical properties of the oil for the quality control of hydrogenated products. Due to its utility, the importance of iodine has been included in the requirements for some agricultural products derived from vegetables oils and fats, including biodiesel. *Jatropha* oil, which is a valuable commodity for its use in the production of biodiesel, must also be examined to determine the amount of unsaturation present in it as the standard requirements for unsaturation present in biodiesel have been very sensitive criteria for its further use in a smooth- functioning diesel engine. The average iodine value of *Jatropha* oil belongs to the semi-drying oil category used for industrial applications.

## CONCLUSION

In the current investigation, the iodine value of accession number K12 was registered at a maximum of 120.50. It is worth noting that the number of cetane decreases by increasing the iodine content f the oil. The decrease in the number of cetane which affects the ignition quality of the oil as a fuel that adversely affects the quality of its fuel. Thus it is desirable to have oil derived from *Jatropha* accessions with moderate iodine value but with high cetane number, and therefore the existence of unsaturated fatty acids in moderate amounts is essentially needed for oil that can act as biodiesel without causing any functional difficulties.

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