Effect of hull content and moisture content on oil expression from dehulled *Jatropha curcas* seeds

B. K. Yaduvanshi[1], T. K. Bhattacharya [2], S. K. Patel[3*], K. Kundu[4], P. Rajan[4]

(1. College of Agricultural Engineering and Technology, Anand Agricultural University, Anand, Gujarat, 389151, India;
2. College of Technology, G B Pant University of Agriculture and Technology, Pantnagar, 263145, India;
3. College of Agricultural Engineering and Technology, RPCAU, Pusa, Bihar, 848125, India;
4. MERADO, CMERI, CSIR, Ludhiana, 141006, India)

Abstract: *Jatropha curcas* is an ornamental, medicinal and a multipurpose shrub grown widespread throughout arid and semiarid tropical region of the world. The Jatropha seed contains 46.27% oil, 42% hull and 58% kernel. Jatropha seed oil with viscosity of 8.2 cSt is close to that of diesel fuel, the oil is used as fuels for jet, transformer, and high hydrocarbon. The oil from the seeds can be extracted through solvent extraction, mechanical pressing. The solvent extraction method is most efficient, but it is costly and requires more resources. The mechanical pressing, especially hot pressing is more efficient than cold pressing. The seed parameters such as oil content, moisture content, hull content, etc. and machine operating parameters i.e. operating pressure, retention time, temperature, etc, affects the oil extraction efficiency. *Jatropha curcas* seeds with different levels of moisture content viz. 10, 14, 17, 20 and 23% and hull content viz.0, 10, 20, 30 and 40% were pressed through screw press. The additional moisture to the seeds having 7% moisture content was added using hot water sprinkling. The extraction, extraction efficiency, expeller throughput and the oil from the feed having 0% hull resulted in paste formation even at lowest moisture content and consequently, no oil extraction. The maximum oil expression was observed as 29.7 percent for 20 percent hull content mixture at 17.2 percent moisture content. The oil expression as well as the oil expression efficiency was reduced at the levels below and above the optimum moisture content.

Keywords: steaming, hull, kernel, oil expression, expeller throughput, specific power consumption

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1 Introduction

Jatropha curcas is a plant native to the tropical and subtropical regions of India. The high oil content (46.27%) of seeds is of growing interest as a bioenergy resource. A total seed ash of 4.56% by weight indicates the presence of abrasive solids, soluble metal soaps and silica residue in the seed. Conversion of oil to biodiesel is easily accomplished by transesterification (Chavan et al., 2015). *Jatropha curcas* oil is composed of essential fatty acids such as palmitic acid (13%), stearic acid (2.53%), oleic acid (48.8%) and linoleic acid (34.6%). *Jatropha* seed oil with a viscosity of 8.2 cSt is close to diesel fuel and is used as a fuel for jet, transformer and high-hydrocarbon engines. It is also used as a soap stock (Mariod et al., 2017). The *Jatropha* seeds comprise of 30%-40% testa (shells), 60%-70% kernel and 44% – 62% oil content (Oyebanji, 2017).

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***Corresponding author:** **Patel S K.** Ph.D., Professor. College of Agricultural Engineering and Technology, RPCAU, Pusa, Bihar, India. Email: sppiari@gmail.com.

Olaniyan (2010) classified the main methods for extracting oil from oleaginous plant materials into wet extraction (hot water or steam extraction), solvent extraction and mechanical pressing. Traditional methods used by rural communities are considered ineffective in terms of oil recovery. Solvent extraction is considered to be one of the most efficient methods for extracting seed oil because less oil remains in the cake or flour (Buenrostro and López-Munguia, 1986; Tayde et al., 2011; Takadas and Doker, 2017).

Mechanical pressing methods are often used to extract oil from oilseeds with an oil content of more than 20% (Sinha et al., 2015). Typically, these methods have the advantage of low operating costs and a high-quality, light-colored oil with a low concentration of free fatty acids (FFA) (Kirk-Othmer, 1979). However, it has a relatively low oil recovery compared to solvent extraction method. Simultaneously, a large amount of oil is often left in the cake or flour after extraction (Anderson, 1996). It also takes a lot of time and labor (Bhuiya et al., 2015). For example, when extracting castor oil, mechanical pressing removes only about 45% of the oil, while the remaining oil in the flour can be extracted by solvent extraction (Ogunniyi, 2006).

There are two types of mechanical pressing methods, namely cold pressing and hot pressing methods. The cold pressing or scarification method is carried out at a low temperature (below 500°C) and pressure, while the hot pressing method is carried out at an elevated temperature and pressure. Cold-pressed seed oils are safer than hot-pressed seed oils because the former avoids the adverse effects caused by high temperatures. Some of the likely side effects are reduced oxidative stability, degradation of valuable oil components and impairment of oil retention. Cold pressed oils preserve the purity and natural properties of vegetable oils (Bhatol, 2013). This includes the preservation of valuable nutraceuticals such as phytosterols and tocopherols in the extracted oil (Kittiphoom and Sutasinee, 2015). Because of these attractive qualities, the global demand for cold-pressed oil is growing. In contrast, hot-pressed methods produce higher oil yields, mainly due to a decrease in the viscosity of the seed oil at high temperatures. This increases the oil flow during extraction. Thus, high temperatures increase the efficiency of the extraction process which results in 80% oil recovery (Patel et al., 2016) along with low quality oil. Regardless of the extraction method used, pretreatment of oilseeds is required. The main steps in pretreatment process are peeling, removing pods or seed skins, winding, sorting, cleaning, chopping or grinding, and preheating (Yusuf et al., 2015). Grinding or crushing oilseeds prior to extraction is necessary to ensure that the tiny oil cells embedded in the fibrous structures are destroyed or ruptured to release oil (Tayde et al., 2011). Heat treatment further facilitates oil release by reducing moisture content and hardening the interior of oilseeds (Patel et al., 2016). Recently, the traditional hot air oven preheating of oilseeds has been replaced by microwave heat treatment, the latter offering several advantages (Mgudu et al., 2012). Considering the above points, the present study was undertaken to find out the effect of hull content and moisture content for maximum oil expression from the broken *Jatropha curcas* seeds.

In cold pressing the presence of impurities (up to 10%) and hulls (up to 32%) has an adverse effect on the sensory and chemical characteristics of the oil. The adverse influence on the oils colour is also evidence from the results of measuring their transparency. The presence of impurities and seed hulls cause a decrease in the oxidative stability of oils (3.63 h to 4.63 h), while the Totox values are in the range from 2.25 to 5.87 (Dimić et al., 2012). However, some amount of fibre is important for enhancing oil recovery from dehulled flaxseed (Mridula et al., 2015). But, the woody structure of jatropha seed hull may absorb the extracted oil from the kernel and excessive hull quantity may create problems during passing through the press cylinder. Keeping above in consideration the study was taken to optimize the hull content at different moisture content for jatropha seeds.

2 Materials and methods

A one tonne per day (TPD) capacity screw press (oil expeller) developed by Mechanical Engineering Research and Development Organization (MERADO), Ludhiana, India (Figure 1) was used to optimize the operating parameters for oil recovery from *Jatropha curcas.* The seeds (Figure 2) were of commercial grade having 10 percent overall impurities. The impurities included seeds of other crops, crop residues and some debris. The initial moisture content of seeds was 7% and oil content was around 36%. Moisture content was determined by standard method. However, treatment wise oil content was determined by solvent extraction method. The seed contained approximately 42 percent kernel. The physical analysis of the seed is given in Table 1.

The movement of the feed inside the expeller cylinder also depend on the content of the fibrous material present in it. Originally seeds were contained 42% hull rest 58% was the kernel. During the experiments the hull content varied between 0-40 % with an increment of 10 percent. The available oil content of different hull content mixtures was calculated and presented in Table 2.

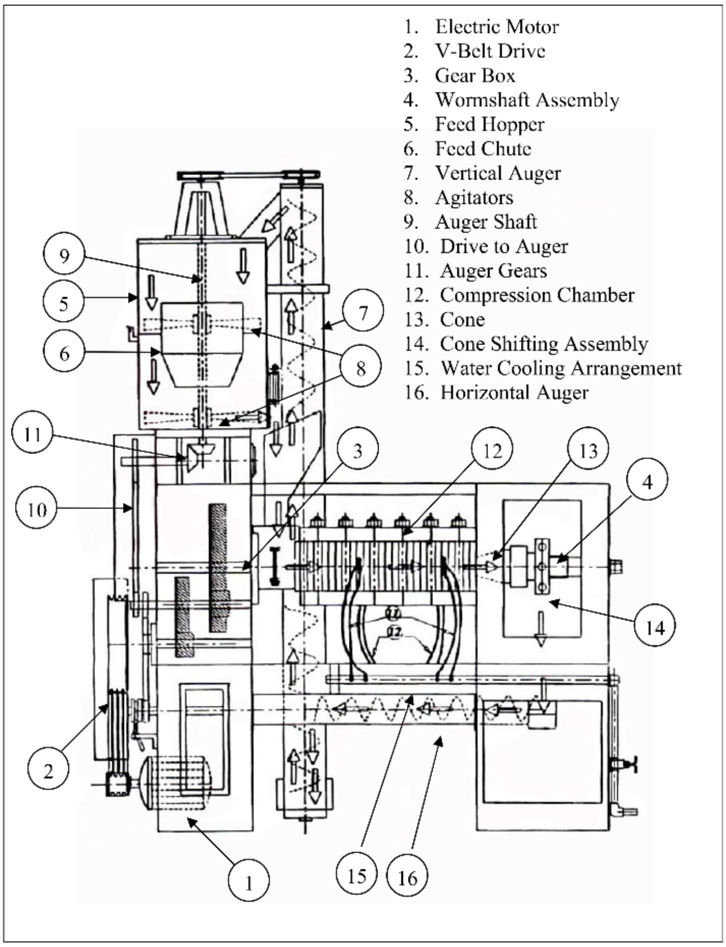

Figure 1 Technical details of 1 TPD MERADO make oil expeller

(a) whole seeds (b) 100 % kernel (c) 10 percent hull

(d) 20 percent hull (e) 30 percent hull (f) 40 percent hull

Figure 2 *Jatropha* seeds and kernel-hull mixtures used in the experiment

Table 1 Physical properties of Jatropha seeds

Sl. No.	Parameter	Seed	Kernel	Hull
	Dimensions, mm			
	Length	17.8	-	-
	Width	11.1	-	-
	Thickness	8.6	-	0.5
	Geometric Mean Diameter, mm	11.9	-	-
	Sphericity	0.67	-	-
	Mass of 1000 grains, g	581.4	402.4	-
	Bulk Density, g cm^{-3}	0.407	0.410	-
	True Density, g cm^{-3}	0.669	0.670	-
	Porosity, %	39.2	38.7	-
	Angle of Repose, degree	34.31	19.16	-
	Angle of Internal Friction on wooden surface, degree	29.27	30.16	-
	Angle of Internal Friction on GI sheet Surface, degree	23.02	25.04	-
	Moisture Content, % (wb)	7.3	7.1	7.5
	Oil Content, % (db)	36.6	61.2	-

Table 2 Oil content of the feed of different kernel-hull mixtures

Sl. No.	Seed kernel–hull Mixture		Oil content in mixture (%)
	Seed kernel (%)	Hull (%)	
1	100	0	61.1
2	90	10	55.0
3	80	20	48.9
4	70	30	42.8
5	60	40	36.7

3 Treatments and observations

The seeds were soaked in hot water, shelled and partial fraction of shell removed at selected moisture contents. The moisture content of the seeds was raised from 7% to 14% to initiate expelling operation with a gradual increment of 3% under different treatment till overall seed moisture content reached up to 26% (Yaduvanshi et al., 2019). Similarly, the same moisture addition strategy was adopted for disintegrated *Jatropha* seeds. The seeds were disintegrated to separate hull and hot water sprinkled. The hull content levels were taken 10, 20, 30 and 40 % at moisture content levels of 10, 14, 17, 20 and 23 percent, respectively. Available oil content in the seed kernel-hull mixtures was calculated and presented in Table 2. The actual moisture content was also measured for each sample just before expelling which is presented in the result section.

The amount of hot water sprinkled were taken 34, 82, 121, 163 and 208 g kg^{-1} to raise the moisture content to the levels 10, 14, 17, 20 and 23 %, respectively. The oil expression, oil expression efficiency, specific power consumption and expeller throughput were calculated for the given treatments.

The moisture content of seed and cake was determined by IS: 3579–1966. The formula for moisture content is given.

$$M_c = \frac{w}{W} \quad (1)$$

where,

M_C= moisture content, % (wb);

w= weight of moisture in sample, g;

W= weight of sample initially, g.

Oil recovery during expulsion of the samples was measured by collecting the oil output in a tray. The percentage of oil recovery was calculated based on the total material fed to the hopper.

The oil content of the seed and cake samples was measured using Gerhart make soxtherm, based on the principle of solvent extraction using a standard technique. The following formula was used to calculate oil content.

$$O_c = \frac{W_2 - W_1}{W} \quad (2)$$

where,

O_C = Oil content, % (wb);

w_1 = Weight of oil extraction flask before oil extraction, g;

w_2 = Weight of oil extraction flask after oil extraction, g;

W = Weight of crushed sample, g.

The power requirement was measured by a power meter that directly gives the power consumption in kW. The least count of the power meter was 0.01, with a maximum capacity of 9999.99 kW without tare. It was fitted to the control panel of the expeller. Power readings were noted down at the start and end of each pass. The specific power consumption was calculated using following relationship.

$$S_{pc} = \frac{P}{W_s} \quad (3)$$

where,

Spc = Specific power consumption, kW kg^{-1};

P = Power consumption during oil expression, kW;

W_s = Weight of seed sample, kg.

A screw gauge with the smallest value of 0.01 mm for the first 5.0 centimeter was used to measure the thickness of the cake. When the working regime returned to normal, at the outlet, flow-through samples of the cake were taken and measured. The machine was adjusted to discharge the cake of 3.5 mm thickness.

The oil expression efficiency of the expeller is the fraction of available oil extracted during the experiment and was calculated using the following relationship:

$$O_e = \frac{W_e}{W_o} \times 100 \quad (4)$$

where,

O_e = Oil expression efficiency, %;

w_e = Weight of oil extracted, kg;

w_o = Weight of available oil in the sample, kg.

4 Result and discussion

The pre-experiment trials on whole seed with added moisture by cold water indicated that the expeller was not able to run at moisture content less than 10 percent. The moisture content of seed kernel–hull mixture under different disintegration treatments was kept in the between 10.0 to 20.0 percent by sprinkling hot water (80 ^{0}C) over feed material. At 0% hull content the experiment could not be conducted due to kernel formed paste formation inside cylinder and get discharged through the openings without extraction of oil Figure 3. However, it contained 61.1 % oil. Oil was not extracted due to paste formation of kernels inside the compression chamber of expeller, which moved along with the wormset and paste got discharged from the expeller outlet as shown in (Figure 3).

Figure 3 Paste discharged from expeller when expressing oil from seed kernel only

4.1 Oil Expression

The oil expression results from a mixture of seed kernel-hull of *Jatropha* seed at different moisture content and hull content are shown in Table 3.

It can be observed from table that when the seed kernel was added with 10 percent hull, the oil expression was 18.7 and 16.5 % at moisture content of 10.3 and 14.0 %, respectively. The oil expression from seed kernel–hull mixture containing 20 percent hull was maximum i.e. 29.7 % at 17.2 % moisture content of mixture followed by 29.2 % and 25.2 % with hull content 30 and 40 % hull at 17.0 and 20.2 % moisture content, respectively.

The results also reveal that, in general, the oil expression was more when the seed kernel was mixed with 20 and 30 percent hull content as compared to a mixture containing 10 and 40 % hull. It is evident from the table that the oil expression increased with increase in moisture content of mixture. Also, an increase in moisture content of mixture beyond 20 % resulted in decrease in oil expression. The lesser oil expression at higher moisture content might be slipping of feedstock occurs inside the compression zone.

4.2 Oil expression efficiency

The variation in oil expression efficiency observed at different moisture contents and seed kernel-hull mixture is shown in Table 3. Table shows that maximum oil expression efficiency was 68.7 % among all treatments for 40 percent hull content at moisture content of 20.2 %. However, the corresponding oil expression was 25.2 %. Further, comparison of results indicated that for 20 and 30 % hull content at 17.0 % moisture content, the maximum oil expression efficiency was 60.7 and 68.2 %, respectively. Further, it was observed that oil expression efficiency was maximum for 30 % hull at 17.0 % moisture content. Hence, it could be said that 30 % hull at 17.0 % moisture content was more efficient than other treatments.

Table 3 Moisture content, oil expression, oil expression efficiency, Specific power consumption at different hull content and moisture levels

Hull Content, %	Treatment No	Moisture content, %	Oil Expression, %	Oil Expression Efficiency, %	Specific Power Consumption, kW kg^{-1}	Expeller Throughput, kg h^{-1}
0	T_{11}	10.3	-	-	-	-
	T_{12}	14.0	-	-	-	-
	T_{13}	17.2	-	-	-	-
	T_{14}	20.3	-	-	-	-
10	T_{21}	10.3	18.7	34	0.364	8.9
	T_{22}	14.0	16.5	30	0.363	8.1
	T_{23}	17.2	-	-	-	-
	T_{24}	20.3	-	-	-	-
20	T_{31}	9.8	20.7	42.3	0.322	10.8
	T_{32}	14.2	26.1	53.4	0.296	11.6
	T_{33}	17.2	29.7	60.7	0.238	13.3
	T_{34}	20.3	29.2	59.7	0.235	12.3
30	T_{41}	9.8	17.2	40.2	0.28	13.2
	T_{42}	14.2	21.3	49.8	0.248	13.8
	T_{43}	17	29.2	68.2	0.23	13.7
	T_{44}	20.3	28.3	66.1	0.224	12.9
40	T_{51}	10.1	16.5	45	0.252	14.7
	T_{52}	14	17.8	48.5	0.225	15.3
	T_{53}	17	20	54.5	0.205	15.4
	T_{54}	20.2	25.2	68.7	0.221	14.3

4.3 Specific power consumption of expeller

The minimum specific power consumption was 0.363, 0.235, 0.224 and 0.205 kW kg^{-1} at 10, 20, 30 and 40 % hull content with 14.0, 20.3, 20.3 and 17.0 % moisture content of mixture, respectively (Table 3). The specific power consumption decreased with increase in hull content in the seed kernel - hull mixture. It was also observed that specific power consumption decreased with increase in moisture content of mixture. The decrease in specific power consumption of expeller with increase in hull content in the mixture might be attributed to the facts that increase in hull content increases the friction between the feed which helps in reducing retention time of feedstock in compression zone.

4.4 Expeller throughput

The maximum expeller throughput for seed kernel-hull mixtures was observed as 8.9, 13.3, 13.8 and 15.4 kg h^{-1} at 10, 20, 30 and 40 % hull content. The corresponding moisture contents were 10.3, 17.2, 14.2 and 17.0 %, respectively. The expeller throughput increased with increase in hull content in the mixture. Further, the increase in moisture content of mixture resulted in decrease in expeller throughput. It might be due to the reason that at high moisture content wrapping of feedstock occurs with the worm set. While higher hull content improved the movement of feedstock inside the expeller chamber.

5 Conclusions

The maximum oil expression was observed as 29.7 % for 20 % hull content in kernel - hull mixture at 17.2 % moisture content. The oil expression efficiency, power consumption and expeller throughput were 60.7 %, 0.238 and 13.3 kg h^{-1}, whereas the maximum oil expression efficiency among the experiments was 68.2 % for same treatment. The maximum expeller throughput and minimum power consumption among conditions were 15.4 kg h^{-1} and 0.205 kW kg^{-1}. The result also revealed that oil expression as well as the oil expression efficiency were reduced at less than 10% and above than 30% moisture content of kernel- hull mixture.

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References

Anderson, D. 1996. A primer on oils processing technology. In *Bailey's Industrial Oil and Fat Products*, 5th ed, ed. F. Shahidi, Volume 4, ch. 1, 10-17. New York, USA: John Wiley and Sons.

Bhatol, K. 2013. Castor Oil Obtained by Cold Press Method. *Shri Bhgwati Oil Mill (SBOM) manufacturer's Info.* Banaskantha, Gujarat, India.

Bhuiya, M. M. K., M. G. Rasul, M. M. K. Khan, N. Ashwath, A. K. Azad, and M. Mofijur. 2015. Optimization of oil extraction process from Australian native beauty leaf seed. (*Calophyllum innophyllum*). *Energy Procedia*, 75: 56-61.

Buenrostro, M., and A. C. López-Munguia. 1986. Enzymatic extraction of avocado oil. *Biotechnology Letters*, 8: 505-506.

Chavan, S. B., R. R. Kumbhar, D. Madhu, B. Singh, and Y. C. Sharma. 2015. Synthesis of biodiesel from *Jatropha curcas* oil using waste eggshell and study of its fuel properties. *RSC Advances*, 5(78): 63596-63604.

Dimić, E., T. Premović, and A. Takači. 2012. Effects of the contents of impurities and seed hullson the quality of cold-pressed sunflower oil. *Czech Journal of Food Sciences*, 30(4): 343-350.1

Kittiphoom, S., and S. Sutasinee. 2015. Effect of microwaves pretreatment on extraction yield and quality of mango seed kernel oil. *International Food Research Journal*, 22(3): 960-964.

Mariod, A. A., M. E. S. Mirghani, and I. Hussain. 2017. Jatropha curcas L. Seed Oil. In *Unconventional Oilseeds and Oil Sources*, eds. A. A. Mariod, M. E. S. Mirghani, and I. Hussain, ch. 31, 199-206. Academic Press.

Mgudu, L., E. Muzenda, J. Kabuba, and M. Belaid. 2012. Microwave assisted extraction of castor oil. In *International Conference on Nanotechnology and Chemical Engineering (ICNCS 2012)*, 21-22. Bangkok, Thailand, 21-22 December 2012.

Mridula, D., P. Barnwal, and K. K. Singh. 2015. Screw pressing performance of whole and dehulled flaxseed and some physico-chemical characteristics of flaxseed oil. *Journal of Food Science and Technology*, 52(3): 1498-1506.

Ogunniyi, D. S. 2006. Castor oil: A vital industrial raw material. *Bioresource Technology*, 97(9): 1086-1091. 1

Olaniyan, A. M. 2010. Effect of extraction conditions on the yield and quality of oil from castor bean. *Journal of Cereals and Oilseeds*, 1: 24-33.

Othmer, K. 1979. *Encyclopaedia of Chemical Technology*, 5: 1-17. Wiley.

Oyebanji, A. I. 2017. Development and Performance Evaluation of a Decorticator for Jatropha Curcas Fruit.

M. S. thesis, Agricultural and Biosystems Engineering Department. University of Ilorin, Ilorin, Nigeria.

Patel, V. R., G. G. Durmancas, L. C. K. Viswanath, R. Maples, and B. J. J. Subong. 2016. Castor oil: properties, uses and optimization of processing parameters in commercial production. *Lipid Insights*, 9: 1-12.

Sinha, L. K., S. Haddar, and G. C. Majumdar. 2015. Effect of operating parameter on mechanical expression of solvent-soaked soybean grits. *Journal of Food Science and Technology*, 52(5): 2942-2949.

Takadas, F., and O. Doker. 2017. Extraction method and solvent effect on safflower seed oil production. *Chemical and Process Engineering Research*, 51: 9-17.

Tayde, S., M. Patnaik, S. L. Bhagt, and V. C. Renge. 2011. Epoxidation of vegetable oils: A Review. *International Journal of Advanced Engineering Technology*, II (IV): 491-501.

Yaduvanshi, B. K., T. K. Bhattacharya, S. K. Patel, and K. Kundu. 2019. Optimization of mechanical oil extraction of Jatropha seeds from oil expeller. *Journal of AgriSearch*, 6(4):181-184.

Yusuf, A. K., P. A. P. Mamza, A. S. Ahmed, and U. Agunwa. 2015. Extraction and characterization of castor seed oil from wild Ricinus communis L. *International Journal of Science, Environment and Technology*, 4(5): 1392-1404.