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Research Paper

Oil expression from Jatropha seeds using a screw press expeller

Rama Chandra Pradhan [a], Sabyasachi Mishra [b,*], Satya Narayan Naik [c], Naresh Bhatnagar [d], Virendra Kumar Vijay [c]

[a] Department of Farm Engineering, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India
[b] College of Agricultural Engineering and Post Harvest Technology, Central Agricultural University, Gangtok, Sikkim, India
[c] Centre for Rural Development & Technology, Indian Institute of Technology, Delhi, India
[d] Mechanical Engineering Department, Indian Institute of Technology, Delhi, India

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Experiments were conducted to determine the effects of moisture content, cooking temperature, and cooking time on the yield of oil mechanically expressed from Jatropha seed using a screw press expeller. A maximum oil recovery of 73.14% was obtained when Jatropha seeds were conditioned to a dry basis (db) moisture level of 9.69% and cooked at 110 °C for 10 min. Screw press oil recovery, residual oil, pressing rate, and oil sediment content were measured at different moisture contents for uncooked and cooked seed. At optimum processing conditions, oil recovery from cooked seed was 7% higher than that of uncooked seed. Pressing rate decreased from 30.92 to 29.5 kgh^{-1} and 31.38 to 29.87 kgh^{-1} for cooked and uncooked seeds, respectively, where as sediment content increased from 4.27 to 7.86% and 4.02 to 5.27%, respectively, as moisture content decreased. Oil expressed under the processing conditions investigated was of acceptable quality.

1. Introduction

There has been renewed interest in the use of vegetable oils for the manufacture of biodiesel due to their less polluting and renewable nature when compared to conventional diesel. The focus has been mainly on oils from seeds such as soybean, rapeseed, sunflower and safflower (Lang, Dalai, Bakhshi, Reany, & Hertz, 2001), which are essentially edible in nature. In India, with its abundance of forest resources, there are a number of other non-edible tree borne oilseeds with an estimated annual production of more than 20 million tonnes, which have great potential for making biodiesel to supplement other conventional sources (Kaul, Kumar, Bhatnagar, Goyal, & Gupta, 2003). Among these, Karanja (*Pongamia glabra*) and Jatropha (*Jatropha curcas*) have been successfully proved as the potential source for biodiesel (Pramanik, 2003; Raheman & Phadatare, 2004; Senthil, Ramesh, & Nagalingam, 2003).

Jatropha (*Jatropha curcas* L.), is native to South America and has a long history of propagation by Portuguese in Africa and Asia (Bringi, 1987). In unkempt hedges, Jatropha yields around 4 tonnes ha^{-1} of seed (Henning, 1998), whilst under optimal conditions (depending upon local growing conditions, such as water, nutrient availability, and the absence of pests and diseases) a maximum yield of up to 8 tonnes ha^{-1} of seed can be achieved. Jatropha seeds contain around 30–40% oil, thus, depending on seed yields, up to 2200 kg ha^{-1} of oil can be achieved (Lahane and Relwani, 1986; Pradhan, Naik, Bhatnagar, & Vijay, 2009a). It is well adapted to arid and

* Corresponding author. Tel.: +91 8906071295; fax: +91 3592 251390.
E-mail address: s.mishra@usask.ca (S. Mishra).
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Nomenclature

db	Dry basis moisture content, %
M	Moisture content, %
O_c	Oil content of cake, kg,
O_m	Initial oil content of sample, kg
OR	Oil recovery, %
PR	Pressing rate, kg h^{-1}
RO	Residual oil, %
SC	Sediment content, %
W_c	Weight of cake, kg,
W_m	Weight of sample, kg

semi-arid conditions and often used for erosion control (Heller, 1996; Kumar & Sharma, 2008). The productive lifespan of Jatropha tree can be 50 years and it starts to produce fruit after six months. Productivity stabilises after one to three years of plantation (Manurung et al., 2006). In India, Jatropha bears fruit between September and December. The fruit dries and the hull or shell becomes hard and black. The dry fruit, generally containing two to three seeds, remains on the branches. The fruits are usually handpicked. At times, older trees are harvested by shaking the tree/branches. The collected fruits are sun dried for further processing and decorticated to get the seeds (Lakshmikanthan, 1978, pp. 38–39; Pradhan, Naik, Bhatnagar, & Vijay, 2010).

During the extraction of oil and its derivatives, the Jatropha seeds undergo a series of post harvest unit operations, such as expression and/or extraction, to remove the oil. Expression is the process of mechanically pressing liquid out of liquid-containing solids whereas extraction refers to the process of separating a liquid from a liquid-solid system (Brennan, Butters, Cowell, & Lilly, 1990; Khan & Hanaa, 1983). Mechanical expression of oil from the seeds by means of a screw press is considered one of the oldest and most popular methods of the oil production in the world (Mrema & McNulty, 1985). In India, nearly 90% of the total 24 million tonnes of produced oilseeds are crushed using this method (Singh & Bargale, 2000). The main reason for popularity of mechanical oil expellers in India, and other developing countries, is that this equipment is simple and sturdy in construction, can easily be maintained and operated by semi-skilled supervisors, can be adapted quickly for processing of different kinds of oilseeds, and the oil expulsion process is continuous with product obtained within a few minutes of start of the processing operation. The safety and simplicity of the whole process is advantageous compared to more efficient solvent extraction equipment. Furthermore, unlike the solvent extraction method, mechanical pressing yields a chemical free protein rich cake (Fitch-Haumann, 1997; Singh & Bargale, 2000).

Mechanical screw-press performance with a given oilseed depends on the preparation method of the raw material, which consists of a number of unit operations (Singh, Wiesenborn, Tostenson, & Kangas, 2002). Mechanical screw presses typically recover 86–92% of oil from oilseeds (Singh & Bargale, 2000). Adjusting pressing parameters can improve oil recovery; for example, increasing the internal pressure results in a decrease of the residual oil in the cake (Jacobsen & Backer, 1986). Oil recovery can also be enhanced by suitable pre-treatment of the oilseed, such as cleaning, conditioning, decorticating, cracking, flaking, cooking, extruding, and drying to optimal moisture content (Zheng, Wiesenborn, Tostenson, & Kangas, 2003). The cooking or drying conditions for oilseeds preparatory to screw pressing are some of the most important factors that influence screw-press performance. Although some oils are cold-pressed, i.e. there is no thermal treatment before or during pressing, cooking before pressing generally improves oil yield. The heating or cooking of oilseeds increases oil yield as a result of the breakdown of oil cells, coagulation of protein, adjustment of moisture content to the optimal value for pressing, and decreased oil viscosity, which allows the oil to flow more readily (Ward, 1976). The importance of initial moisture content in the screw press has been studied for a wide range of raw materials (Ajibola, Eniyemo, Fasina, & Adeeko, 1990; Singh & Bargale, 1990, 2000; Singh et al., 2002; Mpagalile & Clarke, 2005; Wiesenborn, Doddapaneni, Tostenson, & Kangas, 2001).

Researchers have reported the suitability of Jatropha oil for biodiesel production (Foidl, Foidl, Sanchez, Mittelbach, & Hackel, 1996; Haas & Mittelbach, 2000; Kartika, Pontalier, & Rigal, 2006; Garnayak, Pradhan, Naik, & Bhatnagar, 2008; Ganapathy, Murugesan, & Gakkhar, 2009; Leduc, Natarajan, Dotzauer, McCallum, & Obersteiner, 2009; Pradhan et al., 2009a, 2009b, 2009c). The physico-chemical properties of Jatropha seed, its oil content and fatty acid composition, and energy value of the oil have been investigated and duly reported (Akintayo, 2004; Banerji et al., 1985; Kandpal & Madan, 1995; Kumar, Ramesh, & Nagalingam, 2003; Pramanik, 2003; Shah, Sharma, & Gupta, 2004). However, quantification of cooking-induced changes in oil expression from Jatropha seed has not been investigated.

Considering the importance of cooking (i.e., heating by oven) and moisture content at the time of pressing, a systematic study was deemed necessary to determine the effects of these parameters on pressing characteristics of Jatropha seed. In addition, effects of cooking temperature and time, on oil recovery from Jatropha seeds were investigated. This information would help the processors to select the correct combination of seed moisture level and cooking parameter for optimal screw performance.

2. Materials and methods

2.1. Test procedure

Fully ripe (black) Jatropha fruits were procured from local growers (Delhi, India). The fruits were sun dried for two days and decorticated to get the seeds using a custom built decorticator (Pradhan et al., 2010). These seeds were cleaned and graded manually. The initial moisture content was determined by the standard hot-air oven method at $105 \pm 1\ ^{\circ}C$ for 24 h (Garnayak et al., 2008; Pradhan, Naik, Bhatnagar, &

Swain, 2008). The initial, dry basis (db), moisture content of the seed was 7.22%. The moisture content of the seeds was adjusted to desired levels by spraying the calculated amount of water (Coşkun, Yalçin, & Özarslan, 2005; Pradhan, Naik, Bhatnagar, & Vijay, 2009b). These rewetted seed samples were stored in high-density polyethylene, air tight bags of 100 μm thickness. These bags were kept at 5 °C in a refrigerator for a week to enable uniform distribution of moisture throughout the sample. The final moisture contents of the samples were determined after conditioning. Seed samples were cooked in a hot-air oven (Yorco Sales Pvt. Ltd, India) with preset combinations of cooking time and temperature, and moisture loss in each case was recorded. These uncooked and cooked seeds were then pressed, with four replications, in the screw press oil expeller (Model: 240552, Sardar Engineering, Kanpur, India) (Fig. 1) at an optimum screw-speed of 120 rpm (Pradhan, Naik, Meda, Bhatnagar, & Vijay, 2009c). Raw uncooked Jatropha seeds were pressed, for 10–15 min to condition the screw press to achieve a steady flow of oil and cake, before pressing the seed samples. Upon achieving steady processing conditions, the seed samples were pressed. At each test condition, crude oil and cake were collected in duplicate and weighed. The crude oil was analysed for sediment content and other significant oil properties such as acid value, density, viscosity, iodine value and saponification value. The cake was analysed to determine the residual oil content.

Levels of moisture content, cooking temperature and time, were selected based on preliminary laboratory investigations. Seed samples at three moisture contents (7.22, 9.69, and 12.16% db) were cooked at five temperatures (50, 70, 90, 110 and 130 °C) for four different cooking time (5, 10, 15 and 20 min). Two intermediate moisture levels between 7.22 and 12.16% (db), such as 8.46 and 10.93%, of the samples were also considered to understand the effect of moisture content and cooking on different performance parameters, such as oil recovery, residual oil content, pressing rate, and sediment content.

2.2. *Analytical methods*

The dry basis moisture contents of samples before and after cooking were determined in duplicate by oven drying method at 105 ± 1 °C for 24 h (AOAC 1984, p. 817; Garnayak et al., 2008; Pradhan et al., 2008). The AOAC direct gravimetric method of Soxhlet extraction (AOAC 1984, p. 817) was used for oil content determination. The extracted seed oils at optimum processing conditioned were analysed for some chemical properties (acid value, density, iodine value, saponification value, and viscosity) by methods described by the Association of Official Analytical Chemists (AOAC, 1984, p. 817).

Fig. 1 – Screw press oil expeller.

2.3. Calculation

Oil recovery was defined as the ratio of oil weight in the product oil to original weight in the seed that was pressed (Eq. (1)).

$$OR = \left(1 - \frac{W_c O_c}{W_m O_m}\right) \times 100\% \quad (1)$$

where, W_c is the mass of cake in kg, O_c is the oil content of cake in kg, W_m is the mass of sample in kg and O_m is the initial oil content of sample in kg.

Pressing rate was calculated as the weight of product oil and cake collected in a known period of time. Residual oil in cake was calculated as the weight of oil extracted from the cake by hexane over the weight of cake. Sediment or foots, is the solid particles in the pressed oil. Sediment content was determined by vacuum filtration through filter paper (Whatman-42, Whatman PLC, Maidstone, Kent, UK). The oil container and the solids remaining on the filter paper were rinsed with n-hexane, and the filtered solids were dried by using a hot-air oven at 70 °C for 3 h and weighed.

2.4. Data analysis

An analysis of variance (ANOVA) was carried out to test the effect of moisture content and cooking on the dependent variable using SPSS 14 for Windows (SPSS, Chicago, IL, USA). The data were fitted to polynomial models to obtain best-fit regression equations. A paired t-test was carried out to test the significant difference between cooked and uncooked seeds.

3. Results and discussion

3.1. Effect of moisture content and cooking conditions on oil recovery

Oil recovery from Jatropha seed samples at different processing conditions is shown in Table 1. Oil recovery from the uncooked samples was lower than the cooked samples at same initial moisture content. Cooking makes the seed tissues soft and lowers the oil viscosity. The softening of tissues tends to weaken the cellular structure, making it highly susceptible to failure under pressures, whereas low viscosity enhances the oil flow (Indrasari, Koswara, Muchtadi, & Nagara, 2001), thus, increasing the oil recovery. Table 1 shows that oil recovery was higher for cooked samples at a moisture content of 9.69% (db) and lower for samples at moisture content of 12.16% (db). It was also observed that oil recovery from samples conditioned to an initial moisture content of 12.16% (db) were, in general, lower than samples conditioned to other moisture contents used in this study (Table 1). Reduced oil recovery at higher temperatures could be due to oil degradation and the likely increase in the brittleness of the product. Sufficient heat treatment is needed for adequate coagulation of protein, breakdown of oil cells and reduction in oil viscosity. Oil expression was highest (73.14%) at an optimum moisture content of 9.69% after cooking the sample at a temperature of 110 °C and for 10 min (Table 1). These results prompted further investigation on the relationship between the moisture content after cooking and oil recovery for the cooked samples.

Moisture contents after cooking when Jatropha seed samples were heated under the different processing conditions are shown in Table 2. It was observed that there was higher moisture loss from samples with higher initial moisture content and cooked at higher temperature for longer time. At each moisture level, moisture loss was an indicator of the amount of heat treatment given to the sample during cooking. The higher the amount of heat treatment, the higher was the moisture loss. The initial increase in oil recovery obtained with increased moisture loss during cooking may be attributed to the coagulation of protein in the oilseed samples thus creating larger voids for freer oil flow during expression.

For oilseeds with high-protein content such as Jatropha seeds (23.6% protein), protein coagulation due to heat treatment may have had a significant effect on oil recovery. The data (Table 1) suggest that Jatropha seeds conditioned to

Table 1 – Effects of initial moisture content, cooking temperature and cooking time on percentage of oil recovery from Jatropha seeds.

Moisture (% db)	Cooking temp.(°C)	Oil recovery (%) for corresponding cooking time (min.)				Oil recovery (%) from uncooked sample
		5	10	15	20	
7.22	50	65.88 (3.67)	68.01 (4.56)	66.52 (3.71)	65.97 (2.67)	64.85 (1.92)
	70	65.92 (3.64)	68.11 (2.19)	66.76 (4.22)	66.33 (4.52)	
	90	66.03 (4.52)	68.23 (4.21)	67.09 (2.67)	66.48 (3.67)	
	110	66.42 (3.67)	69.15 (4.23)	67.78 (3.23)	66.76 (4.81)	
	130	65.13 (4.23)	67.27 (3.56)	66.88 (4.65)	66.11 (3.21)	
9.69	50	68.42 (1.23)	68.51 (2.16)	68.38 (3.45)	68.86 (4.12)	68.36 (1.23)
	70	69.76 (2.78)	69.98 (2.67)	68.51 (3.22)	69.44 (2.11)	
	90	70.98 (4.11)	71.22 (1.45)	69.46 (1.78)	69.83 (2.66)	
	110	71.69 (2.18)	73.14 (1.01)	71.81 (3.20)	70.66 (4.11)	
	130	69.02 (2.44)	68.89 (3.09)	68.55 (2.0)	68.41 (1.29)	
12.16	50	64.65 (3.04)	66.12 (3.11)	65.27 (2.19)	64.88 (2.22)	64.38 (1.55)
	70	64.89 (1.78)	66.65 (2.67)	65.72 (177)	65.32 (4.11)	
	90	65.31 (4.01)	67.01 (2.13)	66.42 (1.45)	65.69 (3.22)	
	110	65.54 (2.65)	67.45 (2.78)	66.88 (1.71)	65.87 (3.01)	
	130	64.93 (2.19)	66.24 (3.29)	65.36 (3.01)	69.32 (2.81)	

*Figures in parenthesis represent standard deviation.

Table 2 – Effects of initial moisture content, cooking temperature and cooking time on the moisture content after cooking (% db) of Jatropha seeds.

Moisture (%db)	Cooking temp.(°C)	Moisture content (%db) for corresponding cooking time (min.)			
		5	10	15	20
7.22	50	7.18 (0.78)	6.89 (1.01)	6.53 (0.34)	6.21 (0.12)
	70	7.05 (0.25)	6.76 (0.55)	6.33 (0.78)	6.02 (0.1)
	90	6.78 (0.21)	6.32 (0.67)	6.08 (0.11)	5.91 (0.33)
	110	6.56 (1.11)	6.11 (0.97)	5.73 (0.56)	5.48 (0.69)
	130	6.24 (0.56)	5.76 (0.19)	5.22 (0.52)	5.01 (1.04)
9.69	50	9.45 (1.03)	9.02 (0.07)	8.79 (0.61)	8.36 (0.45)
	70	9.16 (0.67)	8.91 (0.34)	8.67 (0.66)	8.01 (0.17)
	90	8.75 (0.78)	8.58 (0.44)	8.36 (0.18)	7.78 (0.66)
	110	8.36 (0.38)	8.19 (0.71)	7.03 (0.12)	6.91 (0.99)
	130	8.22 (0.15)	7.89 (0.62)	6.68 (0.51)	6.32 (1.01)
12.16	50	11.76 (0.06)	11.49 (0.1)	11.23 (0.06)	11.02 (0.12)
	70	11.39 (0.21)	11.17 (0.61)	11.01 (0.11)	10.87 (1.04)
	90	10.96 (0.97)	10.75 (0.78)	10.55 (0.23)	10.43 (0.56)
	110	10.58 (1.01)	10.21 (0.09)	10.23 (0.17)	10.11 (0.33)
	130	10.12 (0.69)	9.77 (0.55)	9.96 (0.34)	9.86 (0.66)

*Figures in parenthesis represent standard deviation.

moisture contents of 9.69% (db) and cooked such that the moisture content was reduced by about 15% gave the highest oil recovery of about 73%.

3.2. *Performance parameters of screw expeller at optimum condition*

3.2.1. *Oil recovery and cake residual oil*

The effects of moisture content and cooking on oil recovery are shown in Fig. 2. Oil recovery increased with increased seed moisture and reached the highest value at moisture contents of 8.19% (db) for cooked seeds, and 9.86% (db) for uncooked seeds. Further increases in seed moisture, however, resulted in a rapid decrease in oil recovery. This can be related to mucilage development on oil cells (Vaughan, 1970, p. 141). At higher moisture content there was swelling of mucilage which in turn produced a cushioning effect on the seed. The swelled mucilage could have been an impediment to oil flow during expression while the cushioning effect on the seed reduced the rupturing of the particles and internal tissues during pressure application. A comparison of the oil recovery shows that the oil yields obtained from uncooked samples were lower than those from cooked samples indicating the necessity for adequate heat treatment. The increased oil recovery from cooking can be attributed to reduced viscosity of the oil in the capillaries of the seed tissues (Fasina & Ajibola, 1989).

The relationships between moisture content and oil recovery may be represented by second-order polynomial equations as given in Table 3. The relationships were statistically significant ($P \leq 0.01$) for both cooked and uncooked seeds (Table 4). A similar trend was reported for cooked and uncooked flaxseeds (in the moisture range of 5.3–12.4% db) (Singh & Bargale, 1990) and rapeseed (in the moisture range of 5.3–12.4% db) (Bargale & Singh, 2000). However, other reports showed that oil recovery increased while decrease in moisture content for soybean, and crambe seed (Khan & Hanaa, 1983; Singh et al., 2002).

Increased oil recovery implies decreased cake residual oil, as is seen by comparing Figs. 2 and 3. Thus, the residual oil is

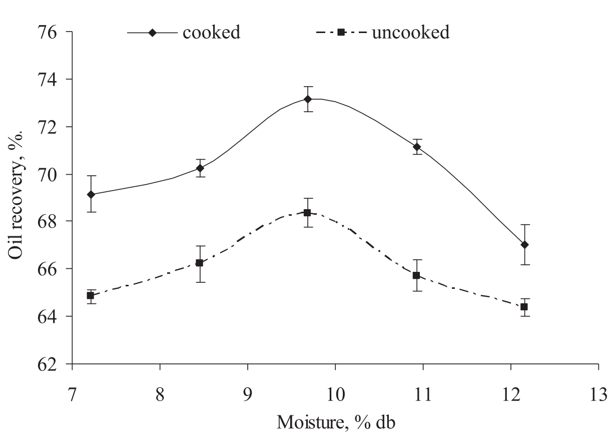

Fig. 2 – Effect of moisture content and cooking on oil recovery. The error bars represent the standard deviation.

Table 3 – Regression equations for oil recovery (*OR*), residual oil (*RO*), pressing rate (*PR*) and sediment content (*SC*) as function of moisture content (*M*).

Parameter	Equation	Correlation coefficient (r^2)
Oil recovery		
Cooked	$OR = 7.59 + 13.63M - 0.72M^2$	0.86
Uncooked	$OR = 23.70 + 9.13M - 0.48M^2$	0.79
Residual oil		
Cooked	$RO = 53.55 - 8.29M + 0.44M^2$	0.99
Uncooked	$RO = 49.43 - 7.03M + 0.36M^2$	0.89
Pressing rate		
Cooked	$PR = 33.15 - 0.94M + 0.06M^2$	0.94
Uncooked	$PR = 35.09 - 1.31M + 0.08M^2$	0.98
Sediment content		
Cooked	$SC = 9.41 + 0.08M - 0.04M^2$	0.99
Uncooked	$SC = 3.47 + 0.52M - 0.04M^2$	0.96

Table 4 – Analysis of variance of oil recovery, cake residual oil, pressing rate, and sediment content.

Parameter	Mean	Variance	df	F
Oil recovery				
Uncooked	65.83	3.19	4	0.288*
Cooked	70.54	11.07	4	–
Residual Oil				
Uncooked	17.13	0.94	4	0.385*
Cooked	16.14	2.45	4	–
Pressing rate				
Uncooked	30.51	1.35	4	1.984*
Cooked	30.05	0.67	4	–
Sediment content				
Uncooked	5.03	0.61	4	0.225*
Cooked	6.54	2.73	4	–
Error	–	–	9	–

*Significant at $P < 0.01$.

decreased with increased in moisture content and reached a minimum at moisture content of 9.69% (db) for both cooked and uncooked seeds. Further increases in seed moisture resulted in an increased residual oil content. This trend might be due to higher frictional resistance offered by low moisture seed in the barrel during pressing. Hoffmann (1989) also suggested that lower moisture content of seed increases friction, whereas higher moisture acts as a lubricant during pressing. Singh et al. (2002) observed a trend of decreased residual oil with decreased moisture content from 9.2 to 3.6% (db) in a mechanical screw pressing of cooked and uncooked crambe seed. The residual oil in cooked seed was 2.8–5.7% lower than that of uncooked seeds, and this difference was statistically significant ($P \leq 0.01$) Table 5. The relationships between moisture content and residual oil content may be represented by second-order polynomial equations as given in Table 3. The relationships were statistically significant ($P \leq 0.01$) for both cooked and uncooked seeds (Table 4).

3.2.2. *Pressing rate*

The pressing rate decreased from 30.92 to 29.5 kg h^{-1} and 31.38 to 29.87 kg h^{-1} for cooked and uncooked seeds, respectively, as

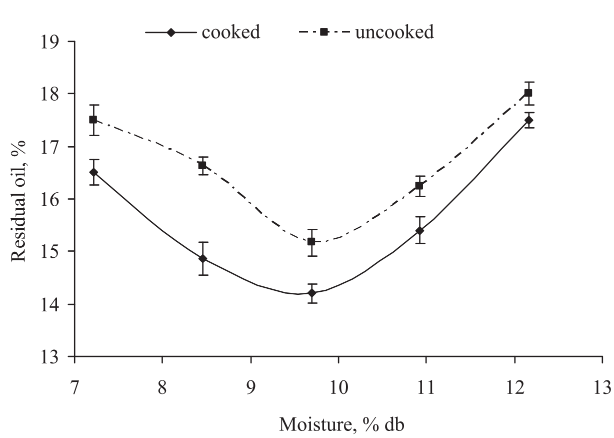

Fig. 3 – Effects of moisture content and cooking on residual oil content. The error bars represent the standard deviation.

Table 5 – Calculated t-values for Cooked and Uncooked Seeds.

Parameter	df	t-value
Oil recovery	4	−3.6167**
Cake residual oil	4	2.9811*
Pressing rate	4	3.0121*
Sediment content	4	−3.8039**

*Significant at $P < 0.01$.
**Significant at $P < 0.05$.

moisture content decreased from 12.16 to 7.22% db (Fig. 4). These rates were achieved at an optimum screw-speed of 120 rpm (Pradhan et al., 2009c). Bargale and Singh (2000) also reported decreased pressing rate with decrease in moisture content (in the range of 5.3–12.4% db) in screw pressing of moisture-conditioned rapeseed but observed a peak at 10.1% db in the screw pressing of hot-water-soaked and sun-dried rapeseed in the above mentioned moisture-content range. However, Blake (1982) reported pressing rate increased from 15 to 25 kg h^{-1} when moisture content decreased from 10 to 6%. From the above, it seems that the relationship between

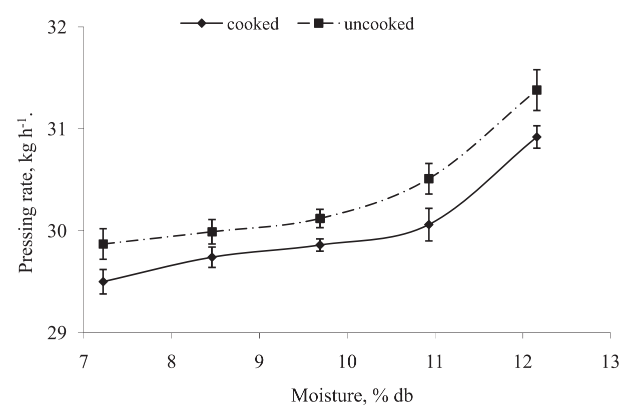

Fig. 4 – Effect of moisture content and cooking on pressing rate. The error bars represent the standard deviation.

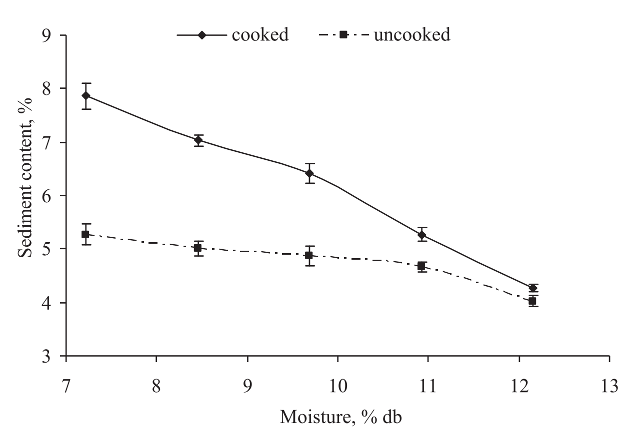

Fig. 5 – Effect of moisture content and cooking on sediment content. The error bars represent the standard deviation.

Table 6 – Some physico-chemical properties of Jatropha seed oil.

Properties	Oil from screw press expeller			Literature values [a]
	Measured average	Measured standard deviation	Measured range	
Acid value (mgKOH/g)	3.21	0.95	3.90–12.2	3.00–38.00
Density (kg m^{-3})	870	260	870–910	800–910
Viscosity @ 40 °C (m^2 s)	34.88×10^{-6}	2.59	34.30×10^{-6}–36.67×10^{-6}	31.0×10^{-6}–51.0×10^{-6}
Iodine value (gI2/100 g)	95.67	2.66	92.45–97.78	93.00–107.00
Saponification value (mgKOH/g)	190.01	8.78	189.20–195.02	188.00–198.00

a source (Akintayo, 2004; Meher, Naik, Naik, & Dalai, 2009).

moisture content and pressing rate varies with method of seed preparation and type of screw press.

The relationships between moisture content and pressing rate were statistically significant at $P \le 0.05$ in both cases, and may be represented by second-order polynomial equations (Table 3). Moisture apparently behaved as a lubricant that reduced resistance during pressing, resulting in higher pressing rate. The higher pressing rate achieved with the higher moisture seed implied a lower press cake residence time in the barrel, which probably contributed to the reduced oil recovery associated with this moisture content. The pressing rate of uncooked seed was slightly higher than that of cooked seed, and the difference was significant at $P \le 0.05$ (Table 5). The reason for this difference could be that denatured protein in cooked seed caused higher frictional resistance in the barrel during pressing.

3.2.3. *Sediment content*

The sediment content dramatically increased from 4.27 to 7.86% and 4.02 to 5.27% for cooked and uncooked seeds, respectively, with a decrease in moisture content from 12.16 to 7.22% db (Fig. 5). This trend is similar to that found by Vargas-Lopez, Wiesenborn, Tostenson, and Cihacek (1999), who observed increasing sediment content from 2.9 to 4.4% when decreasing moisture content from 12.1 to 4.3% (db) in a study on screw pressing of uncooked crambe seed. These followed polynomial second order relationships as presented in Table 3.

The effect of moisture content on sediment content was significant at $P \le 0.05$. The sediment content in cooked seed was slightly higher than that of uncooked seed, which depended upon the moisture content. The difference was significant at $P \le 0.05$ (Table 5). The trends can again be partially explained through frictional resistance; the increased frictional resistance from protein denaturation and decreased moisture results in higher back-pressure (Singh et al., 2002; Ward, 1976). High back-pressure apparently diverts more solids to the barrel openings. The visible discharge of press cake through the barrel openings often foretells plugging of the press.

3.3. *Some chemical properties of Jatropha seed oil*

As the Jatropha oil is usually destined for the preparation of biodiesel, the chemical properties of the oil play an important role in its suitability. The average values of some chemical properties obtained for the oil expressed from Jatropha seed are shown in Table 6. The average values of the properties determined compare favourably with those obtained from the literature.

The acid value of 3.21 mg [KOH] g^{-1}obtained from an oil sample expressed at the optimum processing condition shows that the oil is of good quality when compared with the recommendation that it should be in the range of 3–38 mg [KOH] g^{-1}. The acid value has significant effects on the trans-esterification of glycerides with alcohol using catalyst (Goodrum, 2002). The high free fatty acid content (>1% w/w) will cause soap formation and the separation of products will be exceedingly difficult, and as a result, it has low yield of biodiesel product. Viscosity and density are the parameters required by biodiesel and diesel fuel standards because of being key fuel properties for diesel engines (Alptekin & Canakci, 2008). The density and viscosity of the fuels influences the start of injection, injection pressure, and fuel spray characteristics, hence these properties influence engine performance, combustion and exhaust emissions. From this experimental study, the average value of density and viscosity of Jatropha oil were close to acceptable values quoted in the literature. The iodine value is a measure of the level of unsaturated fats and oils. A higher iodine value indicates a higher level of unsaturated fats and oils (Knothe, 2002; Kyriakidis & Katsiloulis, 2000). The iodine value of Jatropha oil was determined at 95.67 g [I2] 100 g^{-1}. The saponification value of the studied oil was 190.01, which is in the range of values in the literature. A high saponification value indicates that oils are normal triglycerides and very suitable in the production of liquid soap and shampoo. The high saponification value and the low unsaponifiable matter value in the oils suggest that they are normal triglycerides (Akintayo, 2004).

4. Conclusions

In the results there was a high degree of interaction between the effects of seed moisture content, cooking temperature, and cooking time on oil recovery. Oil recovery was found to be dependent on the moisture content of the sample after cooking and the amount of heat treatment given to the sample during cooking. The highest oil recovery of 73.14% was obtained when Jatropha seed was conditioned to 9.69% (db) moisture and cooked at 110 °C for 10 min. Oil recovery from the screw press uncooked Jatropha seed was lower than from the cooked seed, but the pressing rate from uncooked seed was higher than that from cooked seed. The sediment content of screw press Jatropha oil decreased from 7.86 to 4.27% and 5.27 to 4.02% for cooked and uncooked seed respectively, as the moisture content of seed increased from 7.22 to 12.16% (db). The values of chemical properties investigated were similar to literature values. The oil expressed at optimum processing conditioned exhibited good chemical properties and could be useful as biodiesel feedstock and for other industrial applications.

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