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Development of a Hydraulic Press for *Jatropha* Oil Extraction

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ABSTRACT : *Oil from Jatropha curcas plant has been described as the best for biodiesel production. In this study, a hydraulic press for extraction of Jatropha oil was designed and tested. During the design of the machine, the ram press was considered to a piston lorry, the cylinder cage was shrunk fitted with engine sleeve for easy for easy travelling of the piston and the length of traveling of piston in the press cage cylinder was carefully designed for maximum compressive force. The fabricated press was tested using grinded Jatropha kernel which was subjected to pressing at different heating temperature of 70. 80, 90 and 100⁰C in order to determine the oil yield from Jatropha kernel and extraction efficiency of the machine. The test results revealed that the oil yield and extraction efficiency increases with increase in temperature and the optimum oil yield and extraction efficiency of 34.4% and 65.6% respectively was obtained.*

Keyword: Hydraulic pres, *Jatropha curcas,* Heating temperature, Oil yield, Extraction efficiency

1. INTRODUCTION

Oil extraction from *Jatropha curcas* kernel and other oil-bearing seeds involves various preliminary operations such as cleaning, dehulling, drying and grinding. But the total amount of extracted oil depends mainly on the extraction time and temperature, moisture content and particle size of the oil-bearing seed as well as the nature and type of solvent used for the oil extraction. (Gutierrez *et al.,* 2008).

Hydraulic presses are available in a range of configurations, including automatic, manual, power, and motorized. The automatic hydraulic presses are power-assisted, programmable, and microprocessor controlled. They are available in load capacities of 8 – 40 tons for a wide range of applications. Manual hydraulic press is a hand press, suitable for preparing powder samples. It includes an accurate pressure gauge and has tough housing. The motorized hydraulic press is power-assisted and can operate up to 25 tons. The pressure of this instrument can be directly set and it is fully compatible with the dies. Power hydraulic presses operate from 8 to 25 tons and they are designed for a range of pressing applications, including dies sample preparation.

A typical hydraulic press consists of a pump which provides the motive power for the fluid, the fluid itself which is the medium of power transmission through hydraulic pipes and connectors, control devices and the hydraulic motor which converts the hydraulic energy into useful work at the point of load resistance (Sumaila 2002; Sharma 2005).

Over the centuries, three basic methods of separation of oil from oilseeds, nuts and fruits have been evolved. The first, which is now almost obsolete, was the wet rendering method. In this method, oil – bearing materials is boiled in hot water leading to partial separation of oil, which was skimmed off at the top of the vessel (Bredeson, 1983). Hydraulic expression involves application of pressure to the oleaginous material found in a cylindrical cage perforated laterally. The results consist of an axial compaction and a radial oil flow. It was shown that the result is well below that achieved by the traditional method or solvent extraction, being directly affected by the initial conditions of the grains, such as moisture content and temperature, and constructive aspects of the press.

Numerous research studies have been conducted on the effect of heating/drying on oil yield and quality during oil recovery. According to Gikuru and Lamech (2007) stated that the higher the drying temperature of soybean the greater the oil yields. Also Karlovic *et al*. (1992) investigated the effect of temperature and moisture content on oil extraction and kinetics of corn flakes and discovered similar trend.

Oil can be extracted from many raw materials, but not all contain edible oil. Some contain poisons and unpleasant flavors (Frank, 1998). Edible oils are derived from animals and plants (Sagha *et.al.,* 2004). Oil content of vegetable oil-bearing materials varies between 3 and 70 % of the total weight of the seed, nut, kernel or fruit (Bachman 2004). The acceptability of the products at world edible oil market depends on its ability to satisfy basic standard tests for fats and oil (Takakura, 2002).

Various methods for recovering (extracting) *Jatropha* oil from the seeds have been investigated. Conventional method such as solvent extraction is the most widely used technique, owing to their high efficiency in oil recovery (90 to 98%). But the major disadvantage in using solvent extraction technique is its high energy input and toxicity of solvent. This has lead to the development of enzyme-based techniques (Sharma *et al.,* 2002).

Many processing factors have been established as affecting the yield and quality of mechanical expressed vegetable oils. Some of these factors are; the sample preparation before extraction, temperature of extraction, the heating duration of the sample before extraction and the extraction pressure. All this factors are needed to be investigated on the hydraulic press in order to optimize its efficiency. The optimum final moisture varies, with the oilseeds but 6% is common. At lower moisture levels, static effects make the meal difficult to handle and explosive done to hexane residues, oil quality and extraction effectively are favored by more complete cooking while low temperature, low moisture and short cooking time result in more soluble meal protein with high nutritive value and functional properties (Sosulski, 1993)

2. MATERIALS AND METHODS

2.1. Modification of the machine

2.1.1. Modification of the Compression Piston

The Flat-top vehicle type of piston was adopted as compression piston because of its higher compression ratio.

The specification of piston adopted is as follows:

Engine type: Deutz (D914L3)
Maximum power: 43kw at 2300rpm
Maximum torque: 202Nm at 1500rpm
Compression ratio: 1:21
Bore (Diameter): 102mm
Stroke: 132mm
Main piston speed: 10m/s
Material type: aluminum alloy

According to Elijah *et al.,* (2016), the physical properties of Aluminum alloy are given below

Density in Kg/m^3	2770
Coefficient of thermal expansion in C^{-1}	0.00035
Young modulus in MPa	71000
Bulk modulus in MPa	6960.8
Shear modulus in MPa	2669.2
Tensile yield strength in MPa	280

Compressive yield strength in MPa	280
Tensile ultimate strength in MPa	310
Poissons ratio	0.33

(a) Design for thickness of piston head (H_t)

The thickness of piston head is determined by Grashoff's formula.

$$H_t = D\sqrt{\frac{3P}{16\sigma_t}} \tag{1}$$

Where;

H_t = thickness of piston head (mm)

D = cylinder bore/outside diameter of piston (mm)

P = maximum pressure (N/mm^2)

σ_t = permissible tensile stress of the piston

Since the capacity of hydraulic jack is 50kN, therefore,

$$P = \frac{Force}{Area} \tag{2}$$

$$\text{Area of piston head} = \pi r^2 \tag{3}$$

$$\text{Area of piston head} = \pi \times 51^2$$

$$\text{Area of piston head} = 8171.28mm^2$$

Therefore,

$$P = \frac{50\times10^3}{8171.28}$$

$$P = 6.12MPa$$

This implies that maximum mechanical pressure obtainable from the jack is 6.12MPa.

$$H_t = 102 \times \sqrt{\frac{3\times6.12}{16\times280}}$$

$$H_t = 6.52mm$$

(b) Design for piston rings

Radial thickness of the ring (t_1)

$$t_1 = D\sqrt{\frac{3P_w}{\sigma_t}} \tag{4}$$

D = bore diameter (mm)

P_w = pressure of the gass on the cylinder wall

usually ranges from 0.025 to 0.042MPa. Hence, the maximum value is selected

$$t_1 = 102 \times \sqrt{\frac{3\times0.042}{280}}$$

$$t_1 = 2.16mm$$

Axial thickness of the ring (t_2)

$$t_2 = 0.7t_1 \tag{5}$$

$$t_2 = 1.52mm$$

Design for the width of the top land (b_1)

$$b_1 = 0.75H_t$$

$$b_1 = 0.7 \times 6.52$$

$$b_1 = 4.56mm$$

Design for the width of the other land (b_2)

$$b_2 = 0.75t_2$$

$$b_2 = 0.75 \times 1.52$$

$$b_2 = 1.14mm$$

Design for piston pin diameter (d_o)
$d_o = 0.03D$
$d_o = 0.03 \times 102$
$d_o = 30.6mm$

(b) Design for Theoretical Stress of the Piston

The piston crown/head is design for bending when the maximum pressure (P_{max}) is uniformly distributed around the plate surface freely supported by cylinder wall.

The stress acting on the cylinder wall is given as

$$\sigma_b = {}^{M_b}/_{W_b} = P_{max}(r_i/\delta)^2 \quad (7)$$

Where,
$M_b = (1/3)\, P_{max} r_i^{\,3} is\ the\ bending\ moment\ (MNm)$
$W_b = (1/3)\, r_i \delta^2 is\ the\ moment\ of\ resistance\ to\ bending\ of\ the\ flat\ crown\ (m^3)$
$P_{max} = Mechanical\ presure\ = 6.12\text{MPa}$
$r_i = crown\ inner\ radius\ (m)$

$$r_i = [D/2 - (S + t_1 + dt)] \quad (8)$$

Where;
$S = thickness\ of\ the\ sealing\ part\ (mm)$
$S = 0.05D$
$S = 0.05 \times 102$
$S = 5.1mm$
$dt = Radial\ clearance\ between\ the\ piston\ ring\ and\ the\ cylinder\ wall = 0.0008m$
$t_1 = radial\ thickness = 2.16mm$
$r_i = [0.102/2 - (0.0051 + 0.00216 + 0.0008)]$
$r_i = 0.0429m$
$\delta = \text{thickness of the piston crown} = 6.52\text{mm}$

$$\sigma_b = P_{max}(r_i/\delta)^2 \quad (9)$$

$\sigma_b = 6.12\ \left[\frac{0.0429}{0.00652}\right]^2$
$\sigma_b = 265MPa$

For the design to be safe, the obtained value the theoretical stress (265MPa) should be less than the maximum allowable stress of the aluminum alloy (290MPa).

2.1.2. The Press Cage Cylinder

The press cage cylinder is considered as a compound cylinder with a vehicle cylinder sleeve shrunk fitted inside the mild steel pipe for easy traveling of the piston.

2.2. Sample Preparation

Fresh, matured and dried *Jatropha curcas seeds* (Figure 1) used for the study was harvested from jatopha plants within Edo State. The seed were cracked and the kernels were manually separated from the chaff. The initial moisture content of the sample was determined to be 8.5%wb before it was sundried to a moisture content below 7% (Sosulski, 1993) which is the minimum moisture content required for the experiment. The sample was then grinded to a uniform granular size using attraction mill before pressing operation.

Figure 1: Pictorial view of the Sample of Kernel used for the Study

2.3. Evaluation Procedure

The evaluation was carried out with the sample subjected to four levels of temperatures, that is 50, 60, 70 and 80^{0}C and three replications was made for each of the temperature. The 300g of the sample was weighed using weighing balance and transferred in to the pressing cloth before pressing, in order to prevent the grinded samples from coming out of the perforations made on the press cage cylinder. During the pressing operation, the electronic controller device was set in place to regulate the temperature of the sample inside the cage and appropriate measurement was taken and recorded.

2.2 Description of Machine

The modified hydraulic press is as shown on Figure 2. The components of hydraulic press include the frame, piston, press cage cylinder, piston rod, and the return spring. The frame supports the other components, it enables the hydraulic press to stand independently and it carries most of the component parts, the frame is made in a rectangular form of dimension 1290 x 500mm and it is made rigid so that it can withstand any stress occurred as a result of the pressure that will be generated by the hydraulic jack during pressing. A piston valve of diameter 100mm shrunk fitted inside the mild steel pipe for easy traveling of the piston, the head of the piston make contact with the oil seeds under pressing and transfer the force that is generated by the hydraulic jack. The piston rod connects the cross head of the hydraulic press and the piston head together. While the return springs helps to return the hydraulic press to its initial state during unloading, it also helps in holding the cross-head in position.

Figure 2: Pictorial view of the Hydraulic Press during Pressing Operation

2.3 Measurement and Calculation

2.3.1. Determination of oil yield

The oil yield is defined as the amount of oil recovered from a certain kilogram of the seed and it can be expressed mathematically as:

$$OY\ (\%) = \frac{W_{OE}}{W_{OE}+W_{CK}} \times 100\% \qquad (10)$$

2.3.2 Determination of Extraction Efficiency

The extraction efficiency of the machine is expressed as optimum extraction capacity of the machine and it is determined mathematically as:

$$EE\ (\%) = \frac{W_{OE}}{XW_{TS}} \times 100\% \qquad (11)$$

Where;

OE= Oil yield (%)

EE= Extraction Efficiency (%)
W_{OE} =Weight of oil extracted (Kg)
W_{CK} =Weight of cake (Kg)
W_{TS} =Total Weight of Sample (Kg)
X = Oil content (42%)

3. RESULTS AND DISCUSSION

3.1. Results of the Testing

The data generated from the calculated values of the average oil yield and extraction efficiency of the sample at four levels of temperature are presented in the Table 1.

Table 1: Oil Yield and Extraction Efficiency Crushed at Different Temperatures using the Hydraulic Press

	Temperature (^{0}c)			
	70	80	90	100
Oil Yield (%)	19.4± 0.80	22.8± 0.81	24.4± 0.80	23.9±0.80
Extraction Efficiency (%)	44.2±1.79	51.8±1.79	55.6±1.79	54.3±1.79

Each value is the mean of triplicate ± standard deviation

3.2. Effect of Heating Temperature on Oil Yield

Figure 3 showed the effect of heating temperature on oil yield. The oil yield at 70^{0}c was recorded to be 15.7% and it increases gradually as the temperature increases but tends to decreases as the temperature increases above 90^{0}c. Generally, the higher the temperature the higher the oil yields.

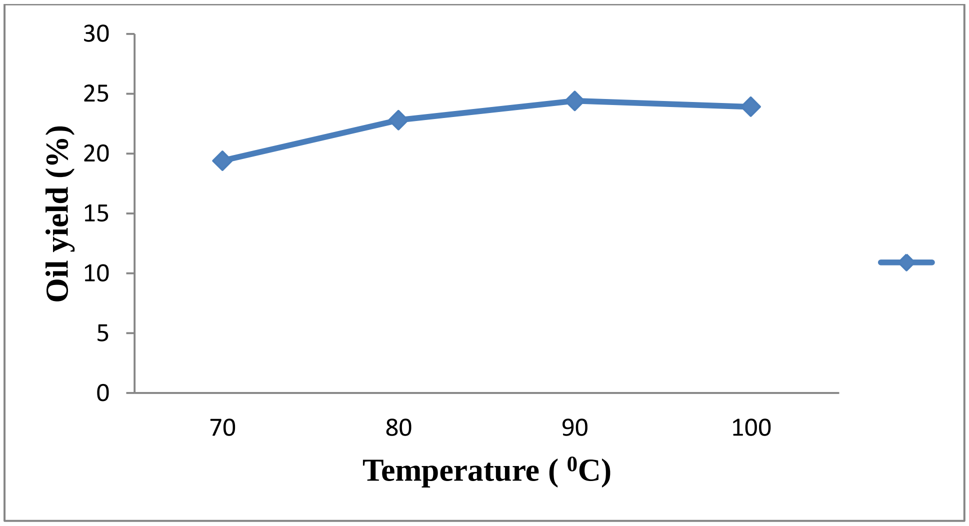

Figure 3: Effect of Heating Temperature on Oil Yield

3.3. Effect of Extraction Temperature on the Extraction Efficiency

It can be deduced from Figure 4 that the extraction temperature has a significant effect on the efficiency of the machine. That is, extraction efficiency increases with increase in extraction temperature but tends to decrease as the extraction temperature increases beyond 90^{0}c and that shows that the machine performs at its maximum efficiency when the extraction temperature is 90^{0}C.

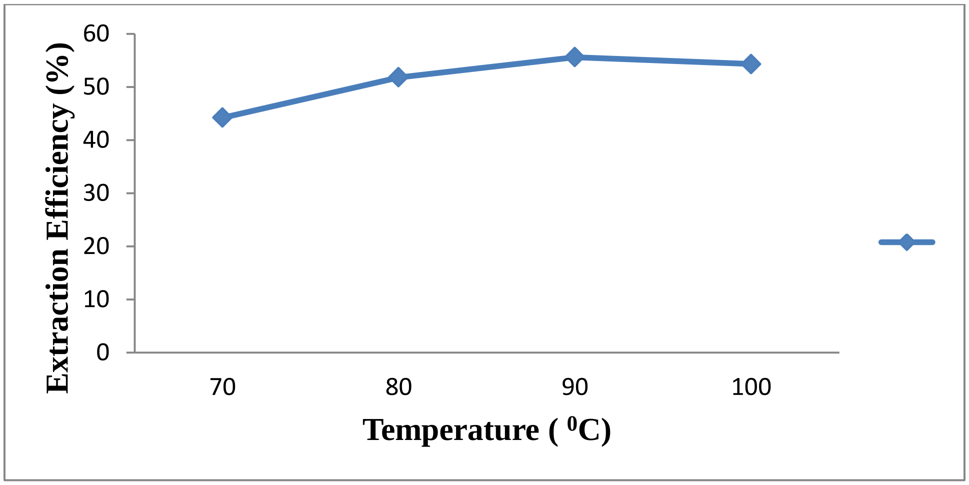

Figure 4: Effect of Extraction Temperature on the Extraction Efficiency

4. CONCLUSION

The hydraulic press was designed, fabricated and tested aiming at improving the extraction efficiency of the press and producing high quality oil from *Jatropha* kernel. The machine was capable of extracting *Jatropha* kernel oil in a more efficient manner and with less time as compared with traditional method of squeezing the oil which is more strenuous, time consuming and inefficient. Also, the study result established that maximum oil yield was obtained from grinded *Jatropha* kernel when the extraction temperature was 90^{o}C and the maximum oil yield of 24.4% at an average time of 10 minute and extraction efficiency of 55.6%.

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