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Design of a Manual Hydraulic Press for Oil Extraction from Oil-Bearing Seeds

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ABSTRACT

Oil extraction is a crucial process necessary for sustainable food production and energy generation. While oil producers in developed countries may face little challenges during oil production, local oil producers in developing countries are on the other hand, faced with numerous problems, one of which is, the difficulty involved in acquiring suitable oil extractors which are cost-effective and capable of functioning without electricity. For this study, a manually operated hydraulic press was designed for extracting oil from oil bearing seeds. The capacity of the hydraulic jack needed for the press was determined to be 18.6 tons. The designed press can be fabricated using wrought iron from unserviceable vehicles or mild steel. This press, if utilized in low income countries, would be useful in uplifting oil production activities for small and medium scale enterprises in the agricultural sector.

1. Introduction

The fast-rising world population which has led to an increase in food and energy consumption, has necessitated the need to increase global food production as well as energy generation [1]. For food production, nations around the world, are now, more than ever, focused on improved agriculture for sustainable food production to meet the ever increasing world population [2]. In Nigeria, for instance, this need for increased food production has necessitated local farmers to search for ways to improve their farming methods as well as their food processing techniques. Like other foods produced, vegetable oil, which is one of the major types of oils produced in Nigeria, is also experiencing a massive increase in demand. With this increase in demand, it is paramount that new technologies for the extraction and production of vegetable oils from agricultural seeds be introduced to farmers. The oil extraction process is a very important chemical engineering process used in oil production. Asides from food production, oil extraction also provides the oil feedstock necessary for the production and manufacture of chemicals and other oil-based products, such as cosmetics and body lotions [3], [4]. However, the competition that arises from the use of oil for other processes other than for food production, has necessitated a shift in focus from edible seed oil production, to non-edible seed oil production [5].

For energy generation, the increase in energy consumption as a result of increase in world population has prompted researchers to search for other sources of energy that could augment and possibly replace the already depleting existing energy resources [1], [6], [7]. One of such new technology for the generation of energy is the biodiesel technology [8], [9]. Biodiesel which is a clean energy resource is primarily produced from oil [10], hence it is paramount that for sustainable biodiesel production, better oil extraction techniques be developed to meet both food production and energy generation needs [8].

Generally, the rise in demand for oil has prompted researchers to develop cheap and easy methods of oil extraction [4]. Oil extraction involves the separation and removal of oil from oil bearing agricultural products like oil seeds (sunflower, castor, cotton, etc.), oil nuts (groundnut, coconut, shea nut, etc.) and fruits (oil palm, water melon, etc.) [11]. The cultivation of these oil-bearing agricultural products has made a significant contribution to the economic development of many countries in the world, and more especially in West Africa, where the products are grown commercially. The conventional extraction of oil is done using either of the following extraction methods; mechanical extraction methods, manual extraction methods and chemical extraction methods using solvents like n-Hexane. It is however, worthy to note that for the chemical extraction method of oil extraction, the solvents used for the extraction process , has the tendency to contaminate the oil after extraction thereby posing risks to health and safety [4]. Hence chemical method of extraction is not a suitable method for high purity extraction. The mechanical method of oil extraction is the most suitable method to be utilized in the production of high purity oils.

1.2. The need for a manually operated hydraulic oil press in low-income countries

Nigeria has been found to have a high variety of oil producing seeds. However, these seeds have not been optimally utilized for the production of oil, largely owing to unavailability of cheap and quality oil extraction tools and machines. Generally, the purchase and importation of state-of-the-art oil extraction machines is expensive and largely unaffordable for local farmers in developing nations like Nigeria. Hence the need to develop cheap and easy to use oil extraction devices like the manual hydraulic oil press. Also, in the 21^{st} century, electricity is crucial for mechanized agriculture and improved oil production [12]. However, the poor power supply in developing nations like Nigeria, makes it difficult for local oil producers to use electric machines for oil extraction, hence the need to develop manually operated machines which can be used without electricity.

2. Methodology

The design of component parts of the press was carried out using mathematical equations and derivations from published literature. **AutoCAD 2017** was used to produce the 2D and 3D design of all component parts.

2.2.Design Analysis

Design objective

a) High oil quality with high percentage purity.
b) Manually operated so as to function in communities without access to electricity.
c) High yield of oil.

d) Low cost.

2.3.Component parts of the press

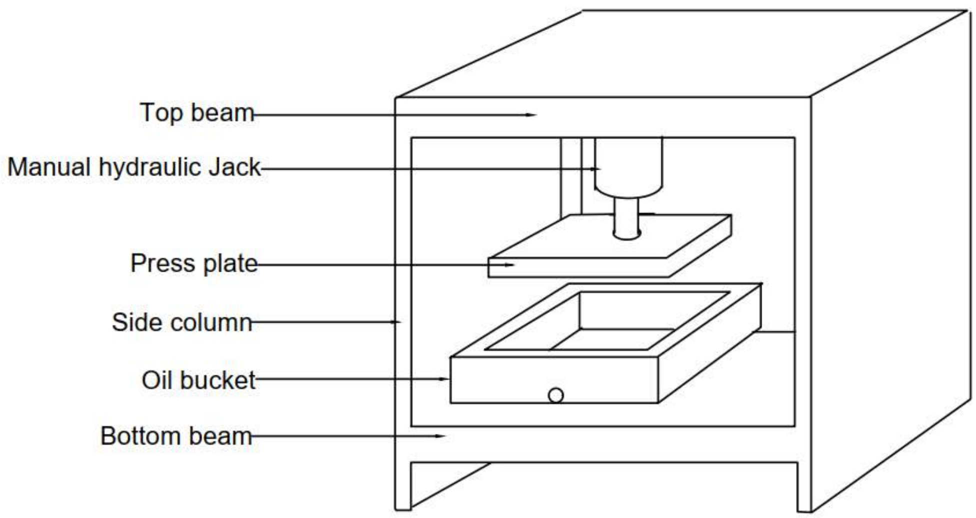

Figure 1. The manual hydraulic oil expeller

a) Manual hydraulic bottle jack: For this system, the hydraulic bottle jack provides the compressive force needed for the extraction of oil from the agricultural seeds and nuts. Traditionally, the hydraulic bottle jack is designed for lifting vehicles for maintenance and repair purposes.
b) Body frame: the body frame provides the needed structural support as well as aesthetics. The body frame consists the top beam, bottom beam, and the side columns. The top beam bears the hydraulic jack and distributes its weight evenly on the side columns. It is crucial that materials with high tensile strength, be selected in constructing the body frames.
c) Plate press: the plate press evenly distributes the force exerted by the jack along all parts of the feedstock material. The thickness of the plate must be adequately designed to withstand the point force of the jack.
d) Extraction bucket: the perforated bucket houses the feedstock material during compression. It is perforated so as to provide sufficient exit points for the extracted oil. The bucket should eb well designed so as to prevent oil wastage and contamination.

2.4.Design of component parts

2.4.1. The press plate.

The plate press evenly distributes the force exerted by the jack along the all parts of the feedstock material. The thickness of the plate must be large enough to withstand the point force of the jack.

2.4.1.1.Calculating thickness of plate

The desired dimension for the press plate is 0.3m length and 0.3m width. Hence the area of the plate becomes 0.09m. The thickness of the plate can be calculated using the Equation presented by [13].

$$t = \sqrt{\frac{3F_pL}{2\sigma b}} \tag{1}$$

Where;

$$\mathrm{t = Thickness\ of\ plate}$$

$$\mathrm{F_p = Force\ exerted\ on\ plate}$$

$$\mathrm{\sigma = Compressive\ strenght\ of\ mild\ steel = 320N/m^2}$$

$$\mathrm{L = Length\ of\ plate}$$

$$\mathrm{b = width\ of\ plate}$$

The optimum compressive force of sunflower seed, a popular agricultural seed is estimated 110kN [14]. Hence for effective oil extraction, the force exerted on the plate should be equal to the compressive force of the feedstock material. For this design, an assumption is made taking general compressive force of agricultural seeds to be 110kN. Therefore $\mathrm{F_p = 110kN}$. Thus, from Equation (1), t = 0.0227m.

2.4.1.2. Calculating the plate pressure

The pressure to be exerted by the plate on the crushed agricultural seeds can be calculated using the Equation as described by [13].

$$\mathrm{P = \frac{F_C}{A}} \tag{2}$$

Where; $\mathrm{F_c}$ is the compressive force of the crushed agricultural seed, and A is the area of the plate.

From Equation (2), plate pressure becomes:

$$\mathrm{P = 1222kP_a}$$

2.4.2. Determining the capacity of the hydraulic jack

In selecting the desired hydraulic jack to use for the compression duty, it is crucial that the capacity of the jack be determined. Generally, force of the jack would be exerted on two materials, the press plate and the oil seed. Hence, the combined force of these two materials gives the required capacity of the desired jack. This can be expressed mathematically as:

$$\mathrm{F = F_P + W} \tag{3}$$

Where W is the weight of the press plate, calculated using Equation (4);

$$W = m\,g \quad (4)$$

Mass of the plate can be gotten using the mass-density relationship;

$$\text{Mass} = \text{Density} \times \text{Volume} \quad (5)$$

$\text{Density of mild steel} = 7850\text{kg/m}^3$ [13].

But;

$$\text{Volume of plate} = \text{Length} \times \text{width} \times \text{thickness} \quad (6)$$

$$\therefore \text{Volume of plate} = 0.002\text{m}^2$$

From Equation (6), $\text{Mass} = 7850 \times 0.002$

$$\therefore \text{Mass} = 16.04\text{Kg}$$

From Equation (4), $W = 16.04 \times 9.81$

$$W = 157\text{N}$$

From Equation (3), $F = F_P + W$

$$F = 110000 + 157$$

$$F = 110157\text{N}$$

$$F = 12.4\text{Ton}$$

Considering a safety factor of 1.5, the capacity of hydraulic jack becomes;

$$F = 12.4 \times 1.5$$

$$F = 18.6\text{Ton}$$

2.4.3. Design of base and top frame

The force exerted on the base of the column is the total force exerted by the hydraulic press, this has been calculated as 18.6Ton, which is equal to 165473.8N. The dimension of the base is given as; length = 0.5m, width = 0.4m Therefore, the area becomes 0.2m^2.

The thickness of the bottom plate therefore can be calculated using Equation (1);

$$t = \sqrt{\frac{3F_pL}{2\sigma b}} \tag{7}$$

$$\text{Therefore, } t = 0.03\text{m}$$

The force exerted on the bottom frame, will have an equal and opposite reaction on the top frame, therefore thickness of the top frame is also 0.03m.

2.4.4. Design for vertical supporting columns

Since there are two columns, the force acting on each column becomes;

$$F = \frac{165473.8\text{N}}{2}$$

$$\text{Therefore, force on each column} = 82734\text{N}$$

Let the column be taken to have a square surface, and the area of the square represented as “A”.

Tensile strength of mild steel bar = 400MPa

Using Equation (8);

$$\sigma = \frac{F}{A} \tag{8}$$

$$A = \frac{82734}{400}$$

$$\therefore A = 206.8\text{mm}^2$$

Therefore, dimension of column is; Length = 14.38mm, width = 14.38mm.

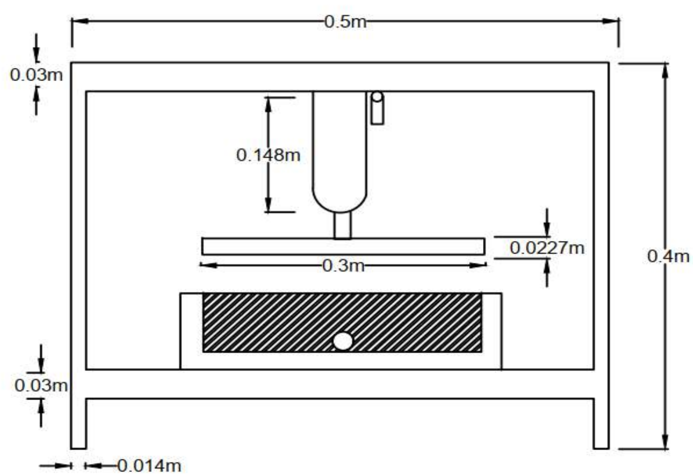

Figure 2 Press design

2.4.5. Orthographic drawing of the hydraulic press

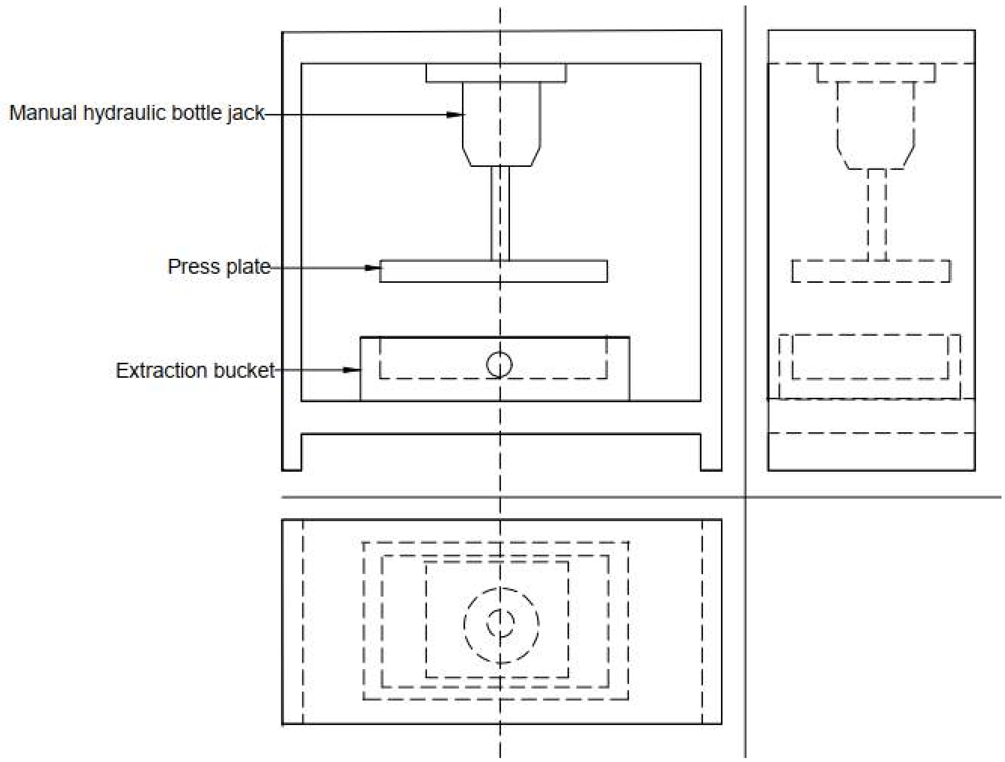

Figure 3 First angle orthographic projection of the press showing component parts

3. Cost analysis

Table 1 Cost analysis

Item	Manufacturer	Amount (₦)*	Reference
Mild steel plate (0.014m)	-	4,248	Using the conversion ₦2427/8mm of mild steel as presented by [15].
Mild steel plate (0.03m)	-	9,102	-
20Ton Hydraulic jack	Big Red	15,500	Jumia retail store (www.jumia.com.ng)
Labour wage	-	8,738	-
	Total	**37,588**	

*All conversions are done using the exchange rate ₦411.58/$.

As shown in Table 1, the approximate cost of locally fabricating the manual hydraulic oil press is ₦37,588. This is relatively cheaper when compared with imported oil expellers. An example of this is a hydraulic press which sells at ₦2,304,848 on the e-commerce store, Alibaba (www.alibaba.com). Hence, this locally designed manual hydraulic oil expeller, is cost effective and can be afforded by local oil producers in low income counties.

4. Conclusion

It is paramount that for continuous and sustainable oil production from agricultural seeds, the process of oil extraction must be made cheap, easy and affordable for local farmers or oil producers in developing countries like Nigeria. Also, with the issue of poor power supply in developing countries, it is crucial that machines for food production be designed to be able to either simultaneously work "manually or with electricity", or solely work manually without electricity. The design, fabrication and deployment of locally produced hydraulic press in rural communities, would provide local oil producers the necessary tools and empowerment needed to continue oil production process needed for global food sustenance. From this study, it has been seen that component parts of the local hydraulic oil press can be sourced locally, and fabrication also done locally, thereby promoting local production, saving foreign exchange, and ultimately boosting the nation's economy.

Credit authorship contribution statement

Ejiro Thelma Akhihiero: Initial conceptualization, Writing - review and editing, General supervision and Funding. **Steve Oshiokhai Eshiemogie**: Methodology, Writing - original draft, review and editing, Mathematical calculation and AutoCAD drawing. **Daniel Kanayo Oginenwa**: Writing and editing. **Eleazer Chibuzor Gbandi (jnr.):** Writing and editing. **David A. Akhihiero:** Writing and editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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