

DEVELOPMENT AND PERFORMANCE EVALUATION OF A SPINDLE PRESS FOR OIL EXTRACTION

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Abstract

A manually operated spindle oil press adaptable to rural areas was designed, constructed using locally available materials and tested to evaluate its performance. The spindle press, which consists of tool frame, power transmission unit made of a spindle and its lever arm, and oil expression unit comprising of the upper and lower press plates and the perforated cage, operates on the principle of power screw to express oil from milled oil seeds. Each of these components was analyzed and the results obtained were used as parameter for sizing and fabrication of the components. The raw material used for testing the developed spindle press was groundnut paste and a nylon clothing material was used as filter.

Results of the performance tests carried out on the machine using groundnut paste showed a maximum oil recovery of 78.1% and the cake produced is of the same quality when compared with those produced with the traditional method. Also the oil extraction time is reduced by about 50%.

1. Introduction

It is an indisputable fact that there is a universal demand for vegetable oil due to its use in domestic cooking as an ingredient for other food products such as baking and frying of snack foods and as a raw material for the manufacture of soap, body/hair oils and detergents (Peter and Ann, 1992). Peter and Ann (1992) also reported that oil provides twice as much energy as the same quantity of carbohydrate and is therefore, considered to be a valuable part of a well-balanced diet. Diffus and Slaughter (1980) reported that oil seeds attract high economic interest because they are good sources of cooking oil and their protein rich residues serve as good feed for livestock. Two reasons were given by Olaniyan and Oje (2000) for the increase in the demand for oils of vegetable origin as follows:

- (a) Vegetable oils are usually cheaper than animal oils.
- (b) Animal fats and oils contain saturated fatty acids that may be harmful to health.

According to Peter and Ann (1992) vegetable oils contain a range of fat soluble vitamins (A, D, E and K) and essential fatty acids, both of which are necessary for the healthy functioning of the body. They further explain that the process of oil extraction produces a by-product known as oil cake (kulikuli). This is very nutritious, and can be used either for animal feed or as an ingredient in the production of other food products such as spices for food, boiled, roasted or fried meat, fish and root crops such as yam, coco yam, cassava, sweet potatoes, Irish potatoes etc.

In Nigeria, the major oil seeds/nuts that are processed include groundnut, melon (egusi) seed, palm kernel, palm fruit, cotton seed, guna seed, sheanut and castor seed (Asiedu, 1989). Extraction of oil from these oil seeds and nuts is still based on traditional procedures in most of the rural areas in Nigeria. This is as a result of financial incapability of the local oil producers to purchase the available power operated processing equipment. Also lack of electrical power

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supply to the rural areas poses handicap and prevents local investors from establishing small-scale vegetable oil plants in the rural areas.

Wiemer and Korthals (1989) described the process of oil extraction in India using equipment known as 'ghani' oil mill. The *ghani* consists of a mortar and pestle in which the seed is crushed. Pulverization and oil extraction are carried out at the same time by rubbing the seed between the pestle and the wall of the mortar. The *ghani* process requires much mechanical energy. A *ghani* operated by one bullock can only process 5 kg oil seed in about one hour. Wiemer and Korthals (1989) also described a hand-operated screw press capable of processing 21 kg of sunflower seed per batch in a one-hour cycle. ILO (1983) reported a developed hand-operated screw press for extracting groundnut and copra oils. The extractor consists of a lever arm, power transmitting unit, the oil extraction unit and the frame. The market value of the groundnut cake produced by this machine is less compared to that produced using the traditional method.

Itanye (2001) constructed and tested a spindle oil press. Results of his tests showed that oil recovery of about 48% was achieved and the cake obtained is not as good as that obtained from the traditional method. The major problem with the modern equipment is that they extract almost all the oil thereby reducing the nutritious value of the oil cake. This result in reducing the economic value of the cake because it can only be used as animal feed. A mechanical oil extraction device that is manually operated is therefore necessary to increase and improve the quality and quantity of the oil production and at the same time retain the nutritious value of the oil cake. This could minimize the rigours involves in the present traditional procedures since it could be made available for use by the rural populace.

This study is aimed at developing a manually operated spindle oil press that will increase and improve the quality and quantity of oil production and retain the nutritious value of the cake.

2. Materials and Methods

2.1 Materials

The material used for each component was selected based on function of the component and properties of the material. Stainless steel was used for the fabrication of the perforated cylindrical cage, top and bottom press plates and the oil receiver. Carbon steel was used for the fabrication of the spindle, collars, nut and the lever arm. A 'C' section carbon steel was used for the construction of the frame while a carbon steel angle iron was used for the construction of bottom frame.

2.2 Design Considerations

The spindle press consists of the following major components:

- i) Lever arm
- ii) Spindle (square thread)
- iii) Perforated cage
- iv) Top and bottom press plates
- v) Oil receiver
- vi) Frame.

In order to effect an acceptable design, the question of workability, durability and reliability of the components constituting the oil press must be given due consideration. The workability of the press is a question of providing components, which perform in accordance with the design specifications and integrating these components into an operational feasible system. Durability ensures that the machine will continue to operate during its design life without material or

component failure, while reliability ensures that the machine performs in accordance to the design.

2.3 Design Calculations

2.3.1 Perforated Cylindrical Cage

This is a thin walled perforated cylinder made of stainless sheet. The pressure, P , required to express oil from groundnut paste is 6 N/mm^2 (Wiemer and Korthals, 1989)

$$P = W/A \quad 1$$

Where

P = pressure required to express oil from groundnut paste, N/mm^2

W = load required to generate the pressure, N

A = cross-sectional area of the perforated cage, mm^2

For a perforated cylindrical cage of 75 mm internal diameter, the load, W required to generate this pressure is given as:

$$\begin{aligned} W &= P.A \\ &= (P \pi D^2)/4 \\ &= (6 \times \pi \times 75^2)/4 \\ &= 26507 \text{ N} \end{aligned}$$

According to Levinson (1970) the hoop stress in a thin walled cylinder is given as:

$$\sigma_h = P R n / t \quad 2$$

$$t = p r n / \sigma_h \quad 3$$

where

σ_h = hoop stress, N/mm^2

t = thickness of the perforated cylindrical cage, mm

n = factor of safety

R = radius of the perforated cylindrical cage, mm

For a perforated cylindrical cage of radius 37.5 mm and allowable hoop stress of 480 N/mm^2 and taking factor of safety of 3 (Hall *et al.* 1982)

$$t = 1.41 \text{ mm.}$$

2.3.2 The Spindle (Square thread)

This is the component that transmits the power to the pressing unit. According to Shigley (1977) the torque required to produce the load, W is given as:

$$T = W/2[d_m ((l + \pi \mu d_m)/(\pi d_m - \mu l)) + \mu_c d_c] \quad 4$$

$$d_m = d_r + l/2 \quad 5$$

$$d_o = d_r + l \quad 6$$

$$d_c = (d_{ci} + d_{co}) \quad 7$$

where

T = required torque, Nmm

W = load parallel to screw, N

d_m = mean thread diameter, mm
 d_r = root diameter, mm
 d_o = crest diameter, mm
 d_c = effective diameter of collar, mm
 d_{ci} = collar inner diameter, mm
 d_{co} = collar outer diameter, mm
 l = lead (for single thread, lead = pitch)
 μ_c = coefficient of friction at collar

For root diameter of 25.4 mm and lead of 6.35 mm (Deutschman *et al.*, 1975), Equations 5, 6, and 7 gives $d_m = 28.6$ mm, $d_o = 31.75$ mm and $d_c = 41$ mm respectively. Substituting these values into Equation 4 gives

$$T = 156729 \text{ Nmm}$$

2.3.2 The lever arm

The torque on the lever arm is given as:

$$T = F L \quad 8$$

$$d = [32 M n_1 / \pi \sigma_b]^{1/3} \quad 9$$

where

d = diameter of lever arm, mm
 M = bending moment at critical section, Nmm
 L = length of lever arm, mm
 F = force exerted on the lever arm, N
 σ_b = bending stress, N/mm²

The force exerted by average man is 294.3 N (Balami, 2000). Substituting this value into Equation 8 gives

$$L = 532.5 \text{ N and from Equation 9, } d = 24.2 \text{ mm}$$

2.4 Machine Description

The spindle oil press consists of tool frame, made of 'C' section carbon steel 45 x 80 x 45 mm. This frame consists of two vertical frames 950 mm in height; top frame 360 mm long and bottom frame 270 mm long. At the center of the top frame is a hole 50 mm in diameter and a nut welded on the hole for the spindle. The top frame is firmly bolted to the two vertical frames at the top. The bottom frame, which serves as a base for the oil receiver, is bolted to the two vertical frames 400 mm below the top frame. The power transmission unit consists of the lever arm 25 mm in diameter and 530 mm long with a collar of 52 mm external diameter, 44 mm internal diameter and 50 mm height at its center and a vertical spindle (square thread) directly under the lever arm. The lever arm is mounted on the spindle through the collar and bolted with two lock bolts that locked into two indentations made 25 mm below the upper end of the spindle on the opposite sides. The spindle is then passed through the nut on the top frame.

The pressing unit consists of the top and bottom press plates made of stainless steel rod 74 mm diameter and 5 mm thickness with a collar 50 mm external diameter, 9 mm thick and 50 mm height is welded to the top press plate at its center. Two threaded holes (for lock bolts) are on

the center surface of the collar on opposite sides. A hole of 5 mm diameter is made 5 mm below the threaded holes for greasing nipple. The top press plate is mounted on the spindle through the collar and the two lock bolts were used to hold the press plate onto the spindle. The two bolts on the opposite sides of the collar locked into the groove cut around the spindle at its lower end to allow free rotation of the spindle without turning the top press plate. The perforated cylindrical cage (with perforation of 3 mm diameter round the surface of the cage) is made of stainless steel sheet 1.5 mm thick, 75 mm in diameter and 200 mm high with a bottom press plate support at its lower end mounted on the oil receiver placed on the lower frame.

This machine can easily be dismantled and properly packed for easy transportation. The photograph of the assembled spindle oil press is presented in Figure 1.



Figure 1: Photograph of the spindle oil press

2.5 Machine Construction and Assembly

Each component of the spindle oil press was fabricated based on the results obtained from the design calculations. The tool frame consisting of two vertical frames, top and bottom frame was constructed using a 'C' section carbon steel 45 x 80 x 45 mm. The two vertical frames each 950 mm long, the top frame 360 mm long and the bottom frame 270 mm long were cut to size. A 50 mm diameter hole was drilled at the center of the top frame and a nut was welded on this hole for the spindle (square thread). The top frame was bolted to the two vertical frames at the top end while the bottom frame, which serves as a base for the oil receiver, was also bolted to the two vertical frames 400 mm below the top frame. The collar (with 52 mm external diameter, 44 mm bore and 50 mm high) was welded on the lever arm at its center. The lever was then mounted on the spindle through the collar and bolted with two lock bolts. The spindle is then

passed through the nut on the top frame. The top press plate was bolted on the spindle through the collar and welded on the top press plate.

The perforated cylindrical cage was made of stainless steel sheet 1.5 mm thick 200 x 236 mm. Perforations of 3 mm diameter was made on this stainless steel sheet, which was then folded into cylindrical shape and the free ends welded together. A bottom press plate support was welded on the inner surface (lower end) of the perforated cylinder. A bottom press plate 74 mm in diameter and 5 mm thick was then placed on the bottom press plate support and has a provision for draining the expressed oil. The oil receiver was placed on the bottom frame and directly under the top press plate. The orthographic drawing and part lists of the spindle oil press is presented in Figure 2.

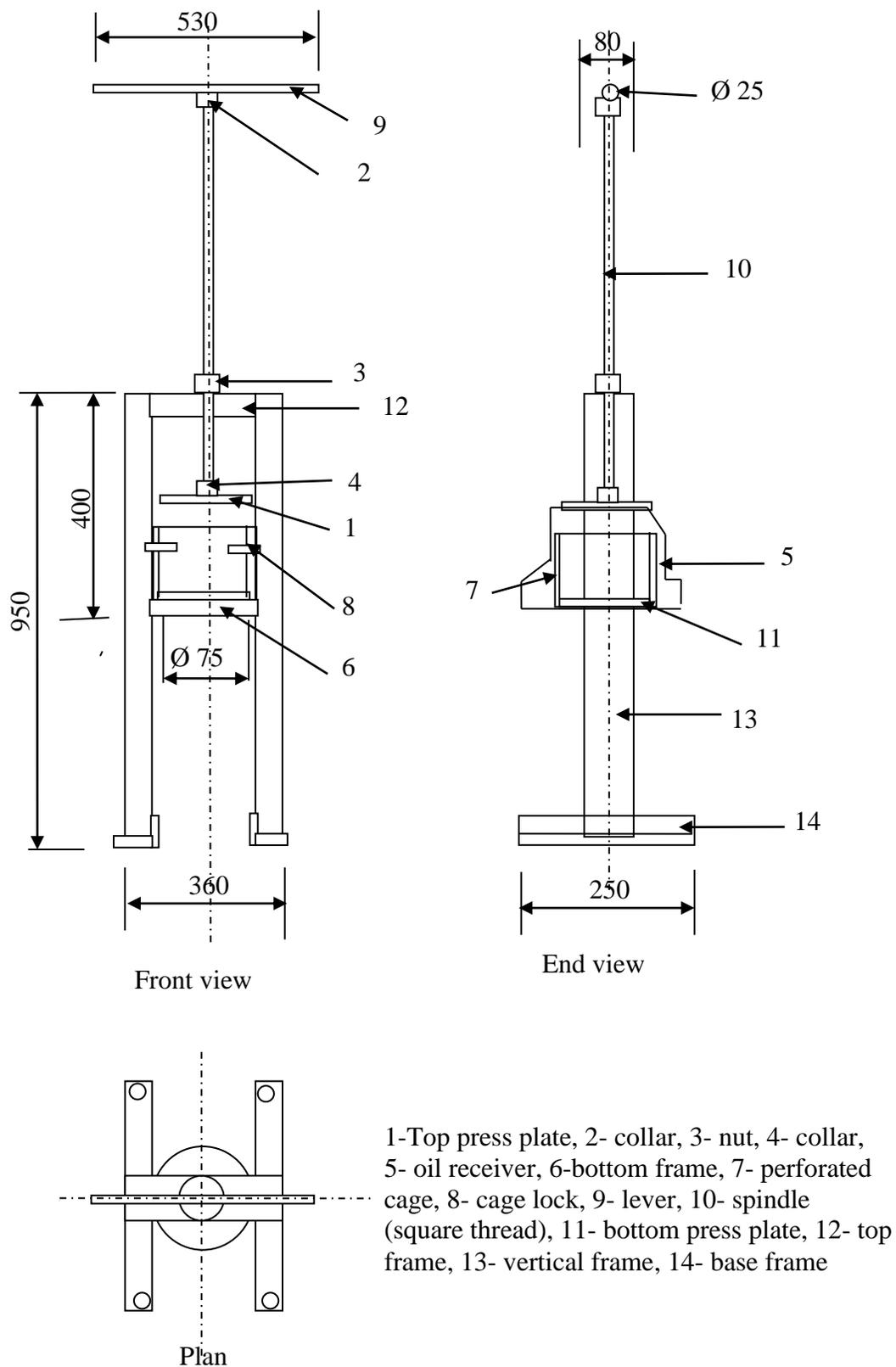


Figure 2: Orthographic drawing and part list of spindle oil

2.6 Production Cost Estimate

The cost estimate of the machine is presented in Table 1.

Table 1: Production cost estimate

S/No.	Material	Qty	Specification	Cost (₦)
1	Galvanized pipe	1	Ø25 x 533 mm	250
2	Stainless steel rod	1	Ø75 x 10 mm	1000
3	Square thread spindle	1	650 mm	1000
4	'C' section carbon steel	1	3000 mm	1000
5	Angle iron	1	50 x 50 x 500 mm	100
6	Stainless steel sheet	1	Gauge 18 (700x600 mm)	600
7	Mild steel rod	1	Ø5 x 1200 mm	70
8	Bolts and nuts	16		160
9	Nylon cloth	1		100
10	Sand paper	1		100
11	Electrode	45	Gauge 12	220
12	Paint	1	900 ml	200
13	Labour			1000
14	Transport			500
			TOTAL	6300

2.7 Principle of Operation of the Spindle Oil Press

In operating the machine, a moistened and heated groundnut paste was put inside a small bag made of nylon clothing material. The bag, which serves as a filter with its content is placed inside the perforated cage. Clockwise rotation of the lever allows the spindle with the top press plate to move downwards and subsequently compressing the material in the bag against the bottom press plate. As the pressure increases, oil starts gushing out through the perforations on the cage and collected through the oil receiver.

2.8 Performance Tests and Evaluation

Forty kilogram (40 kg) of groundnut (peanut) was purchased in the local market and prepared for the test. The preparation involved cleaning the peanut by removing dirt and spoiled peanut, roasting the nut and dehulling/winnowing to remove the pellicles (the brown skin). The cleaned peanut was then crushed to paste and then cooked (moistened and heated) and continuously stirred and hot water was added intermittently until oil started to come out on the surface. Three kilogram (3 kg) of the paste was taken in the cloth bag. The bag with its content was placed inside the perforated cage and the lever was then rotated clockwise to compress the material. As the compression increases oil gushed out through the perforation on the cage. The compression continued until there was no oil flow stopped with further increase in pressure. At the end of the compression process, the mass of oil collected and mass of 'Tunkusa' were recorded. These tests were repeated ten times and the average was recorded as the oil recovery. The percentage of oil collected was calculated as follows:

$$\eta_{oil} = (M_{oil} / M_{GP}) \times 100\%$$

and the percentage of oil recovery was calculated as

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$$(\eta_{oil} / 45) \times 100\%$$

Where

M_{oil} = mass of oil collected, kg

M_{GP} = mass of groundnut paste, kg

45 = oil content in kg per 100 kg of groundnut (Wiemer and Korthals, 1989).

5. Results and discussions

The results of the performance tests carried out on the machine are presented in Table 2.

Table 2: Performance data of the machine

s/no.	Mass of paste (kg)	Mass of oil collected (kg)	Mass of * <i>tunkusa</i> (kg)	Mass of **cake (kg)	Oil recovery (M_{oil}/M_{GP}) \times (100/45)%
1	3	0.78	1.76	1.74	57.8
2	3	0.89	1.77	1.75	65.9
3	3	0.94	1.75	1.72	69.6
4	3	0.96	1.76	1.73	71.0
5	3	0.98	1.78	1.75	72.6
6	3	1.001	1.77	1.75	74.1
7	3	1.01	1.75	1.74	74.8
8	3	1.03	1.78	1.75	76.3
9	3	1.05	1.76	1.74	77.8
10	3	1.055	1.77	1.73	78.1

*Groundnut dough before frying; **Fried groundnut dough

These results show that the oil recovery was low for the first trial (57.8%). This may have been due to the fact that the filter absorbed and retained some quantity of the expressed oil. With subsequent trials the oil recovery increased, with 66% at the second trial a maximum value of 78.1% by mass. Total time to load the press, apply the pressure and remove the cake was approximately 45 minutes. The time required to process the same quantity of paste traditionally is about 1 hour 30 minutes.

The increase in oil recovery may be due to the fact that the filter may have become saturated and could no longer absorb the expressed oil. Similar results were obtained by Wiemer and Korthals (1989), where the oil recovery ranged from 73.3% to 77.8% from a similar spindle oil press. Introduction of the nylon material as filter prevented particles of groundnut paste from blocking the perforations on the cylindrical cage and thus eliminating the rigours involved in cleaning the machine after use. It can also be seen from Table 2 that the mass of the cake is less than that of the '*tunkusa*'. This shows that more oil was still extracted from the '*tunkusa*' during frying.

4.0 Conclusion

A manually operated spindle oil press was designed, constructed and tested to evaluate its performance. The machine gave a maximum oil recovery of 78.1% and at the same time the cake obtained is of the same quality when compared with those produced from the traditional method. A unit of the machine costs ₦ 6300:00. The machine will not only eliminate the rigours involved in the traditional method of extracting seed oil in rural areas but also reduce the processing time.

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