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# Effect of Operating Parameters on Mechanical Oil Expression from African Oil Bean Seed

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*Abstract-* African oil bean seed is an under-utilized leguminous crop planted mainly as shade tree and condiment. The seed contains considerable amount of oil which if extracted will serve as alternative vegetable oil and also boost the economic status of the crop. The main objective of this study was to study the effect of operating parameters on the mechanical oil expression. Operating parameters considered include heating temperature (50, 70, 90, 110 and 130$^0$C), heating time (5, 10, 15, 20 and 25 minutes) and moisture content (8, 10 and 12 % dry basis).A total of 75 experiments were carried out and the maximum oil yield expressed from 500g of seed was 52.3% which translates to an expression efficiency of 86.8% (achieved at seed moisture content 10%db, 15 min heating duration and 90$^0$C heating temperature), minimum oil yield for the same quantity of seed was 25.6% (42.4% expression efficiency, achieved at 50$^0$C heating temperature, 12% moisture content dry basis and 5 minutes heating time) while the mean oil yield was 36.2% (59.9% expression efficiency of the raw material, at 130$^0$C heating temperature, 20 minutes heating time and 12% moisture content dry basis). It was discovered that operating parameters had significant effect on the yield oil. Regression model was developed to predict the oil yield at known operating parameters.

*Keywords: moisture content, roasting time, roasting temperature, oil yield, expression efficiency, regression model.*

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## I. Introduction

Oil obtained from seeds and nuts are of paramount importance to mankind as food either for baking or transfer of heat during frying. Oils are a source of calories and of fast soluble vitamins. Moreover, oil also have a number of non-food uses with numerous applications in paint industries as lubricants and also as ingredients in cosmetics. Oil extracted from oleaginous plants are termed vegetable oil. Obi (2013) reported that the vegetable oil market in Nigeria has been flooded with adulterated and different types of vegetable oil due to existing huge market for the product, these oils include health hazard products which cause heart problems, obesity, hypertension and cancer among others.It's quite unfortunate that to most people, there is no difference between vegetable oil productssince they all almost look alike and can perform the same function, they believe all are good for consumption (Obi, 2013). Oil seed plants are good preventive sources against numerous ailments including arthritis, rheumatism, sexually transmitted diseases, hypertension, boils and several other life-threatening diseases (Eilert *et al*., 1981). There is a steady rise for the demand of vegetable oil in most developing countries for nutritional, pharmaceutical and industrial importance;this oil can be obtained from various agricultural products especially oleaginous crops. Vegetable oil has been extracted fromcotton, sesame, groundnut, melon, palm kernel, castor oil, soybean, corn, pumpkin, moringa, sunflower, rapeseed, roselle among other crops however, African oil bean (*Penthaclethra macrophylla* Benth) seeds remains undertilized as it is been used only as a food source. It isa leguminous tree of the family leguminosae and sub-family mimosoideae cultivated in Nigeria since 1937 (Ladipo, 1984; Ladipo and Boland, 1995), its seed contains oil which can serve as an additional vegetable oil if extracted since no oil from a single source can be suitable for all purposes (Ramadan and Morsel, 2003). The seed is one of the most widely eaten fermented foods in the Eastern part of Nigeria (Abiodun and Sanni, 2006; Aremu and Iroakazi, 2011; Aremu *et al.,* 2014a, Aremu *et al.,* 2014b); it is very rich in vitamin and minerals thus making its demand for both local consumption and export very high (Enujiugha, 2003) and the condiment is taken as a delicacy or added to soups and sauces as flavouring agents. Aremu and Iroakazi (2011) reported that the tree provides economic products such as food, fodder and fuel, it protects the soil against erosion by wind through its canopy and root system and recycles plant nutrient from the deeper soil horizons to the top soil in the form of litter fall and decaying organic plant residues. Allinor and Oze (2011) evaluated the nutritive values of *Penthaclethra macrophylla* Benth and reported that it contains 11.87% moisture content, 2.95% ash content, 46.95% crude fat content, 20.95 crude fibre content, 14.79% carbohydrate content and 2344.56 kJ available energy. Moreover, the mineral composition of the seeds shows that they are rich in iron value (140.97 mg/100g) with potassium being the most abundant mineral, and they possess a high Ca/P ratio which indicates that the seeds are good source of food (Enujiugba and Agbede, 2000), Oyeleke *et al.* (2014) reported that the seeds are rich in protein, oil, energy and have abundance of mineral salts like sodium, potassium, magnessium, calcium, phosphorus and lower concentrations of iron, zinc, copper and lead; this denotes that the seed has a potential for dietary

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improvement in food industries. African oil bean seeds have been found to cure numerable diseases; notable among which are: heart disease, diarrhea, epilepsy, malnutrition, stomach disorder, iron deficiency, eye problem and insomnia; consumption of the seeds will reduce the risk of cancer and tobacco-related diseases (Bonnie, 2010). The common uses of African oil bean seeds in West Africa is presented in Table 1:

*Table 1 :* Common Uses of *Pentaclethramacrophylla* in West Africa

| Uses | Parts of plant | Countries |
|---|---|---|
| Food | Seed | Nigeria/ Ghana |
| Salt substitute | Pod ashes | Ghana |
| Edible oils | Seeds | Nigeria, Ghana, Togo, Cameroon |
| Fences and palings | Wood | Nigeria, Ghana, Togo, Cameroon, Cote d'ivoire |
| Charcoal | Wood | |
| Caroling bowls, etc | Wood | Nigeria, Ghana |
| Sees craft (beadings) | Seed | Nigeria, Ghana |
| Dye (mordant) | Pod ashes | Nigeria |
| Mild poison | Bark and seed | Ghana |
| Medicine (Convulsion) | Pod | Ghana |
| Medicine(convulsion) | Crushed seed | Cameroon |
| Medicine (convulsion) | Burnt leaf | Ghana, Nigeria |
| Medicine (diarrhea) | Leaf / steam bark | Ghana |
| Medicine (itch) | Bark as liniment | Ghana |
| Medicine (lactogenicity) | Bark decoction | Ghana |
| Medicine (wound treatment) | Bark as lotion | Ghana |
| Ornamental | Whole tree | Ghana, Nigeria |

*Source: Abbiw (1990).*

There are gaps in the vegetable oil market as the present production level in Nigeria cannot meet the demand of Nigerians (Obi, 2013), African oil bean seeds can be utilized to produce inexpensive and readily available oil suitable for food, pharmaceutical and industrial applications by separation of oil from the seed. The process employed in oil separtion of seeds has direct effect on the quality and quantity of oil obtained.Ibrahim and Onwualu (2005) stated that oil extraction from agricultural products can be carried out in two ways; traditional and improved methods (mechanical or chemical). The chemical method of extraction requires the use of organic solvents while the mechanical method requires application of varying degrees of pressure to already pre-treated oil bearing products using devices like screw or hydraulic press (Gunstone and Norris, 1983) or oil expellers and improved ghanis (UNIFEM, 1993). The most widely used method of oil extraction is the pressing method in which the raw material bearing the oil are compressed and squeezed in a perforated chamber. Ojomo *et al.* (2011) and Olaniyan*et al.* (2010) reported that the pressing method is effective in extracting and recovering oil from oil-bearing agricultural materials. It generally consists of the screw conveying system, cylindrical barrel and the die (Fellows, 2000). The yield and quality of oil extracted using mechanical expression method depends on crop, operating and machine parameters like moisture content, heating time, pressure, operating temperature, seed size, speed of operation etc (Adekola, 1991; Ibrahim and Onwualu, 2005). Thus, the main objective of this study was to determine the effect of moisture content, heating time and roasting temperature on the yield and expression efficiency of oil from African oil bean seed using mechanical expression method.

## II. Materials and Methods

*Materials:* The main materials used for this research include: African oil bean seeds (Plate 1a and b), Electronic Digital Compact Scale (SF 400A, 5000g x 0.1g), electric oven, mechanical oil expeller (Plate 2).

*Sample Collection and Preparation:* Fresh seeds of African Oil Bean were procured from Ojoo market, Akinyele Local Government, Ibadan, Oyo State. The seeds were visually inspected to discard the defective ones, they were decorticated by removing the hulls and the beans were kept in air-tight polythene bags. Fresh un-dehulled and dehulled African oil bean seedsamples are presented in Plate 1 while Plate 2 shows the oil expeller used for the experiment.

*Plate 1 :* a- Undehulled, b- Dehulled African Oil Bean Seeds

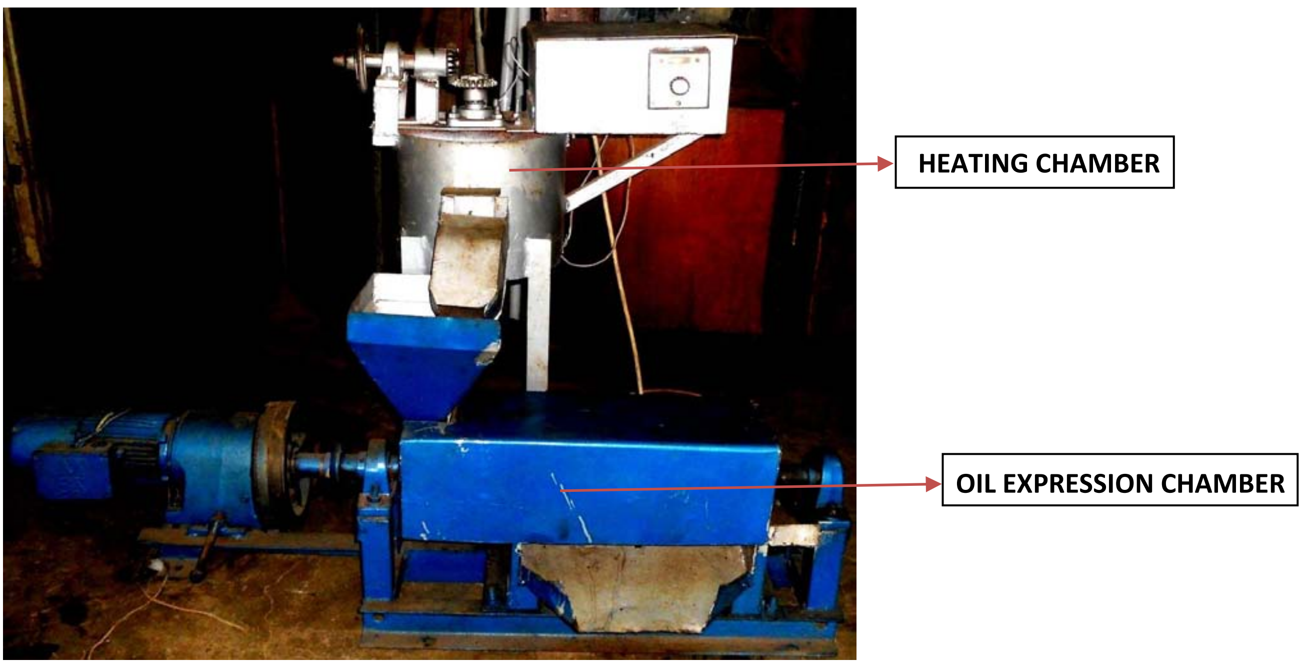


*Plate 2 :* The Oil Expeller

*Moisture Content Determination and Adjustments:* The initial moisture content of the seeds was determined using ASAE (1998) method for determining moisture content of oil seed crops by oven drying the seeds at 105$^0$C to constant weight. Initial moisture content of the seeds was found to be 10% dry basis. However, they were conditioned to desired levels by dehydration and rehydration; mass of water added to obtain a predetermined moisture content level during rehydration was obtained using Equation 1 (Bisht, 1986):

$$Q = \frac{A(b-a)}{(100-b)} \qquad \ldots 1$$

Where: $Q$ is the mass of water added (g), $A$ is the initial mass of samples, $a$ is the initial moisture content of samples and $b$ is the final (desired) moisture content of samples.

*Evaluations and Data Analysis:* The oil yield and expression efficiency was determined in accordance with Phillipines Agricultural Engineering Standard PAES 230 and 231 for oil expellers. The weight of oil expressed and input materials were measured; the following relationships were used accordingly to obtain the oil yield and expression efficiency (Equations 2 and 3):

$$Oy = \frac{Wo}{Wi} x100\% \qquad \ldots 2$$

$$E_e = \frac{w_o}{X.w_i}\ x\ 100\% \qquad \ldots 3$$

Where: *Oy* is the oil yield (%),*Wo* is the weight of oil collected (g), *Wi* is the weight of seeds fed into the hopper (g), *Ee* is the extraction efficiency (%), *X* is the oil content of African oil bean seeds [0.604].

Heating/roasting temperature and time are interactive factors that influence the yield of oil from African oil bean seeds. The seeds are roasted at five different temperature and time intervals before the extraction of oil using an automated heating chamber in order to determine the effect of heat treatment on the oil yield and expression efficiency.

The number of experiments for the determination of effect of moisture content and seed dimension on oil yield and expression efficiency was determined using the Equation 4 (Harper and Wanninger, 1969).

$$N = (L_1)(L_2)(L_3) \dots \dots \dots \dots \dots \dots \dots \dots \dots (L_m)(5x5x3)$$

Where: N is the number of experiment (75), L is the levels of independent variables and m is the number of independent variables.

An equal mass of seed (500g) was fed into the hopper for the 75 total number of experiments to determine the effect of operating parameters. Three moisture contents were considered for the seeds (8, 10 and 12 %db) and the seeds were heated at 50, 70, 90, 110 and 130 $^0$C at varying durations 5, 10, 15, 20 and 25 minutes. Historical Data Design of Design Expert Software 6.0.6 was used for the analysis of result and generation of regression model.

## III. Results and Discussions

The percentage oil content of African oil bean seeds used for this experiment as determined by soxhlet method was 60.4%. Maximum oil yield expressed from the 500g of seed was 52.3% which translates to an expression efficiency of 86.8%, this was achieved at seed moisture content 10%db, 15 min heating duration and 90$^0$C heating temperature. Minimum oil yield for the same quantity of seed was 25.6% (42.4% expression efficiency, achieved at 50$^0$C heating temperature, 12% moisture content dry basis and 5 minutes heating time). The mean oil yield was 36.2% (59.9% expression efficiency of the raw material, at 130$^0$C heating temperature, 20 minutes heating time and 12% moisture content dry basis).Sodiq (2012) reported 60.6% oil yield for the same seeds using solvent extraction method and microwave heating and Enujiugha and Ayodele (2003) reported that African oil bean seed contains more than 52% oil in its cotyledon and proper processing of the seeds has the possibility of increasing the oil content from around 52 to more than 60.1 percent (Enujiugha and Akanbi, 2005) however, the oil yield obtained are in the same range with some other oil seeds and nuts reported in literature including (Ibrahim and Onwualu, 2005) castor oil 35-55%, linseed 35-44%, Niger seeds 38-50%, neem kernels 45%, rape/mustard seed 40-45%, sesame 35-50%, fresh coconut 35-50%, dried coconut copra 64%, palm kernel nuts 46-57%, sheanut 35-44%,Akinoso *et al.* (2006a) reported average oil yield 47% for palm kernel, Akinoso *et al.* (2006b) for sesame seeds with 34.78%, Ejikeme (2013) reported 42.42% oil yield for wild bush mango seed, Premi and Sharma (2013)reported 33.3% oil yield for moringa seeds, Bamgboye and Adejumo (2013). However, some lower oil yields were reported for some seeds and nuts like cotton seeds 15-25%, sunflower seeds 25-40%, Adepoju and Okunola (2013) for sorrel seeds with 17.85% oil yield.The summary of the results obtained from the study is presented in Table 2.

*Table 2 :* Summary of the effect of Operating Parameters on oil Yield from African oil Bean

| HT($^0$C) | Ht(min) | MC (%db) | | |
|---|---|---|---|---|
| | | 8 | 10 | 12 |
| | | | Oil yield (%) | |
| 50 | 5 | 28 | 31 | 25.6 |
| | 10 | 32.5 | 34.7 | 28.5 |
| | 15 | 34 | 35.6 | 26.7 |
| | 20 | 33.5 | 34.8 | 31.1 |
| | 25 | 34.5 | 35.2 | 30 |
| 70 | 5 | 34.5 | 35 | 30.5 |
| | 10 | 35.5 | 36.7 | 29.5 |
| | 15 | 35 | 36.9 | 33.3 |
| | 20 | 34.5 | 35.8 | 33 |
| | 25 | 36 | 37.3 | 34.2 |
| 90 | 5 | 39.5 | 41 | 33.6 |
| | 10 | 41.5 | 43.5 | 31.2 |
| | 15 | 50.5 | 52.3 | 48.5 |
| | 20 | 44.5 | 45.6 | 36.9 |
| | 25 | 40.5 | 41 | 36.5 |
| 110 | 5 | 38.5 | 39 | 37.5 |
| | 10 | 40.5 | 41.9 | 36 |
| | 15 | 39.5 | 42.3 | 32.1 |

| | | | | |
|---|---|---|---|---|
| | 20 | 39 | 41 | 29.4 |
| | 25 | 35 | 37 | 31.3 |
| 130 | 5 | 34.5 | 35.2 | 31.4 |
| | 10 | 36.5 | 37.4 | 34.7 |
| | 15 | 36 | 37 | 33.4 |
| | 20 | 37.5 | 38.5 | 36.2 |
| | 25 | 38.5 | 39 | 37 |

It is apparent to note that oil yield varies with operating parameter, this apparent variations may be due to optimum level for appropraite physicochemical changes in oil seed.Model equation for predicting the oil yield from African oil bean seed is stated as below:

$$OY = -72.639 + 0.693\,HT + 0.897Ht + 15.81\,Mc - 0.00339HT^2 - 0.023Ht^2 - 0.879Mc^2 - 0.00187HT * Ht + 0.00235HT * Mc + 0.006Ht * Mc$$ ($R^2$= 0.62, S= 3.25)

Where: OY= oil yield (%), HT= heating temperature ($^{o}$C), Ht = heating time (mins), Mc = moisture content (%db), R = regression coefficient, S = Standard error of estimate.

The response surface plots showing relationships between the operating parameters and oil yield from African oil bean seeds is presented in Figures 1a-c while the predicted and actual oil yield obtained is presented in Figure 1d.

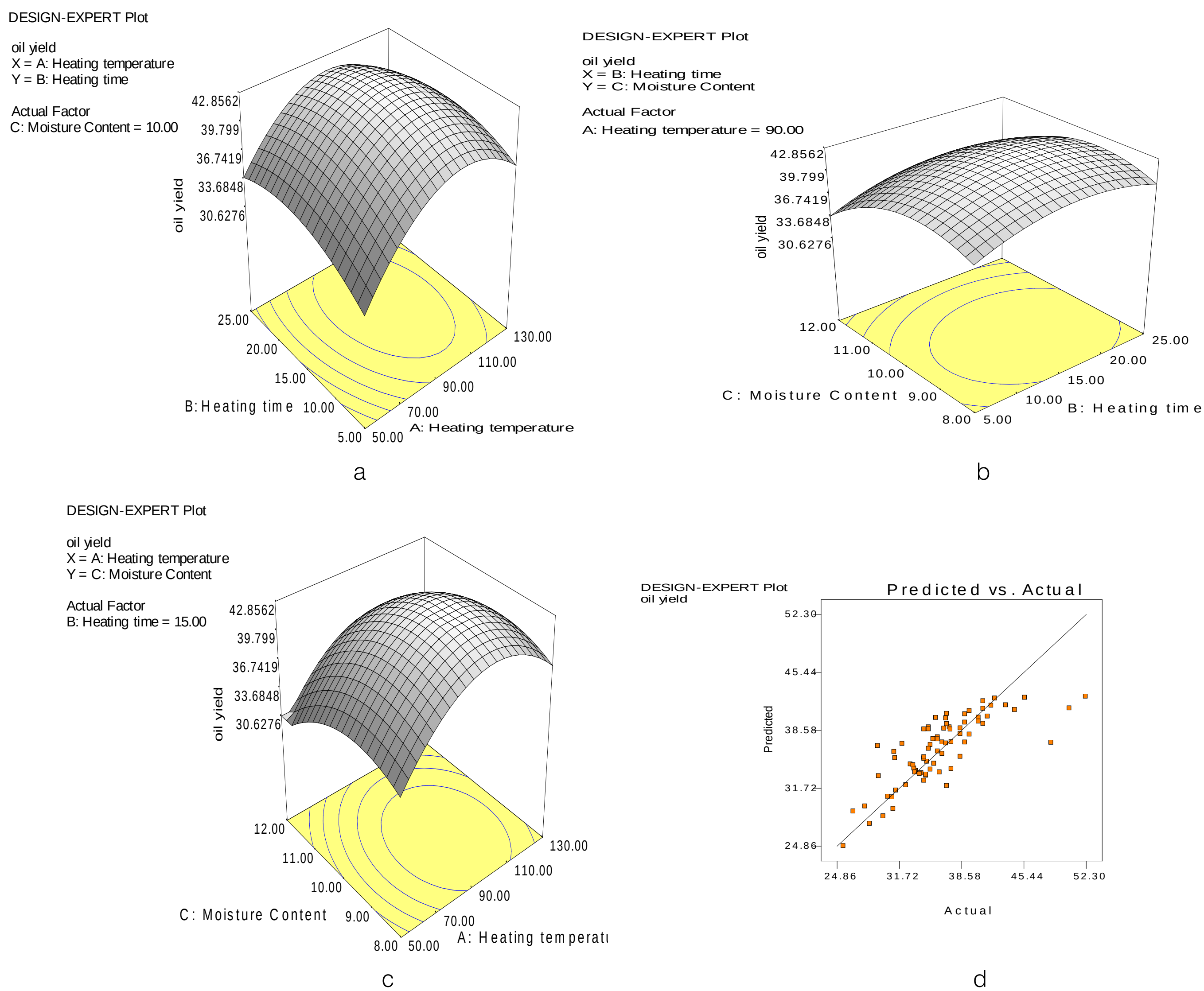


*Figure 1 a-c :* Response Surface Plots of Percent Oil Yield Extracted at Different Operating Conditions, d- Predicted Oil Yield VS Actual

## IV. Discussions

Pre-treatment conditioning is a preliminary processing activity that involves size reduction, moisture content adjustment, heat treatment and pressure application (Ibrahim and Onwualu, 2005). These activities depend on the nature of the oil-bearing material, methods and devices adopted in the oil extraction. The moisture content of seeds is an important factor that affects the yield and quality of the oil extracted thus, moisture adjustment of the seed is necessary before pressing. From the studies, it was observed that moisture content, heating time and temperaturehad significant effect on oil yield from African oil bean seeds; a similar trend was reported by Akinoso *et al.*(2006a), Akinoso *et al. (*2006b)Ogunsina *et al.*(2008), Lawson *et al.* (2010), Abidakun *et al.* (2011), Bamgboye and Adejumo (2013),Santos *et al.* (2013), Adejumo *et al.* (2013a), Adejumo *et al.* (2013b), Orhevba (2013), Yusuf *et al.* (2014), Ogunsina *et al.* (2014) for sesame, palm kernel and sesame, palm kernel, cashew kernels, soybean, dika nut, roselle, highenergetic potential plants, moringa, watermelon seeds, neem seeds, groundnut oil, dika kernelsrespectively,

Heating of the seeds increases the oil yield due to beakdown of oil cells and decrease in oil viscosity which allow the oil to flow more readily though, prolonged heating beyond 15 minutes and temperatures above 90$^0$C did not improve the oil yield as there was vapourization and volatilization. This findings are in tandem with Adeeko and Ajibola (1990) for groundnuts, Sivakumaran*et al.* (1985) for peanut, Manuwa and Adenuga (2000) for palm kernel.

## V. Conclusion

The effects of some operating parameters on oil yield and expression efficiency of African oil yield was determined, this is provide adequate guide/information needed for the separtion of oil from the seeds of African oil bean. The operating parameters considered include heating temperature, heating time and moisture content, mathematical model was developed to obtain the oil yield at any given operating parameter.

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