Indigenous Design and Manufacture of Palm Kernel Oil Screw Press in Nigeria: Problems and Prospects

S.L. Ezeoha, C.O. Akubuo and A.O. Ani*

Department of Agricultural and Bioresources Engineering
University of Nigeria, Nsukka
E-mail: sunday.ezeoha@unn.edu.ng, akubuoclem1945@yahoo.com
*Corresponding Author E-mail: aniozoemena@yahoo.com

Abstract

Palm kernel is a product of the oil palm tree (Elaeis guineensis). This paper provides some information on the composition of palm kernel and oil, the uses of palm kernel oil (p.k.o), and palm kernel oil extraction methods. Most enterprises involved in palm kernel oil extraction business in Nigeria employ the screw press, most of which are imported from Malaysia, England, and Germany and lack certain important local content in the design and development. This paper expresses the need to develop indigenous capacity for rational design and manufacture of efficient palm kernel oil screw press in Nigeria. The inherent problems of this developmental need have been identified to include: dearth of p.k.o screw press design information, unavailability of the right kind of steel locally, limited data on relevant properties of palm kernels, etc. However, the increasing number of researchers in vegetable oil extraction, the availability and use of imported presses in Nigeria, the steel development efforts of the Nigerian Government, and the present ICT capabilities are considered strong indicators of high prospects. It was recommended that more research should be directed at physical and mechanical properties of palm kernel, the effect of screw parameters on the performance of oil screw press, the theory of oil expression from palm kernel using the screw press, and screw press model development to enhance optimum design and development of p.k.o screw press in Nigeria.

Keywords: Palm kernel oil extraction, screw press design variables, physical and mechanical properties of palm kernel, properties of palm kernel oil.

Introduction

This article presents a brief overview of the oil palm tree major economic products
and an outline of the products processing unit operations. It narrows down on palm kernel oil, its common uses, composition and quality indicators. The various methods for extraction of palm kernel oil were discussed and compared. Particularly, the article focuses on the problems and prospects of indigenous design and manufacture of palm kernel oil screw press in Nigeria. Palm kernel is a product from the oil palm tree (*Elaeis guineensis*) (Fig. 1). It is generally believed that the oil palm tree originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Nigeria, Ghana, Cameroon, Côte d’Ivoire, Liberia, Sierra Leone, Togo, and into the equatorial region of Angola and the Congo. Processing oil palm fruit (Fig. 2) has been practiced in Africa for thousands of years; although the traditional process is simple, it is tedious and inefficient [1]. The oil palm fruit when processed yields palm oil, fibre, and palm nut; and the nut when cracked yields palm kernel and shell. The importance of palm kernel derives from the economic importance of the bye-products, namely, the palm kernel oil (p.k.o), and the palm kernel cake (p.k.c). Figs. 1-5 illustrate the oil palm tree and some of the important products including the palm kernel which yields the p.k.o. Table 1 presents an ideal composition of oil palm fruit bunch.

![Figure 1: Picture of a typical oil palm tree with fruits on it](image1)

![Figure 2: Picture of harvested bunches of oil palm fruits](image2)
Figure 3: (a) Oil palm fruits removed from the bunch (b) Cross section of a fruit showing the kernel

Figure 4: A longitudinal section of oil palm fruit showing kernel, shell and pulp diagramatically

Figure 5: Picture of shelled oil palm kernel ready for extraction of p.k.o. Source:[2]
Table 1: Ideal composition of oil palm fruit bunch

<table>
<thead>
<tr>
<th>Composition</th>
<th>Quantity/bunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch weight</td>
<td>23-27 kg</td>
</tr>
<tr>
<td>Fruit/bunch</td>
<td>60-65 %</td>
</tr>
<tr>
<td>Oil/bunch</td>
<td>21-23 %</td>
</tr>
<tr>
<td>Kernel/bunch</td>
<td>5-7 %</td>
</tr>
<tr>
<td>Mesocarp/bunch</td>
<td>44-46 %</td>
</tr>
<tr>
<td>Mesocarp/fruit</td>
<td>71-76 %</td>
</tr>
<tr>
<td>Kernel/fruit</td>
<td>21-22</td>
</tr>
<tr>
<td>Shell/fruit</td>
<td>10-11</td>
</tr>
</tbody>
</table>

Source: [1]

Uses of palm kernel oil
Palm kernel oil has many uses which include the following [3,4,5,6,7,8,9,10,11,12].

i. Palm kernel oil as food is a source of concentrated energy; vegetable oils generally enhance palatability of other foods.

ii. The oil could be used to serve as lubricants and emulsifiers, ingredient in paint making as a drying base, and in the manufacture of candles.

iii. Upon hydrogenation, the oil can be used to produce margarine.

iv. The oil is an important constituent in the manufacture of shorteners and confectioneries.

v. Palm kernel oil is extensively used to make soap. In fact, lauric acid from the oil when boiled with alkali is used to make soap of the best quality due to its superior lathering characteristics.

vi. The oil is used to produce glycerol as a bye-product of soap making process.

vii. Palm kernel oil is also useful in the production of cosmetics.

viii. Locally, the black oil extracted by the roasting process is used medicinally for convulsion concoction.

ix. Residue cakes from palm kernel oil extraction are used for livestock feed formulation, because apart from carbohydrates and fats the cake contains proteins.

x. Palm kernel oil could be modified and used as non petroleum-based alternative fuel.

Composition of palm kernel and oil
Palm kernel is composed of oil, protein, cellulose, ash, some non nitrogenous matter, and water (Table 2). The palm kernel oil itself consists of free fatty acids, volatile matter, impurities, and peroxides (Table 3).
Table 2: Proximate composition of palm kernel

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent (weight basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>47 – 49</td>
</tr>
<tr>
<td>Crude protein</td>
<td>7.9 – 9.0</td>
</tr>
<tr>
<td>Extractable non-nitrogenous matter</td>
<td>23 – 24</td>
</tr>
<tr>
<td>Cellulose</td>
<td>9</td>
</tr>
<tr>
<td>Ash</td>
<td>2</td>
</tr>
<tr>
<td>Water</td>
<td>7.5 – 9.0</td>
</tr>
</tbody>
</table>

Source: [13]

Table 3: Palm kernel oil composition

<table>
<thead>
<tr>
<th>Content</th>
<th>Percent (weight basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Fatty Acid (FFA)</td>
<td>3 – 4</td>
</tr>
<tr>
<td>Volatile matter including water</td>
<td>0.15 – 0.20</td>
</tr>
<tr>
<td>Impurities</td>
<td>0.05 – 0.10</td>
</tr>
<tr>
<td>Peroxide (inch equivalent/kg)</td>
<td>2.0 – 4.0</td>
</tr>
<tr>
<td>Saponification value</td>
<td>242 – 222</td>
</tr>
</tbody>
</table>

Source: [3]

Quality indicators
According to [14], [15] as reported in [16], characteristics such as free fatty acids (f.f.a.), peroxide value (pe-value), thiobarbituric acid (TBA) value, iodine value, saponification value, colour, viscosity, refractive index, specific gravity, etc. are used in evaluating the quality of vegetable oils. The free fatty acid is a good indicator of the level of degradation by hydrolysis. The peroxide value is a measure of active oxygen in 1kg of oil, that is, it is a measure of stability of the oil. The TBA is a secondary oxidation test used for detecting incipient oxidation of lipids. The iodine value expresses the unsaturation level of the oil. The saponification value is an indicator of the average molecular weight of the mixed triglycerides constituting the oil. Free fatty acid (f.f.a.) and peroxide values in vegetable oils are often seen as quality parameters in the commercial transactions. High levels of f.f.a. are associated with degradation by hydrolysis and high refining losses. It should be less than 5% according to [17]. High peroxides are associated with rancidity development, and the value should not be more than 10 for fresh oil according to [18].

Oil palm fruit processing unit operations
The unit operations from bunch reception to palm kernel recovery and storage are illustrated in Fig. 6 as follows:
After the palm kernels are recovered from cracking and separation, the next stage in processing is the extraction of the palm kernel oil. This could be achieved through various methods as discussed in section 1.5.

**Extraction methods**

Palm kernel oil extraction methods can be classified into three, namely: the traditional methods, the chemical methods and the mechanical methods [19,5,7,20].
Traditional methods

i. Traditional roasting method: This method employs the principle of rupturing of oil glands by heating. In this method, palm kernels are put into a clay pot and heated over a fire. At a high temperature, oil is released by the kernels and is collected.

ii. Traditional pressure methods: The traditional pressure methods include the following:

   iii. Hand Pressing: Where crushed kernels are wrapped in cloths and hand pressed to squeeze out oil.

   iv. Stone and lever pressing: Where wrapped, crushed kernels are pressed using devices operated by stones and levers.

   v. Pestle and mortar pressing (Ghanis method): The mortar is fixed to the ground while the pestle driven by one or a pair of animals is inserted in the mortar to crush the kernels by friction and pressure, and the oil runs out through a hole at the bottom of the mortar.

   vi. Traditional aqueous method: Where crushed or ground kernels are boiled in water to liberate oil which floats on the water surface. The oil on the surface is scooped with mug into another pot. The recovered oil is then heated to remove the water.

Chemical or solvent extraction method

In this method, ground kernels are treated with a solvent which dissolves or washes the oil out of the ground kernel. The pure oil is then obtained by evaporation of the solvent.

Solvent extraction processes can be divided into three main unit operations: kernel pre-treatment, oil extraction, and solvent recovery from the oil and meal. For small-scale operations, the solvent extraction process is an alternative for high capacity mills. However the process is not recommended for small enterprises [1].

Mechanical methods

Mechanical extraction involves several processes as shown in Fig. 7 and there are three basic steps: (a) kernel pre-treatment, (b) screw-pressing, and (c) oil clarification. In these methods, mechanical compressive forces are used to separate oil from solid-oil systems under permitting conditions. The mechanical methods of oil expression include the following:

Hydraulic pressing method

This method is based on the principle that pressure applied to a confined body of fluid is transmitted undiminished in all directions. Here, a hydraulically operated ram or piston is used to press out oil from ground kernels. A modern hydraulic press consists of a stack of horizontal boxes inside each of which is placed a batch of ground kernel particles wrapped in a cloth. The stack of boxes is compressed by a hydraulic ram, and the oil moves out through the openings in each box.
Screw pressing method
The screw press consists of a series of continuous worms built on a steel shaft that rotate within a perforated housing and operates against a restricted opening. The worm flights provide the means of conveyance for the kernels being processed. The conditioned kernels are fed through a hopper into the housing and are forced along as the screw rotates, compressing and heating up the mass. The heating and the crushing facilitate oil extraction [7].

Figure 7: Mechanical extraction of palm kernel oil by screw press method (Adapted from [1])
Line (A) is for direct screw-pressing without kernel pre-treatment; Line (B) is for partial kernel pre-treatment followed by screw-pressing; and Line C is for complete pre-treatment followed by screw-pressing.

**Kernel pre-treatment**

[1] reported that to adequately extract p.k.o., pre-treatment of the kernel is usually very important. The kernels are first cleaned of foreign materials that may cause damage to the screw-press, resulting in increased maintenance costs and down time, as well as contamination of the products. Magnetic separators are used to remove metal debris, while vibrating screens are used to sieve sand, stones or other undesirable materials. A swinging hammer grinder, breaker rolls or a combination of both then breaks the kernels into small fragments. This process increases the surface area of the kernels, thus facilitating flaking. The kernel fragments subsequently are subjected to flaking in a roller mill. A large roller mill can consist of up to five rollers mounted vertically above one another, each revolving at 200-300 rpm. The thickness of kernel cakes is progressively reduced as it travels from the top roller to the bottom. This progressive rolling initiates rupturing of cell walls. The flakes that leave the bottom nip are from 0.25 to 0.4 mm thick.

The kernel flakes are then conveyed to a stack cooker for steam conditioning, the purpose of which is to adjust the moisture content of the meal to an optimum level, rupture cell walls (initiated by rolling); reduce viscosity of oil, and coagulate the protein in the meal to facilitate separation of the oil from protein materials. The meal flows from the top compartment down to the fifth compartment in series. At each stage a mechanical stirrer agitates the meal. Steam trays heat the cookers, and live steam may be injected into each compartment when necessary. The important variables are temperature, retention time and moisture content. In the palm kernel, the meals are normally cooked to a moisture content of 3 percent at 104-110°C.

**Screw-pressing**

The cooked meal is then fed into the screw-press, which consists of an interrupted helical thread (worm) that revolves within a stationary perforated cylinder called the cage or barrel. The meal is forced through the barrel by the action of the revolving worms. The volume axially displaced by the worm diminishes from the feeding end to the discharge end, thus compressing the meal as it passes through the barrel.

The expelled oil drains through the perforation of the lining bars of the barrel, while the de-oiled cake is discharged through an annular orifice. In order to prevent extreme temperatures that could damage the oil and cake quality, the worm-shaft is always cooled with circulating water while the barrel is cooled externally by recycling some cooled oil.

**Oil clarification**

The expelled oil contains certain quantity of ‘fines and foots’ that need to be removed. The oil from the press is drained to a reservoir. It is then either pumped to a decanter or revolving coarse screen to remove a large part of the solid impurities. The oil is then pumped to a filter press to remove the remaining solids and fines in order to
produce clear oil prior to storage. The cakes discharged from the presses are conveyed for bagging or bulk storage.

Not all crushers use the same procedure for mechanical extraction of kernel oil. There are three variations: direct screw-pressing, partial pre-treatment, and complete pre-treatment.

i. Direct screw-pressing: Some mills crush the kernels directly in the presses without any pre-treatment. Double pressing usually is required to ensure efficient oil extraction. The screw-presses used normally are less than 10 tons per unit per day.

ii. Partial pre-treatment: The kernels are first broken down to smaller fragments by grinding prior to screw-pressing. In some cases, cooking is also carried out.

iii. Complete pre-treatment: The full pre-treatment processes described earlier are carried out prior to screw-pressing. Plants with larger capacities (50-500 tons per day) choose complete pre-treatment and the equipment is usually imported from Europe.

Comparison of extraction methods
A comparison of the methods indicates that the traditional methods of roasting, hot water floatation, and pressure applications are more laborious, time-consuming and less effective while the modern methods of solvent extraction and mechanical press express oil more efficiently [21,22,7,23]. The solvent extraction equipment is relatively expensive and the proneness of the method to fire explosion hazards makes it unsuitable for the small and medium-scale farmers who form the majority of oil processors in the developing countries of which Nigeria is an example [24,25,26,7]. Therefore, most of the commercial PKS oil extractions in Nigeria are done with mechanical screw press usually known as expeller [26]. Other differences include:

i. The traditional roasting method produces black-coloured palm kernel oil [7].

ii. The traditional pressure methods exert low pressures and often extract not more than 20 to 25% of the inherent oil [23].

iii. The chemical method of solvent extraction is efficient and leaves only about 1% oil in the cake, but it is capital and volume intensive and requires extra skills. Therefore, the chemical method does not suit the small scale rural and urban processors [25].

iv. The continuous screw press is a compact machine and requires high initial cost. Operation of the press, however, does not require much skill. It does not require much labour, and maintenance problems are low when properly managed. It can operate at capacities as small as 3 tons or as much as 1000 tons per day. The housing and the worm flight wear fast if friction is not reduced. Power consumption is usually high [7].

Justification of the need for indigenous design and manufacture of p.k.o. screw press in Nigeria
As already stated earlier, most processors of palm kernel oil in Nigeria fall within small and medium scale enterprises which use mostly screw press method for extraction. Apart from the obvious need for national development and self-reliance in this area of national economy, most of the screw press machines imported to Nigeria lack important local contents in the design and development process of the equipment. This subsequently often leads to certain inefficiencies in performance, problem of spare parts, and general maintenance and sustainability of the equipment.

Problems facing indigenous design and manufacture of p.k.o. screw press in Nigeria
Problems facing indigenous design and manufacture of p.k.o. screw press in Nigeria include: inadequate screw press design information, limited data on relevant properties of palm kernels, unavailability of suitable construction materials locally, harsh manufacturing environment, market uncertainties, insufficient relevant indigenous manpower, poor research funding and coordination, weak institutional establishment.

Inadequate screw press design information
There are different types of design, which include: adaptive design, empirical design, rational design, optimum design, etc. [27]. In adaptive design, the designer is concerned with adaptation of an existing design, making minor modifications in the existing design. An empirical design is based on empirical formulae realized from practice and past experience. An optimum design is the best design for a given objective function under specified constraints. A rational design is based on mathematical formulae of principles of mechanics.

Obviously, there is a problem of inadequate or even unavailability of design information for the rational, empirical, or optimum design of screw presses for palm kernel oil expression in Nigeria. There are no established theories for screw pressing of palm kernel for oil expression. The effects of screw geometry on p.k.o. screw press performance are not well known. Suitable expressions for predicting torque requirements and pressure of a p.k.o. screw press are not readily available. Data on the effects of screw pressing and kernel conditions on p.k.o. quality and yield are limited. Mathematical modelling of screw pressing of palm kernel is almost non-existent. Most presses are, therefore, developed by cut and try methods.

Limited data on relevant properties of palm kernels
Data on the physical and mechanical properties of palm kernels relevant to processing are still limited in Nigeria. These properties include size, shape, density, angle of repose, coefficient of friction, hardness, specific heat capacity, compressive strength, moisture content, coefficients of permeability, volume change, and consolidation, etc. Consequently, research is needed to generate more data that could be collated and analysed to realize average or optimum design values for maximum oil expression.
Unavailability of suitable construction materials locally
Suitable construction materials for palm kernel oil screw press are not readily available in Nigeria. For example, rust-free aluminium and stainless-steel are not being produced in the country. Strong and tough metals and alloys suitable for shafts, pins, gears, screw-thread, axle, etc. are also not being produced in Nigeria. Such materials include Nickel-Chrome Steel, Chrome-Vanadium steel, and Manganese alloy steel. It appears the strongest construction steel available in Nigeria is mild steel. Chilled cast Iron or cast steel is suitable for the manufacture of high profile pulleys. Good power transmission belts are usually made of reinforced fibres. Case hardened steels for gears, worms, etc. include: 10C4, 14C6, etc. Unfortunately, most of these suitable materials are not locally produced or sold in Nigeria.

Harsh manufacturing environment
A situation where manufacturers in Nigeria are forced to provide public utilities and infrastructures such as electricity, water, roads, telecommunications, and security for themselves is harsh and very discouraging. The requisite industrial base is lacking, as most of the needed facilities and machine tools such as welding machines, lathes, drills, folding machines, etc are imported at exorbitant costs via diverse importation difficulties. There are no local ancillary industries needed to supply at reasonable prices the required machine elements such as bolts and nuts, gears, chains and sprockets, belts and pulleys, gaskets and seals, and various grades and sizes of flat and standard sections of steel products, etc. There is also the problem of inferior quality of industrial consumables such as electrodes, hacksaw blades, power-saw blades, sandpaper, cutting tools, etc. Also, inimical socio-political climate in Nigeria drastically reduces direct foreign investments in local manufacturing projects [28].

Market uncertainties
Obviously, there is high potential demand for p.k.o. screw press in Nigeria, because there is raw material availability, and p.k.o. extraction business is lucrative [29]. Unfortunately, the actual demand level is not known. In fact, there are no readily available research results on actual annual demand of p.k.o. screw press in Nigeria to stimulate the interest of local manufacturers in the risky business venture of manufacture of new and commercially untested screw press prototypes.

Insufficient relevant indigenous manpower
It is evident that Nigeria has insufficient indigenous agro process machine design manpower. Engineering R&D work in agro process machinery demands for a certain measure of inventiveness, ingenuity, perseverance, and patience [28]. Obviously, very few researchers possess the requisite design capability and attributes in the area of screw press design and development. Generally, design of agricultural machinery is time consuming, and least productive in terms of quick economic returns. Consequently, not many agricultural engineers and researchers like to get involved.

Poor research funding and coordination
Lack of national coordination and poor research funding are obviously major
Indigenous Design and Manufacture

contributors to delayed indigenous breakthrough in p.k.o screw press design and manufacture in Nigeria. If indigenous design and manufacture of p.k.o screw press is correctly seen as a national problem, a research fund should be established and managed to sponsor, coordinate, and control research activities in this area.

Weak institutional establishment
Nigeria has a problem of weak institutional establishment to nurture young engineering manufacturing industries in the country to maturity by way of research funding and provision of technical capability to develop commercial models from shop prototypes. There is therefore the need for a powerful and influential institution in Nigeria that can take up successful and promising designs from R&D efforts and bring them to commercial model stage.

Prospects of indigenous design and manufacture of p.k.o screw press in Nigeria
The prospects of successful indigenous design and manufacture of p.k.o screw press in Nigeria are seemingly high because of increasing interest by researchers, increasing local engineering materials development efforts, availability of information and computer technology, availability of imported palm kernel oil presses in Nigeria, etc.

Increasing research interest and activities
A review of literature shows that research interest is increasing in the area of characterization of palm kernels and palm kernel oil extraction processes in Nigeria [4,5,6,7,30,31,32] etc.
Consequently, there is hope that sooner or later a breakthrough will be made in developing indigenous engineering capacity for the design and commercial production of palm kernel oil screw presses in Nigeria.

Local engineering materials development efforts
The greatest problem of local manufacture of rugged machines in Nigeria is that of lack of the right kind of steels [33]. The establishment of materials research and development companies and institutes especially those related to metals is a good indicator of the prospects for local production of palm kernel oil presses in Nigeria. At least we have Steel Rolling Companies at Ajaokuta, Jos, Katsina, Kaduna, etc. and a Metallurgical Training Institute at Onitsha, Anambra State. There are also several departments of Materials and Metallurgical Engineering in many Universities in Nigeria.

Information and communication technology (ICT)
With the availability of information and communication technology (ICT), research and development has become a lot easier, especially with respect to accessibility to relevant literature materials and contacts and cooperation with many researchers of common interest across the world. With the ICT, there is increased prospects for successful indigenous development of palm kernel oil presses in Nigeria.
Imported industrial palm kernel oil presses
The availability of imported palm kernel oil presses in Nigeria is important in the effort to develop palm kernel oil presses locally. Their availability affords researchers the opportunity to see, touch, and inspect the operational mechanisms of the machines. Such first-hand contacts often generate inspirations necessary for effective indigenous research and development.

Conclusion and recommendations

Conclusion
Large quantities of palm kernels are being produced annually in Nigeria, and most enterprises involved in palm kernel oil extraction business in Nigeria employ the screw press. There is therefore real need to develop indigenous capacity for scientific and rational design and manufacture of palm kernel oil screw presses in Nigeria. This need is now urgent given the fact that all industrial-capacity p.k.o. screw presses in use in the country were imported from England, Malaysia or Germany; and the fact that the locally fabricated smaller-capacity presses have relatively low efficiencies, being mostly products of adaptive designs bereft of sound scientific and engineering know-how. The prospect of successful indigenous design and manufacture of efficient p.k.o. screw press in Nigeria is high. The inherent problems, however, include: inadequate screw press design information, limited data on relevant properties of palm kernels, unavailability of suitable construction materials locally, harsh manufacturing environment, market uncertainties, insufficient relevant indigenous manpower, poor research funding and coordination, weak institutional establishment, etc.

Recommendations
In the all important effort to build the needed capacity for indigenous design and manufacture of efficient p.k.o. screw presses in Nigeria, the following recommendations are proffered:

i. Research is urgently needed to generate standard values of palm kernel properties relevant to rational design of p.k.o. screw press, to investigate the effect of changes in palm kernel conditions on both the yield and quality of extracted oil, to determine the effects of screw parameters on the performance of oil screw press, to explore the theory of oil expression from palm kernel using the screw press, and to develop mathematical models for screw pressing of palm kernels.

ii. The operations of new and existing Steel Rolling Companies, Materials and Metallurgical Engineering Departments in Nigeria should be stream-lined and made to produce the various right kinds of steels and alloys necessary for the manufacture of industrial agro-processing equipment like seed-oil screw presses.

iii. The Government should change the present harsh manufacturing environment in Nigeria by providing public utilities and infrastructures, industrial machine tools and workshops, and by promoting the establishment of ancillary industries for the production of machine
elements of acceptable quality.

iv. Joint ventures and partnership with indigenous and overseas manufacturers should be actively promoted by the Government especially by positively transforming the inimical political climate of Nigeria

References