GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 13 NO. 2 2007 : 145 - 149
COPYRIGHT© BACHUDO SCIENCE CO. LTD PRINTED IN NIGERIA. ISSN 1118 - 0579

A DEVICE FOR THE EXTRACTION OF PALM KERNEL OIL IN A HOT-WATER MEDIUM

S. E. OBETTA

(Received 8 February, 2006; Revision Accepted 27 April, 2006)

ABSTRACT

A fundamental work on developing a device for Palm kernel oil extraction was carried out. The prototype, a hot-water oil extraction system for palm kernel was developed and tested. It consists of a combustion chamber for introducing heat, the extraction unit where extraction of oil from palm kernel takes place and the evaporation unit for drying out traces of water in the extracted oil. Within the extraction unit there is a set of stirrer paddles while the chimney component projects out from the evaporator. The extraction operation involves the introduction of crushed palm kernel into boiling water in the extraction vessel. While boiling continues, there is the stirring of the entire mixture in the extraction vessel until the extraction process is completed in about 45 minutes. The extracted oil is decanted into the evaporator and subsequently the remains of the vessel are finally drained into a meshed container. This extraction equipment was also evaluated economically. The test results of the prototype showed an average oil recovery of 67.3% for an unclassified palm kernel meal aggregate. One obvious interest of this extractor is that it is adapted to use forest products and other agricultural wastes as fuel.

KEYWORDS: Hot-water, Extraction, Palm kernel oil, Meal aggregate, Oil recovery.

INTRODUCTION

The extensive exploitation in the oil palm industries has been motivated by its extremely high potential for productivity and returns and the small scale processors whose primary domicile activity seem to hold the key to much rural poverty reduction are equally stake holders. Palm kernel nuts, a by-product of palm oil extraction provides the best raw material for starting this brand of rural industry. Hitherto, emphasis had been on medium to large scale extraction systems in total neglect to the small scale enterprise in this domain. These extraction systems had de-linked local production of palm kernel oil thereby creating a risk of excluding these producers from contributing to oil supply in urban areas. The 'policy' as it were increases the obstacles of preventing small farmers from integrating into modern supply chains which effectively locked them out of growth opportunities and in most cases made them become potential victim of extortion by the big business entrepreneurs. Wastes in the management of palm oil and its products are usually recorded for the fact that the rural-farmer lacked supply ability to even existing oil palm product managers or that they have no new knowledge of transforming these products into new products beyond what they already know crudely.

Apart from being an essential ingredient in much of the traditional West African cuisine, fats and oils are critical to the well-being of many rural communities as a source of concentrated energy. Adding vegetable oil to our foods can enhance palatability. It is a useful ingredient in baking; as salad and cooking oil and also serves as a means of heat transfer medium in the process of frying, just as they are also sources of calories and fat soluble vitamins. As non-food, by-products (defatted meals, crude oil, hulls, linters) of the vegetable oil expression process find wide application in many secondary industries (energy, medicine, pharmaceuticals, cosmetics, plastics, food and beverages, detergents, paper and synthetics) Bongirwar et al., (1972). Other non-food uses include serving as lubricant, ingredients in paint making as a drying base.

A release from South Africa (du Plessis, 1981) indicates successful operation of an air-cooled, precombustion chamber, engine for 2300 h at a constant 70 % load for 100 % sunflower vegetable oil. It was a major breakthrough in the quest for using vegetable oil as a fuel. Deer and company (Barsic and Hunke, 1981); Caterpillar (Bartholomew, 1981); Volkswagen do Brazil (Pischinger et al., 1981), all did some work in support of the above research which verified that vegetable oil can be used as direct replacement for diesel fuel in the existing engines with no modifications required if used for short periods. Engine tests with palm kernel oils and other vegetable oils were carried out in single-cylinder, air-cooled diesel engines by placing these test materials in the fuel tank and obtaining average thermal efficiencies as shown on Table 1.

Table 1: Average Indicated Thermal Efficiency with Palm and other Vegetable Oil Fuels in two Diesel engine Designs – Percent

Precombustion Fuel	Direct injection	Chamber engine
Diesel fuel (no. 2)	40.66	42.86
Palm oil	35.40	41.04
Palm kernel oil	34.10	39.60
Peanut oil	37.92	41.34
Sunflower oil	42.44	42.42

Source: (Wiebe and Nowakowska, 1984)

The implication of such investigations is that palm kernel oil has, among other uses, the good potential as fuel oil as demonstrated by Wiebe and Nowakowska (1984).

It is therefore an objective of this study to develop a simple technology for small-scale processing of palm kernel oil, taking into consideration the existing traditional methods and how to improve on them. Efforts in this direction will mechanise and improve the drudgery of traditional methods.

S. E. Obetta, Department of Agricultural Engineering, University of Agriculture, Makurdi. Nigeria.

BACKGROUND REVIEW

Oil palm fruit, (*Elaeis guineensis*), belongs to the tribe *ceroxylimae* of the family *palmaceae*. Its origin is traced to the tropics of Africa and found abundantly in the forest regions, river banks, valleys and fresh water swamps. The major producers are Nigeria, Benin Republic, Zaire, Sierra Leone, Cameroun, Angola, Congo, Malaysia and Indonesia (Wood et al., 1976). Palm kernel, a product of oil palm, is one of the abundant natural resources and an important economic biomaterial in Nigeria. Several thousand metric tonnes of oil palm kernel products are sold in the international market annually. In 1994 alone, over 1.2 million metric tonnes of oil palm product growth was attributed to the expansion of 300,000 hectares to 5.1 million hectares in matured land area (PORLA,1996). Of the projected output of 7.6 million metric tonnes of palm products in 1996, Malaysian export is put at 1.47 million metric tonnes. In Nigeria, oil palm production was 2.74 million metric tonnes between 1995 - 1997 covering a matured land area of 1.04 million hectares (FMA,1999).

In Nigerian traditional communities, oils have been extracted from palm kernel by the process of roasting. Oils from this process though medicinally useful, are not edible or consumed as food. Historically, oils have been extracted from oil bearing vegetables by wrapping crushed seeds or nuts in cloth, and then using devices operated by stones and levers to exert pressure on them, followed by the traditional aqueous extraction method (Onwuka, 1991). With time, improved forms of mechanical devices were evolved, which allowed considerably more pressure to be exerted.

This process involves the use of mechanically operated rams: a simple, hand-operated cylinder pump, used to press flat plates or hollow cages attached to the ram against a fixed-position ram. Another improvement on vegetable oil extraction was the screw press or the expeller (GRET, 1984). Screw presses use electric motor to rotate a heavy iron shaft, which has flights of worms built into it to push the seeds through narrow openings. The pressure of forcing the seed mass through this slot releases part of the oil, which comes out through tiny slits into a metal barrel fitted around the rotating shaft. Expellers require a continuous flow of seed through the machine in contrast to the ram system which uses small, individual packages or batches of seed. Because most presses and expeller processes leave out much of the high value oil in the seed cakes, and also for their high technical resource requirements, methods of oil extraction with solvent were developed. The solvent extraction method is common with seeds of low oil content (Stanley, 1971 and Brennan et al; 1971). In some cases, it serves as a finishing stage in expeller systems where part of the oil is extracted, then the solvent system is used to extract what oil that remains in the already crushed charge. Solvent extraction is simple in principle but rather complex in operation.

The seed is prepared by being crushed into chips. These chips are warmed and passed through smooth flaking rolls. The flaking rolls flatten the chips into paper thin, flat flakes. These flat flakes can then be mixed with an appropriate solvent, which dissolves and washes the oil out of them. Solvents that boil at fairly low temperatures (65 oC) are usually recommended so that the solvent can be readily removed from both the oil and flakes. Solvent extraction recovers most all the oil (Nathan, 1985), leaving out only one percent or less in the flakes. Solvent extraction, however, needs a lot of skill to handle and poses a greater risk of danger to the operator that is not adequately trained. In addition, the extracted vegetable oil from the solvent system needs a further refining operation to at-least free it from the poisonous solvent.

MATERIALS AND METHODS

Equipment Design and Description

The equipment was designed with certain criteria considered appropriate which include:

1. The process requiring no electricity - this feature makes it adaptable to any location in a rural environment.
2. The extractor should run on locally available biomass energy sources such as wood, rice husks and other agricultural by-products.
3. Construction materials not locally and easily available must not be used.
4. The building technique must be known to local craftsmen and/or farmers.
5. The basic extracting unit should be a batch extractor that should be operated and maintained by the farm family. The batch size will be such that will encourage faster operation.
6. Cost of the extractor should be affordable to the intended users either as co-operatives or as individuals.

The combustion chamber, constructed with burnt bricks, has overall dimensions of 80 cm x 80 cm and a height of 80 cm from the foundation level and this is made up of the ingress stoker and the ashpit. The stoker in addition, has a chimney with a right cylindrical evaporator that projects out of it. The chimney is designed to maintain a steady draft, continuously sucking in fresh air to the ingress stoker through the ashpit openings of the chamber. The combustion chamber is built with the following materials.

Burnt bricks measuring 29 x 13 x 11 cm.
Ingress door of cast metal sheet measuring 3.8 cm x 3.2 cm
Grates made up of iron rods held together by a perforated metal plate.
An ashpit which has an opening measuring about 32 cm x 20 cm.

The ingress stoker is such that it has enough room above the grate bars separating the ashpit for sufficient combustion to take place, allow easy access for raking out the ash and charcoals and has an adequately sized openings leading to the chamber. Other guidelines for designing a functional stoker include;

R Placing the grate bars at appropriate point above the ashpit floor - at least a of the chamber height.
R Spacing of the grate bars is extremely important for fuel and firing control to ensure improved air draft.
R No rule can be stated for determining the height of the stoker but one half of the height should be allotted the combustion chamber while the remaining can be taken up by the ashpit (Olsen, 1983). If the grate is too low, the fuel (wood or coal) tends to build up and cause choking.
R The ashpit must be easily accessible for raking out charcoals. The grate bars must also be accessible in other to rake down the wood flinkers and to feed in the fuel.

In the construction of this chamber, the bricks are laid upon one another using the stretcher course with the bricks running along the crest. The bricks are held together by adobe adhesive soil. The size of the combustion chamber is determined in such a way as to accommodate the base diameter of the boiling vessel yet allowing adequate space for the management of the stoker and ashpit. Details of other component designs are found in Obetta (2003).

The Hot-Water palm kernel oil extractor equipment as shown in Figures 1 and 2 comprises of majorly three basic units of a combustion chamber **(A)**, the extracting unit **(B)**, the drying or refining unit **(C)** and other accessories (see Fig. 1).

The combustion chamber is made of known refractory materials such as clay bricks, adobe stone laid up right on all sides thereof. This chamber consists of two components, of an ingress stoker, (20) (as in Fig. 2), which facilitates the charging of the chamber with fuels such as wood, husks, trunks and other renewable biomass energy fuels. The ingress is separated from the ash pit (23) by a set of grate bars and this compartment, in addition to providing an air intake means for combustion, creates a structure for separating the chamber active combustion and the remnant ash from combustion. The temperature achieved during combustion is dependent on the rate of heat production and that of heat loss, and the ingress stoker is designed to maintain heat loss to a minimum.

The extracting unit comprises of the boiling vessel placed on the combustion chamber for direct contact with the heat, the viewing screen **(10)** at the upper part of the vessel, and the stirrer paddle **(14)**. The boiling vessel contains the free charge of ground kernel seeds and water mixed in a definite proportion depending on the variety of seeds.

At a horizontal re-aligned level of the glass viewing screen, is located a pipe with valve **(12)** extending to the evaporating or drying unit. This unit also holds the stirrer paddle that operates by a hand operated pulley motion-transmission arrangement **(1, 2, & 3)**. The vessel is also equipped with a valve tap **(19)** at the base to drain the charge of a completely extracted batch.

The drying or refining unit is linked to both the combustion chamber and the boiling vessel. To the boiling vessel, the drying unit is linked with a valved pipe located above the glass-viewing screen as earlier described. And to the combustion chamber, the drying unit is linked by the exhaust port **(18)** through which heat and smoke pass to the evaporator. The residual heat is used up for drying the extracted oil while the smoke finally escapes via the chimney **(24)** extending from the evaporator to the surrounding atmosphere.

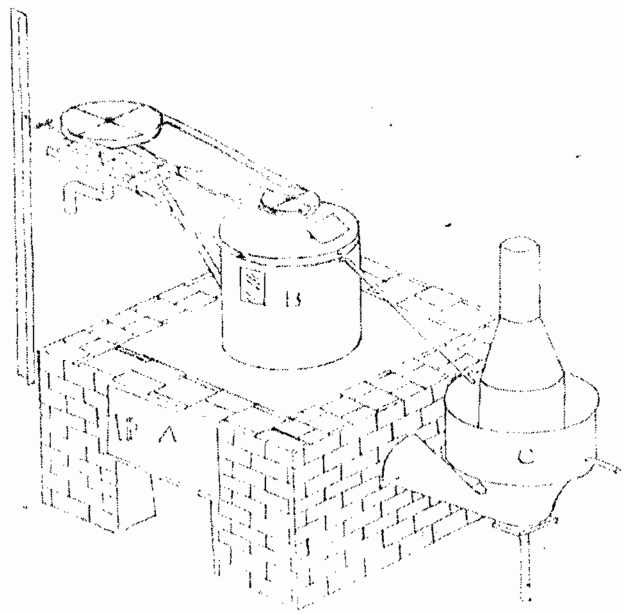
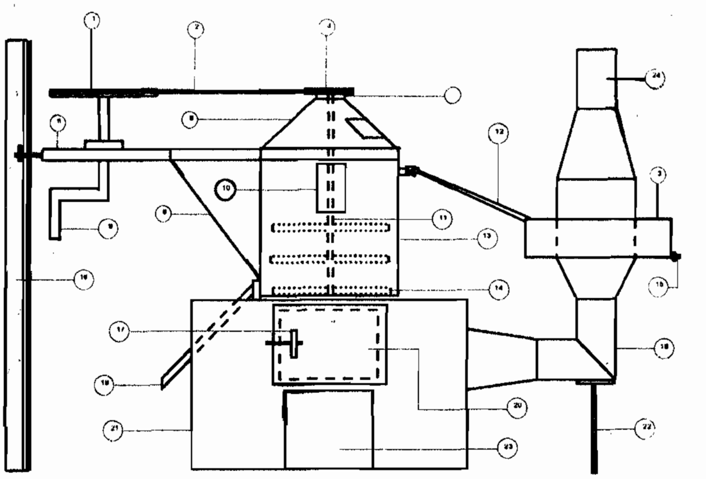


Fig. 1: A Perspective view of the Hot-water Oil Extractor
B- Combustion chamber, B-Extraction unit
C - Evaporator



LEGEND
1 - Large dia. Pulley
2 - V-Belt
3 - Small dia. Pulley
4 - Evaporator
5 - Motion Platform
6 - Support Arm
7 - Ball bearing
8 - Vessel cover
9 - Torque Arm
10 - Viewing screen
11 – Agitator shaft
12 - Oil outlet pipe
13 - Extraction vessel
14 - Agitator paddle
15 - Evaporator valve
16 - Torque arm support
17 - Door lock
18 - Heat channel
19 - Sludge outlet
20 - Stoker door
21 - Combustion chamber wall
22 - Supporting stud
23 - Ash pit
24 - Chimney

FIG. 2: SIDE ELEVATION OF THE EXTRACTING DEVICE

TESTING AND EVALUATION

The device for this operation is a batch type and the design is meant to carry out a process of extraction of oil from palm kernel nuts in a two-phase liquid system for degummed edible or industrial oils. The extraction is facilitated by a reduction in material particle size in a definite medium-to-seed ratio with clean water serving as a common medium. The size reduction is such that a greater surface area is exposed while ensuring that the sizes are not so small as to form ashes, hence making the extraction difficult to separate the extracted oil and sludge. The crushed-reduced material is completely immersed into a boiling vessel with water, and after blending and stirring the heated charge; a quiescent period of between 45 mins and 50 mins is allowed for a definite extraction to take place. As boiling progresses, more oil is melted out of the charge and this floats on the water medium as a result of density differences between the oil and water. The micella, containing mostly oil is piped off the boiling vessel by gravity into the evaporator for further drying and clarification. During this further drying exercise, traces of water piped off together with the oil are completely removed. The dried oil is finally received while the meal sediments and sludge are drained out through a port located at the bottom of the boiling vessel.

The prototype extraction system was evaluated by expressing the weight of oil extracted as a percentage of the total weight of oil originally in the palm kernel meal. Average value of the performance was reported after three independent tests were carried out in the case of the prototype test as follows:

Capacity of the extraction vessel = 48.1 litres

Capacity of vessel used = 43.29 litres (with only 90% of the extraction vessel in use).

Water to crushed feed (charge ratio) = 3:1, giving a combination of 32.46 litres of water and 10.82 litres of feed volume.

The weight of the aggregate particle size used in the batch process is 4.33 kg of palm kernel meal. And 1 litre true volume of the extraction vessel contains the equivalent of 0.4 kg (400 gm) of the palm kernel meal. Therefore, the 4.33 kg (4328 gm) of palm kernel meal takes up an equivalent true volume of 10.82 litres of the extraction vessel while the remaining volume of 32.46 litres is occupied by water.

We then have 32.46 litres of water to 4.33 kg of of palm kernel meal aggregate in a 3:1 charge ratio.

From literature, 47.3% palm kernel oil is in a unit weight of palm kernel meal as in the Tenera variety used for the determination.

Therefore, 4.33 kg meal of palm kernel contains a total of 2.05 kg of palm kernel oil. And after the three independent tests carried out using the prototype, an average of 1.37 kg of oil was extracted. This value therefore gave an oil recovery of 67.3 %.

It was observed that heating in water medium improves oil extraction quality and increases yield. This process is also found useful if there are enzymes present in the kernel tissue capable of having a deteriorating effect on the oil quality. This extraction process is of such a quality that further refining is unnecessary especially if the extracted oil comes from kernels that are fresh and of good quality, though a little filtration may be needed to remove some clouding particles.

If the removal of excess colour is necessary, bleaching earths are effective. The oil is heated and mixed with 1- 2 percent of its weight of an effective bleaching earth. After a contact time of approximately one hour, the bleaching earth is separated by filtration. Activated carbon can also be used as an alternative to bleaching earths. Unwanted flavour are however more difficult to remove. They may be due to excessive free fatty acids. If the oil-bearing kernels are stored at a high moisture level, or are bruised and mouldy, there is the tendency to increase the free fatty acid, which makes the oil go rancid. In all, the acidity of over 10 percent is common but if above 20 percent acid, the oil may be used for soap making and other industrial uses.

Operational Cost Analysis of the Extractor:

The engineering bill of quantity put the overall (material and labour) cost of the prototype at ₦17,515.00 (Obetta, 2003) equivalent of US $133. This conservative cost has made the device attractive to both individuals and cooperatives. But the cost analysis has gone further to study the recouping period of the investment as shown below:

The average processing capacity per batch is about 4.33 kg per hour of cleaned crushed palm kernels for 10 hours per day. Oil output depends on the variety of the palm kernel. Operational cost evaluation was based on the 67.3% oil recovery of the prototype. The estimation of production cost is broken down as follows:

(a) Fixed capital investment which comprises equipment, infrastructure and other ancillaries, etc

(b) Working capital which includes purchased raw materials, salaries etc., calculated on daily basis, unit/product basis or on annual basis. In this estimation, the daily basis procedure is adopted.

Table 2: Basic Operational Costing Data

Capacity of oil extractor	43.3 kg per day
Rate of oil extraction per kg	67.3%
Current cost of palm kernel per kg	₦19/Kg
Cake sale per kg	₦5/Kg
Oil sale per Kg	₦92/Kg
Labour cost per day (2 men)	₦800.00
Building cost per kg - at 5% per annum	
Device depreciation per kg - at 5% per annum	

The production cost is given as the sum of direct and indirect costs as follows:

Production cost = Direct cost + indirect cost

Direct cost (Expenditure) per day:

(a) Raw material (PK purchase) - ₦822.70

(b) Maintenance at 5 % per annum - 24.00

(c) Crushing cost at ₦5/Kg - 216.50

(d) Fuel/water/sundry costs - 400.00

Total - ₦1463.20

Indirect cost (Expenditure) per day:

(a) Depreciation (D) of the processing shade with expected life of 8 years.

Value of the shade, P = ₦8000.00

salvage value after 8 yrs = 0

Therefore, D = (P - S)/n where n = expected life

D = (8000 - 0)/(8 x 365) = ₦2.74

(b) Interest on the processing shade using 5% annually.

I = 8000 x 5/100 x 1/365 = ₦1.10

(c) Depreciation of the Extractor valued at ₦17,515.00 with expected life of 5 years.

D = (17515 - 0)/(5 x 365) = ₦9.60

(d) Interest on extractor at 5% annually

I = 17515 x 5/100 x 1/365 = ₦2.30

(e) Labour for 2-man operator = ₦800.00

(e) Labour for 2-man operator = ₦800.00

Total Indirect cost per day = ₦815.74

Therefore the total production cost per day

= ₦(1463.20 + 815.74) = **₦2278.94**

Daily Revenue (Income) per day:

Total palm kernel material handled per production day is 43.3 Kg and based on 67.3 % oil yield recovery of the prototype, the total oil production per day is

43.3 x (67.3)/100 = 29.1 kg

and at ₦92 per kg gives (29.1 x 92) = ₦2677.20

Cake produced = 21.9 kg valued at ₦5 per kg giving ₦109.50

Total Income per day = ₦(2677.20 + 109.50) = ₦2,736.70

Income less Expenditure = Total production cost - Revenue

= ₦(2736.70 - 2278.94)

= ₦457.76

The above evaluation indicates that all things being equal, the owner of this kind of extractor can realise his capital investment of acquiring the extractor in about 40 days of continuous production. It is also observed that the source of palm kernel seed plays a major role in making greater returns. Where oil extractors can grow their own oil palm kernel seeds, income will definitely increase.

CONCLUSION

The system presented in this work is an improved traditional extraction process meant to eliminate the drudgery usually encountered by local extractors of palm kernel oil and the operation of this improved extraction system has added value and performance in terms of oil recovery. The throughput of most traditional extraction system are put not more than 20 - 30 % with their scale of operation depending on non-commercial needs (UNIFEM, 1987) but this device was able to achieve 67.3 % oil recovery. This device enjoys an initial comparative investment profile in contrast to other modern extraction systems. In 1986, a medium scale screw press of output 5.1 thousand tons/year was valued at ₦ 604,700.00 without variable and operating costs (Ikeh, 1986). This cost put in correct valuation now cannot be afforded by formidable cooperatives let alone individual extractors. The technology, suitable for small-scale extractors in formal commercial situation, is far less common except for the existing traditional methods. This work has made it expedient to provide for an alternative extraction technology appropriate enough to cater for the needs of small-scale processors of palm produce who are major players in the vegetable oil extraction industry.

REFERENCES

Bongirwar, D.R.; Pordwal-Desai, S. R. and Sreenivasam, A., 1972. Studies on the defatting of peanuts and soybeans for developing ready-to-eat snack items. Indian Food Packer. 31(3):61-76.

Barsic, N. J. and Humke, A . L., 1981. Vegetable oils: diesel fuel suplements? Automotive Engineering 89(4):37-41.

Bartholomew, D., 1981. Vegetable oil fuel. Journal of American Oil Chemists Society, April, pp 286-288.

Brennan, J. S., Butters, J. R., Ckowell, N. D. and Lilly, A.E.V., 1971. Food Engineering Operations. Applied Science Publishers, London.

duPlessis, P.T.C., 1981. Sunflower oil as tractor fuel:research report, News release, Department of Agriculture and Fisheries, Republic of South Africa, 15 June. P. 10.

FMA, 1999. APMEU Publications. Federal Ministry of Agriculture (FMA), 1999.

GRET, 1984. Le Point sur L'Extraction des Huiles Vegetales. Group de Recherche et d'Echanges Technologiques(GRET) 213 rue Lafayete, 75010, Paris, France. pp. 12 - 14

Ikeh, J. N., 1986. Vegetable Oil plant (A feasibility study). Unpublished B. Eng. Project Report. Dept. of Mechanical Engineering, University of Nigeria, Nsukka. P. 72.

Nathan, K., 1985. Understanding solvent extraction of vegetable oils. Volunteers in Technical Assistance (VITA) TP#41:12/85. Arlington Virginia. P. 12.

Obetta, S. E., 2003. Development of a Hot-Water Palm Kernel Oil Extraction System. Unpublished PhD Thesis of the Dept. of Agricultural Engineering, University of Nigeria, Nsukka. P. 168.

Onwuka, G. I., 1991. Aqueous Extraction, Characterization and Refining of Palm Kernel Oil. Unpublished Msc Thesis of Food Sc. and Technology, University of Nigeria, Nsukka. pp. 51 - 53.

PORLA, 1996. Palm Oil Registration and Licensing Authority, Malaysia. World Oil Journal, 1996. P.16

Pischinger, G., Clymans, F.C., and Sickman, R.S., 1981 Diesel oil substitution by vegetable oils-Fuels Requirements and Vehicle Experiments. Volkswagen do Brazil S/A, 04217, Sao Paulo, Brazil.

Stanley, E. C., 1971. Fundamentals of Food Engineering, 2nd Edition, Avi. Pub. Co., Inc., Westport, Connecticut.

UNIFEM, 1987. Oil Extraction. 1 Food Cycle Technology Source book. ITD Group United Kingdom. P. 46.

Wiebe, R. and Nowakowska, J., 1984. The technical literature of agricultural motor fuels. United States Department of Agriculture Bibliographical Bulletin no. 10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Wood, B. J., Hardon, J. and Corley, R.H.V., 1976. Development in Crop Science. Oil Palm Research. Elsevier Scientific Publishing Corporation, Amsterdam.