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# Effect of processing conditions on yield and quality of hydraulically expressed palm oil

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A b s t r a c t. An investigation was carried out on the effect of processing conditions such as sterilization time, digestion time and expression pressure on the yield and quality of hydraulically expressed crude palm oil. Palm fruits were collected, cleaned and sterilized for 30, 60 and 90 min. The fruits were then digested for 3, 5, and 10 min and later pressed with pressures of 0.5, 1 and 1.5 MPa for constant pressing time of 5 min. The results show that increase in sterilization time from 30 to 90 min, digestion time from 3 to 10 min and expression pressure from 0.5 to 1.5 MPa generally increased oil yield. The highest yield of oil of 35% was obtained at the sterilization time of 60 min, digestion time of 10 min and expression pressure of 1 MPa. The solid impurity content of the oil (as a measure of crude palm oil quality) at 30 and 90 min sterilization was observed to be generally high. The solid impurity at 60 min sterilization time was, however, observed to be low. Increase in digestion time and expression pressure increased the solid impurity at all sterilization times.

K e y w o r d s: palm fruit, processing-operations, oil yield, quality, optimization

## INTRODUCTION

Processing of oil palm fruit into palm oil yields a lot of by-products including palm kernel, palm kernel cake, palm frond, palm bunch and palm trunk which have numerous domestic and industrial applications. Palm oil, the principal product of the crop, has a great number of uses. About 80% of production is destined for human consumption with the balance going to animal feed and to various industries. Palm oil serves as the main cooking oil in Nigeria. In common with all fats, palm oil is a good source of energy and in addition the crude oil provides carotenoids (pro-vitamin A) and tocopherol or vitamin E (Babatunde, 1987).

Palm oil is consumed as margarine, as a base vegetable fat, as industrial frying oil and several special purpose fats. Margarine takes several forms *ie* refined or table margarine, cooking margarine, and industrial margarine used for baking. Its crystallization behaviour, particularly its effect on crystallization of fats with which it is mixed, makes palm oil highly valued for the manufacture of table margarine (Tropical Agriculturalist, 1998). Tropical Agriculturalist (1998) also reported that the derivatives of palm oil are used world wide for a wide range of purposes. These include the manufacture of ice cream and confectioneries, soaps, detergents, inks, epoxy resins and animal feeds.

Palm oil production output in Nigeria is at low ebb. Nigeria has lost its premier position on the list of world major palm oil producers for the past two decades (Owolarafe *et al.*, 2007). It is on record that Nigeria presently import palm oil to supplement the domestic production which is estimated at about 800 000 t per annum (MPOB, 2002; NEODA, 2007; Index Mundi, 2007). The cause of this poor Nigeria palm oil situation have been traced to lack of improved variety of palm fruit (the plantations are dominated by wild palms), land tenure system, and lack of appropriate processing technologies. Lack of appropriate processing technologies constitutes the major obstacle to palm oil production in Nigeria (Owolarafe *et al.*, 2002).

Palm fruit processing involve five basic operations: fruit sterilization, fruit loosening/stripping, fruit digestion, oil extraction and oil clarification. Machines for each of these processing operations are available in different versions at the small scale level, but the whole is yet to be optimized (Taiwo *et al.*, 2000; Owolarafe *et al.*, 2002). Hydraulic press is common among the small scale processors due to its low initial and maintenance costs (Babatunde, 1987; Owolarafe *et al.*, 2002).

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Processing factors known to affect yield of oil include sterilization time, digestion time and applied pressure (Baryeh, 2001; Owolarafe *et al.*, 2002). Increase in sterilization time and digestion time has been observed to increase oil yield. Previous work (Owolarafe *et al.*, 2007) has provided data on macro-properties of palm fruit at different processing conditions. It is important to explore the range of processing conditions with a view to providing data for modelling of palm oil extraction and hence optimise the processing stages.

This study undertakes the investigation of sterilization time, digestion time, and expression pressure on the yield and quality of oil to provide the data.

## MATERIAL AND METHODS

Palm fruit bunches were obtained fresh and processed immediately in order to get accurate results. The raw materials made use of were strictly Tenera variety of fresh palm fruit bunches obtained from Sedot Farm, Gbongan, Osun State.

Palm fruits were stripped from the fresh fruit bunches and washed to remove dirt and foreign matter present in the fruit mass. 5 kg of the stripped freshly harvested fruits was sterilized at different times of 30, 60 and 90 min at the range of temperature of 90-93°C. It was then transferred into a digester and digested for 3, 5 and 10 min. The temperature of the mash just after the digestion was taken. The resulting mash was put into a hydraulic press and subjected to the pressing pressures of 0.5, 1.0 and 1.5 MPa. The mass of the press cylinder was measured before and after the pressing using weighing scales. The volume of the oil extracted was collected with measuring cylinder and the reading was taken.

Pressing was done by loading the mass container while the hydraulic jack, of 10 t capacity, raised the lever arm. Then, the cylinder was released to allow the raised lever arm to be lowered down and rest on the pressing ram with the compression piston transferring the pressure generated on to the mash in the press cage.

At the end of each pressing operation, the hydraulic jack was used to raise up the lever arm so that the pressing cage and the compression piston could be removed.

The data collected include oil yield and volumetric flow rate. The oil yield in percentage was calculated using the formula below:

$$Y = \frac{M_{oe}}{M_m} 100\% , \quad (1)$$

where: $Y$ – oil yield, $M_{oe}$ – mass of oil extracted, $M_m$ – mass of the mash.

The crude oil samples were analysed chemically for solid impurities (as an important parameter in crude oil extraction) using Soxhlet extraction method (AOAC, 1994).

Aluminium dishes were washed and dried in an oven. The dishes were weighed. About 3 g of the oil sample were weighed into the dish. The dish was placed in an oven regulated at 102°C for 4 h during which time the mass was checked at specific time intervals. This was done until consecutive weighing agreed within 0.05 mg. This made it possible to obtain the moisture content of the original mass of the sample.

$$M_c = \frac{M_w}{M_s} 100\% , \quad (2)$$

where: $M_c$ is moisture content, $M_w$ – mass of water, $M_s$ – mass of sample.

Dried palm oil samples from the moisture content determination were subjected to Soxhlet extraction with 60- 80°C anhydrous petroleum ether using the Soxhlet apparatus. The solvent was evaporated and the sample was dried to constant mass at 100°C. The difference in mass was used to determine oil content in the sample:

$$O_c = \frac{M_{or}}{M_s} 100\% , \quad (3)$$

where: $O_c$ is oil content, and $M_{or}$ – mass of oil removed.

The resulting final mass of residue in oil content determination gave the mass of the solid impurities:

$$S_i = \frac{M_{si}}{M_s} 100\% , \quad (4)$$

where: $S_i$ is solid impurities, and $M_{si}$ – mass of solid impurities.

## RESULTS AND DISCUSSION

Figure 1 shows the graphs of oil yield at sterilization time of 30, 60 and 90 min. Oil yield could be observed to increase with increase in digestion time, sterilization time and expression pressure. Increase in oil yield with sterilization time is expected since sterilization is a heat rendering and moisture absorption process which achieves the objectives of lowering the viscosity of oil as well as coagulation of protein. This tends to facilitate oil flow (Babatunde *et al.*, 1988; Owolarafe *et al.*, 2002). Thus the degree of attainment of these objectives increases as sterilization time increases form 30 to 90 min. Oil yield was also observed to increase with increase in digestion time. Digestion is a wet comminution process of size reduction that induces rupturing of oil cells and, in some cases, complete loss of cellular architecture (Owolarafe *et al.*, 2002, 2007) to release oil. Adequate digestion also ensures homogenous mash devoid of undigested fruits, which enhances the chance of obtaining maximum oil yield (Owolarafe *et al.*, 2007; STORK, 1960).

The increase in oil yield with pressure can be explained in the sense that there is better compaction of the mash matrix, thereby forcing more oil out of the inter-kernel voids to reduce the void volume. This is in agreement with the findings of other researchers on oil expression (Ajibola *et al.*, 1993; Schwartzberg, 1997; Owolarafe *et al.*, 2002; Baryeh, 2001). The extent of digestion of the fruit determines the degree of exposure of the oil cells (Owolarafe *et al.*, 2002).

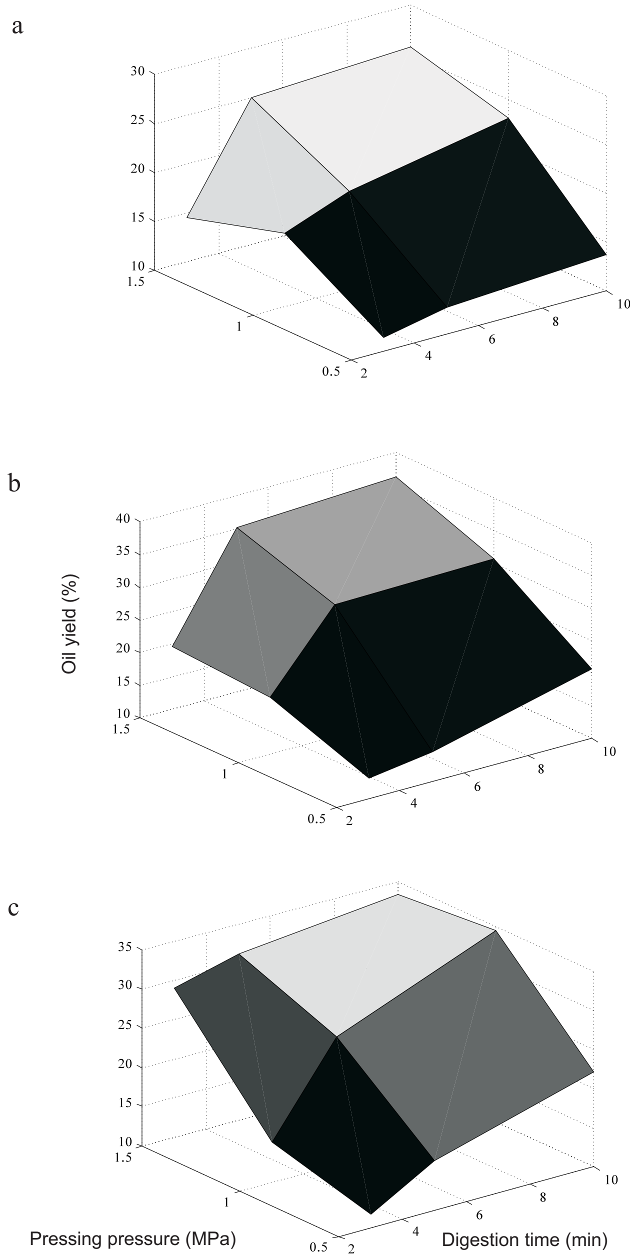


**Fig. 1.** Effect of digestion time and pressure on oil yield at: a – 30, b – 60, c – 90 min sterilization time.

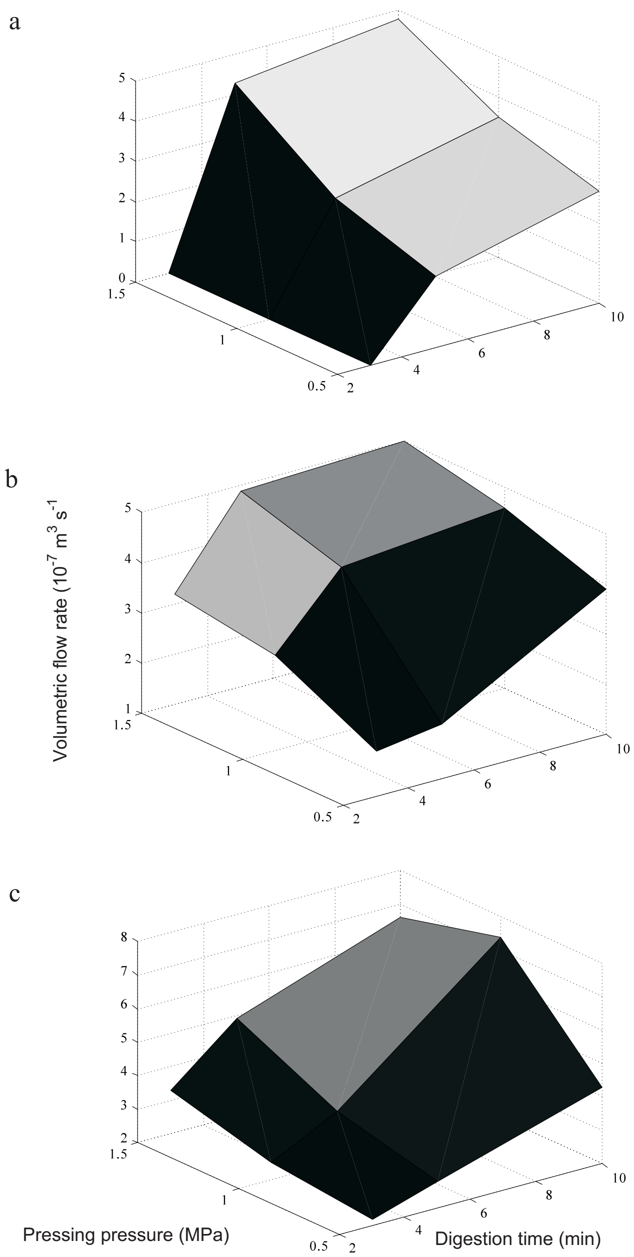


**Fig. 2.** Effect of digestion time and pressure on volumetric flow from: a – 30, b – 60, c – 90 min sterilization time.

There is a variation in volumetric flow rate from 1.8 $10^{-7}$ to 7.4 $10^{-7}$ $m^3$ $s^{-1}$ when the sterilization time increases from 30 to 60 min, digestion time from 3 to 10 min, and expression pressure from 0.5 to 1 MPa. Figure 2 shows the effect of sterilization time on volumetric flow of oil at different processing conditions. It could be observed that volumetric flow rate increases with increase in sterilization time from 30 to 90 min. The effect of heat treatment is more pronounced here. Thus it could be observed that though there was oil yield at sterilization time of 30 min, it was difficult to measure the flow rate and that is why the flow rate at the point was accepted to be zero. Similarly here, increase in digestion time and expression pressure increases volumetric flow (Fig. 2).

Table 1 shows the data on quality (solid impurity) of crude palm oil expressed at different processing condition s. It was observed that solid impurity at sterilization time of 30 min was generally high except for the points at digestion time of 10 min. The oil yield at the sterilization time of 30 min was very low and at fair digestion of 5 and 10 min contained little

**Table 1.** Solid impurity content of crude palm oil at different processing conditions

| Sterilization time | Digestion time | Pressure (MPa) | | |
|---|---|---|---|---|
| | | 0.5 | 1.0 | 1.5 |
| 30 | 3 | 3.50 | 3.10 | 3.90 |
| | 5 | 5.66 | 5.70 | 4.13 |
| | 10 | 0.34 | 1.11 | 2.46 |
| 60 | 3 | 0.33 | 0.40 | 1.50 |
| | 5 | 0.53 | 0.73 | 1.62 |
| | 10 | 0.92 | 1.06 | 1.56 |
| 90 | 3 | 1.23 | 3.01 | 3.69 |
| | 5 | 2.25 | 3.00 | 7.74 |
| | 10 | 1.93 | 3.70 | 8.20 |

viscous oil mixed with undigested particles and might have caused the high percentage impurity. However, at sterilization time of 60 min the percentage impurity was observed to drastically reduce. This is probably due to better heat treatment achieved under the conditions leading to readily flow of oil from the digested mash. However, at sterilization time of 90 min, the solid impurity of oil was observed to increase with digestion time. This result may be due to that excessive sterilization combined with over digestion might have caused fine fibrous materials to have been expressed with the oil. Hartley (1988) reported that solid impurity of 1% is desirable in crude palm oil to facilitate clarification.

Percentage solid impurity was also observed to increase with pressure (Table 1). This may be due to the fact that, with higher pressure, there is the tendency that more of the fine fibres may be forced out of the mash causing the oil to look like slurry. Oil containing high percentage solid impurity generally results in heavy sludge and loss of oil to the sludge (Owolarafe, 1999). It could, therefore, be stated that sterilization time of 60 min and digestion time of 5 min satisfy the condition of minimum solid impurity.

## CONCLUSIONS

1. The study revealed that increase in sterilisation time, digestion time and expression pressure increased oil recovery but this was accompanied by increase in impurity (in form of digested fibre).

2. The impurity content may eventually reduce the quantity of the final clarified oil. Thus a balance has to be struck between the yield of crude oil and impurity content of the oil and this calls for adequate selection of combination of processing conditions and monitoring of the whole process.

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