Variability In Yield, Oxidative Status And Appearance Of Palm (*Elaeis Guineensis* Jacq) Oils As Affected By Fruit Type And Extraction Equipment

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Abstract: This study investigates the variability in yield, oxidative status and appearance of palm oils as affected by fruit type and extraction equipment in the small scale industry. A 2×3 factorial experimental design with palm fruit types (Dura and Tenera) and extraction equipment (digester screw, hand spindle and hydraulic presses) were studied. Quality indices of oils (i.e. free fatty acid (ffa), peroxide value, moisture content, impurities, colour) and yield were accessed using standard methods. The ffa values obtained for oils produced from both Dura and Tenera fruit types and the extraction equipment ranged 5.25% - 5.71%, were above the CODEX standard of 5.0 %. Furthermore, significant differences were also recorded in both moisture contents and impurities from the same oils produced. The oil yield from Tenera fruit types were two folds higher than the Dura fruit types. The redness colour of palm oils for Dura fruit types was a little above the Tenera fruit types. However, the yellowness and lightness of colour of palm oils for Tenera were higher than oils from Dura fruit types. Therefore the study concludes that the oil processors in the small scale industry preferred the digester screw press machine because it gave low level of impurities and moisture content than other presses. Tenera fruit type is the best choice for palm oil processing because of its higher oil yield content. However, in terms of oil colour Dura fruit type is preferred.

Keywords: palm fruits, extraction, equipment, yield, palm oil

1 Introduction

The oil palm tree (*Elaeis guineesis*) is indigenous to most West Africans especially those in the coastal and forest zones [1, 2]. The oil palm fruits produce two types of oil, palm oil which is extracted from the mesocarp of the fruits and palm kernel oil from the seeds. Both of which are important in the world trade [3 ,4]. Chemical analysis of the fatty acids composition of the red palm oil indicates that it contains approximately 50% saturated fats and 40% mono unsaturated and 10% poly unsaturated fatty acids [5]. The light yellow to orange-red colour of palm oil is due to the fat soluble carotenoids which are responsible for the high vitamin A content [6, 7]. Nevertheless, palm oil could be refined industrially to give a light coloured product which could be used in the manufacture of margarine, shortenings, biscuits, cooking fats, ice cream, bakery fats as well as cooking oils [8, 9]. Furthermore, there are three major oil palm (E. guineensis) types: Pisifera, Dura and Tenera. Each of the fruit types has three basic characteristics; the Dura type is characterized by thin mesocarp content (35 % - 55 % of fruit weight), 2 – 8 mm thick endocarp (shell) with generally large kernel. Pisifera type is characterized by thick mesocarp about 95 % (with very little oil content), no endocarp (shell-less) with small kernels. However, the Tenera fruit type is a mono-factorial hybrid between Dura and Pisifera. This is characterized by 60 % - 95 % thick mesocarp, 0.5 – 3 mm thin endocarp with small kernel size [3, 2, 7].

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Palm oil extraction operations in small scale industries are carried out in different ways, including the extent to which machines are involved in the extraction process [10, 11, 12]. In small-scale processing mills (cramers) varieties of extraction equipment have been developed. In Ghana, the hand spindle presses are most common in a lot of milling sites due to its low initial and maintenance costs. Hydraulic press systems are few and cost of purchase and maintenance are high. However, the digester–screw press systems in small scale mills are few and are efficient. Besides its efficiency, the digester press is expensive based on its initial and maintenance cost. Its digestion and pressing units are combined into a single machine. This complete system is used to curtail the losses incurred by palm oil processors [3, 11]. Therefore, the study investigates the variability in yield, oxidative status and appearance of palm oils as affected by m fruit types (Dura and Tenera) and extraction equipment.

2. MATERIALS AND METHODS

2.1 Collection of Materials

Freshly harvested palm fruit bunches from two palm fruit types (Tenera and Dura) were obtained from the Oil Palm Research Institute (OPRI) of Council for Scientific and Industrial Research (CSRI), Kusi in the Eastern Region of Ghana. The fruits were then transported to the processing sites at Kusi and Kade in the Eastern Region of Ghana for processing into palm oil for subsequent analysis.

2.2 Methods

2.2.1 Sample Preparation

About 630 kg each of Dura and Tenera palm fruits from trees aged about 10 years were obtained for the oil extraction. Out of the 630 kg, 210 kg of each palm fruit type was used for the oil extraction. The oil was extracted using the three types of oil expellers – (1) hand spindle press, (2) hydraulic press and (3) digester screw press. Three samples were taken from each extraction point into sterilized sampling bottles and transported to the laboratory for analysis. Duplicate experiments were conducted and the mean values reported.

2.2.2 Experimental design

A 2 x 3 factorial experimental design was conducted and the factors used were two palm fruits type - Dura and Tenera and three oil expellers – the digester screw, hand spindle and hydraulic presses. The samples were evaluated for yield, moisture content and impurities (dirt), free fatty acid, peroxide value, saponification value, iodine value and colour.

2.2.3 Analytical Methods

2.2.3.1 Determination of Free Fatty Acids

The oil sample 1.0 g was weighed into 250 ml conical flask and 50 ml of 1:1 ethanol and diether ether was added. Two drops of phenolphthalein were added and the mixture was shaken to dissolve the oil sample which is then titrated with 0.5 N NaOH solutions with constant shaking until the pink colouration remains permanent (i.e 15 sec.) (x ml). Similar procedure was done for the blank (b ml). The results were calculated and reported as oleic acid [13].

2.2.3.2 Determination of Peroxide Value

The oil sample 1.0 g was weighed into a dry 250 ml stoppered conical flask and 10 ml and 15 ml 0f chloroform and glacial acetic acid were added respectively. Also 1.0 ml fresh saturated potassium iodide aqueous solution was added to the mixture. The flask was stoppered and shaken for one minute and the placed in the dark for further one minute. After that 75 ml of water was added and mixed and then titrated with 0.01N Sodium thiosulphate solution using starch as indicator (V ml). A blank was also prepared alongside the oil samples (Vo ml). The results were calculated and reported as meq / kg [13].

2.2.3.3 Determination of Impurities

Dry conditioned Gooch crucible was weighed. The palm oil sample 5.0 g of oil sample was weighed into dry 250 ml beaker and 100 ml of 1:1 ethanol and diether ether was added to dissolve. The mixture was filtered through a conditioned Gooch crucible connected to vacuum pump and the residue was washed several times with the solvent. The Gooch crucible and the content were dried in an oven at 105oC± for 30 minutes and then placed in dessicator and allow cooling [13].

2.2.3.4 Determination of Moisture Content

The dry hot air oven was conditioned at 105oC and moisture cans was placed the oven for 1 hour. The cans were removed and cooled in a dessicator and further weighed. About 5g of oil sample was weighed into the moisture cans and placed in the oven for 3 hours. After heating the can and the sample, there was reweighing to determine the weight of the sample [13].

2.2.3.5 Determination of Palm Oil Colour

The colour of palm oil samples was measured using the Hunter Lab Colour Difference Meter (CDM), Model CR-300 (Minolta Camera Co. Ltd. Inc., Tokyo, Japan). Colour measurements were described according to the following coordinates: lightness (L*), redness (a*, ±red-green) and yellowness (b*, ±yellow-blue).

2.3 Statistical Analysis

The data was entered into Statistical Package for Social Scientist (SPSS) version 16. Then Analysis of Variance (ANOVA) was carried out to establish the effects of the factors (Fruit types and extraction equipment) on variables studied (free fatty acid, peroxide value, iodine value, saponification value, moisture content, colour, impurities, yield). Significance was determined at probability of $p < 0.05$. Multiple comparison test (i.e. Least Significant Difference) was used to analyse the differences between means.

3.0 RESULTS AND DISCUSSION

3.1 Palm Oil Yield

Yield of oils produced from the palm fruit types used in this study varied. The results indicated that oil yields from Dura fruit type were lower (12.43 %, 9.43 % and 10.46 % for digester screw, hand spindle and hydraulic presses respectively) than oil yield from Tenera fruit types (26.27 %, 21.43 % and 23.52 % for digester screw, hand spindle and hydraulic presses respectively) (Figure 1). In addition, higher yields obtained from Tenera were due to its high mesocarp content (Teoh, 2002). Therefore, oil yields from the Tenera fruit type was more than twice that of Dura and this was statistically significant ($p < 0.05$). Furthermore, the extraction equipment used for palm oil extraction had significant effect ($p < 0.05$) on the yield for both palm fruit types. Effective oil yield depends on the carefulness of the digestion operation (crushing and pulverisation of the fruit into a pulp) and the pressing method. This determines how easily oil is released during expression. The use of the screw press in the digester screw machine enhances the size reduction operation thus allowing for better exposure of the oil cells and subsequently easing the flow of oil from the cells. Hence, the high oil yield obtained from the two palm fruit types. It was further observed that the digester screw press had a higher extractive efficiency than hand spindle press and hydraulic press equipment. These results are in line with [11], who also observed that using the digester screw press had a significant effect on the final oil yield and extraction efficiency of palm fruit processing. This was attributed to further reduction of the oil bearing material notably the mesocarp tissues by the digester screw press relative to hydraulic press, thereby exposing more of the oil cells.

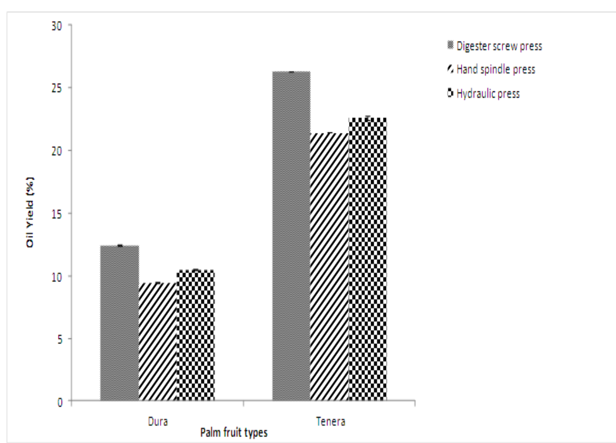

***Figure 1**: Yield of palm oil produced from Dura and Tenera palm fruits, using three different types of presses.*

3.2 Moisture Content of Palm Oil

The moisture content of oils varied significantly ($p < 0.05$) for both fruit types and the extraction equipment ranged from 0.22 % - 0.41 %. (Figure 2). Least significant difference showed significant variation ($p < 0.05$) for equipment and fruit types. For instance, oils produced from Tenera fruits had higher moisture contents (0.29 %, 0.37 % and 0.40 % for digester screw, hand spindle and hydraulic presses respectively). The increase in moisture content was above the Codex Alimentarius Standard and Ghana Standard Authority of 0.25 %. This effect could be due to the manual method of boiling crude oils in locus (drums) employed by the processors. In addition the duration of heating the oils was subjective at the milling sites and this might have affected the moisture levels in oils. Furthermore, the processors determine clarified oils when no water is found on top layer of the oils [10]. However, in most of the palm oil milling sites the crude oils were not clarified after the expression operation before being stored in plastic tanks, gallons and metal drums, except in places where digester screw pressing machines were used. It could be further observed that the boiled fruits that were digested contain a little water which leads to the high moisture content of the oils. This might have resulted from the ineffectiveness of the draining system of the water from the boilers. The high moisture contents in the oils could increase the rate of deterioration, hence short shelf life and poor quality of palm oils.

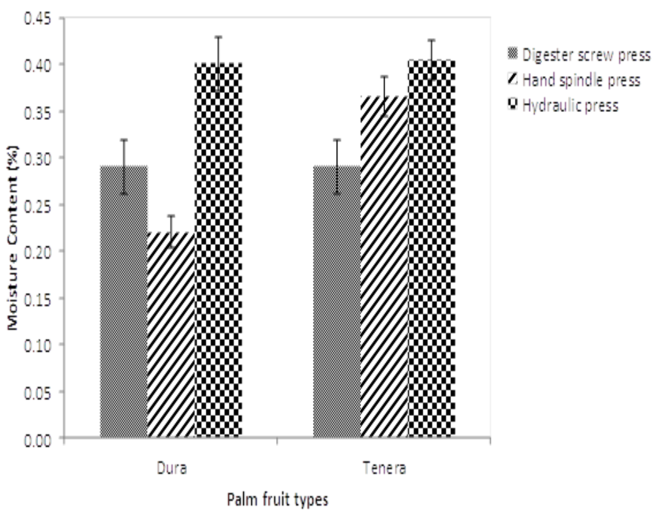

***Figure 2**: Moisture content for palm oil produced from Dura and Tenera palm fruits, using three different types of presses.*

3.3 Free Fatty Acids (FFA)

There were varying levels of FFA produced in oils from the different fruit types and the different extraction equipment (Figure 3). FFA levels in oils from Tenera fruit types were 5.46 %, 5.64 % and 5.70 % for digester screw, hand spindle and hydraulic presses respectively. Similarly, the FFA value for Dura fruit types were 5.24 %, 5.56 % and 5.71 % for digester screw, hand spindle and hydraulic presses respectively. There was a significant difference ($p < 0.05$) in FFA value for oils from Tenera fruit types compared to Dura using digester screw and hand spindle press. However, FFA value for oils extracted from Tenera and Dura fruit types using hydraulic press were not significant. This effect could be due to the low concentrations of tocopherol (vitamin E) which acts as a source of antioxidant in reducing FFA values in palm oil. Studies conducted by [5, 9] indicated that the concentration of tocopherol in Dura is about one and a half fold higher than Tenera. Furthermore, extraction equipment also had a significant effect ($p < 0.05$) on FFA of oils extracted. In the case of the Dura fruit type, least significant difference (LSD) indicated that there were significantly differences ($p < 0.05$) in FFA values for the various equipment used. However, least significant difference in FFA values for Tenera fruit types using the same extraction equipment was not significant ($p > 0.05$). Storage of fruits and bruises had strong influence on FFA level of oils (Hadi et al., 2009). In this study, the fruits storage period for both Dura and Tenera (i.e. seven days), in the palm oil milling sites (cramers), bruising effects during harvesting, transportation, quartering, methods of fruit loosing and degree of ripening might be the cause of the high FFA value. However, a study conducted in Nigeria showed that processing methods (i.e. mechanized, semi-mechanized and traditional) have significant effect on quality of oil [12]. In this study the FFA values obtained in oils ranged from 5.2 to 5.7 (% oleic acid) and these values were above the maximum standard of 5 % for palm oil [12]. This implies that the palm oils produced from both fruit types were likely to go rancid, irrespective of the extraction equipment used.

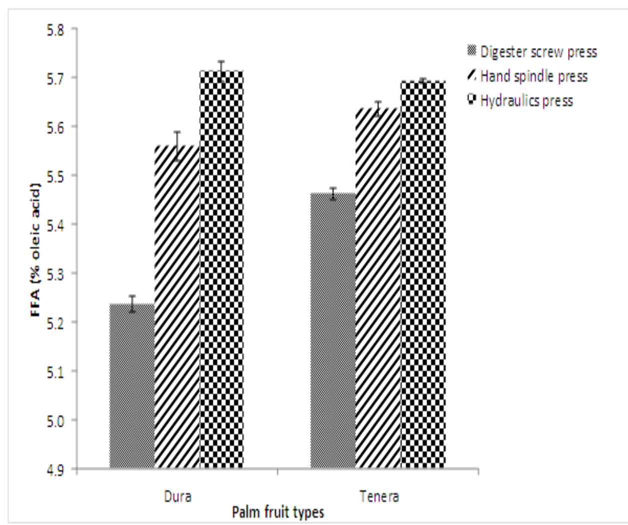

***Figure 3:** Free fatty acid for palm oil produced from Dura and Tenera palm fruits, using three different types of presses.*

3.4 Peroxide Value (PV)

The peroxide values for the oils extracted from the two palm fruit types ranged from 0.71 to 1.06 meq/kg, which were actually lower than the standard value of 10 meq/kg [13]. Peroxide values from the study showed significant differences ($p < 0.05$) for both fruit types and extraction equipment (Figure 4). This effect from both fruit types and the extraction equipment might be due to oxidation in the oils leading to the formation of hydroperoxides from light or heat and metal catalysis [12]. The metals (eg. iron) could probably come from the digester machines and the expression equipment used at the various milling sites.

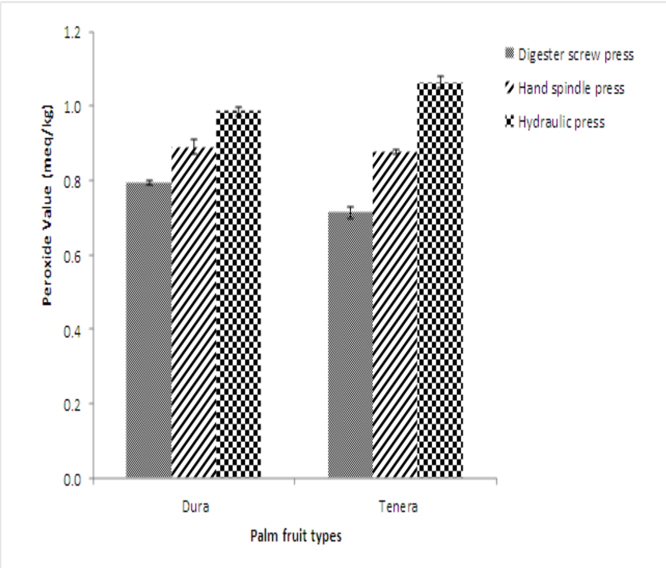

Figure 4: *Peroxide Values for palm oils produced from Dura and Tenera palm fruits, using three different types of presses*

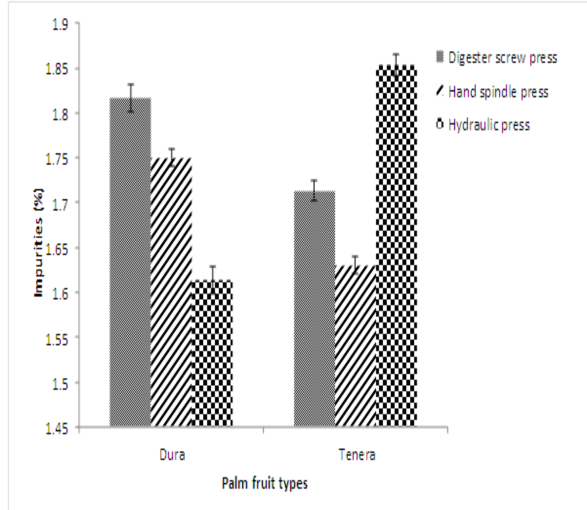

Figure 5: *Levels of Impurities in palm oil produced from Dura and Tenera palm fruits, using three different types of presses.*

Furthermore, the oils were not well cooled before bottling and this might result in steam being collected at the inner top of the container. The steam then condensed latter to increase the moisture content of the oils. Hence, variation in peroxide values could be due to the number of unsaturated fatty acid content, in view of the fact that rate of autoxidation of oils increases with increasing level of unsaturation. Therefore, the oils produced from both fruit types and equipment was of high quality and stable. The low peroxide values of the oils indicated that induction of the oil has just started. However, the high moisture content of the oils (0.22 % - 0.41 %) could affect the quality of oils. These values were higher than the Ghana Standard Authority specification and that of Codex Alimentarius standard (1992) of 0.25 %. This clearly suggests that the extracted oils would have a shorter shelf life and more liable to rancidity. In addition, peroxide value is a function of processing methods, storage conditions, packaging and high water content of oil resulting in the formation of peroxide [8, 14].

3.5 Impurities

Generally, the level of impurities in palm oils ranged from 1.61 % - 1.85 % which were higher than the specification of 0.25 % from both Codex Alimentarius (1992) and Ghana Standard Board. Hence, the palm oils produced were of poor standard. There was a significant increase ($p < 0.05$) in the impurities from palm oils for both palm fruit types and extraction equipment (Figure 5). These increases might have resulted from dirts from palm fruit bunches, overcooking of fruits which lead to nut softening and subsequent breakdown of nuts during digestion and broken fibers. In the case of oil produced from Dura fruits, the digester screw press machine had higher impurities compared to hand spindle press and hydraulics press machines.

Studies conducted in Ghana and Nigeria eluded to the fact that over-heating of palm fruits, and breakdown of fibers contributed to the level of impurities in palm oils [3, 15].The differences in impurities might probably be due to the different storage sites (cramers) for the fruits since the storage floors in almost all the palm oil milling sites are not cemented. Furthermore, the dead empty spikelets and the over - heating of fruits which soften the kernel nuts, hence the breakdown of nuts during digestion operation. Besides, poor oil clarification operation could contribute to the high level of impurities in oils as small plastic bowls were used to fetch the oils. In the process there was agitation of the oils which could introduce settled impurities into the oils. Interestingly, when the stored oils are transferred from their containers into other holders for a day or more a lot of dirt were observed to settle at the bottom of the containers. Hence, the final volume of oil yields could be affected leading to the poor quality of the oils produced.

3.6 Colour measurements

Table 1 shows the L*, a* and b* values of palm oils produced from Dura and Tenera fruit types using different extraction equipment which differed significantly ($p < 0.05$). The results indicated that the colour of palm oils produced from Tenera fruits showed slightly higher lightness (L* = 40.82) and yellowness (b* = 25.33) compared to Dura (L* = 38.10 and b* = 20.19). However, the redness in palm oils produced from Dura fruits (a* = 12.14) was relatively higher than oils from Tenera fruits (a* = 11.67). This effect in colour of oil might be due to the lower concentration of carotenoid contents in Tenera palm fruits. Palm oil from Dura palm fruits has been shown to have a higher concentration of carotenoids (997 ppm) than palm oil from Tenera (673 ppm) [5, 9].

***Table 1**: Palm fruit types on colour of palm oil*

Palm fruits types	Extraction Equipment	Colour		
		L*	a*	b*
Dura	Digester screw press	38.10 (± .12)*	12.14(± .06)**	20.19(± 13)**
	Hand spindle press	38.92(± .11)*	11.74(± .03)*	21.37(± 38)*
	Hydraulic press	38.30(± .04)*	12.32(± .15)**	20.27(± 20)**
Tenera	Digester screw press	40.82(± 10)**	11.67(± .13)*	25.33(± 73)**
	Hand spindle press	40.70(± 04)**	11.20(± .02)*	24.13(± 7)**
	Hydraulic press	40.79(± .04)**	12.74(± .02)*	24.76(± 21)**

Figures in brackets are standard deviations (n= 36). Means with single asterisk in the same column are significantly different ($P < 0.05$). While means with double asterisks in the same column are not significantly different ($p < 0.05$) L*= Lightness of palm oil, a* = Redness of palm oil, b*=Yellowness of palm oil

4. Conclusion

Wide variations exist in oil yields from (Dura and Tenera) fruits. Oil yield using the three extraction equipment (the digester screw, hand spindle and hydraulic presses) also varied. The Tenera type of oil palm produces more than twice the quantity of oil yield as compared to that of the Dura type. This was due to the thick mesocarp of Tenera fruit type compared to Dura fruit type. Averagely, oil yield produced from both fruit types using digester screw press was relatively higher than those of the hand spindle press and hydraulic press. The FFA values obtained for oils produced from the extraction equipment for both Dura and Tenera fruit types were above the CODEX standard of 5.0 %. Furthermore, significant differences were also recorded in both moisture contents and impurities for oil produced from both fruit types as well as the extraction equipment. Peroxide, iodine and saponification values recorded for oils produced were low and within the accepted CODEX standard.

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