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Influence of Duration of Heat Treatment and Screen Pore Sizes on Palm Oil Yield and Quality

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ABSTRACT

Palm Oil was extracted by boiling and digesting the Oil Palm fruits, pressing the mash and finally clarifying the pulp extract by heating. This study aimed at investigating how duration of boiling Oil Palm fruits, screen pore sizes and pulp extract heating influence yield and quality of manually extracted Palm oil. The yield of crude oil increased with increase of duration of boiling of fruits from 25 to 50 minutes and press pore size of 3 to 6 mm, followed by a drop in the yield as the duration of boiling was increased from 75 and 100 minutes. Similarly, there was a drop in oil yield as the pore size was increased to 9 and 12 mm. The quality of clarified oil increased as duration of boiling increased from 5 to 25 minutes. The maximum crude oil yield was achieved at 50 minutes of boiling the fruits and screen pore diameter of 6 mm; while optimum clarification was achieved when the pulp extract was heated for 25 minutes. Therefore, it is appropriate to boil Oil Palm fruits for 50 minutes, use press cages of 6 mm pore diameter and heat pulp extract for 25 minutes for optimum extraction and clarification of Palm oil. A control experiment was conducted where oil was extracted using Hexane solvent; the oil yield was 23.2 % of weight of fruits and the density of the extracted oil were 0.812 grams per cubic centimeter. The results of the study will be useful when designing the equipment and system for processing Palm Oil since there is some data on the press pore size, duration of boiling fruits and pulp extract that give optimum yield. The study has also given some data on palm oil extraction rates that can be used to assess performance of either palm oil processing equipment or a system.

Key words: Crude oil, oil extraction, clarification, boiling, efficiency

INTRODUCTION

Palm oil is edible plant oil derived from the mesocarp and kernels of the oil palm *Elaeisguineensis*. The Palm Oil is widely used for cooking, as an ingredient in margarine, and as a component of many processed foods. It is also an important component of many soaps, washing powders and personal care products, it is used to treat wounds, and also as a feedstock for production of bio-fuel [2], [11]. According to Hamburg based oil world trade journal, Palm oil is the second world's major oil after Soya beans oil. The Oil Palm is of economic value in many countries, for example, in Papua New Guinea (PNG), Oil palm is a major cash crop. The crop is the major driver of rural development in the four provinces where it is grown [9].

Kenya's domestic production of edible oils covers about 30% of its annual demand, estimated at around 380,000 metric tonnes. The rest is imported at a cost of about US$140 million a year, making edible oil the country's second most important import after petroleum. The Palm Oil constitutes 95% of edible oil imports to Kenya [6]. The country has tried to alleviate the deficit of edible oils by encouraging domestic production of Oil Palm. Since 1993 a new hybrid variety of Cold-Tolerant Oil Palm (CTOP), high-yielding Oil Palm was promoted by the Food and Agriculture Organization (FAO) of the United Nations in Western Kenya [12]. Since the inception of the CTOP project in Kenya over 100,000 Oil Palm trees have been planted by small holder farmers in Western Province of Kenya [4]. Oil Palm trees take 3 years after planting to start bearing fruits. Therefore, the trees that were planted from 1993 to 2009 are already bearing fruits. Hence the farmers require an appropriate technology for processing Palm Oil.

The Ministry of Agriculture (MOA) carried out studies which revealed that most farmers have between 5 and 50 oil palm plants [3]. These farmers use Pestle/Mortar and some imported motorized processors to extract oil from the Oil Palm fruit. The access to the motorized processors by the farmers is limited because the growers are dispersed over a large geographical area. Therefore, the predominant method of extraction of the oil is by pounding the fruits after boiling followed by washing pounded fruit mash in warm water and hand squeezing the mash to separate fibre and kernels from the oil/water mixture. Clarification of the oil is achieved by boiling the pulp extract. Field surveys carried out in Mumias district by Bukura Agricultural Technology Development Centre (BATDC) have shown that an average of 0.75 litres of oil is extracted per man hour. The farmers extract one litre of crude oil from 7 to 8 kilograms of Oil Palm fruits.

A mature Oil Palm tree yields between 8 -12 bunches per year and each bunch weighs approximately 15-25 kgs. The documented extraction rates of oil from Oil Palm fruits using efficient machines is 23- 24 percent of the bunch by weight [1]. The major challenges of the Palm Oil processing in Kenya are extraction and clarification of the oil. The technologies in use are time consuming, in hygienic and of low efficiency. However, little has been done to come up with appropriate Palm Oil processing technologies. In order to develop Palm Oil processing technology with high output, efficiency and hygienic, it is important to understand how processing parameters would influence such process characteristics as oil yield and quality.

Specific Objectives

- Determine the influence of duration of boiling Oil Palm fruits on crude Palm Oil extraction.
- Determine the influence of press pore sizes on crude Palm Oil yield from boiled and mashed fruits.
- Determine the influence of duration of heating Oil Palm fruit extract on the oil clarification.

MATERIALS AND MEHODS

The primary data was collected from the four experiments conducted at Masinde Muliro University (MMUST) chemistry Laboratory and Mechanical Engineering workshop. MMUST is situated in Kakamega Town of Kakamega Central District, Kakamega County, Kenya. The geographical location of Kakamega Town is; 0° 17' 1" North, 34° 44' 58" East.

In the study full factorial experimental design was used. The three factors namely; press pore sizes, duration of boiling fruits, and duration of heating pulp extract were tested at four levels. Three specimens were prepared for each of the factor level combinations, yielding three replications of a complete 43 factorial experiment.

Materials and Apparatus

The following apparatus and materials were used in the experiments; perforated cylindrical cage presses, measuring cylinders, hexane solvent, thermometer, sauce pans with covers, tape measure, Wooden Pestle and mortar, Stop watch, jars beakers, Matchet, Stainless Steel basins, vials, Refrigerator, Oven and mature ripe Oil Palm (harvested at 20 WAA). Figures [1-4] show some of the materials and equipment used.

Fig. 1 Mature threshed Oil Palm fruits

Fig. 2 Digital Balance used for weighing Oil Palm fruits

Fig. 3 Rotary Evaporator set for recovering Hexane from Palm Oil

Fig. 4 Separation funnel set to remove solid impurities from clarified Palm Oil

Preparation of the Fruits

Randomly selected mature bunches of fresh Oil Palm fruits of Tenera type were harvested from Alupe –KARI Substation farm in Chakol Division, Teso South District, of Busia County within Agro Ecological zone Lower Midland 1(LM1). Bunches were stripped off fruits using machetes, followed by manual sorting of the threshed fruits; the damaged and rotten fruits were removed. The sorted fruits were washed three times using clean water at 35-400 C. All the stains, loose parts and foreign materials on the surface of the fruits were removed. Fig. 5 shows a mature Oil Palm fruit bunch.

Fabrication of the Pressing Cages

A mild steel metal sheet of 3 mm thickness was cut into four pieces of dimensions 47cm by 40 cm. Holes of 3, 6, 9, and 12 mm diameter were drilled in the sheets at a spacing of 25 mm square. The number of holes per square metre was 1600. The drilled sheets were rolled into a cylindrical cage of diameter 15cm. Pieces of drilled sheets of diameter equal to the diameter of the cylindrical cages were welded at the base of each cage. The cages were fitted with suitable cylindrical pistons made from 5mm thick mild steel metal. Each of the pistons was fixed on a screw shaft well secured at the top through a nut welded on a support frame bracket. The cylindrical cages were fixed on 20mm square channels leaving 15 cm space at the bottom to facilitate collection of the pulp extract. Fig. 6-9, shows pattern of holes drilled through the plates used to fabricate press cages. The fully assembled press cage is shown in Fig. 10.

Fig. 5 Mature ripe Oil Palm Bunch

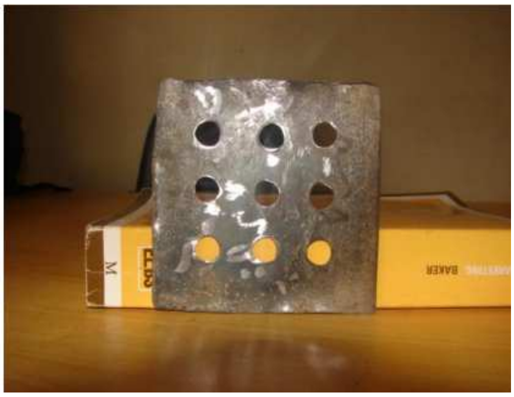

Fig. 6 The 12 mm diameter holes

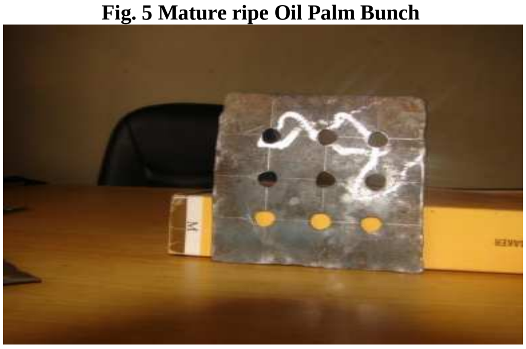

Fig. 7 The 9 mm diameter holes

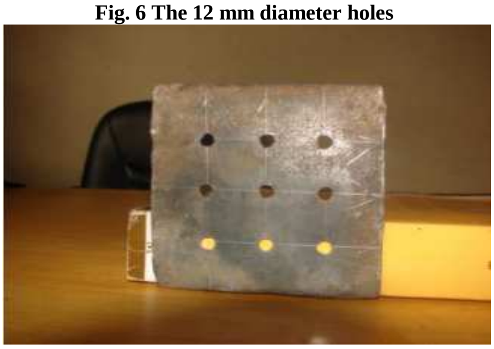

Fig. 8 The 6 mm diameter holes

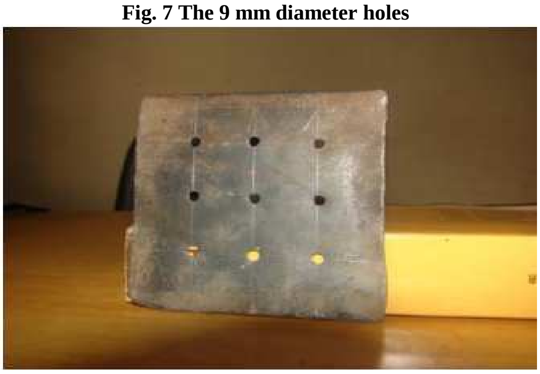

Fig. 9 The 3 mm diameter holes

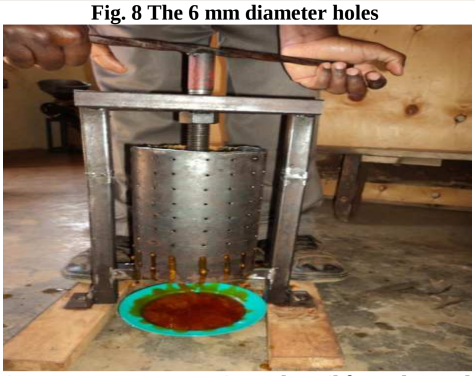

Fig. 10 Press cage extracting Palm Oil from the mash

EXPERIMENT SET UP

The experiments were carried out to investigate the influence of duration of Oil Palm fruits boiling and press pore size on oil yield; the influence of heating Oil Palm fruit extract on oil clarification. Finally a control experiment was carried out by extracting Palm oil using hexane solvent.

Fig. 11 Oil Palm fruits boiling before pounding

Fig. 12 Samples of clarified oil in Vials ready for quality analysis

Fig. 13 A column of mechanically extracted oil showing clarified Palm Oil at the top and water soluble impurities at the bottom

Fig. 14 A sample of Hexane extracted Palm Oil

Influence of Duration of Fruits Boiling and Press Pore Size on Oil Yield

After cleaning the fruits, four samples of one kilogram each were taken from the bulk, put in pan, added two litres of water and boiled at temperature of 95° C to 96°C for 25, 50 , 75 and 100 minutes. Each of the samples was removed from the pan at the end of the boiling period and immediately transferred to a wooden mortar where they were pounded with 500 regular strokes using a 0.26 Kg wooden pestle from a height of 0.5 metres. The resulting mash was transferred to perforated cylindrical press cages, and then evenly spread out. The mash was pressed by moving the piston screw through a distance of 6 cm. The piston was left in the position for 5 minutes to allow the extract drain on the receiver plate by gravity. The pulp extract from each trial was collected and weight determined using an electronic balance. This procedure was repeated three times for different durations of boiling and cages of different pore sizes. Fig. 10 shows the press cage piston fully pressed to extract oil.

Influence of heating Oil Palm fruit extract on oil clarification

The Oil Palm pulp extract described above was used in this experiment. Water was boiled to 95°C -96°C and mixed with the extract in the ratio of 1:5 and the mixtures were heated for 5, 15, 25 and 35 min. The mixtures were left to cool to between 35°C-40°C then transferred to a clear glass separation funnel. The mixture was left undisturbed for 10 minutes to allow the various components segregate. The water and visible impurities were drained from the funnel after settling at the bottom. The remaining oil was thoroughly mixed by shaking and samples of 10 mls each taken in glass vials shown in Fig. 12 and stored in a fridge at 10°C. Later the 64 specimens were removed from the fridge warmed to temperature range between 35°C - 40°C. The mass of empty vial and the weight of the vial plus the oil were determined. The difference in weight for all the samples was recorded in Table -1.

Extraction of Palm Oil using Hexane Solvent

The fruits prepared as described above and then a sample of one kilogram of the fruits was taken from the bulk. The mesocarp of the fruits was peeled off the kernel using knives. The peels weight was determined and recorded. Then the peels were pounded in a clay mortar using 500 pestle strokes. The resulting mash was transferred to a glass bowl and evenly spread to cover the entire base. Hexane solvent was added until a layer of about one centimeter formed above the mash. The bowel was then stored for 24 hours. After 24 hours the extract was drained and put in a rotary evaporator shown in Fig. 2 where the hexane was recovered. The extracted oil was transferred to an oven at a set temperature of 100°C for one hour. After the period, the oil was removed from the oven weighed and the weight recorded in Table -1.The procedure was repeated twice. The amount of oil extracted in the three trials was summed and results recorded.

Table -1 The Density of Clarified Palm Oil

Duration of Boiling pulp Extract (Minutes)	Press pore Diameter (mm)	Duration of boiling Oil palm fruits (minutes)			
		25	50	75	100
		Densities of clarified Palm Oil kg/m^3			
5	3	842	888	966	942
	6	854	896	938	936
	9	828	948	964	946
	12	844	968	992	938
15	3	840	896	928	928
	6	818	914	914	948
	9	910	914	954	920
	12	878	950	900	924
25	3	920	936	954	928
	6	808	968	980	896
	9	824	976	940	924
	12	834	988	932	902
35	3	832	892	928	912
	6	840	928	978	914
	9	800	962	950	896
	12	830	950	938	914

Table -2 Effect of Duration of Boiling Oil Palm Fruits on Crude Palm Oil Yield

No.	Duration of Boiling (Minutes)	Screen Diameter (mm)			
		3	6	9	12
1.	25	194	204	154	118
2.	50	221	224	223	212
3.	75	136	181	174	154
4.	100	156	182	190	142

RESULTS AND DISCUSSION

Computer software namely SPSS and MS-Excel was used to analyse the data.

Influence of Duration of Boiling Oil Palm Fruits on Crude Oil Yield

Four samples of Oil Palm fruits each weighing one kilogram were boiled for 25, 50, 75 and 100 minutes at about 95°C-96°C, while the digestion time was kept constant in all the four cases. The diameter of press cages used to extract oil at each level of boiling was varied four times i.e. 3, 6, 9 and 12 mm. The crude Palm Oil yield in each of the trials and the mean oil yield per duration of boiling or screen diameter are presented in Table -2.

The crude oil yield increased with the increase in duration of boiling the fruits. The increase in crude oil yield with increase in duration of boiling fruits could be attributed to more heat the fruits were exposed to as the duration of boiling increased. The increased exposure to heat leads to higher absorption of moisture by the fruits hence lowers the viscosity of the resulting paste after digestion. [8] Observed that heat treatment leads to oil readily flowing from the oil mash. The study further showed that there was increase in oil yield as the duration of boiling increased from 25 to 50 minutes, after 50 minutes of boiling the oil yield decreased as the time of boiling increased to 100 minutes. This could be as a result of the breaking of the fibres leaving the kernels loose to move. The rapid movement of fibres and kernels led to blocking of the press cage pores resulting to poor drainage of the oil as the duration of boiling increased. The second reason for reduced oil drainage as the duration of boiling fruits was increased beyond 50 minutes could be attributed to reduced void ratio during pressing. The reduced void is caused by fibres breaking hence the hard kernels surfaces come in contact with each other. The contact of kernel surfaces was likely to trap some oil in the fibres between the seeds, leading to reduced oil yield. The crude oil yield pattern with variation of duration of boiling fruits is presented in Figure 4.2.Generally boiling fruits for duration of 50 minutes recorded the highest oil yield across all pore sizes as shown in Table -2 and Fig. 15.

The results shown in Table -2 and Fig. 15 are further confirmed by t-test analysis that shows that the highest oil yield can be achieved when the duration of boiling fruits is between 25 and 50 minutes when using a screen of 6 mm pore diameter.

The trend shown in Fig. 15 is that after 75 minutes of boiling fruits there was no significant change in oil yield except for the pore diameter of 9 mm where there was increase in oil yield as the duration was increased from 75 minutes to 100 minutes. At 100 minutes of boiling fruits the oil yield by the 9mm diameter was the highest. This could be attributed to large pore facilitating good oil drainage. The mean oil extraction of 22.0 % achieved when the fruits were boiled for duration of 50 minutes compares well with the extraction rate of 23.2 % using Hexane solvent in the control experiment. Therefore, 50 minutes of boiling fruits can be considered as optimal duration of boiling Oil Palm fruits for extraction of the oil.

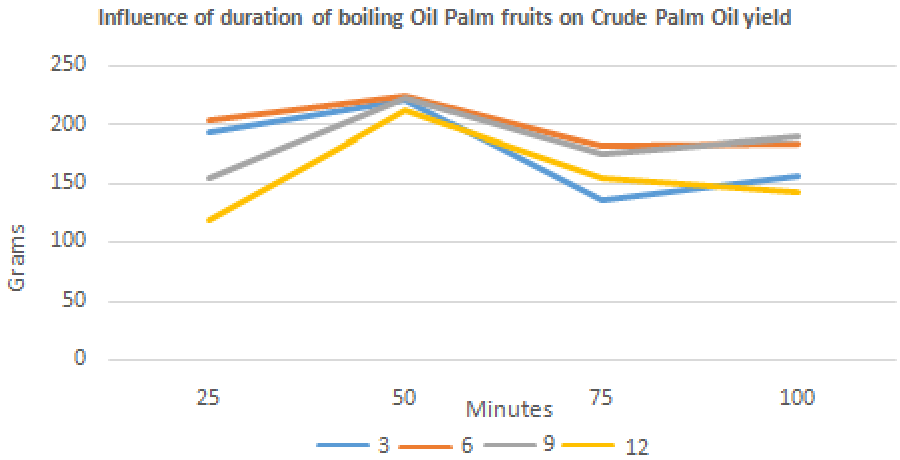

Fig. 15 Influence of duration of boiling Oil Palm fruits on Crude Palm Oil yield

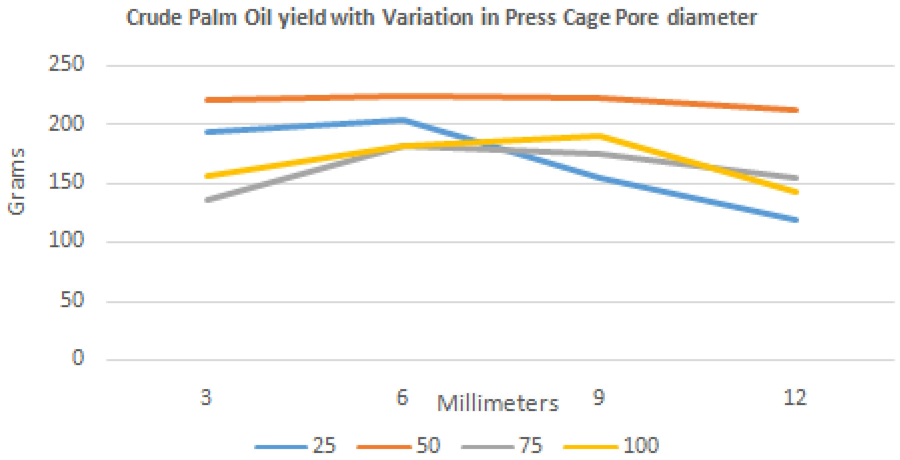

Fig. 16 Crude Palm Oil yield with Variation in Press Cage Pore diameter

Influence of Press Cage Pore Diameter on Crude Palm Oil Yield

The extraction of crude Palm Oil from the mash was done by use of perforated press cages of diameters 3, 6, 9 and 12 mm. The crude oil yield at various pore diameters is presented in Fig. 16. The crude oil yield increased as the press cage pore diameter increased from 3mm to 6mm but declined as the pore size increased from 6 mm to 12 mm. This could have been caused by kernels and fibres tending to pass through the bigger holes therefore, partially blocking the pores allowing only a limited quantity of oil out of the cage. While for the smaller holes the kernels remain on the surface of the holes allowing substantial amount of oil to go through the holes. The duration of boiling Oil Palm fruits is observed to have influence on oil yield per press pore size. Generally the 50 minutes of boiling recorded the highest oil yield across the various press pores sizes, but duration of 25 minutes recorded higher oil yield for smaller pore sizes than bigger pore sizes. These observations can be explained as follows: when fruits are boiled for 25 minutes the fibres remain attached to the kernels hence bigger spheres that remain at the surface of the large holes leading to better drainage of oil; while longer duration of boiling leads to reducing the kernels to the size of the press holes.

Therefore, under pressure the kernels block the holes as they tend to perfectly fit the diameter of the holes making the filter less porous. [7] Observed that the effect of pore size can be extended to the effect of porosity which increases permeability of fluids. This means that the means are not equal and thus varying the screen diameter affects the yield in crude palm oil.

Influence of Duration of Boiling Oil Palm Pulp Extract on Quality of Oil

Table -3 shows the mean densities of clarified Palm Oil at 5, 15, 25 and 35 minutes of heating pulp extract. The mean density of clarified Palm Oil for 25 minutes of pulp heating was between 913 and 934 kg/m^3 which fall within the range of Palm oil at 350°C i.e. 912 to 947 kg/m^3 [10].

The density of the clarified oil on average increased as the durations of clarification increased from 5 minutes to 25 minutes. The combined effect of boiling fruits and heating pulp extract on quality of clarified oil was more evident. It was observed that when the fruits were boiled for more than 50 minutes followed by heating the pulp extract for more than 15 minutes the density of the clarified oil at 35°C-37°C was generally greater than 910 kg/m^3. The results are close to the density of Palm Oil at 35°C i.e. 921 to 947 kg/m^3. [10] When the fruits were boiled for duration of less than 50 minutes followed by heating the pulp extract for less than 15 minutes the density was approximately 850 kg/m^3. The density range observed for the later case is approximately the density of semi solid Palm oil or crude Palm oil, which is 847 kg/m^3 at 35.8°C [10].The observations in the variation of densities as the duration of boiling fruits followed by the duration of heating the pulp extract could be caused by the soluble gums and resins getting dissolved in water due to good heat treatment as the duration of exposure to heat is increased. The converse is true at shorter duration of boiling fruits followed by shorter duration of pulp extract heating. The density of crude oil extracted using Hexane was 812 kg/m^3 at 35°C-37°C .The deviation of density of the oil extracted by Hexane solvent from either the density of crude Palm Oil or clarified Palm Oil is high. This may imply that Hexane extracts Palm oil and other substances from the mesocarp. The data of the quality of clarified oil in Table 4.6 is presented using bar graphs in Fig. 17 for comparison.

It was observed that when the duration of boiling fruits was in the range 50 to 75 minutes and the duration of heating pulp extract was varied from 15 to 25 minutes; the density of the extracted oil varied from 914 to 950 kg/m^3 at 35-37°C. The achieved density is close to the density of Palm Oil at 35°C. When the fruits were boiled for 100 minutes followed by clarification time of 5 minutes to 35 minutes; the densities of the clarified oil dropped from 940 kg/m^3 to 912kg/m^3 respectively. The variation may be as a result of the carotene being denatured due to prolonged exposure to heat treatment. According to [5] the difference in sterilization time contributes to the difference in the total loss in the palm oil whole extract, while the USDA, [13] "Palm oil is naturally reddish because it contains a high amount of beta-carotene but boiling it destroys the carotenoids".

Table -3 The Mean Densities of Clarified Palm Oil in kg/m^3

Time of heating pulp extract (Minutes)	Screen Pore Diameter (mm)			
	3	6	9	12
5	910	906	923	936
15	898	899	924	913
25	934	913	916	914
35	891	915	902	908

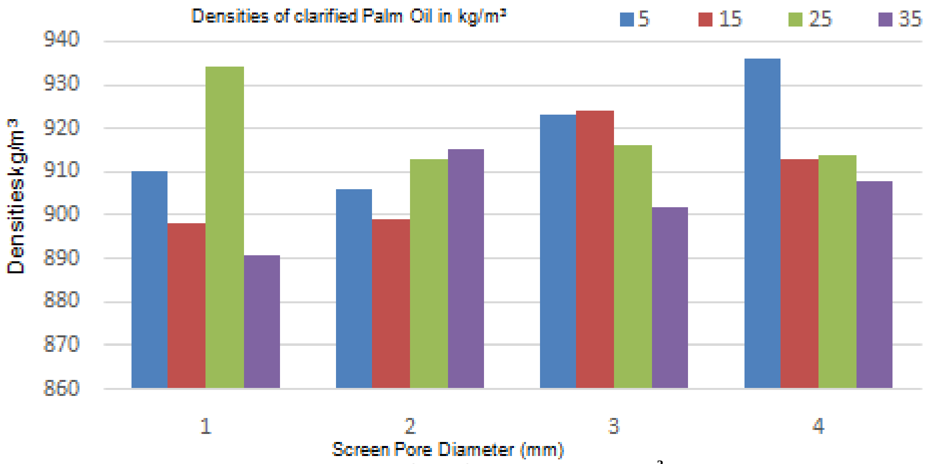

Fig. 17 Densities of clarified Palm Oil in kg/m^3

CONCLUSIONS

The study showed that the duration of boiling fruits influences the amount of crude oil yield and the increase in duration of boiling fruits led to increase in the oil yield up to 50 minutes of boiling fruits, after which there was decline in the oil yield. Increase in the press pore diameter led to increase in oil yield up to 6 mm diameter, beyond this size there was decline in oil yield from the mashed fruits. The increase of duration of heating Palm Oil pulp extracts up to about 25 minutes leds to increase in the quality of the oil extracted.

Recommendations

Filter pore diameter influences the separation of oil from the mash. Further studies should be done to ascertain the optimum number of holes per square meter for press cages used in clarifying Palm Oil. The use of heat treatment in softening the mesocarp before pounding is significant; therefore, further studies should be carried out to determine the optimum energy required for the unit operation. Optimum crude palm oil extraction using intermediate technology to be carried out by boiling oil Palm fruits for about 50 minutes press the pulp using cages of pore diameter of 6 mm and clarify the oil by heating the pulp extract for 15 to 25 minutes.

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