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# AN EXPERIMENTAL STUDY ON THE EFFICIENCY OF A PALM MESOCARP SEPARATION MACHINE

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## ABSTRACT

*A bench-top machine would be suitable for farmers to separate palm mesocarp from palm kernels on a small scale. The purpose of this study was to conduct an experimental investigation on the efficiency of such a machine for palm mesocarp separation from the palm kernels with the following operational steps: (1) developing a separation machine having a pressing force measurement by upgrading an existing palm mesocarp separation machine; (2) conducting an experiment to determine a suitable operating point; and (3) examining the efficiency of the newly developed separation machine and analysing the extracted palm oil properties. The results show that suitable weight loadings for the cases without heating, with steaming, and with roasting are 1000, 1500 and 1500 g, respectively, whereas the optimal pressing distance is 19 cm. Deterioration Bleachability Index (DOBI) of palm oil extracted from oil palm mesocarp in the cases of no heating, steaming and roasting are 2.99, 3.68 and 4.15, respectively. In addition, the free fatty acid (FFA) in the cases of no heating, steaming and roasting are 3.89%, 3.14% and 2.72%, respectively. Therefore, DOBI and FFA levels satisfy the standard requirements for DOBI is not less than 2.00 and for FFA is not more than 5.00%.*

**Keywords:** Oil palm, palm mesocarp, separation machine.

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## INTRODUCTION

Oil palm is an important economic plant that plays a significant role to the availability of vegetable oil for human consumption (Basiron, 2007; Lai *et al*., 2012). It is also the main raw material for producing biodiesel in Southeast Asia (Mukherjee and Sovacool, 2014; Purnomo *et al*., 2020). This economic plant provides income to farmers, large and small farms, and entrepreneurs in the palm oil industry, including the palm oil mills that extract the oil from the fruit (Corley and Tinker, 2008; Lai *et al*., 2012; Poku, 2002). The Thai government has continuously provided encouragement and support to this industry in many aspects, for instance by encouraging farmers to extend their plantation areas and to plant better oil palm varieties with increased yields. The government has also supported the entire cycle of research and development on various aspects related to palm oil production (Chaisongkram, 2019).

In addition, palm oil production technology has been developed further and upgraded, along with the encouragement to build low-cost small-scale palm oil mills in various communities, for small-scale production without the need for a large investment (Chaisongkram, 2019; Ekine and Onu, 2009; Ilechie *et al*., 2011; Poku, 2002). A high-technology palm oil pressing machine can be used to separate palm mesocarp from the palm kernels prior to oil pressing. Many studies have designed and implemented various devices to increase the efficiency of producing palm oil, for use in small-scale palm oil mills, or in community palm oil mills. For instance, Sopajarn and Thongwichean (2017) designed and built a centrifuge to separate palm mesocarp from palm kernels, especially from dropped loose fruit which is a palm fruit that separates from a palm bunch, without the need for steaming prior to this separation.

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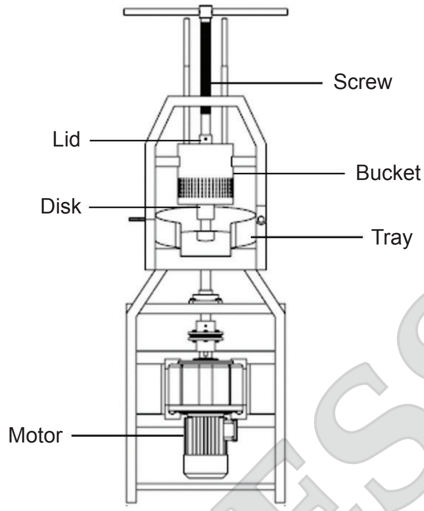
The centrifuge is able to efficiently separate fresh palm mesocarp from palm kernels, with a small amount of the palm kernels broken and some mesocarp leftovers after the separation. Similarly, Pukapak *et al.* (2015) also designed and built a stripping machine to separate palm kernels from oil palm fruit, functioning efficiently at 483 rounds/ min operating speed, and with a peak separation purity of 91.76%. Khalid and Shuib (2017) fabricated and tested the performance of oil palm loose fruits separating machines. It was found that the machine can separate the loose fruits from the trash effectively with 98.90 % cleanliness. Alam *et al.* (2020) developed a manually operated palm oil extraction machine to press the pulp of palm fruit to extract oil. Tamrin *et al.* (2020) designed and made prototypes of palm seed sorting machines. Okoko *et al.* (2017) designed, fabricated and tested a fragmentation unit to enhance palm kernel separation by a dry method, using a designed fragmentation unit. Onyekachi and Nwankwojike (2020) analysed and compared the potentials of recently developed indigenous dry process based palm kernel shell separation systems to select the best one for adoption by small scale processors in Nigeria. Simultaneously, Mueangdee (2012) designed and built a separation machine to divide palm mesocarp from palm kernels, and this machine has been optimised for small-scale farmers and community palm oil industry. It is able to entirely separate the mesocarp from palm kernels. However, the earlier versions of this machine are unable to measure the pressing force in the machine while it is operating.

Therefore, this study developed a palm mesocarp separation machine with force sensors by upgrading the existing device for separating palm mesocarp from palm kernels. The developed machine is able to measure the pressing force while it is functioning, so that a suitable force for separating the mesocarp from the palm kernels can be determined. The suitable force is the maximum force that can be applied on the upper disk to separate palm mesocarp from palm kernels based on the criteria of no broken palm kernels before finishing the process of separation.

## MATERIALS AND METHODS

### Materials

The materials used in this research were as follows: (1) A machine to separate mesocarp from palm kernels (Mueangdee, 2012; Mueangdee and Prasertsan, 2014; 2015), as shown in *Figure 1*; (2) Oil palm fruits of varieties Suratthani 1, Suratthani 2 and Suratthani 3, as shown in *Figure 2* in different shapes and colours. In addition to being physically different, Surathani 2 provides the highest annual fresh fruit branch yield of 22.6 t/ha when compared with Suratthani 121.5 t/ha and Suratthani 318.4 t/ha. Regarding the percentage of oil extraction rate Suratthani 1, 2 and 3 can provide 26%, 23% and 27%, respectively (Ministry of Agriculture and Cooperatives (2020); (3) Devices




Source: Mueangdee (2012); Mueangdee and Prasertsan (2014; 2015)

*Figure 1. Drawing of a bench-top machine for oil palm mesocarp separation.*


Source: Ministry of Agriculture and Cooperatives (2011; 2020)

*Figure 2. Palm fruit bunches of three varieties: (a) Suratthani 1, (b) Suratthani 2, and (c) Suratthani 3.*

for measuring distance, speed, force, weight, and time. The distance is measured by a metal ruler. The speed is measured by a digital tachometer. The force is measured by a load cell. The time is measured by a stopwatch; and (4) Devices for heating the palm fruit are an oven and a steamer.

**Methods**

There were four main stages in the study: (1) Developing a separation machine with runtime pressing force measurement. A machine for separating palm mesocarp from palm kernels, with pressing force measurement, was established by installing to the device a tool for measuring the distance between the upper disk surface and the lower one, as well as a sensor to record the force; (2) Setting up an optimised value. In order to look for a suitable operating point for separating mesocarp from palm kernels in the separation machine, equipped with a pressing force measurement, the following three steps were conducted *(Figure 3)*.

(I) Sampling of loose fruits from fruit bunches of three palm varieties, Suratthani 1, Suratthani 2 and Suratthani 3, for use in the experiments.
(II) Finding an appropriate weight for operation, by use of the implemented pressing force measurement.
(III) Finding an appropriate distance between the upper and lower disks;

(3) Test of the machine efficiency. The separation machine equipped with a pressing force measurement was tested at the operating point obtained in stage 2. The next step was to record the data on force, speed, distance between disks, duration, palm mesocarp weight, palm mesocarp percentage, weight of palm kernels, and palm kernels percentage. Further, analytical results were obtained on properties of the palm oil extracted from separated mesocarp for the palm varieties Suratthani 1, Suratthani 2 and Suratthani 3, along with three preconditioning methods before separation: (a) no heating; (b) steaming for 45 min; and (c) roasting at temperature of 100 for 120 min; and (4) Statistical analysis. Descriptive statistics (percentage, mean, and standard deviation) were assessed along with comparison of means by one-way analysis of variance. The indicated differences of means were confirmed by using Tukey's HSD test at significance requirement $p<0.05$.

## RESULTS AND DISCUSSION

**Developing the Separation Machine Equipped with a Pressing Measurement**

*Figure 4* shows a schematic of the machine with a pressing force measurement installed. The set-up has a tool for measuring the length in centimetres to observe the pressing distance between the upper and lower disk surfaces, and a load cell to measure the force.

**Experiments for Determining Optimal Operating Point to Separate Mesocarp from Palm Kernels**

The results to determine a suitable operating point comprised the following data: (1) The results for the three palm varieties with three alternative preconditioned states: Not heated, steamed, and roasted; (2) The results on proper weight loading for the palm fruit; and (3) The results on the distance between upper and lower disk surfaces.

***Experimental outcomes on separating mesocarp from palm kernels for the three palm varieties and the steamed preconditioning method.*** 1 kg of palm fruit for each variety was subjected to the separation and the results are summarised in *Table 1*.



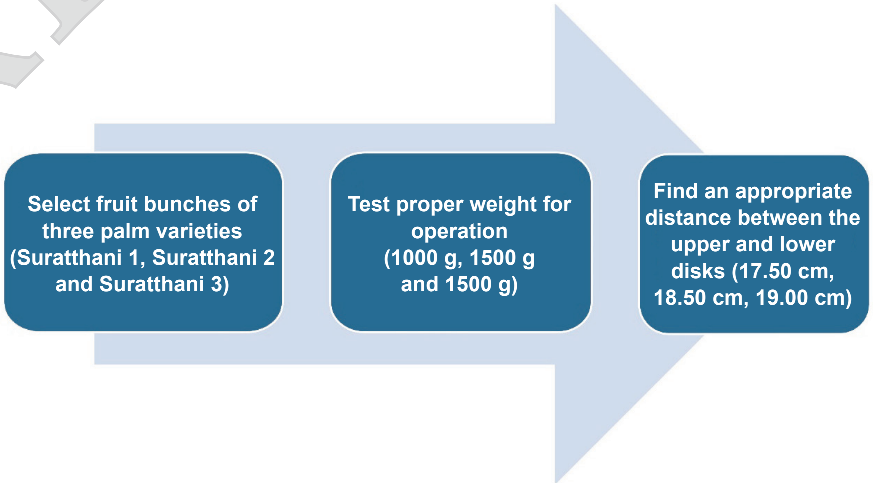



*Figure 3.* *Experimental setup and procedure.*

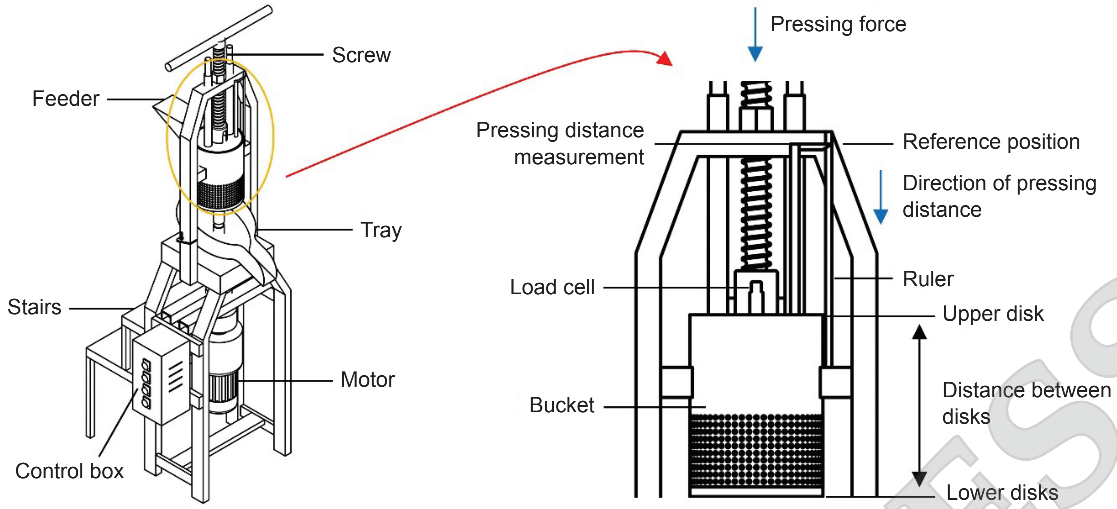



*Figure 4. Drawing of the machine equipped with pressing measurements.*

**TABLE 1. EXPERIMENTAL RESULTS FROM SEPARATING MESOCARP FROM PALM KERNELS FOR THREE VARIETIES, SURATTHANI 1, SURATTHANI 2 AND SURATTHANI 3**

| Experiment | Suratthani 1 | Suratthani 2 | Suratthani 3 |
|---|---|---|---|
| Force (N) | 1 882.88$^{b}$ 35.36 | 1 961.33$^{b}$ 19.61 | 1 719.43$^{a}$ 49.36 |
| Speed (RPM) | 9.89$^{b}$ 0.05 | 9.90$^{b}$ 0.03 | 9.80$^{a}$ 0.01 |
| Distance between disks (cm) | 2.23$^{a}$ 0.11 | 2.10$^{a}$ 0.10 | 2.23$^{a}$ 0.06 |
| Duration (min) | 1.35$^{a}$ 0.01 | 1.32$^{a}$ 0.01 | 1.33$^{a}$ 0.02 |
| Palm mesocarp weight (kg) | 0.63$^{ab}$ 0.01 | 0.64$^{b}$ 0.02 | 0.60$^{a}$ 0.01 |
| Palm mesocarp percentage | 69.90$^{a}$ 1.79 | 72.04$^{a}$ 2.94 | 68.07$^{a}$ 2.10 |
| Palm kernels weight (kg) | 0.27$^{a}$ 0.02 | 0.25$^{a}$ 0.03 | 0.28$^{a}$ 0.02 |
| Palm kernel percentage | 30.10$^{a}$ 1.79 | 27.96$^{a}$ 2.94 | 31.93$^{a}$ 2.10 |

Note: The values are given as mean ± standard deviation; different superscripts in the same row indicate significant differences ($p$<0.05) upon testing by using Tukey's HSD.

The palm fruits have no significant difference in mean force for Suratthani 1 and 2 varieties, yet Suratthani 3 has a significant difference in mean force. Moreover, the mean of revolving speed for Suratthani 3 differs from the others. The average percentages of palm mesocarp did not differ between the varieties. The analysis of palm mesocarp weight, separated from palm kernels, showed no difference between Suratthani 1 and 2 varieties or Suratthani 1 and 3 varieties. So, only Suratthani 1 is used in further experiments, as shown in *Table 1*. The final recovery of mesocarp and kernel based on starting mass of 1 kg has presented in *Table 1* and *Figure 5*. It can be clearly seen that mesocarp separation is a complete separation for the steaming precondition as shown in *Figure 5*.

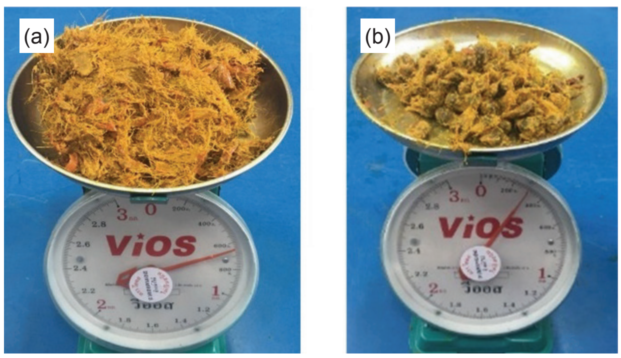



*Figure 5. The (a) separated mesocarp and (b) palm kernels for the steaming precondition.*

***Experimental outcomes for optimising the weight.*** From the experiments to look for the appropriate weight to use in separating palm mesocarp of Suratthani 1 variety from the palm kernels, without heating, or with steaming or roasting, the results reveal the proper weight loadings as 1000, 1500 and 1500 g, respectively, as shown in *Table 2*.

***The results on proper pressing distance.*** The results on separating Suratthani 1 palm mesocarp from palm kernels without heating, or with steaming or roasting, show that the proper pressing distance is 19.00 cm. The details are given in *Table 3*.

**The Experimental Results on Efficiency**

The outcomes on the separation of Suratthani 1 mesocarp from palm kernels without heating, or with steaming or roasting, using weight loadings of 1000, 1500 and 1500 g and the pressing distance of 19.00 cm reveal, as shown in *Table 4*, that the mean palm mesocarp fractions were at 56.59%, 70.31% and 55.72% while the palm kernels contributed 43.41%, 29.69% and 44.29%, respectively *(Figure 6)*. These figures are similar to the mean of mesocarp and the one of palm kernels obtained from the mesocarp separation from palm kernels without heating, or with steaming or roasting.

Upon subjecting the obtained mesocarp to palm oil extraction and conducting a palm oil quality analysis, it was found that the DOBI of palm oil without heating, or with steaming or roasting was 2.99, 3.68 and 4.15 ppm, while the FFA values were 3.89%, 3.14% and 2.72%, respectively. These are consistent with the set standards. The palm oil quality analysis was conducted under the standard of the test methods at Surat Thani Palm Oil Research Center, Field Crops Research Institute, Department of Agriculture, Thailand. The results are summarised in *Table 5*.

## CONCLUSION

The study improved and demonstrated an existing mesocarp separation machine by equipping it with measurement of pressing force, and of the distance between upper and lower disk surfaces. The improved machine was tested to find an appropriate operating point for separating mesocarp from palm kernels, with maximum efficiency of this separation. The suitable weight loadings for oil palm kernels without heating, steamed, or roasted, were 1000, 1500 and 1500 g, respectively, whereas the proper pressing distance was 19.00 cm. The optimised pressing distance



**TABLE 2. THE EXPERIMENTAL RESULTS ON LOOKING FOR PROPER WEIGHT IN THE SEPARATION OF MESOCARP FROM PALM KERNELS FOR SURATTHANI 1**

| Experiment | No heating | | | Steaming | | | Roasting | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 000 g | 1 300 g | 1 500 g | 1 000 g | 1 300 g | 1 500 g | 1 000 g | 1 300 g | 1 500 g |
| Force (N) | 4 560.00 | 5 099.46 | 7 433.44 | 1 892.68 | 3 314.65 | 3 550.01 | 2 402.63 | 3 706.91 | 4 530.67 |
| Distance between disks (cm) | 3.20 | 4.50 | 4.80 | 2.10 | 3.50 | 3.90 | 3.30 | 3.70 | 4.20 |
| Duration (min) | 3.02 | 3.42 | 4.31 | 1.36 | 1.54 | 2.19 | 2.05 | 2.52 | 3.40 |
| Palm mesocarp weight (g) | 570.00 | 654.90 | 747.50 | 640.00 | 711.25 | 961.95 | 490.00 | 622.55 | 822.10 |
| Palm mesocarp percentage | 57.58 | 54.65 | 54.91 | 71.91 | 63.47 | 74.60 | 54.44 | 51.52 | 60.28 |
| Palm kernels weight (g) | 420.00 | 543.45 | 613.85 | 250.00 | 409.35 | 327.45 | 410.00 | 585.80 | 541.65 |
| Palm kernel percentage | 42.42 | 45.35 | 45.09 | 28.09 | 36.53 | 25.40 | 45.56 | 48.48 | 39.72 |

**TABLE 3. THE RESULTS ON EFFECTS OF PRESSING DISTANCE ON THE SEPARATION OF SURATTHANI 1 PALM MESOCARP FROM PALM KERNELS FOR SURATTHANI 1**

| Pre-treatment | Pressing distance (cm) | Palm weight (g) | 1st experiment | | | | 2nd experiment | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Force (N) | Duration (min) | Palm mesocarp weight (g) | Palm mesocarp percentage | Force (N) | Duration (min) | Palm mesocarp weight (g) | Palm mesocarp percentage |
| No heating | 17.50 | 1 000 | 1 125.35 | 0.13 | - | - | 1 647.52 | 0.15 | - | - |
| | 18.50 | 1 000 | 2 922.38 | 2.10 | - | - | 2 671.27 | 2.25 | - | - |
| | 19.00 | 1 000 | 4 450.09 | 2.56 | 520.45 | 56.22 | 4 213.75 | 3.13 | 507.35 | 56.95 |
| Steaming | 17.50 | 1 500 | 1 157.18 | 0.27 | - | - | 1 206.22 | 0.25 | - | - |
| | 18.50 | 1 500 | 2 745.86 | 0.58 | - | - | 2 687.02 | 0.45 | - | - |
| | 19.00 | 1 500 | 3 138.13 | 1.49 | 864.35 | 70.97 | 3 089.09 | 2.05 | 910.45 | 69.65 |
| Roasting | 17.50 | 1 500 | 1 353.32 | 0.36 | - | - | 1 255.25 | 0.42 | - | - |
| | 18.50 | 1 500 | 3 012.71 | 1.54 | - | - | 3 138.13 | 2.15 | - | - |
| | 19.00 | 1 500 | 3 418.79 | 2.5 | 788.85 | 60.94 | 3 464.78 | 3.12 | 644.50 | 50.49 |

TABLE 4. EXPERIMENTAL RESULTS OF SEPARATING MESOCARP FROM PALM KERNELS BY USING THE DEVELOPED SEPARATION MACHINE FOR SURATTHANI 1

| Method | Pressing distance (cm) | Palm weight (g) | Force (N) | Duration (min) | Palm mesocarp | | Palm kernels | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Weight (g) | % | Weight (g) | % |
| No heating | | | | | | | | |
| 1st attempt | 19.00 | 1 000 | 4 450.09 | 2.56 | 520.45 | 56.22 | 405.35 | 43.78 |
| 2nd attempt | 19.00 | 1 000 | 4 213.75 | 3.13 | 507.35 | 56.95 | 383.55 | 43.05 |
| mean | 19.00 | 1 000 | 4 331.92 | 2.85 | 513.90 | 56.59 | 394.45 | 43.41 |
| Steaming | | | | | | | | |
| 1st attempt | 19.00 | 1 500 | 3 138.13 | 1.49 | 864.35 | 70.97 | 353.50 | 29.03 |
| 2nd attempt | 19.00 | 1 500 | 3 089.09 | 2.05 | 910.45 | 69.65 | 390.65 | 30.35 |
| mean | 19.00 | 1 500 | 3 113.61 | 1.77 | 887.4 | 70.31 | 372.08 | 29.69 |
| Roasting | | | | | | | | |
| 1st attempt | 19.00 | 1 500 | 3 418.79 | 2.50 | 788.85 | 60.94 | 505.55 | 39.06 |
| 2nd attempt | 19.00 | 1 500 | 3 464.78 | 3.12 | 644.50 | 50.49 | 632.05 | 49.51 |
| mean | 19.00 | 1 500 | 3 441.79 | 2.81 | 716.68 | 55.72 | 568.80 | 44.29 |

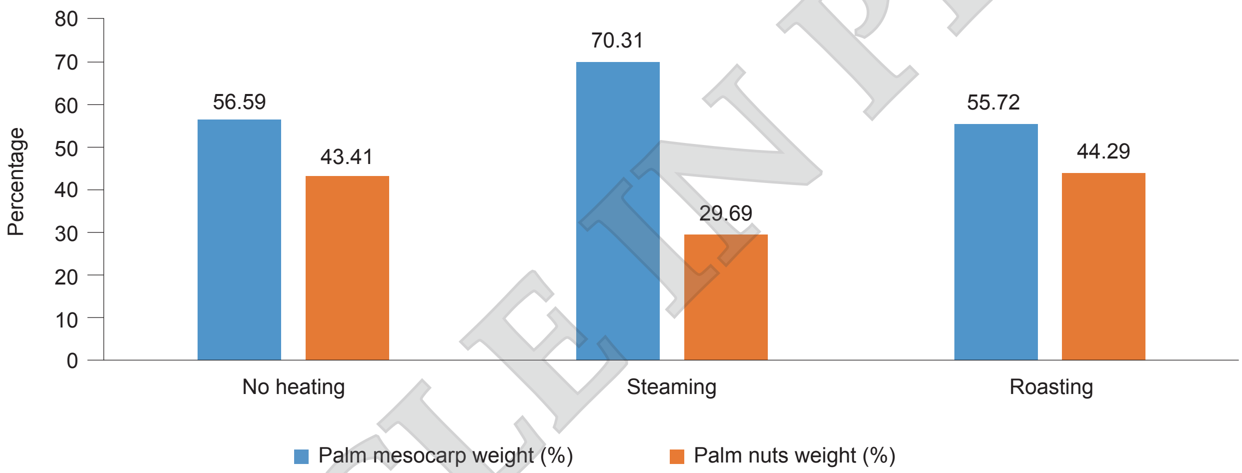



*Figure 6: The mean fractions of palm mesocarp and palm kernels.*

TABLE 5: RESULTS FORM THE QUALITY ANALYSIS OF PALM OIL EXTRACTED FROM MESOCARP, SEPARATED FROM PALM KERNELS BY THE DEVELOPED MACHINE FOR SURATTHANI 1

| Pre-treatment | DOBI (ppm) | Vitamin A (ppm) | FFA (%) | Moisture (%) |
|---|---|---|---|---|
| No heating | 2.99 | 895.04 | 3.89 | 3.23 |
| Steaming | 3.68 | 765.49 | 3.14 | 4.62 |
| Roasting | 4.15 | 779.66 | 2.72 | 1.40 |

Note: The set standard for DOBI is not less than 2.00 and for FFA it is not more than 5% (Johansson and Pehlergaard, 1976; Lai *et al.*, 2012).

produced the maximum amount of palm mesocarp without breaking the palm kernels. This distance is a key factor in increasing the production while reducing losses in the separation process. In addition, quality analysis of the extracted palm oil demonstrated values of DOBI, vitamin A, FFA and moisture being consistent with set standards: DOBI was not less than 2.00 ppm; vitamin A ranged within 500-1600 ppm; FFA was less than 5%; and moisture was less than 5%. Regarding future work for this research, attention could be drawn to the design for different shapes of upper disk surface for faster separation process with higher efficiency. In addition, The experiment of the separation machine with the palm farmers should be further explored in the future study.

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