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PERFORMANCE OF OIL PALM LOOSE FRUITS SEPARATING MACHINE

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ABSTRACT

Oil palm loose fruits contain a high amount of oil, hence they need to be fully collected. Handpicking may be the ideal way to get clean fruits but this practice is inefficient. Raking is a faster option to gather scattered fruits but the trash that comes together during the gathering process is high. The oil palm loose fruits separating machine offers a mean to separate loose fruits from trash using vibration and airstream principles. Parameters that were observed included productivity, time-motion, loose fruits cleanliness and noise levels produced by the machine. It was observed that the machine was able to separate the loose fruits from the trash effectively with 98.9% cleanliness and at the productivity of 30.6 kg of clean loose fruits in 99.9 s. However, the machine produced a sound level above 90 dB during operation, hence, the use of personal protective equipment (PPE) is required. With the introduction of separating machine, it is anticipated that the productivity of the current collection of loose fruits can be increased, hence, contribute to higher national oil extraction rate (OER).

Keywords: oil palm, loose fruits, separating machine.

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INTRODUCTION

A cost-effective loose fruits collection system remains a great challenge to oil palm estates. Several prototypes of loose fruits collecting machine have been developed, however the acceptance by the industry is still limited due to several reasons such as technical limitations as well as high cost. In 2012, Abd Rahim *et al*. (2012) developed a loose fruits collecting machine using vacuum suction concept. Although the productivity seems to be promising but the machine is yet to be commercially available. Therefore, despite the high percentage of debris, manual raking is still widely practiced. Referring to *Table 1*, the advantage of raking is in the speed of loose fruits recovery, particularly during periods extended harvesting rounds due to labour shortage (Amirshah and Hoong, 2003).

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Debris content in raking activity is around 30% (Amirshah and Hoong, 2003; Darius and Fairulnizam, 2014) and can be as high as 60% by weight (Ahmad *et al*., 1995). Hence, there is a need to get rid of the debris before the loose fruits are sent for processing. The goal of having clean loose fruits before sending them to the mill is to get a higher oil extraction rate (OER). A large amount of trash will affect the mill productivity, as trash will absorb oil, hence, resulting in the reduction of OER. Penalty will be given to the estate if a large quantity of trash is sent to the mill together with the loose fruits. However, with the new loose fruits collection system via the introduction of loose fruits separating machine, the high percentage of debris can be reduced to an acceptable level (*Figure 1*).

Separation of loose fruits from debris can be done at the field (mobile type) or centralised at the collection point (stationary type). Gemka (2017) has developed a machine for separating loose fruits from debris using a rotating drum with air blast system. With a 6 hp diesel engine, the machine was able to produce approximately 1.5 t hr^{-1} clean loose

TABLE 1. PRODUCTIVITY OF WORKERS WITH DIFFERENT LOOSE FRUITS COLLECTION SYSTEMS

	Hand picking*	Raking*	Machine**
Worker ratio (ha^{-1})	1:18	1:26	n.a.
Debris content	2.5%	30%	<15%
Productivity (ha day^{-1} team^{-1})	25	31	n.a.
Worker's output (kg man^{-1})	177	273	500

Source: *Amirshah and Hoong (2003); **Abd Rahim *et al*. (2012).

fruits. Ahmad Zamri and Mohd Zulfahmi (2017) invented a mobile type machine that utilised a layer of rotating drums with variable speeds to segregates debris from loose fruits with minimal damage.

With the separating machine, it is anticipated that the productivity of the current collection of loose fruits can be increased since the workers are now able to collect loose fruits without having to consider the amount of debris that they are picking up. Then the mixtures will be separated using the loose fruits separating machine.

MATERIALS AND METHODS

The Separating Machine

The separating machine used in this study is a mobile type hence, it can be moved from one place to another (*Figures 2* and *3*).

The separating process was done via two methods of separation: (1) vibrating tables, and (2) a blowing mechanism. The upper vibrating table, lower vibrating table and the twin fans were coupled directly to an engine via belts and pulley systems. General specifications of the machine are shown in *Table 2*.

During the operation, the operator pour the bags of loose fruits into the feeding compartment or the receiving hopper, and clean loose fruits will be collected at the end of the second vibrating table. The feeding compartment acts as a first separating mechanism throughout the separating processes by retaining materials larger than the loose fruits from going through the feeding compartment. The feeding compartment can be

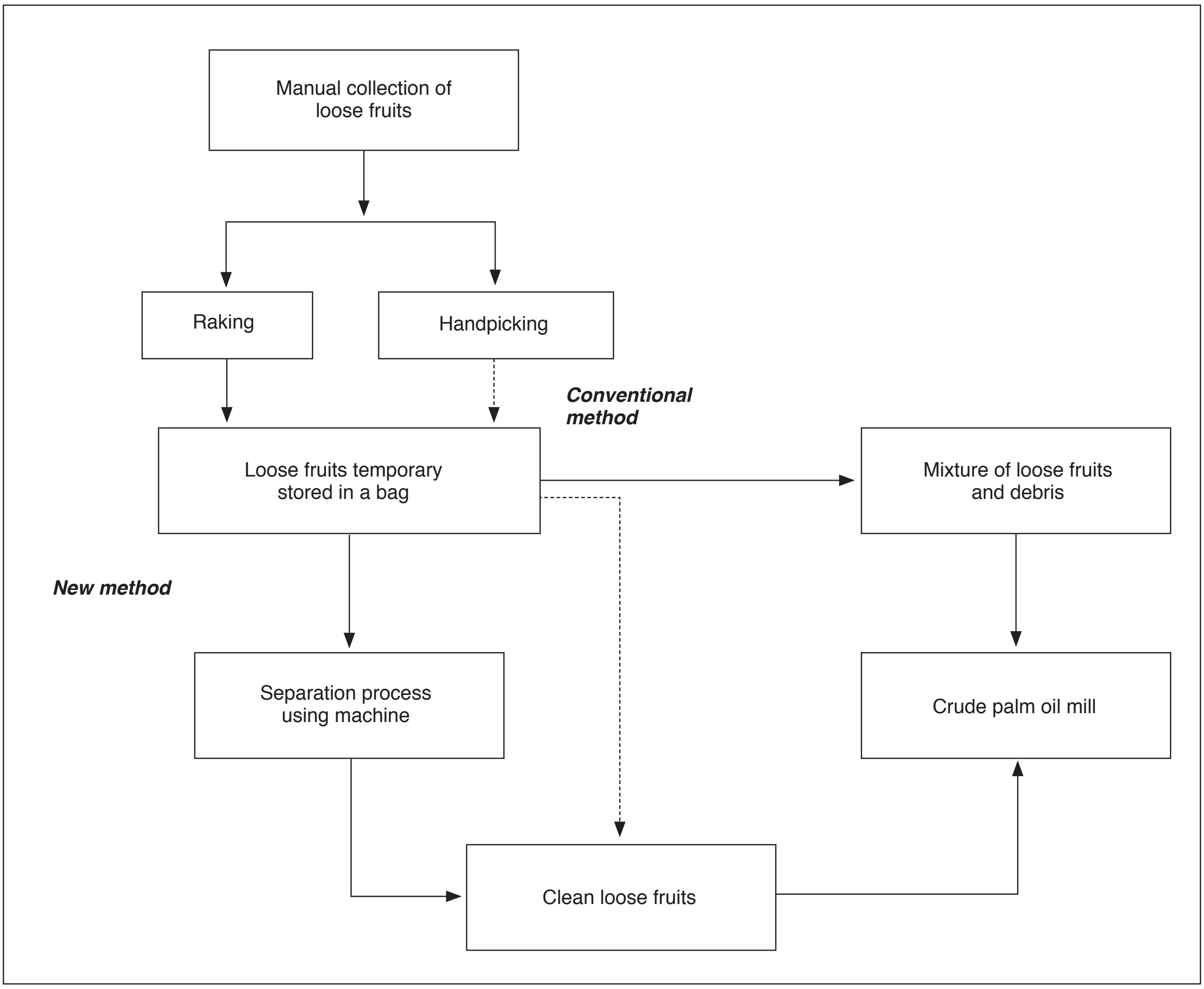

Figure 1. Flow chart of loose fruits collection system using conventional and new methods.

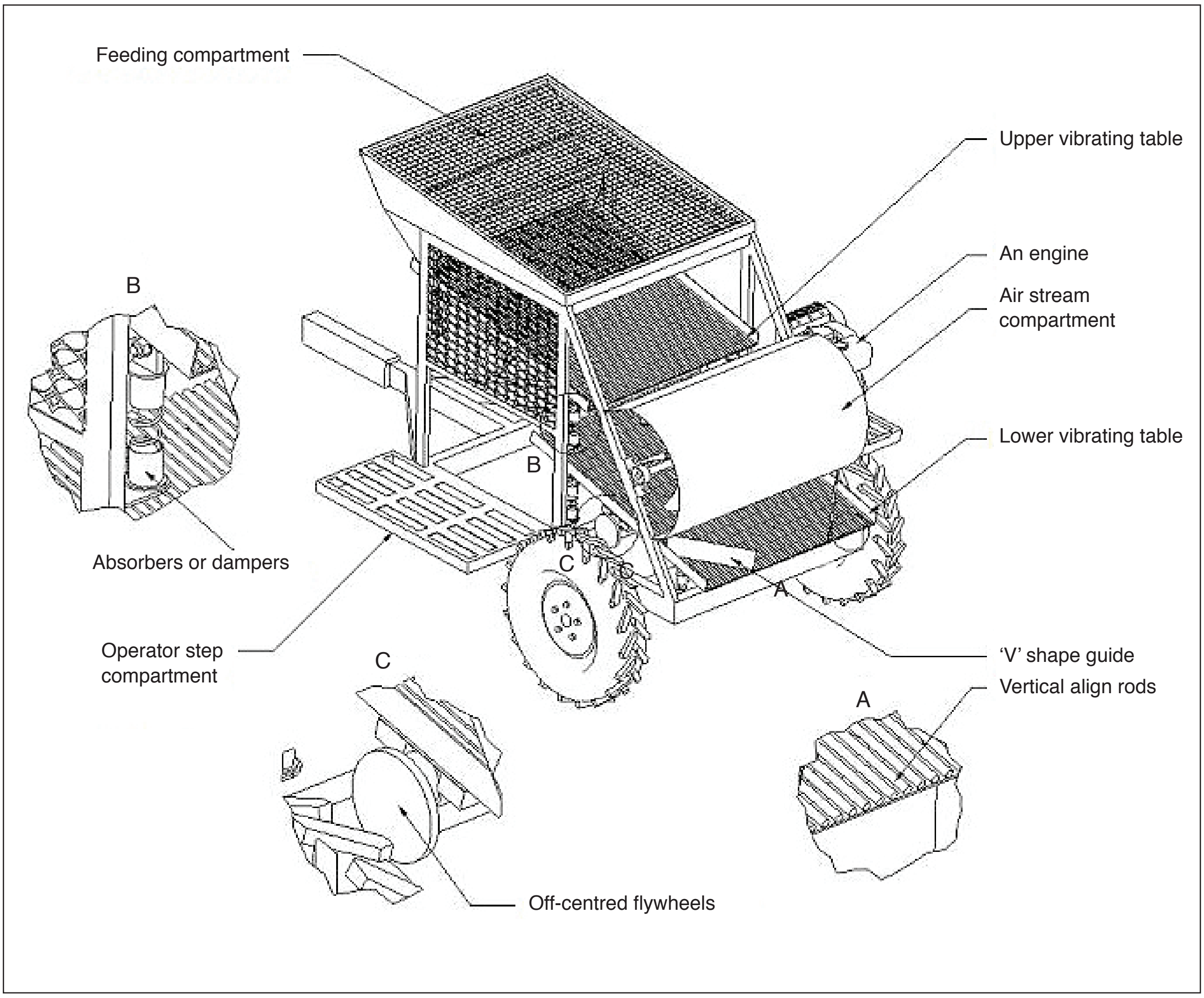

Figure 2. Isometric view of the loose fruits separating machine.

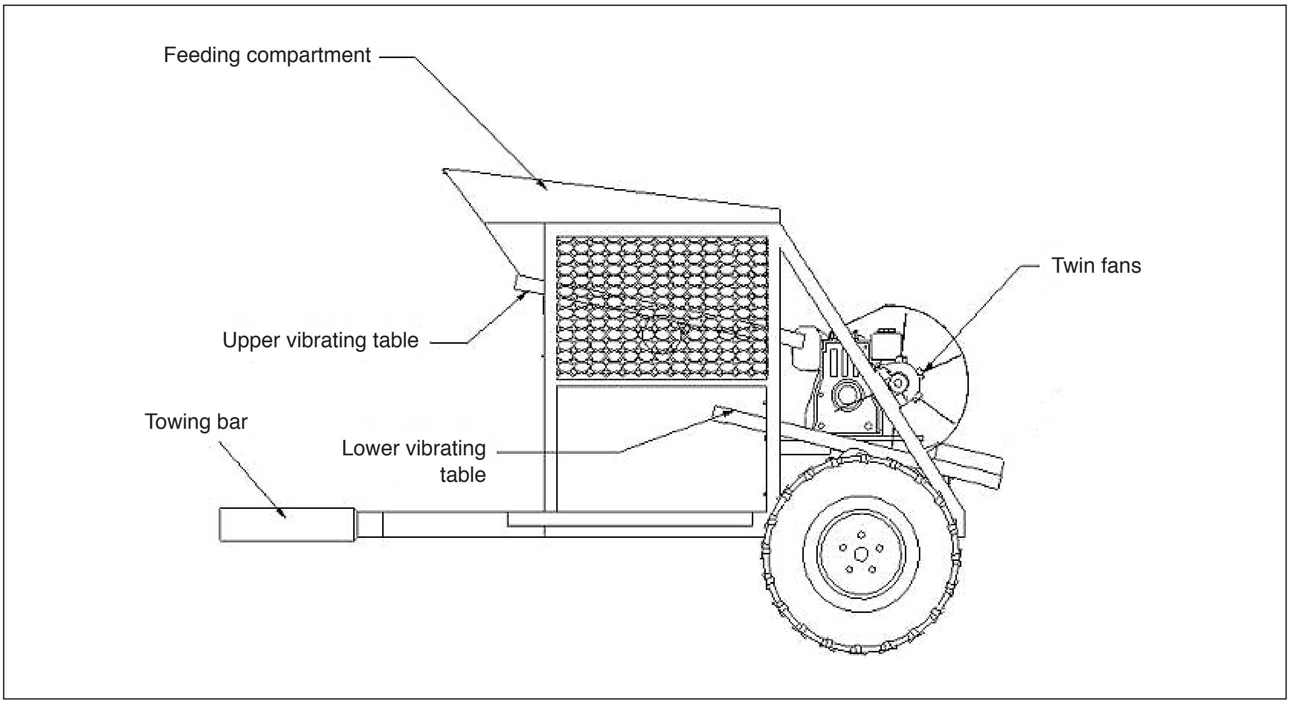

Figure 3. Side view of the loose fruits separating machine.

manually folded up to remove the stacked debris on it.

The upper and lower vibrating tables consist of parallel aligned rods that are designed in such a way as to allow the debris (smaller than the loose fruits) to fall down between the gap. The gap between the aligned rods is calculated based on the optimum size of the loose fruits. The high-velocity air stream is created by the twin fans to blow out the lighter materials such as dried leaflets, small stones, *etc.* directly between the upper and lower vibrating tables.

TABLE 2. SPECIFICATIONS OF THE OIL PALM LOOSE FRUITS SEPARATING MACHINE

Items	Specifications
Engine	6 hp air-cooled diesel
Overall dimension (mm)	2800 (L) x 1100 (W) x 1600 (H)
Dry weight (kg)	250
Fan	2 units axial fan (6 blades each)
Feeding capacity (kg)	30
Tyres	6.70 x 15

Productivity and Cleanliness

Collection of loose fruits was done manually using a raking and bag method. Bags of loose fruits were weighed before (W1) and after (W2) the cleaning process (*Table 3*). Time to complete the operation for each bag was taken (T1). After that, the remaining trash in the bag was manually removed and the bag was weighed again (W3). Three samples (bags) per day were collected randomly for three consecutive days. The trials were conducted during a sunny day (no rain occurred on the previous day). The speed of the engine was maintained at 1000 rpm during the separation process and the air velocity produced by the fan was at approximately 10 m s^{-1} at 1600 rpm.

Sound Level Measurement

The sound level test was conducted to ensure that the operators of this machine are not exposed to high noise levels during their working hours which may be hazardous in the long-term. Some noise level examples are 60 dB (normal conversation) to 120 dB (fire crackers). In general, sounds above 85 dB are unsafe, subjected to the period of the exposure. For this machine, a higher noise is expected due to the movement of the vibrating tables.

Initially, off-centred flywheel mechanism was used to create the vibrating movement of the vibrating beds, however, the vibration produced was not sufficient. Therefore, a crankshaft mechanism was used to replace the off-centred flywheel mechanism with the purpose of generating more vibration movement (*Figure 4*). The vibrating action was improved but it created too much noise as the metal parts brushed against each other during the rotation. To reduce the level of noise, one of the metals was replaced with a high-grade synthetic material (Teflon). Apart from using Teflon, other modifications were made such as dismantling the crankshaft at the second vibrating table and optimising the table angle, inclined at 16°-19°.

Measurement of noise levels was conducted in an open area (no obstacles within 10 m radius from the machine) using the Sound Level Meter (Brüel and Kjǽr: 2238 Mediator) at six different locations around the machine, before and after the modifications (*Figure 5*). Three readings were collected at a distance of 30 cm from each location. The accuracy of measurements was within ± 2 dB.

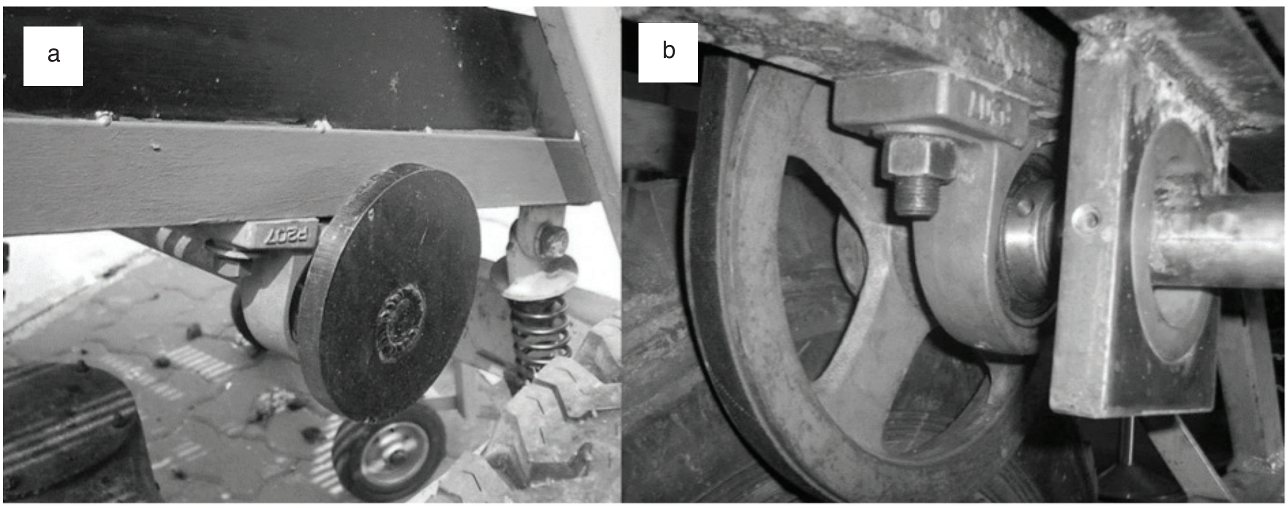

Figure 4. Vibrating mechanism was changed from (a) off-centred flywheel to (b) crankshaft system.

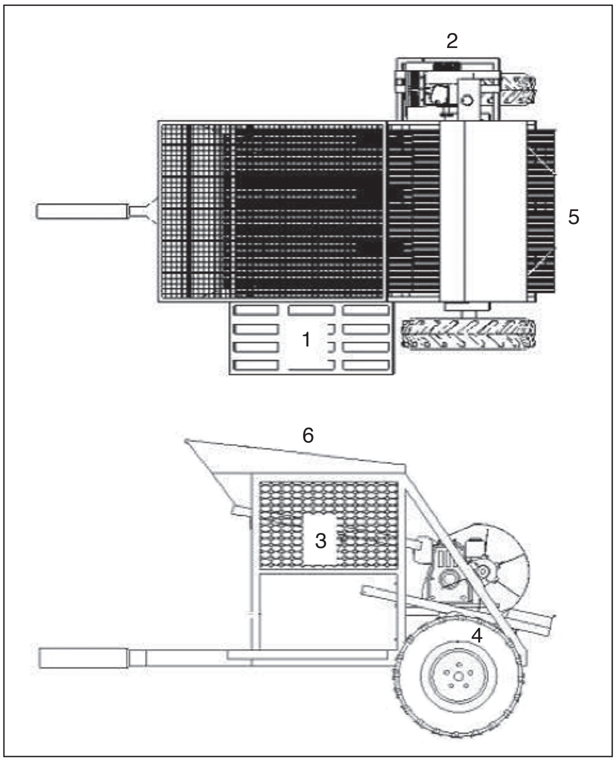

Figure 5. Points of sound level measurement.

Cost-effectiveness

Based on the productivity, the cost analysis was done to find the operating cost of the machine. The cost is calculated using the formula below:

Machine cost = total fixed costs (interest in capital, depreciation, tax) + total variable cost (fuel, repair and maintenance, labour)

Data Analysis

All the statistical analyses were performed using SAS package version 9.4.

RESULTS AND DISCUSSIONS

Productivity

Table 3 shows that the machine is able to separate an average of 3.4 kg of debris from 30.6 kg of loose fruits in an average time of 99.9 s. The table also shows that the average total of debris is 3.4 kg bag^{-1} or 11% debris weight per bag. This amount is much lower than what were reported by Amirshah and Hoong (2003); Darius and Fairulnizam (2014), *i.e.* 30% - 35%. The variations may be contributed by good estate management practices such as keeping a clean palm circles from vegetation. It reduces debris accumulation and avoid possibility of loose fruits from not being collected.

The study also indicates that the average remaining debris left after using the separator machine is 0.3 kg or 1.1%. Hence, this machine is capable of providing a cleanliness level of loose fruits at 98.9%. Most of the remaining debris were small stones with similar sizes to the loose fruits. With only 1.1% debris remained, comparatively it is better than manual picking method, which contained 2.5 % debris (Amirshah and Hoong, 2003). From the observation, the loose fruits damage or bruising is minimum as there is no contact between fan and loose fruits.

From this study, the machine is able to separate 30.6 kg of loose fruits in 99.9 s or an estimation of 1 t hr^{-1}. This productivity is gained by using a bag-to-bag method where the operator needs to pour one bag of loose fruits at one time. He had to step down and collect the clean loose fruits in the receiving bag and subequently place a new empty bag into its position before repeating the pouring process again. This method is time-consuming but is suitable to be used in the field at the fresh fruit bunches (FFB) or loose fruits collection point. The clean loose fruits in the bags can then be collected via mainline transportation direct to the mill.

Another alternative method is to place the machine permanently at a certain height from the ground (*e.g.* at the FFB collection ramp) in order to directly channel the clean loose fruits into a waiting lorry or a bin. This method is expected to give at least double output since the operator is able to continuously load the bags into the machine.

Sound Level Measurement

Table 4 shows the average level of noise created by the machine before and after the modifications. The average level of noise created by the machine before the modifications was 99.6 dB (A). The highest and the lowest noise level recorded were 102.0 dB (A) and 97.3 dB (A), respectively. The result indicates that the highest sound level is at position No. 4, which is at the second vibrating table. This is the area where the crankshaft is located to create the vibrating action.

After modifications, there was a significant difference ($p<0.05$) in the sound levels produced by the machine. The sound levels were reduced 8.4% compared to before the modifications. Referring to *Figure 5*, the highest noise value was 96.3 dB (A) that occurred at location No. 2 which is the engine. However, this value had decreased compared to before the modifications were made [101.8 dB (A)]. Noise at location No. 1, which is the place for the operator to stand during the operation was also reduced to 87.5 dB (A).

Recommendation of exposure limits by the National Institute for Occupational Safety and Health (NIOSH) are shown in *Table 5* (NIOSH, 1998). At the exposure of 91 dB (A) and without any protective equipment, the operator of the loose

TABLE 3. SUMMARY OF PRODUCTIVITY AND LOOSE FRUITS (LF) CLEANLINESS

(n=9)	Weight of LF sample, W_1 (kg)	Cleaning time, T_1 (s)	Weight of cleaned LF, W_2 (kg)	Weight of LF after manually cleaned, W_3 (kg)	Weight of debris, (kg)	
					by machine, W_1-W_2	by manual, W_2-W_3
Mean	30.6	99.9	27.2	26.9	3.4	0.3
SD	2.32	23.44	2.83	2.75	1.19	0.17

Note: W_1- weight of loose fruits before the cleaning process.
W_2 - weight of loose fruits after the cleaning process.
W_3 - weight of loose fruits after manually cleaning.
T_1 - time to complete cleaning process from one bag of loose fruits.

TABLE 4. SOUND LEVELS DURING OPERATION BEFORE AND AFTER MODIFICATIONS

Location	Mean, dB (A) (n=3)		Differences (%)
	Before	After	
1	98.5	87.5	- 11.2
2	101.8	96.3	- 5.4
3	99.6	94.8	- 4.8
4	102.0	89.8	- 12.0
5	97.3	88.8	- 8.7
6	98.2	90.3	- 8.0
Mean	99.6 ± 2.0	91.2 ± 3.5	- 8.4

TABLE 5. AVERAGE SOUND EXPOSURE LEVELS NEEDED TO REACH THE MAXIMUM ALLOWABLE DAILY DOSE OF 100%

Time to reach 100% noise dose	Exposure level per NIOSH REL
8 hr	85 dB (A)
4 hr	88 dB (A)
2 hr	91 dB (A)
60 min	94 dB (A)
30 min	97 dB (A)
15 min	100 dB (A)

Note: REL - recommended exposure limits.

fruits separating machine is only allowed to work for 2 hr per day to reduce the risk of damaging the hearing system.

For that reason, a protective equipment such as ear plug or ear muff should be provided to the operator due to high noise level to enable them to work at normal working hours and at the same ime protect their hearing and health. Under the Factories and Machinery (Noise Exposure) Regulation 1989, Part V, Regulation 17 (1) employers shall make approved hearing protectors available at no cost to all employees that exposed to noise greater than the permissible limits.

The source of the noise is mostly due to the vibrating mechanism, which is the crankshaft system. Although it produced sufficient vibration to the tables, however, the system created too much noise. *Table 6* shows the summary of the advantages and disadvantages of using different vibrating mechanisms.

Cost Analysis

The following parameters and assumptions were used in cost analysis of the machine as shown in *Table 7*.

With an estimation of machine output at 6 t loose fruits per day, the total operational cost for the machine for both type of usages (stationary and mobile) were calculated at RM 22.60 t^{-1} and RM 26.37 t^{-1}, respectively (*Table 8*). This additional cost can be justified with the extra payment received from the mill due to the higher OER. As discussed earlier, the productivity of oil palm loose fruits separating machine is also potential to be increased if used as a stationary type, hence, this should further lowering the operating cost.

CONCLUSION

The concept of debris separation from the loose fruits via a combination of double layer vibrating tables and high velocity of air is proven to be effective for separating loose fruits from debris.

However, several factors need to be considered in order to successfully recommend this machine to the oil palm industry. It was noted that the noise produced by the machine is considered high and may risk the health of the operator for long-term exposures. Safety precaution such as wearing earplug is recommended to reduce the risks. Other mechanisms to create the vibrating action also should be considered such as using an oscillating arm to change the rotation movement from the engine to the linear movement of the vibrating tables.

Along the project duration, comments from the industry were also noted and considered. The

TABLE 6. ADVANTAGES AND DISADVANTAGES BETWEEN USING OFF-CENTRED FLYWHEEL AND CRANKSHAFT SYSTEM

Off–centred flywheel system	Crankshaft system
Advantages	Advantages
1. No metal to metal contact hence less noise produced	1. Created more vibrating action
Disadvantages	Disadvantages
1. Created less vibrating action especially when large amount of loose fruits dumped on the vibrating bed	1. Crankshaft system created noise (above 90 dB)
2. Possibility of shaft bearing broken due to vibrations	2. Need to change the Teflon periodically as the Teflon worn out after 100 hr of operation
3. Extra weight to the machine	

TABLE 7. PARAMETERS USED IN THE COST ANALYSES OF THE OIL PALM LOOSE FRUITS SEPARATING MACHINE

Parameters	Remarks
Estimated initial cost	RM 15 000 without tractor RM 55 000 with tractor
Estimated operating hours (hr yr^{-1})	1 800
Working hours (day^{-1})	6
Total economic life (hr)	9 000
Economic life (yr)	5
Salvage value	10% of the initial cost
Tax, shelter and insurance	2% of the initial cost
Interest on investment	5% of the initial cost
Fuel consumption (l hr^{-1})	2
Fuel price (RM $litre^{-1}$)	2.2
Lubricant cost	15% of the fuel cost
Repair and maintenance cost (RM hr^{-1})	5% of the initial cost
Labour requirement	1
Labour wages (RM man^{-1} day^{-1})	50
Machine's productivity (t day^{-1})	6

TABLE 8. SUMMARY OF OPERATIONAL COST OF THE OIL PALM LOOSE FRUITS SEPARATING MACHINE

	Stationary type (without tractor)	Mobile type (with tractor)
Estimated total machine cost (RM hr^{-1})	14.27	18.04
Estimated total machine cost (RM day^{-1})	85.62	108.24
Operational cost (RM t^{-1})	22.60	26.37

planters and millers agreed that the loose fruits have to be separated from trash in order to have better OER. Therefore, mechanisms need to be implemented to overcome this problem. Some incentives should be considered for those who send clean loose fruits at a certain percentage of debris to the mill. The mill should also consider processing the clean loose fruits separately from the FFB. A dedicated sterilisation compartment or cages for the clean loose fruits during processing should also be considered. This measure is so important and crucial to increase the national OER.

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