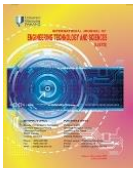
INTERNATIONAL JOURNAL OF ENGINEERING TECHNOLOGY AND SCIENCES (IJETS)
ISSN: 2289-697X (Print); ISSN: 2462-1269 (Online) Vol.6 (2) December 2019
© Universiti Malaysia Pahang
http://dx.doi.org/10.15282/ijets.6.2.2019.1006



Loose Fruit Collector Machine in Malaysia: A Review

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ABSTRACT

Malaysia is the world's second largest producer of palm oil after Indonesia. In harvesting, the collection of loose fruit is an important process because the loose fruit contain the highest percentage of oil compared to fresh fruit bunch. Thus, the process of loose fruit collection needs to be seriously considered. In order to properly manage the collection of clean loose fruit, there is a need for a loose fruit-collecting machine that can collect the loose fruit efficiently. In this paper, a loose fruit-collecting machine and roller type oil palm loose fruit picker in Malaysia are reviewed and the advantages and disadvantages of these two machines are discussed. These two types of machines could provide significant advantages to the industry by increasing productivity through the efficient collection of loose fruit.

Keywords- Oil palm, loose fruit, fresh fruit bunch

I. INTRODUCTION

Malaysia is the world's second largest producer of palm oil after Indonesia, with a total planted area of 5.64 million hectares and contributing approximately RM60 to RM70 billion to the Gross Domestic Product (GDP) in 2015. This contribution to the GDP is projected to touch RM78 billion by 2020 [1, 2]. This optimistic projection is influenced by the current state of the palm oil industry practices.

The harvesting procedure in most commercial oil palm plantations involves six processes which are, cutting the bunches, stacking the fronds, collecting the fresh fruit bunches (FFB), unloading the FFBs, collecting the loose fruit (LF) and transporting them to the mill. Among these processes, the process of collecting the LFs is paid more attention because the LFs offer the highest amount of oil extraction rate (OER). OER represents the actual oil production in a mill. As stated by [3,4], the OER is increased by up to 40% due to efficient LFs collection compared to FFBs with the OER up to 25% per weight ratio. Thus, the LFs should be properly managed and be free from contamination [5-7].

The implementation of harvesting standard, mill efficiency, and estate practices are among the factors that influence the overall OER performance [8-10]. In some commercial oil palm plantations, the estate practices involve the implementation of long harvesting round intervals which result in increasing the overall collection of leftover LFs [11-14]. Hence, improper LFs collection can cause significant loss of potential income. In other words, if LFs collection is properly managed and LF collected are non-contaminated, the highest OER can be achieved, and the higher potential lost income can be saved.

Therefore, this paper focuses on a review of LF collecting machine innovation in Malaysia. Description and discussion of the harvesting processes will form the first part of this paper, followed by a detailed description of the LF collecting machine and its advantages and disadvantages. The summary concludes this paper.

II. HARVESTING PROCESS

In the palm oil industry, harvesting is a year-round process and Figure 1 presents the flow of the harvesting processes. The overall harvesting cycle comprises a series of processes such as cutting the FFBs and subtending fronds, stacking the fronds, collecting the FFBs, collecting the LFs and finally, sending them to the mill. In practice, a team of harvester is assigned a specific area of the plantation for the various specific tasks. For example, in commercial estates a team of harvesters comprises four cutters, two frond stackers, four LF collectors and a machine operator. They perform all the tasks of the harvesting processes.

A cutter will go from palm to palm to look for a ripe FFB and will cut bunches by using a sickle or chisel based on the age of the palm. Then, the frond stacker will stack the fronds, trim the bunches, stalks and arrange the FFBs in the field for collection. Mini Tractor Grabber (MTG) operated by single machine operator is used to collect the FFBs. Later, the LF collector team will collect all the LFs scattered in the field by handpicking or raking and putting the LFs into bags and then emptying them into wheelbarrows to be sent to designated platforms.

Several studies [15-17] have reported that up to 70% of the harvester's time is spent collecting the LF and it the estimation is that the time taken to collect LF is about 30% of the total fruit handling time. In addition, as reported by [18,19], the total debris collected with the LFs can be as much as 60% of its total weight and this large amount of debris will affect the mill productivity, as the debris will absorb the oil content of the LF. As a result, the OER will be significantly reduced.

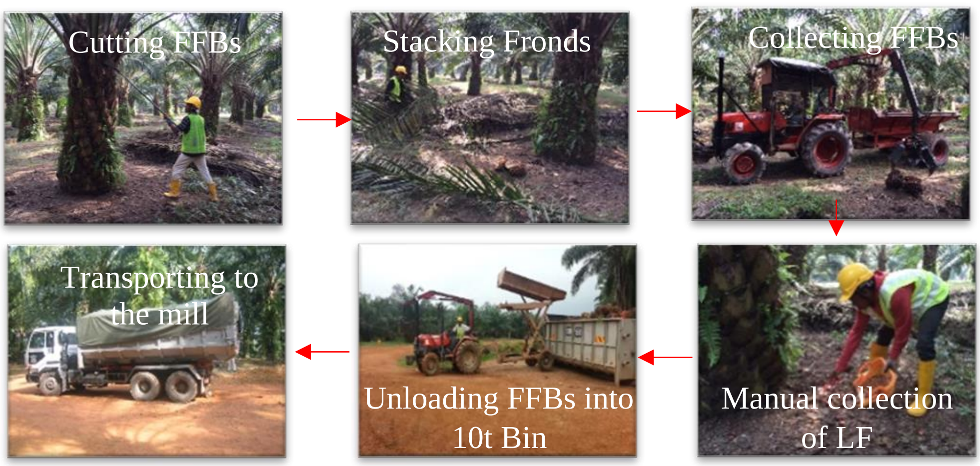


Figure 1: The harvesting processes

III. LOOSE FRUIT COLLECTION

The manual collection of LF is laborious and tedious work. Generally, most oil palm plantations have to deal with less than maximum collection of LF per day during the harvesting. Mechanisation is the solution to this problem and there is an urgent need for a LF collecting machine that will maximise the amount of fruit collected, with minimum debris, and requiring less workers. There have been a few designs of LF collecting machines developed in Malaysia and the next section will discuss on promising model that could eventually be used in commercial oil palm plantations in Malaysia.

2.1 Mechanical Loose Fruit Collector

The Palm Oil Research Institute of Malaysia (PORIM) and Universiti Putra Malaysia (UPM) jointly developed a mechanical loose fruit collector (MK I) in 1995 [19]. MK I consists of an air-cooled petrol engine and push cart fitter comprising two separate compartments, one for the LF and the other for debris.

Figure 2 (a) shows the MK I with the direct suction method, which is the core concept of the machine. The field trial was conducted which showed the capability of the machine in collecting 300 kg to 400 kg of relatively clean LF per day from scattered locations in the plantation. The productivity from this field trial was slightly lower than expected because the pushcart had a small container and the workers were required to walk and push the collector.

In 1999, PORIM introduced another mechanical loose fruit collector in the form of an enhanced version of the earlier machine [20]. Known as MK II, it was developed with bigger capacity, coverage and easily handled by the workers. The MK II comprised a three-wheeled FFB carrier, fan, and two container-fans to create the suction for the two containers storing the clean LFs and debris separately. The direct suction mechanism is used as the main method to pick up the LF. Figure 2 (b) shows the prototype of the MK II. The field trial was carried out and the daily productivity in LF collection was 1,400 kg to 1,700 kg per day or five times more compared to the MK I productivity. Furthermore, the MK II was able to operate fully with three workers compared to manual collection. However, the field trial showed that the MK II could still be further improved in terms of engine capacity, as the vacuum created by the engine was not strong enough to avoid choking of the LF. This problem may lead to lowered collection rate and increase in collection time. Hence, in 2012, the Malaysia Palm Oil Board (MPOB) introduced MK III [21].

The MK III as shown in Figure 2 (c), introduced the new design of suction, which is the cyclonic vacuum. This vacuum is able to increase the suction power creating a cyclone atmosphere inside the cylindrical barrel and the LFs are sucked in. The heavier LFs will drop to the bottom of the barrel while the lighter material will be sucked out of the system. There is minimum bruising to the LF and the choking problem is insignificant, occurring mainly during wet weather when the fruits are moist, which slows down the collection process. The field trial showed that the MK III could collect a daily average of 1200 kg to 1500 kg of LF.

As the palm oil industry continues to grow, productivity becomes an important parameter to be constantly measured. Hence, the MK IV [22] was introduced in 2017 with bigger capacity as shown in Figure 2 (d). Still maintaining the suction concept as in MK III, in which the LFs were sucked into a cylindrical-shaped barrel, the additional feature was enhanced including the barrel, which now acts as a temporary storage area. This barrel is able to store at least 500 kg of LF. The field trial was performed and the average collection of LF was from 1,500 kg to 2,000 kg, which was a 20% to 25% productivity increase compared to the MK III.

(a) MK I (b) MK II

(c) MK III-Collecting the LF (left) and storing into bag (right)

(d) MK IV-Collecting the LFs (left) and Unloading LFs into steriliser cage (right)

Figure 2: Mechanical loose fruit collector

2.2 Roller-type Loose Fruit Picker (RP)

The Roller-type Loose Fruit Picker (RP) represents a different method of mechanical loose fruit collection. Without involving the usage of an engine, the RP is mostly designed as an oval-shaped case and made from the plurality of wires and rods. The basic function is to pick up all fruits on the ground using a simple mechanism similar to hand picking.

A single operator is required to operate the RP. The RP is rolled with a little pressure against the ground, causing the wires or rods of the case to open and trap the LFs inside the case. Once the LFs are entrapped between the wires or rods, the case will return to its normal position. All debris smaller in size than the spaces between the wires and rods will drop from the case and therefore will result in only debris-free LF being collected.

Figure 3 shows the operation of the RP at base. Since the RP is quite a small operation, the RP is seen to be suitable for all types of field conditions in the plantation environment. Due to its easy operation and minimal maintenance requirements, the RP can be practically applied in oil palm plantations with the introduction of some enhanced design features.

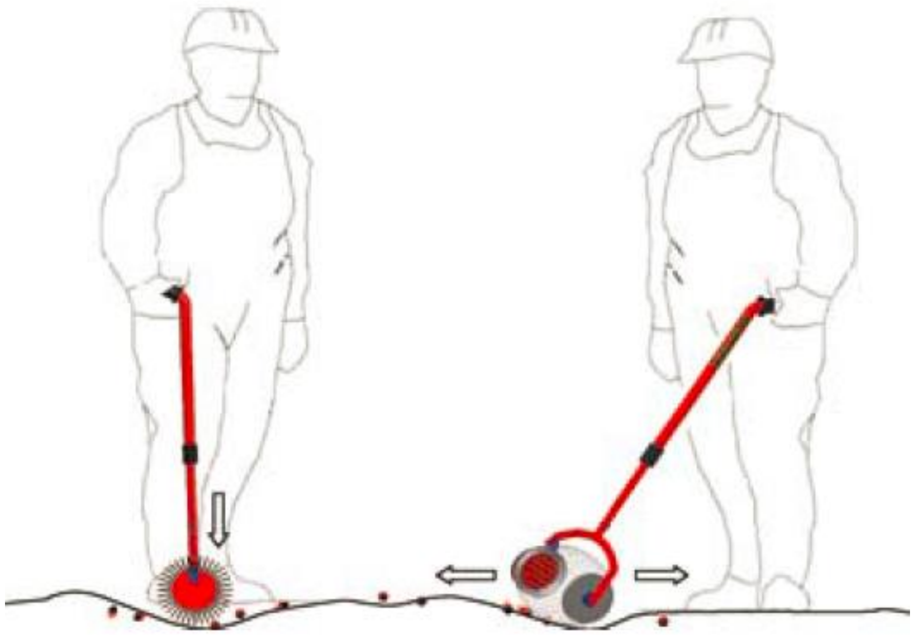


Figure 3: The operation of RP

In 2007, a newly designed of RP was introduced [23]. The main body comprised a chain and rake. As shown in Figure 4, this RF has a nose width 220 mm, 360 mm diameter wheels, an engine speed of 470 rpm and a linear rake speed of 52.4 m/mi. With these structural designs, various conditions of terrain, vegetation and residue around an oil palm tree can be accommodated. Field trials showed that this RP was able to pick up the LF from several types of surfaces and exhibited good maneuverability in several different conditions. Results indicated that this RP characteristics of length, nose width, height, and correct finger-ground clearance are the most significant machine parameters which determine the ability of the collector to follow the terrain. In addition, the machine is able to collect the LFs without bruising them due to the design of nose width.

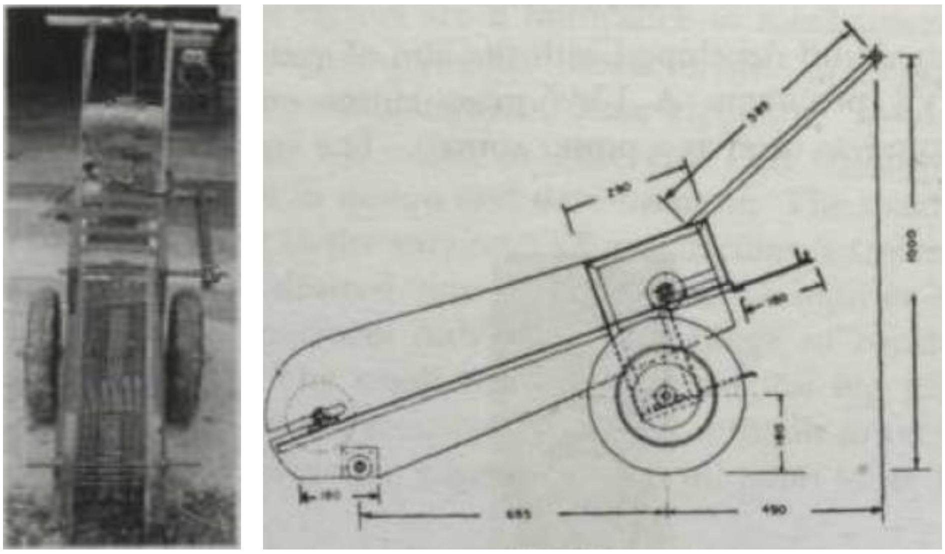
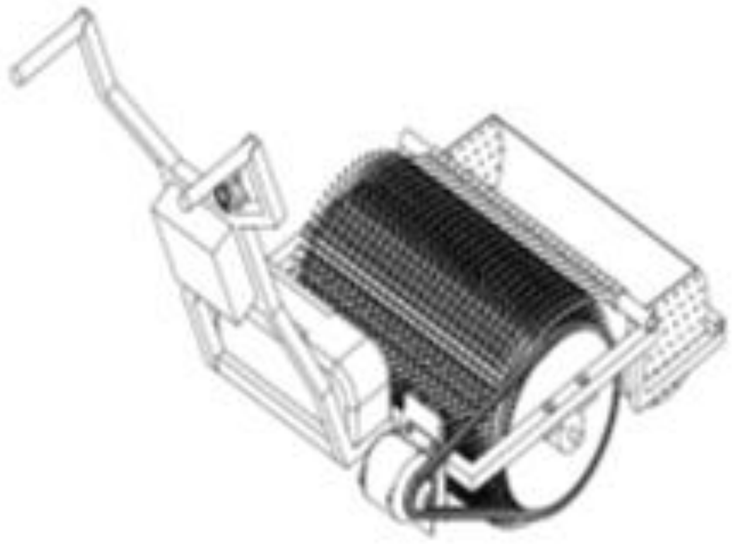


Figure 4: RP at accommodating terrain

In 2009, MPOB introduced an oval-shaped RP as depicted in Figure 5, consisting of two main parts – a roller device and handle [4]. The average amount of collected fruits ranged from 30 kg hr^{-1} to 60 kg hr^{-1} depending on the terrain.

Figure 5: Roller picker-Roller picker device (Left) and field-testing (right)

In 2016, a new concept and design of RP was proposed by Sime Darby Research Sdn Bhd with the introduction of the motorised oil palm loose fruit picker [24], consisting of a multiple rotating wheels, engaged with tines and energised by a DC motor as shown in Figure 6. The LFs collected remain engaged in the tines of the wheels until they hit the ejector fingers. The LFs later drop into the container located in front of the multiple wheels. Note that, the DC motor is connected to the multiple-wheel shafts via sprockets and chain and powered by a rechargeable lithium iron phosphate (LiFePO4) battery. The machine is designed to be battery-operated and therefore no energy is needed to push the machine. The field trial indicated that the average productivity was around 400 kg to 600 kg per day. Besides, LF can be sent to the mill with minimal debris ensuring better quality LF that would enhance the quality of the oil produced.

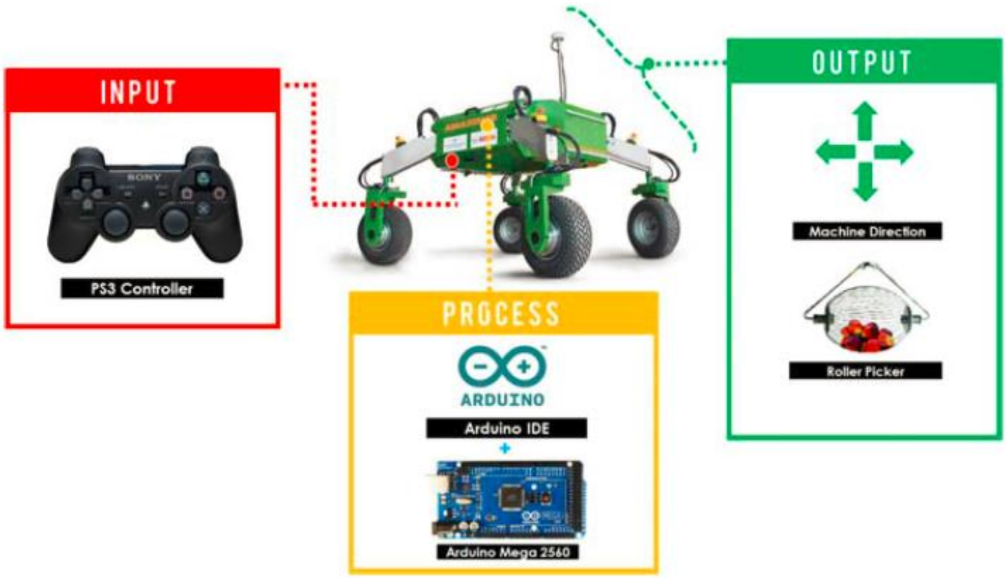


(a) RP motor design

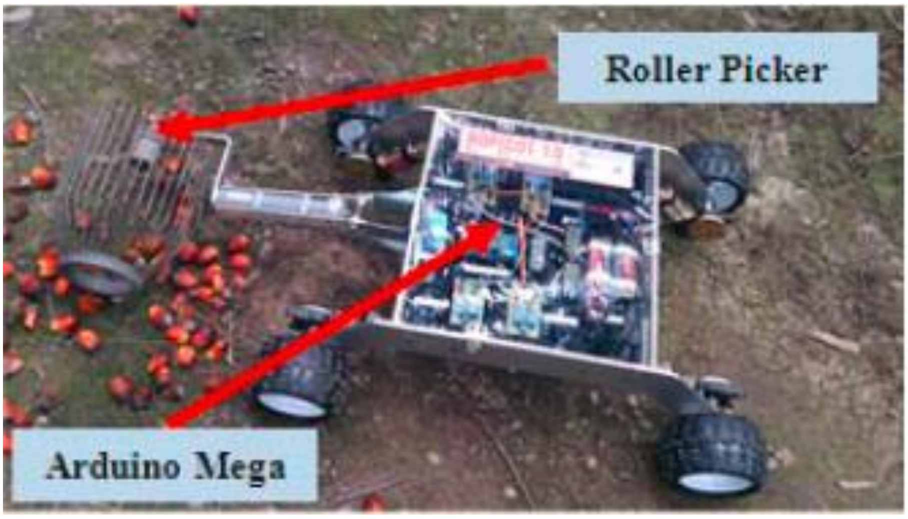
(b) RP with motorized at field testing

Figure 6: RP with motor

In 2016, the RP was innovated with a robotic mechanism [25] and introduced to pick up LF. It consists of hardware circuitry and software architecture development as a main mechanism system. This system is attached with the roller device as depictured in Figure 7. Wireless controller regulates the movement of the RP robot. Note that, the Arduino Mega 2560 and the Arduino software are used as the hardware platform and software architecture, respectively. The system can execute the commands of the programme. The field trial was done and the RP robotic was able to collect LF at an average of 0.5 kg/min in various ground conditions.



(a) RP robot design



(b) RP robot field testing

Figure 7: RP with robotic mechanism

IV. DISCUSSION

Oil palm plantations contributed a total of RM44.8 billion (approximately USD10 billion) of the GDP in 2017. This contribution may have been influenced by the harvesting practices whereby the LFs collection was recognised as one of important processes in harvesting. It is noted that, the LFs contains the maximum oil, which later affects the OER. Thus, the development of the LF collecting machinery or tools in the LF collection process has become a critical requirement to assist the workers and to expedite the process of LF collection. Based on the machines that have been reviewed in this paper, there are advantages and disadvantages of the various models that have been developed.

4.1 Advantages and Disadvantages

Conceptually the mechanical LF collector is a machine comprising an engine, vacuum, a container, and a prime mover. This machine can optimize the operational efficiency and the productivity of the collected LFs is significantly increased. As reviewed, at least 300 kg to 2,000 kg/day of the LF can be collected with productivity increased by 25%. In comparison, the relatively simple RP using a roller made of wires and rods offers at least 40% less collection load than the mechanical LF collector. Thus, in terms of productivity, the mechanical LF collector seems to be a more attractive option, especially for the larger oil palm plantations. Besides, the presence of a prime mover allows for greater mobility and reduces the number of workers; however, mechanical LF collector also has some limitations such as the large size and heavy weight, which could damage the field paths.

Furthermore, the bulkiness of the machine makes it difficult to access some of the terrain in the plantations. Flat and undulating areas will be suitable for the mechanical loose fruit collector but when it comes to the hilly and terraces areas, the stability of the prime mover and the safety of the operator should be considered**.** Other than that, the cost for repair, maintenance and lifespan of the machines and initial capital investments have to be taken into consideration. In this situation, the roller picker becomes a more effective way to overcome the problems posed by mechanical LF collectors. The designs of the RP are lightweight, small and simple, as well as being easy to operate and able to cover different types of terrain. In addition, there is significantly less maintenance that should be considered and the price of RP seems to be viable for the oil palm industry in general. However, the RP picker has issues with regard to the labour shortage and productivity. With the RP, an operator is required to walk from one palm to another palm to collect the LF at the palm base. Thus, the productivity from the RP picker is heavily dependent on the operator although more operators with more RP pickers may increase productivity if labour is available.

Therefore, with the labour shortage in the industry and demand to collect the LF due to the high oil content of the LF, researchers should consider the revolution of Industry 4.0. The basic principle of Industry 4.0 is connecting machines, workplace and systems, and creating intelligent networks along the entire value chain that can control each other autonomously. The researchers and the development of machinery in LF collection should look into the possibility of deploying autonomous LF fruit pickers or LF collectors in the oil palm industry to address the issue of labour shortage. However, some challenges need to be addressed by considering the following:

- Internet of Things (IoT) security and internet connection in the field especially under the palm canopy.
- Design of machines, which should be user-friendly.
- Reliability and stability needed for critical machine-to-machine communication (M2M), including very short and stable latency times.
- Machines safety.

V. CONCLUSION

The development of loose fruit collection in Malaysia has been reviewed and discussed. Mechanical loose fruit collectors and roller picker types are the main tools that may be effectively deployed together in an oil palm plantation to increase productivity, with the ability to access all types of terrain, require less maintenance, less labour requirements and greater operator safety. They complement each other to enhance the performance of the palm oil industry in Malaysia.

VI. ACKNOWLEDGEMENT

The authors would like to thank Sime Darby Plantation Research Sdn Bhd and Universiti Putra Malaysia for supporting much of this work, which was performed under the project, "Loose Fruit Collector Machine in Malaysia: A Review". The authors also want to thank to Chief Research & Development Officer of Sime Darby Plantation Research Sdn Bhd for permission to publish this paper.

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