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Original Research Article

A laboratory study on the Harvesting Force of Mangosteen (*Garcinia mangostana L.*) and Mesta Based on Maturity Indexes

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Abstract: Mangosteen (*Garcinia mangostana L.*) is known as the 'Queen of tropical fruits' and comes from the tropical forests of Southeast Asia such as Malaysia. Mangosteen is used for fresh consumption or as a beauty and health supplement. However, difficulties during the harvesting process with limited effective harvesting machines have prevented large scale mangosteen production. This study was conducted to determine the strength of the harvesting force at each stage of the maturity indexes and the appropriate force required for the development of mangosteen harvesting machines. The study samples were classified based on six stages of the indices of mangosteen and mesta varieties. The fruit samples taken at MARDI Sintok, Kedah were subjected to harvesting force, weight, diameter and stalk size. The result shows that the highest yield strength was mangosteen at maturity index 1 with 51.81 N while the lowest was mesta at maturity index 5 with 13.45 N. The study also found that the optimum harvesting force to drop the mangosteen and mesta from a tree was 30.19 N. This study indicated that the higher maturity indexes the lower the harvesting force needed to harvest mangosteen and mesta.

Keywords: Mangosteen; mesta; harvesting force; maturity index; mangosteen harvester

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1. Introduction

Mangosteen (*Garcinia mangostana*, *L.*) is one of Malaysia's favourite local fruits. The mangosteen area in Malaysia is 3,717 hectares with an output of 26,170 metric tons per annum (DOA, 2018). Mangosteen is used for fresh consumption or as a cosmetic and health supplement. Mangosteen is in high demand and exported to countries like China, Japan, Hong Kong, and the Middle East (Rohzan *et al.*, 2011). In addition, mangosteen is one of the selected fruits for export and received a special grant from the government under the Food and Agriculture Export Council (FACE) to increase the area of cultivation and yield production.

The mangosteen tree is a long juvenility or slow growth. This is due to the fact that it has few hair roots, causing the growth to be very slow. The mangosteen tree has a trunk with a diameter of 25–35 cm and conical clown and height up to 25 m while the mangosteen fruit is round and smooth with a diameter of between 3.4–7.5 cm (Morton, 1987). Mature mangosteen trees can produce fruit between 1,000–3,000 fruits depending on the care and age of the tree (Osman & Milan, 2006). Mangosteen has pinkish-red skin when mature, turning to a dark purple when ripe. The fruit is usually located on the outer end of the tree canopy. Mangosteen maturity index can be based on colour changes in the skin. This index is very important and is used as a guide during the harvesting, selection and grading of fruits. There are six stages of maturity indexing for mangosteen. The third stage is the most suitable stage to be harvested, induce ripening and also for export. Whereas, at the fifth index is the most appropriate stage for the fresh market (Palapol *et al.*, 2009).

Meanwhile, mesta is in the same group as mangosteen but a lesser-known variety. It could be found mainly on the east coast of peninsular Malaysia. Mesta tree is smaller than the mangosteen tree, thus facilitating the process of harvesting easier. Fruits of mesta are smaller and slightly oval with pointed ends while for the mangosteen, the fruits are larger and rounder with a flat end (Joana *et al.*, 2016). The mangosteen has 4–8 sections of edible white aril including 1 or 2 large sections with apomictic seeds. While the mesta, the most edible white aril is seedless or have the undeveloped seed (Paull & Ketsa, 2014).

Nowadays, farmers use a pole with an attached hook to harvest mangosteen. The mangosteen should be carefully harvested to prevent it from being injured or falling to the ground. Physiological disorders or postharvest damage to the mangosteen commonly is “gamboges” and hardening of the pericarp caused by mechanical injury. The “gamboges” disorder occurs where latex seeps into the flesh (aril), turning it yellow and giving it a bitter taste. The “gamboges” also moves onto the outer surface of the fruit. Meanwhile, studies have shown a drop of 10 cm can cause slight pericarp damage, indicated as hardening at the point of impact within 24 hours. Higher drops causing significantly greater damage can often lead to a downgrading of the fruit (Tongdee & Suwanagul, 1989; Ketsa & Atantee, 1998)

In order to avoid injury, it must be picked one by one causing the process to be long and slow harvesting. Therefore, a suitable harvesting method such as the shaking or vibrating method is assisted by the fruit catching system during harvesting can be used for quick and safe harvesting (Chen *et al.*, 2012). This method is also used to harvest citrus in Florida and is capable of increasing harvesting capacity by 96% to 99% (Gupta *et al.*, 2016).

The objective of this study was to determine the appropriate forces needed to detach or drop mangosteen at each stage of the mangosteen index. The force obtained can be used as a guide for the future development of mangosteen harvesters. In addition, the effect of shaking power on the tree should be taken into account as it may affect the root of the tree, as it can inhibit the growth or damage to the tree. Therefore, the development of a prototype of a mangosteen type harvester without affecting the root system should be done to enhance the productivity and production of mangosteen.

2. Materials and Methods

The study was conducted in MARDI Sintok, Kedah in 2019 on mangosteen and mesta study plots with a total area of 2.5 ha and 0.5 ha, respectively. The age of the mangosteen trees were more than 10 years with an average height of 5 m.

2.1 Experimental Equipment

The equipment used in this study to measure the harvesting force was IMADA ZP - 44 digital force gauge meter (IMADA Incorporated, United State of America) (Figure 1). This force gauge is capable of measuring compression and tension force. In this experiment, the force gauge was used to measure the tension force required during the pulling of the fruit to be detached from the tree. Some modifications were made for suitability to carry out the study. A hook-shaped jig as shown in Figure 1 was developed for the fit of the force gauge meter to hold and pull the mangosteen during testing. The developed jig has two hooks that can hold the mangosteen well without damaging them when pulled. Another tool used in this study was Shimadzu UX4200H digital electric scale (Shimadzu, Japan), which was used to weigh each harvested mangosteen. Besides, Mitutoyo CD67-S8 Vernier calliper (Mitutoyo Corp, Japan) was used to measure the diameter and stalk of the mangosteen fruit.

Figure 1. Digital force gauge meter with hook

2.2 Field experiment

The field study required two workers, one assigned to pull the mangosteen using a force gauge meter (Figure 2), and the other worker to record the data on the record sheet. The selection of mangosteen for each maturity ranking is done by visual examination based on Malaysian harvest guidelines for mangosteen export (Ahmad Tarmizi, 2005). There are six maturity stages defined by the extent of red or purple colour on the pericarp. Stage 1 shows pericarp of light greenish-yellow with scattered pinkish spots, minimum stage for harvesting, stage 2 shows pericarp of light greenish-yellow or yellowish pink with distinct irregular pink spots covering the entire fruit, stage 3 would indicate pericarp of pinkish background, spots not as distinct as in stage 2, a stage commonly harvested commercially, stage 4 showing pericarp red or reddish-brown, some with a purple tinge, stage 5 having pericarp darkened to reddish-purple, best eating stage) and stage 6 or more (pericarp of purple, dark purple to black with slight or no red colour remaining.

A total of 20 mangosteen fruits were selected at each maturity index. The force required to detach fruit at the joint of the calyx and the peduncle was measured by a pull action using a force gauge meter. If the breakpoint occurred elsewhere, the test should be repeated with a new sample.

Figure 2. Mangosteen pulled by digital force gauge meter during the experiment

3. Results and Discussions

Figure 3 shows the arrangement of some of the study samples according to the maturity index of the mangosteen and mesta. The arrangement is descending from index 1–6 and the change in colour of the study sample mangosteen and mesta fruit decreases from light greenish-yellow to dark purple. The major difference between mangosteen and mesta is their shape, where the mangosteen is spherical while mesta bottom is conical shape.

(a) (b)

Figure 3. Fruit samples; (a) Mangosteen and (b) Mesta

The average harvesting force against maturity indexes for mangosteen and mesta is presented in Figure 4. The highest harvesting force was recorded for mangosteen for maturity index 1 and followed by mesta in the same maturity index. This factor may be due to the smaller physiological criteria of mesta versus mangosteen (Joana *et al.*, 2016), while the lowest value of harvesting force is mesta in index 5. Index 2 shows a relatively large harvesting force gap between mangosteen and mesta, with a difference in harvesting force of 12.52 N. Indexes 4–6 showed no significant harvesting force between them, with the gap of 6.55 N for both mangosteen and mesta. However, there was a slight increase in harvesting force for mangosteen index 4 to 5 and mesta index 5 to 6. This is due to the size of mangosteen at index 5 and mesta at index 6 being larger than the mangosteen at index 4 and mesta at index 5, resulting in more harvesting force needed to harvest.

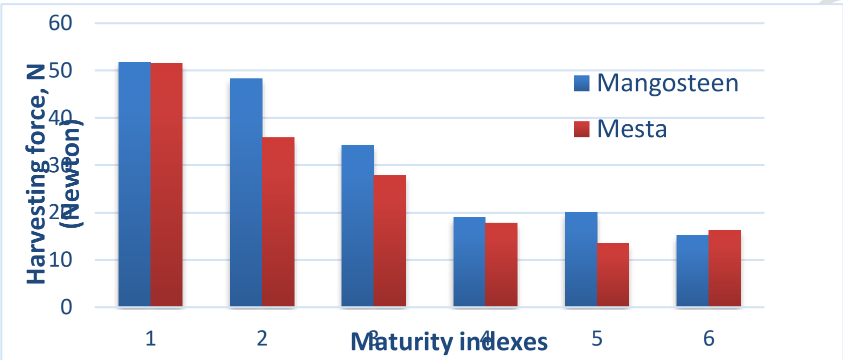

Figure 4. Average harvesting force against maturity indexes for mangosteen and mesta

Mean comparison of harvesting force between maturity index (Table 1) proof that there is a significant difference in harvesting force based on maturity indexes. Maturity indexes 1 and 2 are significantly different compared to other maturity indexes of 3 to 6 at $p \leq 0.05$. From the table, we can postulate that the maximum harvesting force for maturity index 3 to 6 is 30.19 N. There are significant differences between these two groups due to the content of ethylene production in mangosteen. Ethylene content at baseline or index 1 is lower than index 6 (Noichinda, 1992). In addition, the colour change of the mangosteen skin caused by an increase in the internal ethylene, also causes the tip of the mangosteen peduncle to swell. When this occurs the natural part of the abscission layer becomes weaker and the mangosteen stem is easy to fall or pluck (Tongdee & Suwanagul 1989).

Table 1. Mean comparison of harvesting force between maturity index

Maturity Index	Harvesting Force
1	53.67a
2	51.25a
3	30.19b
4	17.73b
5	20.82b
6	22.98b

Mean within a column with the same letter are not significantly different at $p \leq 0.05$ according to DMRT

4. Conclusions

The study shows that harvesting forces were decreasing with increasing maturity indexes. Besides, there were two main groups for required harvesting force classified as index groups 1–2, and index groups 3–6. Therefore, for future development of mangosteen harvesting machines, the maximum harvesting force requirement would be 30 N which is suitable for harvesting mangosteen and mesta and should start from index 3 until 6. Future improvements would focus on the duration of the shaking force applied during the harvesting process.

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