RELATIONSHIP BETWEEN PHYSICAL AND MECHANICAL PROPERTIES OF PINEAPPLE FOR THE DEVELOPMENT OF A MECHANICAL HARVESTER

Mohd Taufik Ahmad,
Engineering Research Center
Malaysian Agricultural Research and Development Institute (MARDI)
43400 Serdang, Selangor
Email: taufik@mardi.gov.my

Rohazrin Abd Rani,
Engineering Research Center
Malaysian Agricultural Research and Development Institute (MARDI)
43400 Serdang, Selangor

Adli Fikri Ahmad Sayuti,
Engineering Research Center
Malaysian Agricultural Research and Development Institute (MARDI)
43400 Serdang, Selangor

Siti Noor Aliah Baharom,
Engineering Research Center
Malaysian Agricultural Research and Development Institute (MARDI)
43400 Serdang, Selangor

Badril Hisham Abu Bakar
Engineering Research Center
Malaysian Agricultural Research and Development Institute (MARDI)
43400 Serdang, Selangor

Mohd Rosdzimin Abdul Rahman
Engineering Research Center
Malaysian Agricultural Research and Development Institute (MARDI)
43400 Serdang, Selangor

ABSTRACT

Pineapple has been identified as one of the tropical fruits that can increase the Malaysian economy. Increase in demand will cause the pineapple cultivation to shift its focus to use mechanization, specifically in harvesting. Physical and mechanical properties of the pineapple are essential to develop a pineapple harvester. This paper aims to observe the physical and mechanical properties of pineapple to develop a pineapple harvester. Essential parameters such as fruit weight, length, maximum diameter, maximum circumference, stem length, stem diameter and crown length were collected and recorded from matured pineapples freshly harvested in peat soil area, MARDI Pontian. The force required to separate matured pineapple from its stem was also measured using a digital force gauge. Relationships between the physical and mechanical properties were observed to identify strong correlations. All pineapple's physical and mechanical properties show strong correlations except for stem length. These parameters and their correlations will be used to develop a pineapple harvester.

Keywords: *Pineapple, Harvester, mechanization, pineapple properties*

INTRODUCTION

Pineapple is one of the tropical fruits with the potential to boost Malaysia's economy. The Malaysian Pineapple Industry Board, MPIB (2020) states that the total pineapple cultivation area in Malaysia is 14,000 hectares, producing more than 320,000 metric tons per year. Out of this whole area, 75% or more than 10,000 hectares are cultivated in Peninsular Malaysia, while 25% are grown in Sabah and Sarawak. The average yield per hectare of pineapple cultivation is 29.6 metric tons. Pineapples are usually sold fresh, canned, or processed into jam.

Usually, pineapple harvesting is done manually (Hossain, 2016; Liu et al., 2022). Generally, harvesting requires a worker to pick fruits from two rows of plants. These two rows are the plants that are easily accessible and can be harvested by a single worker. One hectare of pineapple cultivation with 132 rows of plants typically requires 66 workers for harvesting operations. Due to cost and labor constraints, only 6-10 workers are usually employed. Workers use a machete to cut the pineapple stalks from the plant. These stalked pineapples are placed into bamboo rattan baskets on the worker's back (Mat Lin & Abdul Rahman, 2010). The high labor demand has led to increased labor costs and is impossible to be met by farm owners/farmers. The shortage of labor and increased workload on labor have led the pineapple industry to look towards mechanization as a solution (Singh et al., 2022).

Bakar et al. (2021) reported that Malaysia has a similar mechanization approach to Costa Rica concerning pineapple production. Land preparation is fully mechanized. Planting is in a semi-mechanized stage where attempts have been made to develop machines for transplanting pineapple suckers (Ahmad et al., 2013; Fikri et al., 2019). Harvesting is still done manually using a harvesting aid where workers pluck pineapples manually and put them on a conveyor boom where a collecting bin is located at the end.
Recently, there have been several attempts to reduce the issues related to pineapple harvesting. Guo et al. (2021) designed and simulated an automatic pineapple harvester using a picking manipulator with a collecting device, placed on a continuous tracked prime mover. Simulation of this design revealed that the work rate can achieve up to 1636 plants/hour, which is twice the work rate of manual harvesting.

Singh et al. (2022) designed and developed a semi-automatic, handheld motorized pineapple harvester. This handheld pole device used a battery-operated cutting blade to cut the pineapple stem. They claimed that this device can harvest up to 200 fruits per hour. However, they also mentioned that the harvester consumes 30% more time than manual harvesting.
Liu et al. (2022) designed a multi-flexible fingered roller mechanism for harvesting pineapples. They claimed this mechanism could harvest 78% of pineapples in the field with 8% damage. The harvesting speed was reported to be at 1s per fruit. The mechanism was mounted on a high-clearance transporter with narrow rubber tracks.

There is a need to develop a pineapple harvester that can harvest pineapples inside crop rows. To develop this concept, the physical and mechanical parameters of the crop need to be observed and measured. This paper aims to observe the physical and mechanical properties of pineapple to develop a pineapple harvester.

MATERIAL AND METHODS

Pineapples of the MD2 variety were randomly selected from an experimental plot located at MARDI Research Station, Pontian. The selected pineapples were ensured to be free from defects and had a uniform level of ripeness. Parameters such as weight, maximum diameter, maximum circumference, maximum length, crown length, stem diameter, and stem length were measured for each fruit sample (Figure 1) using a measuring tape and a weighing scale. An additional parameter, the force required to detach the pineapple from the stem (Figure 2), was also measured using a digital force gauge (IMADA, Japan) (Figure 3).

Figure 1: Pineapple physical parameters a) maximum diameter b) fruit length c) crown length d) stem diameter

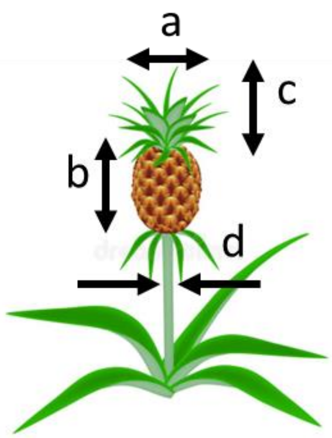

Figure 2: Force to detach pineapple from the stem

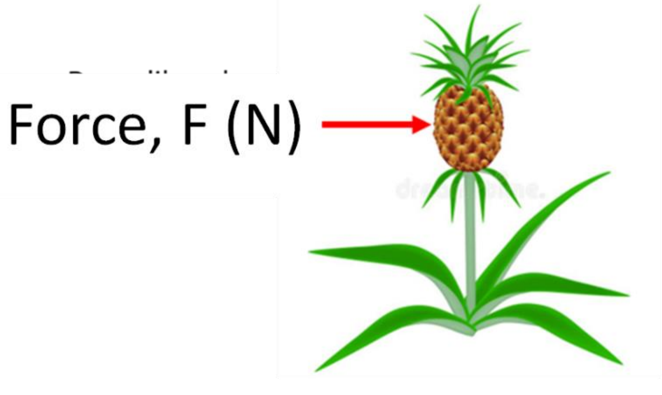

Figure 3: Digital Force Gauge

Statistical analysis

The fruit samples were classified into three size grades: small (S), medium (M), and large (L), similar to the grades used in the pineapple industry. The collected parameter data was analyzed to obtain the mean value and standard deviation. Significant differences between grades for each parameter were also tested using a statistical computer program (SAS Inst., 2023). Correlations between the physical and mechanical parameters were also evaluated.

RESULTS AND DISCUSSIONS

Physical parameters of pineapple fruit

Eight physical parameters of pineapple fruit were measured, recorded, and classified into three primary grades in the market, as shown in Table 1. All parameters showed significant differences except for the stem length. The average weight of small-sized fruit was 0.89 kg, while for medium and large sizes, it was 1.34 kg and 1.91 kg, respectively. The length of the small-sized pineapple fruit was 14.13 cm, while the length of the large-sized fruit was 19.84 cm. The force required to detach the pineapple from its stem was more than 30N, and the maximum force required was 90N. The force measurements were taken from pineapple plants grown in peat soil. The results showed significant differences in physical and mechanical parameters between pineapple grades ($p<0.05$), except for stem length and crown length. Mahmud et al. (2018) obtained similar results for the fruit weight, maximum diameter, length, and crown length. They obtained larger values due to the differences in the types of fertilizer used.

Table 1. Physical parameters of pineapple fruit

Grade	Fruit weight (kg)	Fruit length (cm)	Maximum Diameter (cm)	Maximum Circumference (cm)	Stem Length (cm)	Stem Diameter (cm)	Crown Length (cm)	Push Force (N)
Small (S)	0.89 ±0.13a	14.13 ±2.05a	10.06 ±0.91a	31.6 ±2.85a	12.42 ±0.91a	7.53 ±0.92a	19.5 ±3.76a	45.38 ±14.59a
Medium (M)	1.34 ±0.11b	16.59 ±2.00b	11.07 ±1.36b	34.78 ±4.29b	13.46 ±1.36a	9.15 ±0.85b	21.73 ±3.2b	55.46 ±16.06b
Large (L)	1.91 ±0.31c	19.84 ±3.43c	12.63 ±0.89c	39.68 ± 2.78c	12.12 ±0.89b	10.32 ±1.06c	23.34 ±5.02b	69.17 ±19.09c

Data shown are average values ± standard deviation. Different letters indicate statistically significant differences (Duncan, $p<0.05$)
Table 2 shows the coefficient of regression between physical properties of MD2 pineapple that was obtained from a peat soil location. All the physical and push force parameters showed a high correlation (>0.95), except for stem length. No significant correlation was found between stem length and fruit weight, fruit length, maximum diameter and maximum circumference. The largest correlation was found between fruit length and fruit weight, maximum circumference and fruit length, maximum circumference and maximum diameter, push force with fruit weight and push force with fruit length (0.9999). Montero-Calderón et al. (2010) used a similar approach to observe the mechanical properties of pineapple flesh of the Gold variety and obtained fewer correlations.

Table 2: Coefficient of regression (R^2) values of pineapple physical parameters.

	Fruit weight	Fruit length	Maximum Diameter	Maximum Circumference	Stem Length	Stem Diameter	Crown Length	Push Force
Fruit weight	1							
Fruit length	0.999	1						

Maximum Diameter	0.997	0.998	1					
Maximum Circumference	0.997	0.999	0.999	1				
Stem Length	0.866	0.084	0.110	0.110	1			
Stem Diameter	0.974	0.971	0.954	0.954	0.015	1		
Crown Length	0.974	0.971	0.954	0.954	0.015	1	1	
Push Force	0.999	0.999	0.999	0.999	0.089	0.968	0.968	1

$p < 0.05$

The parameters that were measured are beneficial in the development of a pineapple harvesting machine. The fruit weight will determine the estimated weight of the machine and the pineapple collection tank. The fruit length, maximum diameter, and maximum circumference will assist in designing the size of the conveyor system and the collection tank. The stem parameter is very useful in determining the cutting method for pineapple harvesting, whether to use toothed cutters such as saws, cutting discs, or other suitable cutting methods. The force required to detach the fruit from its stem was taken to assess the use of alternative methods to separate the fruit from the stem, as performed by workers involved in pineapple harvesting activities.

CONCLUSION

Physical parameters of the pineapple fruit were measured and recorded to aid in developing a pineapple harvesting machine. The physical parameters that were measured were classified according to the grades used in the market. The study found that as the size of the pineapple grade increased, the fruit weight, length, diameter, maximum circumference, and stem diameter also increased. The force required to detach the fruit from the stem increased with larger sizes, up to 90N. Relationships between the physical and mechanical properties were observed to identify strong correlations. All pineapple's physical and mechanical properties show strong correlations except for stem length. These parameters and their correlations will be used to develop a pineapple harvester.

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