Pertanika J. Sci. & Technol. 27 (S1): 149 - 157 (2019)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Physical and Mechanical Properties of Unripe *Nipah* Banana Fruit (*Musa acuminata balbisiana)*

Farahana Nabilah Zainal A'bidin[1], Rosnah Shamsudin[1,2]*, Mohd Salahuddin Mohd Basri[1] and Zanariah Mohd Dom[1]

[1]*Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor, Malaysia*
[2] *Halal Product Research Institute, Universiti Putra Malaysia, 43000 UPM, Serdang, Selangor, Malaysia*

ABSTRACT

This paper describes the properties determined to acquire physical and mechanical properties of unripe *Nipah* banana. In Malaysia, most of the banana chips processing companies use a variety from *Nipah Banana,* also known as *Musa acuminata balbisiana* a triploid hybrid banana cultivar. The physical (diameter, weight and peel thickness on edge and side) and mechanical properties (penetration and compression test) of *Nipah Banana* variety were determined through five consecutive days to evaluate its behaviour throughout its ripening period. The average diameter is 38.78±5.77 mm x 29.25±4.92 mm. The average thickness of peel at the edge and side are 5.3±0.93 mm and 3.65±1.01 mm respectively. The average weight of the *Nipah* banana variety is 77.85±28.61 g. Penetration force through 5 ripening days was found to decrease from7.53N to 6.59 N (top position), 7.59N to 6.40N (middle position) and 8.31N to 6.43N (bottom position). The compressive force decreases through 3 days from 1704 N to 1630 N with the sudden increase in day 4 to 1380 Using the following properties accumulated, the machine components specification can be obtained which are the blade force required to slit the banana peel, the thickness of the blade needed for the slitting of banana peel, the roller force to hold the banana in place and the peeler size.

Keywords: Banana, mechanical properties, peeling machine, physical properties

ARTICLE INFO

Article history:
Received: 24 October 2018
Accepted:15 February 2019
Published: 21 June 2019

E-mail addresses:
fara_bila02@yahoo.com (Farahana Nabilah Zainal A'bidin)
rosnahs@upm.edu.my (Rosnah Shamsudin)
salahuddin@upm.edu.my (Mohd Salahuddin Mohd Basri)
nana@upm.edu.my (Zanariah Mohd Dom)
* Corresponding author

ISSN: 0128-7680
e-ISSN: 2231-8526

INTRODUCTION

Malaysia is famous for its tropical weather which results in massive agriculture activities. Agriculture activities contribute to at least a third of the country's population livelihood. Various types of fruits are available in the country such as watermelon, pineapple, orange and banana. However, it is found that banana is the most consumed fruit in Malaysia. Having banana as the second largest production area and the fifth in export revenue for Malaysia, with local consumption per capita of 9.4kg in 2014 (Department of Statistics Malaysia, 2011).

Apart from Malaysia, banana can also be found in many places across the wet tropics and subtropics such as in America, Africa, South Asia, Island South-east Asia and the Pacific. Countries such as India, China, Ecuador, Brazil, and Philippines are the top banana producing countries in the world. In 2001, the annual world consumption of banana reached 5.2kg/person as bananas have been the staple foods for many people around the world as it provides 10 to 27% of daily calorie intake (Ammawath et al., 2001). The fully ripe banana can be consumed raw by all and has a sweet taste. Besides, banana can also be cooked to become fried banana, banana cue, banana chips and maruya. Now, a lot of banana based products has been introduced widely which can contribute in increasing the world banana consumption.

In Malaysia, as banana is a highly consumed fruit, a lot of entrepreneurs are making variety of banana by-products. One of the famous by-products is banana chips. Banana chips are one of the products made for mass production. From the year 1996 until 2000, the industrial growth performance of banana chips shows a 70% increase within Malaysia. Based on the survey reported by Hamir and Ariff (2006), the average production of banana chips should be around 113.8 tonnes per month, however, the production rate is very low which is at 59% (Hamir & Ariff, 2006). Until now, in banana chips processing, the peeling process is still being done using manual hand peeling method which is by using their own hand and knife as a tool to separate the peel. This method is unhygienic and has low production rate. There is a need to develop a banana peeling machine to overcome the 41% of unutilised banana. Thus, a preliminary data gathering for machine components specification is conducted. The physical and mechanical properties of the banana are required to specify the size of the peeling mechanism and other parts of the machine.

Physical and mechanical properties of fruits are important data in food engineering as well as agricultural machine. Which is why, in designing an agricultural machine, most of the inventors examine their properties as a start. Many previous studies for fruit properties have been made with orange (Singh & Reddy, 2006), okro (Owolarafe & Shotonde, 2004), longan (Shi et al., 2016), apple (Ganai et al., 2016) and pomegranate (Radunić et al., 2015). Singh and Reddy (2006) measured the properties of orange peel through days to examine its behaviour. Owolarafe and Shotonde (2004) examined the okro fruit properties for an okro slicer, chopper and grater machine development.

Banana fruits properties were also done by many researchers such as Soltani et al. (2011). Soltani et al. (2011) used the inner and outer length of the banana to measure the banana curvature. They also estimated the ellipsoid volume of banana fruit by weight. Besides that, there is also Kachru et al. (1995) who investigated two varieties of banana followed by their physical and mechanical properties. This paper aims to investigate some physical properties of *Nipah* banana fruit including weight, peel thickness at the plane and edge, diameter, penetration as well as compression force to identify the machine components specifications.

MATERIALS AND METHODS

Sample Preparation

Banana fruits of triploid hybrid banana cultivar which were fully matured but unripe with maturity index 1 were obtained from a small farm in Kampung Sungai Lang, Banting. Maturity index of bananas was referred based on standard grading by Federal Agricultural Marketing Authority (FAMA). The banana was stored at room temperature 25^{o}C. The samples were randomly selected from the bunch and divided accordingly to different types of properties that are diameter (mm), peel thickness (mm), penetration (g) and compression force (N). 20 bananas were used for each property, only diameter and peel thickness used the same banana sample. After being studied, banana chips factories process bananas in the first three days of harvest only. Thus, the sample testing continued until the fifth day to evaluate its difference. For each day, four bananas were used to evaluate the mechanical properties. Experimental data obtained from penetration and compression force test were then plotted in a graph to determine their relationship with ripening period.

Diameter, Peel Thickness and Weight of Fruit

Banana (20 hands) were used to determine the diameter (mm), peel thickness (mm) and weight (kg). The diameter and peel thickness of the banana were recorded at three planes along the longitudinal axis of fruits, one plane in the middle and two in the middle of the banana that was cut in half as in Figure 1(a) similarly to the method by Kachru et al. (1995). It is labelled as top, middle and bottom. Since the banana shape is not circular and has an average of four planes, the diameter is measured as a rectangular shape which is described as height in mm and width in mm. The average height was measured on the upper part of the banana while the width was measured at the side of the banana. As for peel thickness, the thickness was measured at the side and edge of each plane. Diameter and thickness measurement are illustrated in Figure 1(b) for better understanding. Both diameter and peel thickness of the banana were measured using Vernier calliper (Generic, China).The banana weight was measured using electronic weighing scale (Mettler Toledo, Model SB12001, Switzerland). All physical measurement on each plane were replicated three times and averaged out. An average of the banana physical properties measured was determined to get an overall representation of physical properties of banana fruit and reducing the chances of error.

Mechanical Properties of Fruit

Penetration Test. A penetration test is a test whereby a needle probe of 2mm diameter is passed through a sample with customized depth to obtain physical properties. It can be performed on a variety of food which is very useful for simulating the slitting mechanism of the banana peeler. This test is important to evaluate the force to penetrate the banana peel where the data obtained can be used to design agricultural machines. The sample was stored at room temperature of 25^{o}C along 5 days of the test. A penetration test was done by puncturing each sample at the edge of the banana plane at three different spots which were at the top, middle and bottom (Hou et al., 2015) as shown in Figure 1(c) and Figure 2(a). The experiment was replicated four times and made at the same spot with different sides for each day. The test was conducted using texture analyser (Stable Micro Systems,TA.XTPlus, UK) equipped with a 5kg load cell and stainless-steel probe (PN-2) of 2mm diameter needle in compression mode. The operating settings of the instrument were: pre-test speed, 1mm/s, test speed, 2mm/s and post-test speed, 12mm/s. The force at an average thickness of banana with 16 readings of each ripening period was obtained. Penetration force is the force required to cut the edge of the banana in a longitudinal direction. It is used as the first step in peeling the banana.

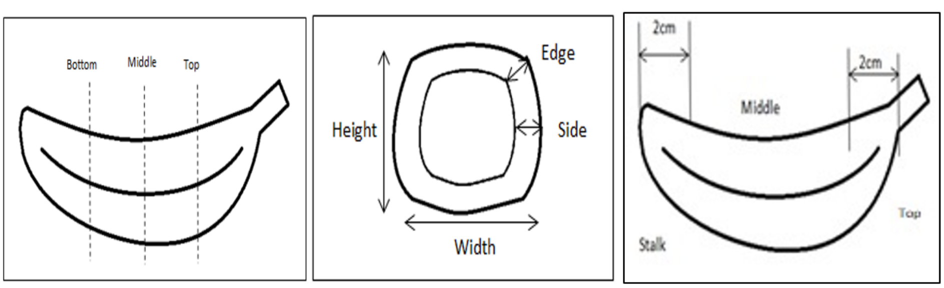

Figure 1(a). Banana section for physical measurement; *(b)* The banana diameter and thickness measurement; *(c)* Banana section for penetration force

Compression Test. A compression test is a test in which a sample is placed on a flat surface with an upper compression probe pushed down to the sample. Compression test is used for obtaining hardness, cohesiveness, springiness, and chewiness. With the test, textural attributes obtained can be used for machine designing. Compression test was

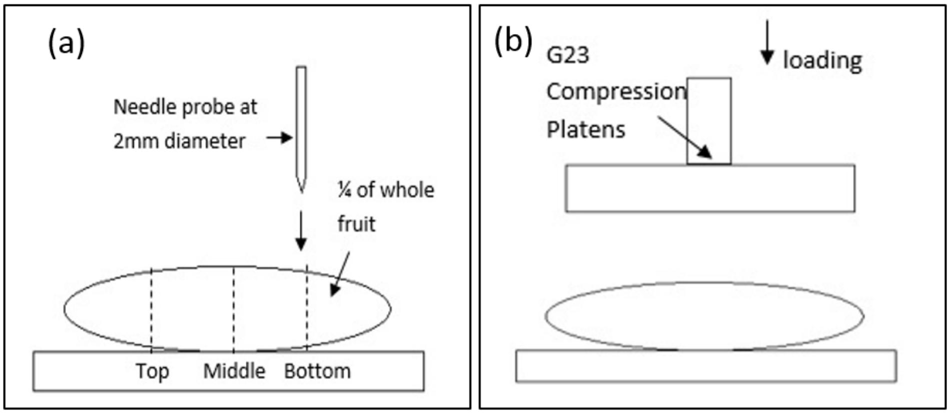

Figure 2(a). Penetration test; *2(b)*. Compression test

done by compressing each sample using a compression test fixture as shown in Figure 2(b). Four readings using four banana samples were obtained for each day. Banana fruits were stored at room temperature of 25^{o}C for 5 days. The test was conducted using Instron Universal Testing Machine (Model 5566, USA) equipped with a 10kg load cell and a G23 Compression Platens. The operating settings of the instrument were: pre-test speed, 1.5cm/s. The test was stopped manually after a cracking sound was heard as it indicatesd the breakpoint. The load at break of banana was obtained and presented as maximum compressive force, C (N). Average of four readings of each ripening period was obtained.

RESULTS AND DISCUSSION

Diameter, Peel Thickness and Weight of Fruit

Physical properties of the banana which are the diameter, thickness of peel and weight are presented in Table 1. The weight of *Nipah* banana varies between 46.40 g and 150.90 g with an average value of 77.85 g while the diameter varies between 25.99 mm x 19.66 mm and 52.48 mm x 43.87 mm with an average value of 38.78 mm x 29.25 mm. Peel thickness at the edge varies between 3.54 mm and 7.37 mm with an average value of 5.3 mm while at the side is between 2.1 mm and 7.16 mm with an average of 3.65 mm. Previous research from Kachru et al. (1995) acquired some physical properties of Scavendish and Nendran banana variety. One of it was peel thickness. They obtained average peel thickness on the side for the two banana varieties with the value of 3.65 mm and 2.95 mm respectively. From the data obtained, both Scavendish and *Nipah* banana variety have similar peel thickness.

From Table 1, it can be concluded that the peel thickness of *Nipah* banana fruit at the edges of the plane is higher than the sides. Average edge peel thickness was measured at 5.30mm.while side peel thickness was 3.65 mm which was 44.18% different. This difference is due to the rectangular shape of *Nipah* banana. Using the data obtained, some of the peeling machine component specifications can be determined. The thickness of the peel is used to determine the blade thickness for banana slitting mechanism. The minimum diameter will be used for entrance gap of the banana peeler. As for weight, it would be used later to calculate the force required on the slitting and peeling mechanism.

Table 1
Physical properties of unripe nipah banana fruit

	Weight of fruit (g)	Peel thickness, edge (mm)	Peel thickness, side (mm)	Diameter (mm)	
				Height	Width
Average	77.85	5.30	3.65	38.78	29.25
Min	46.40	3.54	2.10	25.99	19.66
Max	150.90	7.37	7.16	52.48	43.87
Standard Deviation	28.61	0.93	1.01	5.77	4.92

Mechanical Properties of Fruit

Penetration Test. Graphical output from texture analyser machine representing penetration force was presented in Figure 3. From the graph, the penetration force for all three points is decreasing throughout five days which are from 7.53N to 6.59 N (top position), 7.59N to 6.40N (middle position) and 8.31N to 6.43N (bottom position). The highest penetration force is needed at the bottom while the lowest was at the top for day 1 to 4. As for day 5, the textural behaviour changes as the top position needed higher penetration force compared to the bottom. A one-way ANOVA using SPSS ver. 20.0 and Duncan's multiple range test was used to analyse the significance difference of average penetration force as seen in Table 2.There is a significant difference ($P<0.05$) in the bottom at day 3 to 4, as well as the top at day 4 to 5, while at the top position there is a significant difference between day 2, 3, 4 and 5.This represented the peel behaviour which softened through 5 days. As seen in the graph, the peel started to soften drastically on day 5. This trend follows similarly with results presented in Hou et al. (2015) for Cavendish banana. A study made by Kulkarni et al. (2011) concluded that when the banana started to ripen, moisture content in fruit pulp gradually increased while for peel it was gradually decreased. This softens the pulp and allows the force to penetrate the peel to decrease. As banana chip producers only use banana up to three days after harvest, the average of penetration force on the first three days was averaged out and was used to build the slitting mechanism of the banana peeling machine.

Compressive Test. Figure 4 shows the compressive force of *Nipah* banana variety throughout 5 ripening days. The compressive force decreased from 1704 N to 1336.14 N. The trend shows that when the banana started to ripen, the peel softened, allowing the force to press the banana decreases. A one-way ANOVA using SPSS ver. 20.0 and Duncan's multiple range test was used to analyse the significance difference of average compression force as seen in Table 2. It shows a significant difference (P <0.05) on day 3 to 5. The rapid changes may be due to physicochemical changes during the banana ripening. A study was made by Kiyohide (1996) on pulp softening. Both physical and chemical component played their role in the banana pulp softening. Banana started to exhibits pulp softening after day 2 of ripening. The major components of pulp softening were found to be elasticity and viscosity of pulp, cell wall polysaccharides, pectin, and hemicellulose. Using the average force on the first three days, the force of roller to push the banana into the slitting and peeling mechanism can be obtained.

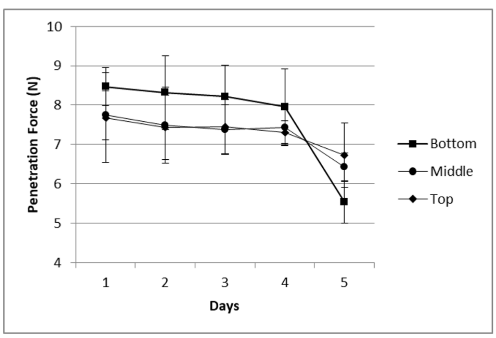

Figure 3. Effect of different positions of nipah banana on penetration force during maturity

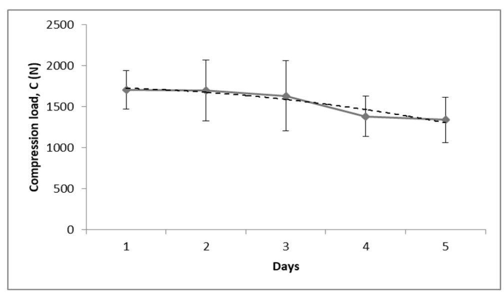

Figure 4. Effect of *Nipah* banana on compression force during maturity

Table 2

Mechanical properties of banana during ripening

Days	Average Penetration Force (N)			Average Compression Force (N)
	top	middle	bottom	
1	7.53[a]	7.59[a]	8.31[a]	1704.00[a]
2	7.29[a]	7.35[a]	8.16[a]	1696.64[a]
3	7.30[b]	7.24[a]	8.14[a]	1630.70[ab]
4	7.17[c]	7.27[a]	7.31[ab]	1380.14[bc]
5	6.59[d]	6.40[b]	6.43[b]	1336.14[c]

In each column, means followed by the same letter are not significantly different (P0.05) according to Duncan's multiple range test.

CONCLUSIONS

The physical properties of *Nipah* banana were measured. changes of mechanical properties of *Nipah* banana fruit as a function of ripeness stage were also conducted. A significant difference was found in both mechanical test. At different level of ripeness, there was a significant difference of penetration force at different positions (top, middle, and bottom) where there were rapid changes from day 3 to 5 at the top position. The compression force also shows a significant difference from day 3 to 5. Both mechanical properties show a significant difference starting from day 3 of ripening. This shows that the banana is unsuitable to be used for banana chip processing after day 3 as suggested by most banana chips factories. By using the average penetration and compression force for the first three days, it provides data to determine the suitable force required to slit the banana peel and maximum force for the roller of the banana peeler machine to transport from one point to another respectively. As for the physical properties, it is used to specify the size of each component. The results gathered are important for engineers working on machine development for bananas. It will be able to assist them to specify the physical dimension and requirements needed in their machine. Besides, it can also be used for postharvest handling and packaging of bananas.

ACKNOWLEDGEMENT

The authors acknowledge with thanks, the financial support (UPM/700-1/2/GPB/2017/9543400) and facility that Universiti Putra Malaysia has provided to carry out research activities.

REFERENCES

Ammawath, W., Che Man, Y. B., Yusof, S., & Rahman, R. A. (2001). Effects of variety and stage of fruit ripeness on the physicochemical and sensory characteristics of deep-fat-fried banana chips. *Journal of the Science of Food and Agriculture*, *81*(12), 1166-1171.

Department of Statistics Malaysia. (2011). *Supply and utilization accounts selected agricultural commodities 2007-2011*. Putrajaya, Malaysia: Anon.

Ganai, S. A., Ahsan, H., Tak, A., Mir, M. A., Rather, A. H., & Wani, S. M. (2018). Effect of maturity stages and postharvest treatments on physical properties of apple during storage. *Journal of the Saudi Society of Agricultural Sciences*, *17*(3), 310-316.

Hamir, N. A., & Ariff, M. K. M. (2006). Market potential of banana chips industry in Malaysia. *Economic and Technology Management Review, 1*(1), 83-90.

Hou, J., Hu, Y., Huo, L., Guo, K., & Takaaki S. (2015). Classification of ripening stages of bananas based on support vector machine. *International Journal of Agricultural and Biological Engineering, 8*(6), 99–103.

Kachru, R. P., Kotwaliwale N., & Balasubramanian, D. (1995). Physical and mechanical properties of green banana (*Musa paradisiaca*) fruit. *Journal of Food Engineering 26*(3), 369–78.

Kiyohide, K. (1996). Softening of banana fruit: Relationship between firmness and chemical composition. *Japan Agricultural Research Quarterly 30*, 269-274.

Kulkarni, S. G., Kudachikar, V. B., & Prakash, M. K. (2011). Studies on physico-chemical changes during artificial ripening of banana (Musa sp) variety 'Robusta'. *Journal of Food Science and Technology, 48*(6), 730–34.

Owolarafe, O. K., & Shotonde, H. O. (2004). Some physical properties of fresh okro fruit. *Journal of Food Engineering, 63*(3), 299–302.

Radunić, M., Špika, M. J., Ban, S. G., Gadže, J., Díaz-Pérez, J. C., & MacLean, D. (2015). Physical and chemical properties of pomegranate fruit accessions from Croatia. *Food Chemistry*, *177*, 53-60.

Shi, S., Wang, W., Liu, L., Shu, B., Wei, Y., Jue, D., Fu, J., Xie, J., & Lui, C. (2016). Physico-chemical properties of longan fruit during development and ripening. *Scientia Horticulturae*, *207*, 160-167

Singh, K. K., & Reddy, B. S. (2006). Post-harvest physico-mechanical properties of orange peel and fruit. *Journal of Food Engineering*, *73*(2), 112-120.

Soltani, M., Alimardani, R., Omid, M., & Karaj, I. (2011). Changes in physico-mechanical properties of banana fruit during ripening treatment. *Journal of American Science*, *7*(5), 5-10.