International Journal of Processing and Post Harvest Technology
Volume 3 | Issue 2 | December, 2012 | 251-255
RESEARCH PAPER

Engineering properties of raw banana (*Musa paradisica* L.) fruit

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SUMMARY : This study was to undertaken to investigate some basic engineering properties of two raw banana fruit cultivar in order to facilitate the design of banana processing machineries. These properties are also important for designing of handling and storage equipments for banana processing industries. These engineering properties were investigated at an average pulp and peel moisture content 219.27 per cent (db) and 907.27 per cent (db), respectively were for Musa Cavendish and 287.86 per cent (db) and 897.34 per cent (db), respectively for Robusta. The weight 93.74 g and 149.19 g, effective length 13.24 cm and 17.32 cm, bulk density 940.09 kg/m^3 and 988.36 kg/m^3 and pulp to peel ratio 1.53 and 1.57, respectively for Musa Cavendish and Robusta. The banana diameter and peel thickness depend upon the variety, maturity and portion of it, *i.e.* top to bottom. Diameter at top, middle and bottom for cultivar Musa Cavendish was 31.66 mm, 34.47 mm and 31.65 mm and for Robusta cultivar it was 32.69 mm, 34.62 mm and 32.18 mm. Thickness of peel was found less in Musa Cavendish cultivar (4.45 mm) than Robusta (4.55 mm). The average load required to puncture banana using 2 mm diameter cylindrical probe with peel and without peel was 7.043 N and 5.355 N, respectively for Musa Cavendish, and 7.719 N and 5.277 N for Robusta and it was found 34.621 N and 19.334 N for Musa Cavendish and 48.08 N and 20.456 N for Robusta by using 5 mm diameter cylindrical probe.

KEY **W**ORDS : Banana, Engineering properties, Cultivar

How to cite this paper : Pawar, K.R., Atkari, V.T. and Sutar, R.F. (2012). Engineering properties of raw banana (*Musa paradisica* L.) fruit. *Internat. J. Proc. & Post Harvest Technol.*, **3** (2) : 251-255.

Research chronicle : Received : 23.07.2012; **Revised :** 25.08.2012; **Accepted :** 25.10.2012

Musa paradisiaca which is commonly called banana is herbaceous plant of the family *Musaceae*. It is originated from tropical region of south East Asia. Banana fruit is grown in more than 120 countries, mainly in sub-tropical areas. Banana is the most important fruit crop in terms of nutritive value, which has large scale demand for table purpose and is available in large quantity throughout the year.

Banana is the second largest produced fruit after citrus, contributing about 16 per cent of the world's total fruit production (FAO, 2009). India is largest producer of banana, contributing to 27 per cent of world's production. The major banana producing states are Maharashtra, Kerala, Tamilnadu, Gujarat, Bihar, West Bengal, Assam, Andhra Pradesh and Karnataka (Mohapatra *et al.*, 2010). According to Indian horticulture database banana cultivation area and production in India was 830 ha, 29,780 MT, respectively in 2010-11(Kumar *et al.*, 2011). Banana is a fast growing and high biomass-yielding plant. There are approximately 1200 seedless fleshy fruit varieties. They are cultivated primarily for their fruit and to a lesser extent to make fiber and as ornamental plants. The fruit stalk, or bunch, is the organ of interest for banana cultivation, primarily for food purposes. A period of about 8-13 months exists between planting the banana tree and harvesting bunches, which can contain 100-400 fruit. Optimum harvest date, or flowering-harvest interval, is determined from flowering, according to the climate zone and variety (Aurore *et al.* (2009).

Bananas are in the shape of a long curving cylinder. The bottom end narrows to a point and the top end has a thick stem that attaches the fruit to the inflorescence stalk. A small group of bananas is termed "hands". Hands are collectively known as "bunches". Banana skin is smooth and thick and often has a few vertical ridges that run the length of the fruit. The flesh is creamy white and soft. Bananas are usually yellow (green when unripe), but there are also red and brown cultivars. Bananas are harvested in the unripe stage when the fruits are still green

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and firm. The harvested bananas pass through three physiological developmental stages, namely the pre-climacteric or 'green life' stage, the climacteric or ripening stage which covers the eat-ripe, and finally the senescence stage when the fruits are over-ripe and dying (Nelson *et al.*, 2006). Banana is considered as critical fruit for peeling due to uneven, irregular shape and certain kind of cellular fibre around flesh as peel. However, peeling as well as slicing by hand is a relatively slow operation and involves substantial labour when a large number of peeled, sliced bananas are desired. The development of the processing technologies will require information on the engineering properties of banana fruit in order to get better outcomes and further investigations. These physical and mechanical properties of the various cultivar banana fruits will be useful in design of peeler, slicing machine and other banana processing machineries.

EXPERIMENTAL METHODS

Fully matured unripe banana fruits of Robusta and Musa Cavendish cultivar were procured from Anand fruit market. All the experiments were conducted at room temperature (25 ± 3^0 C: 58–60% RH). Bananas were sorted according to their size, shape and washed in clean water which was further used to measure engineering properties.

Physical properties like fruit weight, pulp weight, volume, bulk density, effective length, diameter of fruit, thickness of the peel and pulp to peel ratio were measured. In this study banana pulp and its peel at moisture levels of 287.86 per cent and 897.34 per cent, and 219.27 per cent and 907.37 per cent for Robusta and Musa Cavendish, respectively were used as fix parameter for experiments to determine some engineering properties. The moisture content was determined by placing 3.5-4.0 mm thick banana slices with and without peel in a single layer, in an aluminium dish in a hot air oven, at 130 ± 1°C for 1.5 h. Weight loss on drying to a final constant weight was recorded as moisture content by AOAC (1984) recommended method by and using the following equation (1):

$$MC = \frac{M_o - M_d}{M_d} x100 \quad .....(1)$$

where, MC is moisture content (db.), M_o is initial mass and M_d is the final mass of fruit (g).

Mass of individual fruit was determined using an electronic balance with a sensitivity of 0.0l g. Fruit volumes were measured by water displacement method. The bulk density was determined using the mass/volume relationship (equation 2) (AOAC, 1984).

$$\rho b = \frac{M}{V} \quad .....(2)$$

where, ρb is the bulk density (kg/m3), M and V are bulk mass of fruit (kg) and the plastic container volume (m3), respectively.

The principle dimensions, *i.e.* length (L) and diameter (D) were measured by using a Vernier calliper of 0.01 cm least count. The test was performed with 50 replications.

The surface hardness of fruits were measured using texture analyzer (TA-Hdi, Stable Microsystems, UK) with 2 mm dia stainless steel probe and 5mm dia stainless steel cylindrical probe for the both varieties. The operating conditions of texture analyzer were kept as, pre-test speed: 1.5 mm/s, test speed: 0.5 mm/s, post-test speed:10.0 mm/s and trigger force: 0.10 N. Average force recorded by the probe considered as hardness (N) of pulp (Sajeev *et al.*, 2004).

EXPERIMENTAL FINDINGS AND ANALYSIS

The experimental findings of the present study have been presented in the following sub heads:

Physical properties:

Physical characteristics at 219.27 per cent and 907.37 per cent (db) moisture content of pulp and peel for Musa Cavendish and 287.86 per cent and 897.34 per cent (db) moisture content of pulp and peel for Robusta are summerised in Table 1. In case of Robusta cultivar the pulp moisture content were found maximum and peel moisture content were minimum than Musa

Table 1: Some physical constituent and properties of banana

	Moist. content (% db)		Weight (g.)	Effective length (cm)	Volume (m^3)	Bulk density (kg/m^3)	Pulp to peel ratio
	Pulp %	Peel %					
Variety				Musa Cavendish			
Average	219.27	907.37	93.74	13.24	100	940.09	1.53
Maximum	285.57	966.19	99.94	14.1	110	990.33	1.63
Minimum	123.053	831.03	85.82	12.2	90	901.63	1.48
Standard deviation	78.68	54.04	6.18	0.87	10	36.12	0.062
Variety				Robusta			
Average	287.86	897.34	149.19	17.32	153	988.36	1.57
Maximum	302.98	926.17	167.51	18.3	185	1234.83	1.74
Minimum	267.95	876.33	125.91	15	120	899.34	1.39
Standard deviation	12.59	18.59	15.12	1.31	24.39	140.59	0.13

Cavendish cultivar. Fruit weight was measured for both varieties, for Musa Cavendish variety weight varied from 85.82 g to 99.94 g, the average being 93.74 g. and for Robusta variety these values found to be 125 g. and 167.51 g, with an average of 149.18 g. The length of the fruits from cultivar Robusta was higher than the fruits of Musa Cavendish, at the same volume and bulk density of cultivator Robusta were found higher than the Musa Cavendish. The pulp to peel ratio for Musa Cavendish variety and Robusta variety were found 1.53 and 1.57, respectively. Volume as well as bulk density of Musa

Table 2: Variation in thickness of peel and diameter of banana at top, middle and bottom of two varieties

	Diameter of banana (mm)			Diameter of banana without peel (mm)			Thickness of peel (mm)		
	A	B	C	A	B	C	A	B	C
Variety					Musa Cavendish				
Average	31.66	34.472	31.65	23.87	26.61	24.66	3.69	3.95	3.97
Maximum	33.5	35.6	32.55	25.5	28.45	27.9	4.35	4.45	4.45
Minimum	30.35	33.1	30.8	22.8	23.25	23.0	3.15	3.65	3.65
Standard deviation	01.20	1.066	0.68	1.126	2.112	1.992	0.466	0.346	0.305
Variety					Robusta				
Average	32.69	34.622	32.18	26.79	26.54	25.09	3.82	3.94	3.96
Maximum	33.55	35.65	34.3	28.459	28.46	27.15	4.3	4.65	4.55
Minimum	31.9	33.5	29.45	25.00	24.9	23.65	3.2	3.6	3.55
Standard deviation	0.74	0.852	1.87	1.539	1.392	1.371	0.456	0.41	0.378

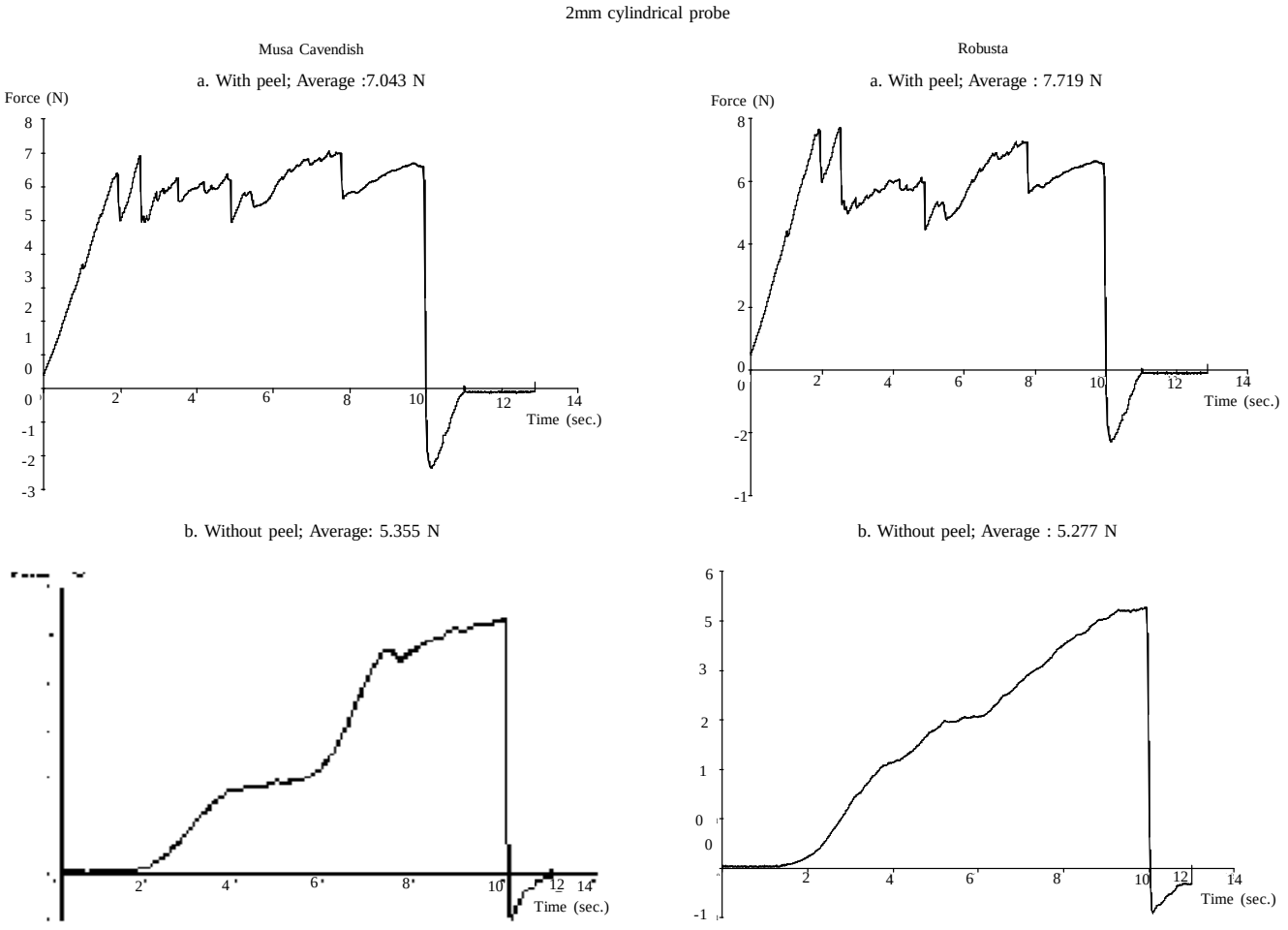

Fig. 1: Graphical representation of deformation curve: by using 2 mm diameter cylindrical probe

Cavendish was minimum as compared to Robusta.

It can be seen that the diameter of fruit was less at both the ends and maximum in the middle portion. The maximum and minimum observed diameters for Musa Cavendish and Robusta banana with peel were 35.60 mm, 30.35 mm and 35.65 mm, 29.45 mm, respectively. These values for the fruit without peel were 28.45 mm, 22.80 mm and 28.46 mm, 23.65 mm, respectively (Table 2).

Thickness for the peel of Musa Cavendish cultivar was 3.65 mm and for Robusta cultivar it was 3.94 mm. The banana peel is formed by 3-5 longitudinal planes and the joint of these planes forms a ridge. The thickness of peel was more at these ridges than other places.

It was observed from Fig. 1 and 2 that the surface or peel hardness was higher than the pulp. Due to the high fibre content of the pulp, the failure was not uniform.

Deformation force by using 2 mm diameter cylindrical probe for Musa Cavendish and Robusta with peel, ranged from 9.158 N to 13.46 N and 11.707 N to 16.119 N, respectively. Without peel the deformation forces ranged from 5.616 N to 6.563 N and 5.3 N to 6.128 N for Musa Cavendish and Robusta, respectively (Fig.1). By using 5 mm cylindrical probe deformation force for Musa Cavendish and Robusta with peel, ranged from 36.105 N to 59.253 N and 45.97 N to 49.052 N. Without peel the deformation forces ranged from 22.871 N to 27.32 N and 20.324 N to 23.668 N for Musa Cavendish and Robusta, respectively (Fig. 2). The hardness of Robusta variety of banana was higher than the Musa Cavendish variety of banana. The deformation force required was higher for 5 mm cylinder probe as compare to 2 mm cylinder probe.

Conclusion :

Minimum deformation force is required for smaller contact area penetrating probe as compared to greater surface contact penetrating probe.

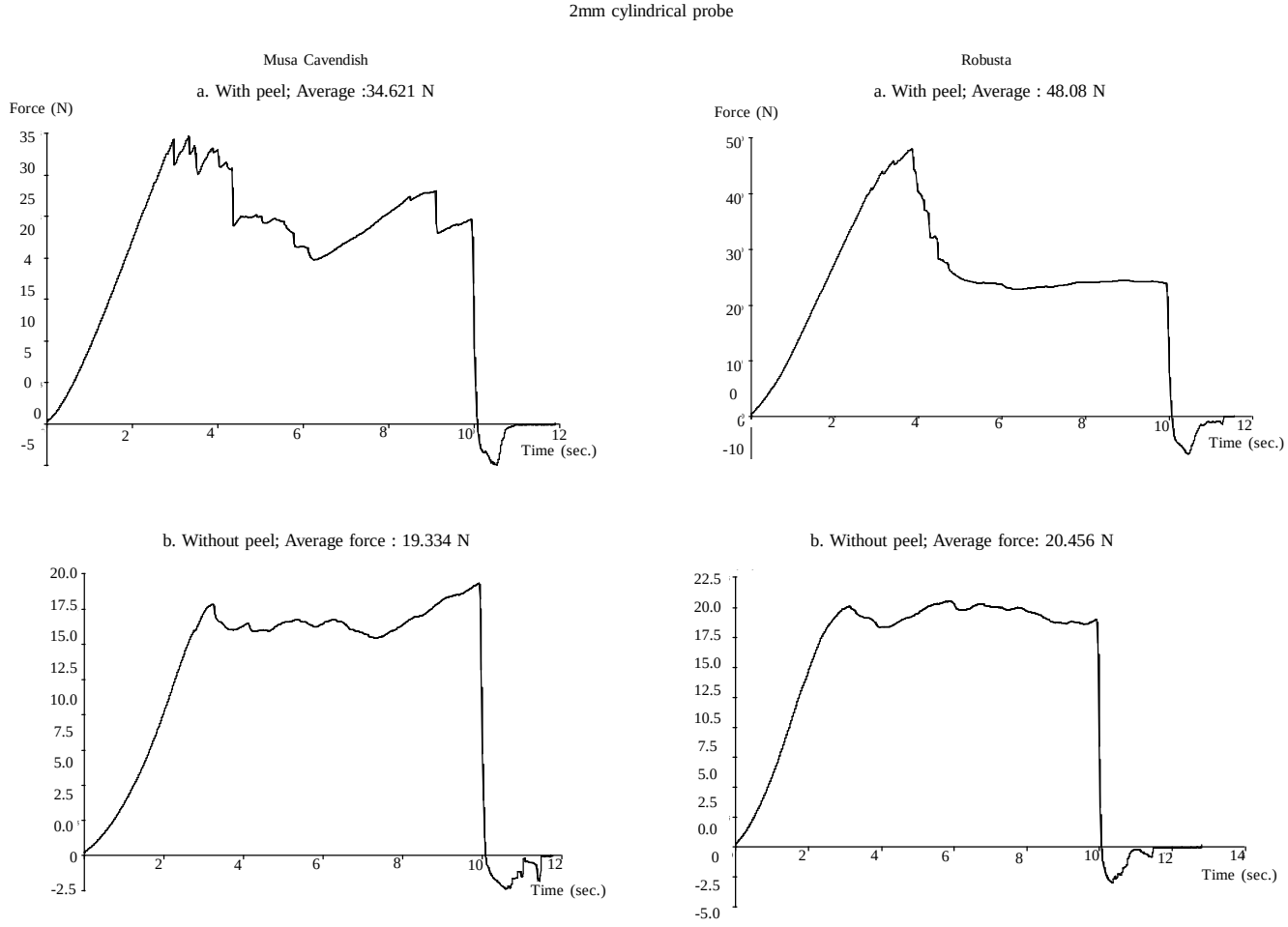

Fig.2: Graphical representation of deformation curve: by using 5 mm diameter cylindrical probe

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