Postharvest Mechanical Damage in Mangosteens

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Abstract

Mechanical damage is one of the limiting factors in mangosteen marketing. Mangosteen fruit were subjected to tests for fruit detachment force, maximum fruit rupture force, and a series of compression forces. Impact damage was assessed by a fruit drop test from various heights singly or packed in columns of 2, 3 or 5 fruit. The fruit detachment force, latex stain at the break point, and the resistance of fruit to compression force reduced as the fruit maturity advanced. Rupture force decreased from over 100 kg for fruit at stage 0 maturity, to about 8 kg for stage 4 fruit. A compression force of 3 to 4 kg caused very slight or no damage to the fruit. At 5 kg or more, the pericarp collapsed in the more mature fruit. Impact damage to the fruit, expressed as a hardening of the pericarp at the point of impact, increased with increasing drop heights. A drop of 10 cm caused slight damage to the pericarp. At 20 cm or higher, damage to the pericarp increased and the aril was also affected. For fruit dropped while packed in columns 2, 3, or 5 fruit high, more damage occurred to the lowest fruit. Mechanical damage in mangosteens would be reduced greatly by careful handling thus avoiding forces sufficient to cause compression or impact damage.

Introduction

Mangosteen, *Garcinia mangostana* L., is one of the most attractive and highly esteemed tropical fruit. It is considered by many people to be the tastiest of tropical fruit but is little known in Western markets. The fruit is native to Malaysia and is widely grown throughout the Southeast Asian countries and the Indian sub-continent.

The fruit about the size of a tennis ball, has a thick (5-11 mm) red-brown or purple pericarp which is not edible. When ripe, the fruit can be cut or opened by finger pressure applied to the equatorial region. Inside, there are 4 to 7 segments of edible aril which vary in width. The aril is juicy, soft, white, and somewhat translucent with a fine pattern of reticulation. It tastes sweet, subacid, slightly glutinous, and with a delicate pleasant flavour (Almeyda and Martin, 1976; Martin, 1980).

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It has been reported that the pericarp serves as an excellent packing material to protect the soft pulp during transportation (Popenoe, 1974). However, most mangosteen fruit reaches the consumer with some degree of mechanical injury caused by compression or impact damage as a result of improper harvesting methods and careless handling. We report here, the relationship between the fruit detachment force from the tree and harvest maturity; and the susceptability of mangosteen fruit at various maturity stages to compression forces and to impact damage.

Material and Methods

Fruit: Experimental fruit was obtained from commercial orchards in Amphoe Klaeng, Changwat Rayong and Amphoe Lang Suan, Changwat Chumphon, Thailand. Fruit were carefully harvested to minimize mechanical damage using a bamboo pole with, at one end, both a hook to pull the fruit off and a net to receive the fruit. Fruit were harvested in the morning and transported to the laboratory in the afternoon of the same day. Fruit was selected for uniformity in size. The fruit maturity stage was determined by visual examination according to a method developed at this laboratory. There are seven maturity stages defined by the extent of red or purple colouration on the pericarp: Stage 0 (pericarp uniformly yellowish - white or with a light green tinge or greyish spottings), Stage 1 (pericarp light greenish yellow with scattered pinkish spots, minimum stage for harvesting), Stage 2 (pericarp light greenish yellow or yellowish pink with distinct irregular pink spots covering the entire fruit), Stage 3 (pericarp background pinkish, spots not as distinct as in stage 2, a stage commonly harvested commercially), Stage 4 (pericarp red or redish brown, some with purple tinge), Stage 5 (pericarp darkened to reddish purple, best eating stage), Stage 6 or more (pericarp purple, dark purple to black with slight or no red colouration remaining).

Fruit Detachment Force: This study was carried out in the orchards at Amphoe Klaeng in May 1984 and Amphoe Lang Suan in August 1984. Detachment force was measured with a mechanical gauge (Chatillon push and pull gauge) having a hook attachment requiring a pull and twist action to detach the fruit from the tree. The break point in most cases was at a natural abcission layer at the peduncle. Fruit detachment force and the severity of yellowish latex stain at the break point of the peduncle were recorded. Latex at the break point of the peduncle was rated as follows: 0 = no latex, 1 = slight, 2 = moderate, and 3 = severe. A minimum of 10 fruit of each of the stages 0, 1, 2, 3, and 4, were selected at random in each orchard. The results are the averages from two locations.

The force required to remove the fleshy calyx was measured by a pull action at the joint of the calyx and the peduncle using a Chatillon push and pull gauge. There were 10 fruit each at maturity stages 3 - 4 and 4 - 5.

Fruit Rupture Force: The rupture force was measured with a Hinde & Dauch crush tester. The fruit was laid on its side on the crush tester to avoid interference of the calyx at the top and the stigma at the end of the fruit. In one experiment (Fig. 1), a single fruit at each maturity stage was used to determine the relationship between maturity stage, the force applied, and the amount of fruit distortion before fruit ruptured. In another experiment (Fig. 2), a steadily increasing force was applied at the equator of the fruit until the fruit ruptured. The maximum force applied and the fruit deflection before the fruit ruptured was recorded. The rupture force was determined for fruit at all maturity stages. There were 8 to 10 fruit of each maturity stage for one replicate. Results are the averages of 4 separate replications of fruit obtained from orchards in the two locations and from local markets.

Fig 1.
Relationship between compression force and fruit deflection of mangosteens at maturity stage O (●), 1 (○), 2 (□), 3 (■), 4 (△), 5 (▲), and 6 (•). Results are from single fruit of each maturity stage.

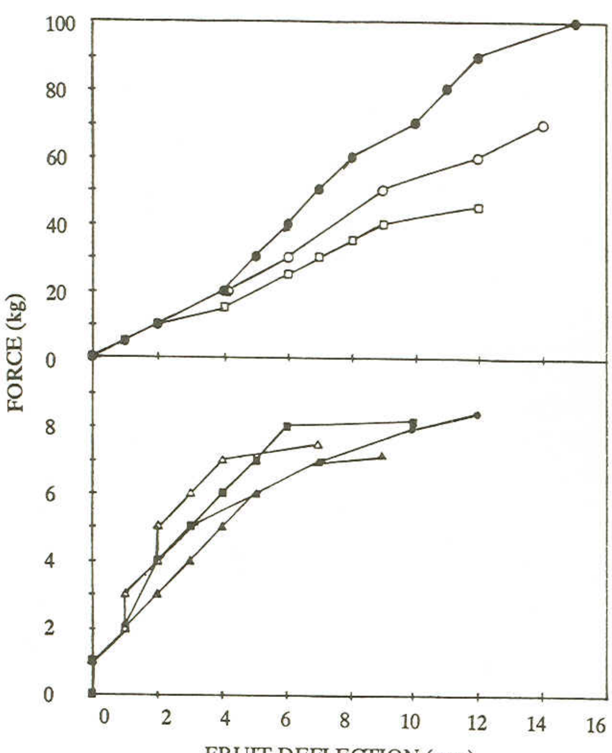
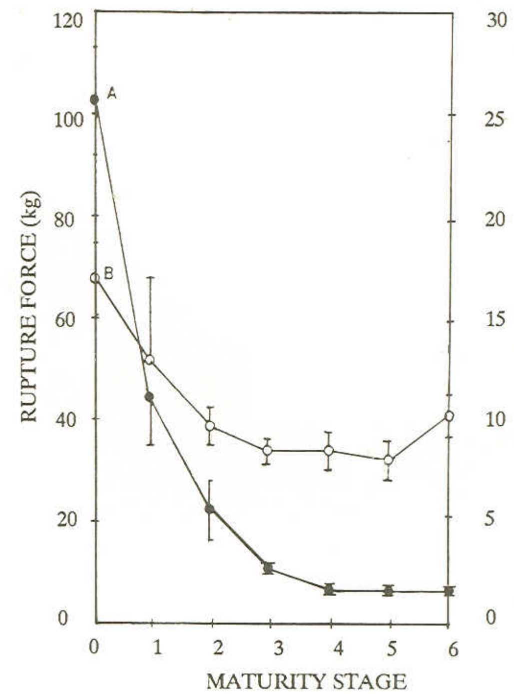


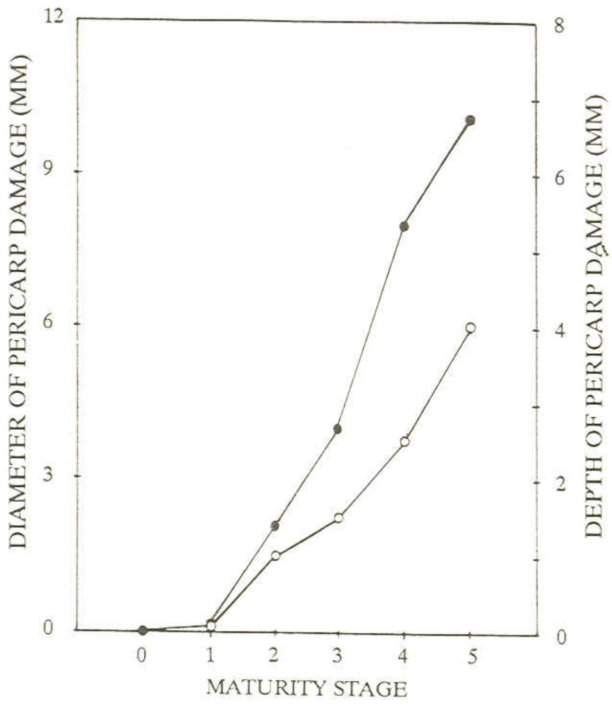
Fig 2.
Relationship between maturity stages and :
A. the rupture force (●) and
B. the fruit deflection when the fruit ruptured (○).
Results are the average of 4 replicates.



Compression Force: Specific compression forces (3, 4, 5 or 6 kg) were applied momentarily to the equator of fruit which were laid between two steel plates of a mechanical gauge (Chatillon push and pull gauge). Fruit were then held at a room temperature from 25-27C. Mechanical injury was assessed 4-6 days later by measuring the diameter and the depth of the damaged area in the pericarp (Table 2). Fruit at maturity stages 2, 3-4, and 5 were tested. There were 20 fruit at each maturity stage. In another experiment (Fig. 3), a steadily increasing compression force up to 5 kg was applied, and then immediately reduced, to fruit of maturity stages 1, 2, 3, 4, and 5. Assessment of injury to the pericarp was made 6 days later. Results are from 10 fruit of each maturity stage.

Drop Test: The fruit were oriented so that the calyx and the stigma were horizontal before being released from various drop heights, viz 5, 10, 20, 40, 60, 80, and 100 cm, to impact a concrete floor. The point of impact on each fruit was marked on the pericarp. After impact, fruit were held for at least 3 days at 25 C to allow symptom development, which was expressed as a hardening of the damaged area. Impact damage was assessed by measuring the diameter and the depth of the hardened pericarp. The condition of the aril was also assessed. Results are from 10 fruit for each drop height. All the fruit tested were at maturity stage 4.

Fig 3.
Relationship between maturity stages and compression damages. Indicated by diameter (●) and depth (○) of damaged pericarp. Compression force of 5 kg was used. Results are the average of 10 fruit of each stage.



Impact Damage of Column-Packed Fruit: Impact damage to the fruit was measured after dropping column-packed fruit, laid on the fruit equator, and packed in light cardboard tubes each containing 2, 3, or 5 fruit. Fruit of maturity stage 4-6 were used. For each fruit, the point of contact with adjacent fruit was marked beforehand so that the impact position could be identified later. Tubes of fruit were dropped vertically from heights of 5, 10, 20, 40, and 60 cm onto a concrete floor. The impact damage was assessed 5 to 6 days later by measuring the diameter and the depth of the hardened pericarp. Assessment was also made of the aril condition. Results are means of 5 replicates.

Results

Relationship Between Detachment Force and Maturity Stage

There was a considerable variation in the detachment force required among fruit within each maturity stage. The fruit detachment force and the severity of latex flow at the break point of the peduncle decreased as the fruit maturity increased from stage 0 to 2 and remained the same as fruit maturity advanced further (Table 1). A greater pull force for calyx removal was recorded for fruit at stage 3-4, 4.9 kg, than stage 4-5, 4.0 kg.

Table 1
Relationship Between Detachment Force, Latex Score, and Fruit Maturity Stage

Maturity Stage	Detachment force (kg)	Latex Score[1]
0 - white	2.96	2.2
0 - white with green tinge	2.30	1.5
1	2.09	0.8
2	1.19	0.6
3	1.24	0.3
4 - 5	1.32	0.2
LSD .05	NS	0.5

[1]Latex Score : 0(none), 1(slight), 2(moderate) and 3(severe). Results are obtained from a minimum of 20 fruit of each stage in two orchards.

Effect of Maturity Stage on Fruit Rupture Force

Fig. 1 shows an almost linear relationship betwen the applied force and the amount of distortion before rupture of fruit at maturity stages of 0 to 6. The slop of the line is steeper for stage 0 indicating harder fruit. As fruit became softer, after stage 3, a straight-line response occurred with forces between 0 and 8 kg. Then the response flattened off before the fruit ruptured.

Fig. 2 shows the relationship between maturity stage, the fruit rupture force, and the amount of fruit distortion when the fruit ruptured. Rupture force decreased from more than 100 kg when the fruit was at stage 0 to about 8 kg. at stage 4. Fruit are considered eating ripe at stage 4 onwards. As fruit reached stage 6, there was a slight increase in the rupture force and distortion.

Compression Damage

With fruit at stage 2 maturity, compression forces of 3, 4, 5 or 6 kg caused very slight or no damage (Table 2). At 6 kg of compression force, fruit of maturity stage 5 broke open. In all other cases, damaged to the pericarp extended to less than 4 mm in depth. The aril quality was apparently unaffected. The type of damage to the fruit caused by compression is limited to the pericarp as hardening of the bruised area occurred a few days later after the compression force was applied.

The relationship between fruit maturity stage and compression force is illustrated in Fig. 3. Fruit at a higher maturity stage were more susceptible to compression force. Damage to the aril was not observed with compression force of 5 kg in any of these fruit.

Table 2
Damage[1] in Mangosteens in Relation to Compression Force

Compression force (kg)	Maturity Stage 2	3 - 4	5
3	0.1	0.4	0.9
4	0.6	5.7	0.7
5	1.4	8.6	7.4
6	0.7	1.8	overall breakdown

[1]Damage assessed by measuring diameter (mm) of damaged or hardened area in the pericarp. Results are the average of 20 fruit at each maturity stage.

Impact Damage

Impact damage was expressed by hardening of the pericarp, occurred 1 to 2 days later, at the point of impact. Impact damage of mangosteen fruit, which were released from various drop heights, is shown in Table 3. Damaged

Table 3
Impact Damage in Mangosteens Dropped Singlely from Various Heights

Drop Height (cm)	Damaged Surface area (%)[1]	Depth of damage area (mm)[2]	Degree of internalaril damage[3]
5	0.3	0.3	-
10	5.2	5.0	-
20	9.4	8.5	±
40	14.7	8.5	+
60	13.4	8.5	+
80	15.7	8.5	+
100	17.1	8.5	+

[1] The surface area of half fruit ($2\pi r^2 = 16.69\ cm^2$, obtained from the average of all experimental fruit) was used in the calculation. Mangosteens of maturity stage 3-5 were used. Results are the average of 10 fruit for each drop height.

[2] The average thickness of the pericarp is 8.5 mm.

[3] Impact damage to the internal aril: - aril not affected, ± aril slightly affected and + aril affected.

Table 4
Impact Damage of Column Packed Mangosteens

Drop Height (cm)	Packing Arrangement (No. of fruit)	Interface (%damaged surface area)[2] 1 (1)[1]	1 (2)	2 (1)	2 (2)	3 (1)	3 (2)	4 (1)	4 (2)	5 (1)	5 (2)
5	2-fruit	1.1	0	0	0	-	-	-	-	-	-
	3-fruit	4.2	1.9	1.4	0.4	1.6	0	-	-	-	-
	5-fruit	10.0	0.9	3.6	1.6	2.50.4	1.0	2.0	0.6	0	
10	2-fruit	9.7	0.4	4.6	0	-	-	-	-	-	-
	3-fruit	7.9	4.1	7.1	0	3.0	0	-	-	-	-
	5-fruit	8.2	3.1	4.2	0.4	3.4	2.0	0.8	1.6	1.4	0
20	2-fruit	12.1(±)[3]	5.2	7.9	0	-	-	-	-	-	-
	3-fruit	12.8(±)	6.2(±)	1.0	2.1	5.5	0	-	-	-	-
	5-fruit	14.6(±)	8.6(±)	3.8	1.0	6.4	1.3	7.4	3.6	2.5	0
40	2-fruit	17.1(+)	4.5(±)	6.4	0	-	-	-	-	-	-
	3-fruit	13.3(+)	3.3(±)	6.2(±)	1.7	4.1	0	-	-	-	-
	5-fruit	28.7(+)	17.3(+)	11.3(±)	10.9(±)	7.7(±)	8.6	15.5(±)	9.7	8.8	0
60	2-fruit	30.3(+)	14.8(±)	11.4(±)	0	-	-	-	-	-	-
	3-fruit	18.7(+)	17.3(+)	19.4(+)	11.7(+)	6.6(±)	0	-	-	-	-
	5-fruit	33.1(+)	14.2(+)	17.8(+)	18.4(+)	17.3(+)	17.9(+)	14.6(+)	9.7(±)	9.4(±)	0

[1] Fruit number in the column. Mongsteens of maturity stage 3 to 5 were used. Results are the average of 5 replicates.

[2] The surface area of half fruit ($2\pi r^2 = 16.69cm^2$ obtained from the average of all experimental fruit) was used in the calculation. Each fruit has two figures which represent damaged surface area of (1) on the lower surface and (2), interface with the next fruit on its top.

[3] Symbol in parenthesis indicates impact damage to the aril : ± aril slightly affected and + aril affected.

area increased with increasing drop height. At drop heights of 5 and 10 cm, there was slight damage to the pericarp. The aril was not affected. At 20 cm, there was slight damage to the internal aril. The surface of the aril turned light pink or brown along the reticulation. Damage to the aril was readily apparent at a drop height of 40 cm or higher. The affected aril tissue collapse, dehydrated and turned pink or brown. For fruit packed in columns and dropped from 5 cm, the damaged area was greater in columns of 5-fruit than in columns of 2- and 3-fruit (Table 4). At a drop height of 10 cm, damaged areas were less affected by the number of fruit in the column. With incresing drop height, damage to the pericarp increased, especially in the lowest fruit. At 20 cm, there was slight damage to the aril of the lowest fruit at the bottom of the column. At 40 cm, the aril of only the topmost fruit were not affected. At 60 cm, all fruit were affected.

Discussion

Harvesting fruit before optimum harvest maturity was associated with excess latex flow at the break point. Exuded latex from immature fruit contaminated other fruit and caused unsightly stains. In order to avoid this problem, mangosteen fruit should not be harvested before maturity stage 2. The forces required in the calyx-removal test, and the observation that some mangosteens in the market have broken peduncles, indicate the physical force some fruit are subjected to. With the advancement in maturity, the susceptibility of fruit to compression damage increased. Mangosteen at stage 5 was unable to withstand a compression force of 6 kg.

Damage due to impact is one of the most serious problems affecting mangosteen quality. Impact damage on the pericarp can be seen as lines radiating out from the point of impact. The damaged pericarp hardened within 24 hours. The damaged aril tissue collapsed, dehydrated, and turned light brown. The most likely cause of impact damage in commercial crops is improper harvesting methods and careless handling. To minimize such injury, mangosteen fruit should not be dropped during harvesting and subsequent handling.

"Gamboge", a disorder of unknown cause, is often confused with damage due to impact. In affected fruit, latex is found inside the aril and its surrounding tissue even in ripe fruit. The disorder causes difficulty in separation of the aril from the pericarp, and hardening of the pericarp. Postharvest diseases may also cause hardening of the pericarp and can easily be confused with damage due to impact.

Acknowledgement

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