Durian Fruit Dehiscence—Water Status and Ethylene

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Abstract. Immature and mature durian (*Durio zibethinus* Murr.) fruit dehiscence was studied. Fruit were stored at 27°C and 65% or 95% relative humidity, with or without 24-hour exposure to 100 ppm ethylene. Low relative humidity and ethylene increased fruit dehiscence. Spraying fruit with 100 ppm GA₃ delayed dehiscence but allowed pulp ripening to continue. The plant-growth regulators IBA; 2,4-D; 2,4,5-T; BAP; daminozide; and mepiquat chloride had no consistent effects on fruit dehiscence. Various coating materials delayed dehiscence and ripening; a sucrose fatty acid ester at 1% concentration gave the best result. All coating materials reduced weight loss 7% to 14% below that of the control fruit. Fruit coated with the sucrose fatty acid ester and 100% apple wax had higher internal CO₂ levels than fruit coated with any other coating. Ethylene is more important in durian fruit dehiscence than weight loss. Chemical names used: 3-indolebutyric acid (IBA); 2,4-dichlorophenoxyacetic acid (2,4-D); 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); 6-benzylaminopurine (BAP); succinic acid-2,2-dimethyl hydrazide (daminozide); 1,1-dimethyl-piperidinium chloride (mepiquat chloride); gibberellic acid (GA₃).

Durian is an important tropical fruit in southeastern Asia. In 1990, it was the major fresh fruit export from Thailand, valued at \$10 million (Dept. of Customs, 1991); the main markets are Hong Kong and Singapore. This climacteric fruit has distinct respiration and ethylene production peaks (Booncheram, 1991; Tongdee et al., 1990). A major postharvest problem of fully ripe durian fruit is dehiscence along the suture in the middle of each locule. Consumers in Singapore prefer fully ripe durian with no splitting; however, Thai consumers prefer less-ripe fruit with a relatively firm pulp texture and a milder scent. Partially ripe durian fruit are difficult to open because the abscission zone along the suture has not fully developed. Splitting fruit with mechanical aids works only on ripe fruit and sometimes damages the pulp.

For most dehiscent fruit, such as pecan [*Carya illinoensis* (Wangenh.) K. Koch], the suture opens because of shrinkage associated with water loss from the tissue (Wood, 1986). In pistachio (*Pistacia vera* L.), shell dehiscence depends on seed growth and development and is not the result of the seed exerting force on the surrounding endocarp (Crane and Iwakiri, 1982). Instead, it results from abscission triggered by some substance(s) emanating from the seed. In durian fruit, an abscission

zone develops along the suture, and as the fruit matures, tannin deposition occurs in those cells (unpublished data).

Our goal is to report the role of weight loss, ethylene, and other plant-growth regulators on durian fruit dehiscence. The efficacy of commercial coating materials in preventing durian dehiscence also is reported.

Materials and Methods

A commercial orchard in Klang district, Rayong province, on the eastern coast of Thailand provided 'Chanee' durian fruit. Fruit of the same size were tagged 10 days after full

bloom, and they were ≈7 to 13 days after anthesis. Fruit were harvested immature or mature in the morning, transported to Kamphaengsaen campus the same day, and used immediately for experiments. Five to 15 fruit were used per treatment. Unless otherwise stated, fruit were harvested at 110 days from anthesis.

Effect of weight loss. Durians were harvested 90 and 110 days after anthesis. Each fruit (≈2 kg) was placed in a metal container for 5 days with air at 65% or 95% relative humidity (RH) circulated at 2 liters·min⁻¹. To obtain 95% RH, air was bubbled through water before entering the container. For 65% RH, 100 g of silica gel was placed in the bottom of the container and replaced every 12 h to maintain RH at 60% to 70%. A hygrometer (Nikei Co., Japan) was placed inside one container of each treatment. Temperature was maintained at 27 ± 2°C.

Effect of plant-growth regulators. For 24 h, durian fruit were exposed to fresh moist air (≈95% RH) or air containing 100 ppm ethylene; then they were transferred to an open shelf at 27 ± 2°C and 70% to 80% RH. Another fruit set was sprayed with IBA (1000 or 5000 ppm); 2,4-D (100 or 1000 ppm); 2,4,5-T (100 or 1000 ppm); GA₃ (10 or 100 ppm); BAP (10 or 100 ppm); daminozide (500 or 5000 ppm); mepiquat chloride (25 or 100 ppm); or water (as a control). Fruit were kept at 29 ± 2°C and 70% to 80% RH for 6 days.

Effect of coating materials. Four commercial coating materials were tested; a sucrose fatty acid ester, Semperfresh (Semper Biotechnology, London); apple wax and storage wax (solid content = 17.3% and 21.7%, unknown composition) (Safepak Product, Kfarsaba, Israel); and Sta-fresh #360 (shellac and rosin, solid content = 18.1%) (FMC Corp., Lakeland, Fla.) at various concentrations according to the manufacturer's general recommendation (see Table 3). Fruit were hand-sprayed and then stored at 29 ± 2°C and 70% to 80% RH for 6 days.

Fig. 1. Dehiscence in durian fruit starts at the styler end and progresses to the stem end.

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Fruit dehiscence and quality evaluation. Durian dehiscence (Fig. 1) was assessed by estimating the proportion of each locule open (0, 1, 2, 3, and 4 = no dehiscence, 1/4, 1/2, 3/4, and full length, respectively) and calculating a dehiscence score (0 to 20, where 20 = all locules dehisced from the styler end to the fruit stem). Husk thickness was measured with a vernier caliper at the fruit equator. Pulp firm-

ness was measured by removing the pulp (including the seed) from durian locules and pressing it with a firmness tester (modified from a commercial weight scale) (Teo Co., Bangkok, Thailand) with a plunger head 5 mm in diameter. Pulp soluble solids concentration (SSC) was measured with a hand-held refractometer (Atago Co., Tokyo) after blending the pulp with three volumes of water and centri-

fuging. Pulp color was estimated by comparing it to a color chart [The Royal Horticultural Society (RHS), London]. Starch was determined from dried pulp (Association of Official Analytical Chemists, 1984).

Internal gas determination. Gas was withdrawn from durian locules by submerging durian fruit under water and using a needle and syringe to extract gas. Gas concentrations were measured by gas chromatography with silica gel column and thermal conductivity detector for CO₂ and Porapak N and flame ionization detector for ethylene.

Results

Relative humidity. Durian fruit weight loss was $\approx 4\%$ per day, even at 95% RH. Five days after harvest, fruit lost $\approx 18\%$ of its weight at the higher RH and $\approx 27\%$ at the lower RH (Fig. 2A). Younger fruit (90 days postanthesis) lost more weight per unit weight than mature fruit. Durian fruit kept at or under 65% RH for 5 days had a dehiscence score of 6 to 7, but it was only 1 to 3 for fruit stored at the higher humidity (Fig. 2B). The immature fruit started to dehisce more quickly than mature fruit after harvest. High RH delayed the onset of dehiscence and reduced the splitting rate. No differences were noted in the pulp quality of the fruit kept at the two humidities. Mature fruit were softer and had a higher SSC than the immature fruit (Table 1). Pulp and seed color were similar in both treatments, but mature fruit had darker pulp and seed color; 15B and 20A vs. 16D and 18B (RHS color chart). Husk thickness was similar at the two humidities and ranged from 5.3 to 6.7 mm.

Plant-growth regulators. Weight loss was slightly higher in fruit treated with ethylene (Fig. 3A). The onset of dehiscence was advanced by ≈ 1 day, and the rate of dehiscence was higher in ethylene-treated fruit than control fruit (Fig. 3B). Immature fruit took ≈ 3 more days to dehisce than mature fruit. Ethylene treatment did not significantly enhance ripening as judged by pulp firmness (Table 1).

Fig. 2. (A) Effect of two relative humidities (RH) on weight loss and (B) dehiscence score of immature and mature durian fruit stored at 27°C. (●) Immature durian (90 days postanthesis), 65% RH; (○) immature durian, 95% RH; (■) mature durian (110 days postanthesis), 65% RH; (□) 95% RH. Vertical bars represent SD ($n = 5$).

Table 1. Effect of storage at two relative (RH) humidities and of a 24-h ethylene treatment on fruit pulp resistance to compression and soluble solids concentration (SSC) of durian fruit following 5 days of storage at 27°C.

Fruit maturity	Treatment	Pulp	
		firmness (N)	SSC (%)
	RH (%)		
Immature	65	6.08 a ^z	13.9 b ^z
	95	8.45 a	14.6 b
Mature	65	1.18 b	23.8 a
	95	1.27 b	23.4 a
	Ethylene (ppm)		
Immature	0	7.26 m	15.0 n
	100	5.69 m	16.7 n
Mature	0	7.16 m	23.3 m
	100	6.34 m	21.3 m

²Mean separation within columns and variables by Duncan's multiple range test at $P \leq 0.05$.

Most of the plant-growth regulators tested had some effect on fruit dehiscence. Mepiquat chloride at 25 ppm enhanced dehiscence relative to the control, but 100 ppm BAP significantly reduced dehiscence scores. Initial tests indicated that fruit treated with 1000 ppm 2,4,5-T or 100 ppm GA₃ did not dehisce (Table 2). A subsequent experiment showed that only GA₃ delayed fruit dehiscence (data not shown). The GA₃-treated fruit remained green until the end of the experiment (6 days), but the control fruit and fruit in the other treatments changed to yellow-green. Weight loss and SSC were similar for the various treatments. However, pulp of fruit treated with 2,4-D or 2,4,5-T was firmer than that from other treatments (Table 2).

Coating material. All coating materials used in this experiment significantly reduced weight loss. Fruit waxed with Semperfresh lost ≈40% as much weight as the control fruit (Table 3). At 9 days, all treated fruit had higher CO₂ concentrations than the control fruit, except those treated with Sta-fresh #360 wax at 20% (Table 3). On all three evaluation dates, ethylene concentration in fruit that were treated with 1% Semperfresh, 100% apple wax, and 100% storage wax was lower than the control fruit. Durian dehiscence was significantly reduced by these three coatings, with the Semperfresh resulting in no dehiscence. There was a reduction in flesh softening and starch degradation by most coatings; however, the increase in SSC was delayed only by Semperfresh (Fig. 4). Semperfresh also delayed the pulp yellowing by 3 days. No off-flavor was detected in treated fruit. Aroma was milder at the end of the experiment in fruit treated with 1% Semperfresh than in control fruit or fruit in other treatments.

Discussion

Weight loss (Figs. 2 and 3) and subsequent shrinkage, which was easily observable, may provide a natural force to pull the fruit open. However, ethylene had a greater effect than weight loss on fruit dehiscence. Ethylene accelerated the onset of dehiscence in immature and mature fruit, suggesting that cell weakening in the separation zone had been induced. However, weight loss can cause stress ethylene production (Abeles, 1973), which may lead to weakening of the suture zone.

GA₃ significantly delayed durian fruit dehiscence with no apparent effect on other ripening changes measured. This finding might be the result of GA₃ failing to penetrate into the fruit's pulp or of evaluating ripening at a stage when treatment differences had already disappeared. However, Booncherm (1991) found that most of the ethylene and CO₂ production occurred in the husk, with low rates in the pulp. Hence, GA₃ could indirectly delay pulp ripening by delaying husk ripening. GA₃ delayed color development in tomato (*Lycopersicon esculentum* Mill.) and banana (*Musa* sp.) without affecting other ripening processes (Dostal and Leopold, 1967; Vendrell, 1970). The mechanism by which GA₃ delays durian fruit dehiscence is not known.

Fig. 3. (A) Effect of a 24-h ethylene treatment on weight loss and (B) dehiscence score of durian fruit stored at 27°C. (○) Immature durian, 0 ppm C₂H₄; (●) 100 ppm C₂H₄; (□) mature durian, 0 ppm C₂H₄; (■) 100 ppm C₂H₄. Vertical bars represent sd (n = 5).

Table 2. Effect of plant-growth regulators on dehiscence and pulp quality of durian fruit stored 6 days at 29°C.

Plant-growth regulator	Concn (ppm)	Dehiscence score	Dehiscence fruit (%)	Pulp firmness (N)
IBA	1000	2.5 ab ²	50.0	2.65 d ²
	5000	1.8 a-d	66.7	3.92 b-d
2,4-D	100	2.7 ab	83.3	5.98 a
	1000	0.8 de	33.3	5.59 a
2,4,5-T	100	2.2 a-c	83.3	5.20 ab
	1000	0.0 e	00.0	4.70 a-c
GA ₃	10	1.2 b-d	33.3	3.14 cd
	100	0.0 e	00.0	2.84 d
BAP	10	2.8 ab	83.3	2.64 d
	100	0.3 e	16.7	2.45 d
Daminozide	500	2.5 ab	50.0	2.65 d
	5000	0.8 de	33.3	3.33 cd
Mepiquat chloride	25	3.2 a	66.7	3.82 b-d
	100	2.5 ab	50.0	3.82 b-d
Control	---	1.2 b-d	50.0	2.26 d

²Mean separation within columns by Duncan's multiple range test at *P* ≤ 0.05.

Table 3. Effect of coatings on weight loss, internal CO₂ and C₂H₄ concentrations, and dehiscence of durian fruit stored at 29C for various amounts of time.

Coating material	Concn (%)	Wt loss at 9 days (%)	CO ₂ (%)			C ₂ H ₄ (ppm)			Dehiscence score at 9 days
			Storage duration (days)			Storage duration (days)			
			3	6	9	3	6	9	
Control	---	23.8 a ^z	9.3 e ^z	20.2 d ^z	40.6 f ^z	10.8 b ^z	24.9 bc ^z	33.9 a ^z	4.7 a ^z
Semperfresh	1	9.8 d	18.1 a	32.2 a	60.2 a	6.1 d	11.1 e	17.7 e	0.0 b
Apple wax	100	12.5 cd	18.8 a	28.7 b	58.8 a	8.9 c	15.8 d	20.3 d	1.6 b
	50	16.6 b	11.4 cd	22.4 c	45.5 c	10.4 b	23.9 c	30.7 c	4.5 a
Storage wax	100	11.4 cd	15.9 b	29.5 b	55.3 b	10.0 b	17.0 d	21.0 d	0.4 b
	50	13.3 bc	12.7 c	20.9 cd	43.3 d	9.2 d	25.9 a	31.9 a–c	4.9 a
Sta-fresh	20	16.0 b	10.4 de	20.1 d	41.1 ef	12.9 d	25.4 ab	31.1 bc	3.9 a
	10	16.6 b	11.1 cd	19.8 d	42.2 de	13.2 a	22.1 c	32.3 ab	4.6 a

^zMean separation within columns by Duncan's multiple range test at $P \leq 0.05$ (n = 15).

Fig. 4. (A) Changes in pulp firmness and (B) soluble solids and (C) starch concentrations of durian fruit coated with various materials and stored at 29C, 70% to 80% relative humidity. (○) Control, (Δ) Semperfresh 1%, (▲) Sta-fresh 20%, (□) apple wax 100%, (■) storage wax 100%. Vertical bars represent SD (n = 15).

Coating materials were effective in preventing durian fruit dehiscence. The coatings prevented fruit weight loss and created a modified atmosphere (high CO₂ and presumably low O₂) in the fruit. This atmosphere modification may interfere with ethylene production and action (Yang, 1985). The main factor influencing durian dehiscence was ethylene production because coating with apple wax 50%, storage wax 50%, and Sta-fresh 10% and 20% reduced weight loss by 30% of the control, but internal ethylene concentration and dehiscence scores were not different (Table 3) from those of the control. In addition, weight loss was similar in durian fruit, whether treated or not treated with ethylene (Fig. 3), but those that were treated had higher dehiscence scores.

In commercial practice, GA₃ alone could be used for a shipment of fully mature fruit to markets that prefer such nondehiscent fruit with ripe pulp. For distant markets, such as America and Europe, or markets within Thailand that prefer less ripe fruit, waxes could be used to delay ripening. A combination of wax and GA₃ should be tested in future experiments to extend durian storage life.

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