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Volume 4: Mangosteen to white sapote

Edited by Elhadi M. Yahia

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Cover image: Fruit stand in Malaysia (Photo: Elhadi M. Yahia).

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Salak (*Salacca zalacca* (Gaertner) Voss)

S. Supapvanich, Kasetsart University, Thailand, R. Megia, Bogor Agricultural University, Indonesia and P. Ding, University of Putra Malaysia, Malaysia

Abstract: The salak is an indigenous palm found throughout the Indo-Malaysian region. It is a small spiny palm that grows on moist well drained soil with high organic matter content. The fruit is drupe oval or spindle shaped (like a fig) with a distinct tip, tapering towards the top and rounded at the top end. The skin is covered with regularly arranged scale, creating an appearance similar to that of snake skin, from which the name 'snake skin fruit' is derived. The salak is a crunchy fruit that has a taste that combines the flavours of apple, banana, and pineapple. It is a good source of antioxidants that cannot be matched by other tropical fruits.

Key words: salak, *Salacca zalacca, Salacca edulis*, snake skin fruit, spiny palm, Indo-Malaysia region.

16.1 Introduction

16.1.1 Origin, botany, morphology and structure

The salak (*Salacca zalacca*, syn. *S. edulis, Calamus zalacca*) belongs to the family Palmae or Arecaceae genus *Salacca*, which is the only family in the monocot order Arecales. It is an indigenous palm found throughout the Indo-Malaysian region, i.e. Thailand, Indonesia, Malaysia, Cambodia and South of Myanmar, Vietnam, Philippines and China (Draft ASEAN Standard for Horticultural Produce, 2009; Lestari and Ebert, 2002; Rangsiruji *et al.*, 2006; Supriyadi *et al.*, 2002; Wijaya *et al.*, 2005). It has been introduced into the countries of New Guinea and Queensland, Australia (Lestari and Ebert, 2002).

There are 21 species and four varieties of *Salacca* (Rangsiruji *et al.*, 2006). In Thailand, the salak is cultivated in the eastern and southern parts of the country and the main commercial species grown are *S. wallichiana* Mart and *S. rumphii*, known as Rakam and Sala, respectively, by Thais (Dangcham, 1999; Thangjatuporn,

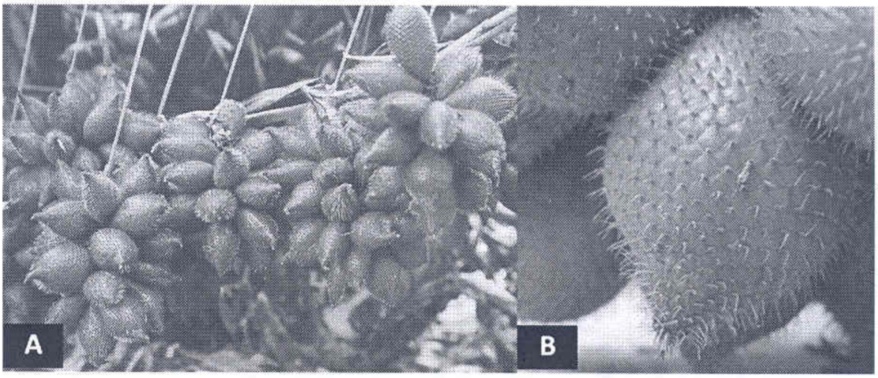

Fig. 16.1 *Salacca rumphii* Wall (Sala) (A) and *Salacca wallichiana* Mart (Rakam) (B).

2000) (Fig. 16.1). There are three main species of salak grown commercially in Malaysia, which are *S. glaberescens*, *S. edulis* and *S. sumatrana* (Abu Bakar and Idris, 2006). *S. glaberescens* is known as local salak and there are nine clones being bred for planting (Tables 16.1 and 16.2), while *S. edulis* and *S. sumatrana* are the two species of salak introduced from Indonesia. In Indonesia, the important commercial cultivars for domestic and export markets are *S. zalacca* (Gaertner) Voss with the synonim *S. edulis* (Reinw) (Mogea, 1982) (Fig. 16.2A) and *S. sumatrana* Becc. *S. zalacca* is subdivided into two varieties, var. *zalacca* from Java and var. *amboinensis* (Becc.) Mogea from Bali (Fig. 16.2B) and Ambon. *S. sumatrana* is more commonly known as salak Padang Sidempuan (North Sumatra).

In Indonesia there are more than 30 cultivars of salak, which are often distinguished by their place of origin (eg.: salak 'Bali', 'Suwaru', 'Condet', or 'Enrekang', 'Padang Sidempuan'), fruit taste (eg.: salak 'gula pasir', 'pondoh', or 'madu'), or fruit colour (eg.: salak 'putih' or 'gading'). The cultivar may also be

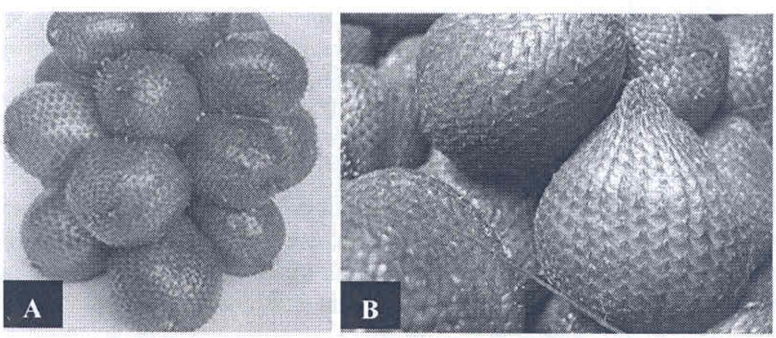

Fig. 16.2 *Salacca edulis*, Reinw (Salak Pondoh) (A) and *Salacca zalacca* var. *amboinensis* (Salak Bali) (B).

Table 16.1 Physico-chemical characteristics of Malaysian salak, *S. glaberescens* clones

Fruit characteristics	Clone					
	SJ15	SJ17	SJ34	SJ36	SJ39	SJ40
Weight (g)	50–62	64–84	65–100	66–85	50–85	
Length (cm)	6–9	7–9	8–10	6–8	6–9	5.7–7.5
Width (cm)	4–6	4–6	4–8	4–6	3–5	5–6.7
Shape	Oval with sharp tip	Round	Oval with long sharp tip	Round	Oval with sharp tip	Round with sharp tip
Skin colour	Dark brown	Brown	Brown	Red brown	Dark brown	Brown
Flesh colour	White	Light orange	Light yellow	Pale orange	Light orange	Red spot at bottom of flesh
Texture	Firm and juicy	Juicy and crunchy		Firm and slightly juicy	Soft	Firm and juicy
Taste	Sourish sweet	Sourish sweet and aromatic	Sweet with slight astringent and aromatic	Sourish sweet	Sweet with slight astringent	Sweet
Soluble solids concentration (°Brix)	14–18	14–18	16–20	18–20	16–19	16–20
Edible portion (%)	57	61	63	64	69	69

Table 16.2 Physico-chemical characteristics of selected salak clones in Terengganu, Malaysia

Fruit characteristics	Clone		
	ST1	ST2	ST3
Weight (g)	80	75	68
Length (cm)	8–10	6–8	6–9
Width (cm)	4–6	4–6	3–5
Shape	Oval to oblong	Round to oval	Oval with long sharp tip
Skin colour	Reddish-brown	Reddish-brown	Reddish-brown
Flesh colour	Creamy white	Creamy white	Creamy white
Texture	Juicy	Juicy and crunchy	
Taste	Sweet with slight astringent	Sweet	Sweet with slight astringent
Soluble solids concentration (SSC) (°Brix)	16–20	15–18	17–19
Titratable acidity (TA) (%)	0.73	0.63	0.73
SSC/TA ratio	22.5	26.7	22.5
Water content (%)	81	83	81
Edible portion (%)	63	64	69

divided into sub-cultivars, i.e. salak 'pondoh' is divided into: 'pondoh super', 'pondoh hitam' and 'pondoh manggala'. Some superior salak varieties that have been officially released by the Department of Horticulture, Agricultural Ministry of Indonesia Government include: salak 'pondoh', 'suwaru', 'nglumut', 'enrekang' (Celebes), and 'gula batu' (Bali).

The salak is an extremely spiny palm, which does not form a trunk and which grows on a wide range of soils but prefers moist well-drained soil with high organic matter content (Kueh, 2003). It requires shade and is best intercropped with banana, durian, rubber, oil palm, coconut and cocoa. It is about 6 m tall. The leaves pinnate can reach 10 m long and 1.50 m wide; each leaf has a 2 m long spiny petiole and numerous leaflets measuring 20–89 cm long and 2–11 cm wide. The upper surface of the leaflets is dark green and shiny, while lower surface is light green. Long, strong, grey to blackish spine clusters are distributed along the frond base at intervals of 3–5 cm.

The palm fruits at about 3–4 years after planting. It is usually dioecious, although some have been found to be monoecious (e.g. Salak Bali) where they could self pollinate. The inflorescence is an axillary compound spadix with a stalk: the female inflorescences are 20–30 cm long, and are composed of 1–3 spadices, 7–10 cm long; the male inflorescences are 50–100 cm long, consisting of 4–12 spadices, each measuring 7–15 cm × 0.7–2 cm. About 20% of the male palms are retained as pollinators, while the rest are removed. Assisted pollination is carried out to improve the fruit set.

The fruit of the salak grows in clusters of 15–40 fruits/spadix, at the base of the palm. The fruit is drupe oval or spindle shaped (like a fig) with a distinct tip; it measures 5–8 cm × 5 cm, tapering towards the top and rounded at the top end and fits comfortably into a human palm and weighs about 70 g, depending on the species and variety. The skin, which is thin and strong, is covered with regularly arranged scales, which serve to create an appearance similar to that of snake skin, from which the name 'snake skin fruit' is derived. The colour of the fruit skin is reddish-brown to brown or dark brown, depending upon the species and cultivars (the skin of mature Thai Rakam and Sala fruits are reddish-brown [Thangjatuporn, 2000]). To peel the fruit, simply pinch the tip of the fruit and pull away, revealing the garlic-like clove inside, which is arranged in 1–3 irregular sized segments. Before eating the fruit, a paper-thin layer of membrane covering each segment needs to be rubbed off. Usually two of the three segments are bigger and each segment contains a large inedible dark brown seed, while the third segment is smaller and seedless. The taste is usually sweet and acidic with a pineapple, pear or banana-like aroma, and an apple-like texture, which can vary from very dry and crumbly to moist and crunchy or soft, depending on the species and cultivar. Rakam and Sala fruits grown in Thailand have creamy, moist, soft and thin flesh (Thangjatuporn, 2000). The salak fruit is astringent too due to its high tannin content. Generally, most salak fruits, such as Thai Rakam and Sala, have a sour and astringent taste during the immature stages (Supriyadi *et al.*, 2002; Thangjatuporn, 2000) but become sweeter and lose their astringent taste during maturation. An exception to this trend is the Salak Pondoh (Lestari and Ebert, 2002; Wijaya *et al.*, 2005).

The salak is usually propagated from seeds, of which 50% of the seedlings will be males and the fruit produced are not uniform in quality (Abu Bakar and Idris, 2006). By propagating using suckers, it is possible to retain the characteristics of mother palms. Unfortunately, a palm can only produce 2–10 suckers in its life cycle, moreover, the mortality rate is about 40%. Recently, a few propagating techniques have been established to increase the number of seedlings using female palms that have produced a good quality of fruit. Splitting a 6–12 month old young palm into pieces with leaf, pseudostem and roots has been proven as one of the techniques. Inducing the growth of suckers using diesel or methamidophos has been practiced too. This technique removes the apical dominance of female palms by killing the meristem cells.

16.1.2 Worldwide importance and economic value

Salak fruit has become an exotic and prominent fruit with good potential for both the domestic market and for export. The demand for the fruit per year is about 420 000 tons, including fresh consumption, processed fruit and export. Recently, the demand for the fruit in China, Japan, Europe and United States has increased. The popularity of the fruit has increased since Salak Pondoh was recognized and became a commercial fruit. Indonesia produces 60–70% (334 000 tons) of the world's salak fruit and exports about 32 755 tons year^{-1} (Dimyati *et al.*, 2008). In

Table 16.3 Production of salak fruit in Indonesia in 2006 and 2007

Region/Island	Production (tons)	
	Th 2006	Th 2007
Sumatera	265 815	260 702
Jawa	479 898	419 298
Bali and Nusa Tenggara	63 073	79 933
Kalimantan	19 039	28 725
Sulawesi	32 600	16 111
Maluku and Papua	1 525	1 110
Total	861 950	805 879

Modified from Dimyati *et al.* (2008).

Table 16.4 Production of salak fruit in Thailand in 2008

Province	Average yield (kg ha^{-1})	Total production (tons)
Jantaburi	8 356.25	1 507
Trad	18 062.50	7 745
Chonburi	4 687.50	15
Kanchanburi	10 181.25	81
Total	41 287.50	9 348

Modified from Department of Agricultural Extension (2008).

2006, Indonesian salak was being exported to Singapore, Malaysia and Hong Kong in volumes of about 4–10 tons per week. In 2008, the consumption per capita of the fruit in Indonesia was about 1.64 kg $year^{-1}$ (Dimyati *et al.*, 2008). The production of salak fruit in Indonesia is shown in Table 16.3. In Thailand, Rakam and Sala cv. 'Nernwong' and 'Saynampueng' are an important commercial fruit in the domestic market and the demand for the fruit both domestically and abroad has been increasing. The fruit has been exported to Singapore, Hong Kong and Malaysia (Thangjatuporn, 2000). The average yield and total production of salak fruit in Thailand are shown in Table 16.4.

16.1.3 Culinary use, nutritional value and health benefits

Salak fruit is a good source of antioxidants (Aralas *et al.*, 2009; Leong and Shui, 2002; Lim *et al.*, 2007). With a level higher than that of other tropical fruits such as mangosteen, avocado, orange, papaya, mango, pomelo, lemon, pineapple, rambutan, banana and watermelon (Aralas *et al.*, 2009; Leong and Shui, 2002). The nutritional values of salak fruit are shown in Table 16.5. The high level of antioxidants is due to salak having a high content of phytochemicals such as

Table 16.5 Phytonutrients and minerals in salak fruit

Dietary fibre (b)	
Insoluble fibre	0.75 ± 0.07 g 100 g^{-1} fresh weight
Soluble fibre	0.35 ± 0.04 g 100 g^{-1} fresh weight
Total dietary fibre	1.1 ± 0.1 g 100 g^{-1} fresh weight
Total antioxidant capacity (b, c)	
Total DPPH	110.4 ± 7.9 mM TE 100 g^{-1} fresh weight
Total ABTS	260 ± 32.5 AEAC mg 100 g^{-1} fresh weight
Flavonoid (b)	
Free flavonoids	14.1 ± 0.9 mg CE 100 g^{-1} fresh weight
Total flavonoids	61.2 ± 4.9 mg CE 100 g^{-1} fresh weight
Phenolic content (b)	
Free polyphenol	33.2 ± 1.7 mg GAE 100 g^{-1} fresh weight
Total phenolic	217.1 ± 13.2 mg GAE 100 g^{-1} fresh weight
Ascorbic acid content (a)	$0.73 - 1.28$ mg 100 g^{-1} fresh weight
Minerals and trace elements (b)	
Na	1.9 ± 0.1 mg 100 g^{-1} fresh weight
K	191.2 ± 12.6 mg 100 g^{-1} fresh weight
Mg	7.16 ± 0.5 mg 100 g^{-1} fresh weight
Ca	6.11 ± 0.4 mg 100 g^{-1} fresh weight
Fe	301.7 ± 11.2 µg 100 g^{-1} fresh weight
Mn	249.9 ± 11.7 µg 100 g^{-1} fresh weight
Zn	35.1 ± 2.9 µg 100 g^{-1} fresh weight
Cu	8.4 ± 0.6 µg 100 g^{-1} fresh weight

Modified from (a) Aralas *et al.* (2009), (b) and (c) Haruenkit *et al.* (2007), Leong and Shui (2002).

lignin, flavonols, and gallic acid. These chemicals have been shown to inhibit proliferation and induce selective cytotoxicity and apoptosis in cancer cells (Aralas *et al.*, 2009; Lin *et al.*, 2008; Surh *et al.*, 1999). Gorinstein *et al.* (2009) found there was similarity between salak (cv. 'Sumalee') and kiwi fruit (cv. Hayward) in terms of their antioxidant and antiproliferative effects on two human cancer cell lines (Calu-6 for human pulmonary carcinoma, and SMU-601 for human gastric carcinoma, 90.5–87.6 and 89.3–87.1% cell survival, respectively). In West Java, the boiled skin of salak cv. 'bongkok' is traditionally used to decrease blood glucose concentration for patients with diabetes mellitus (Pratama, 2009). The fruit of the salak cv. bongkok is known for being sour and bitter, so its economic value is low, but the use of this cultivar as a medicinal product can increase the income of farmers and at the same time conserve the genetic diversity of this fruit.

The fruit are not only consumed as fresh fruit, but they are also processed into many food products, such as minimally processed fruit, fruit juice, deseeded-fruit in syrup, canned fruit, jam, fruit candy and pickle, 'dodol', chips or cracker and salak wine (Aralas *et al.*, 2009; Gorinstein *et al.*, 2009; Thangjatuporn, 2000). The young salak can be used to make a salad called 'rujak' in Indonesia.

16.2 Fruit development and postharvest physiology

16.2.1 Fruit development respiration and ethylene production during maturation

A few reports have been published on the postharvest physiology of salak (Dangcham, 1999; Lestari *et al.*, 2004; Supriyadi *et al.*, 2002; Wijaya *et al.*, 2005). The fruit weight of a salak increases continuously during its development and maturation, which is a common phenomenon in fruit. The weight of salak flesh increases gradually during its maturation, whilst the seed size does not change during maturation (Supriyadi *et al.*, 2002).

It is not clear whether salak fruit is climacteric or non-climacteric. Dangcham (1999) reported that the respiratory rate of the Thai Sala fruit at 36 and 37 weeks after pollination increased continuously during storage. At 38 weeks after pollination the fruit showed a respiration peak at day 3 after storage and then it declined. The increase in respiration was concomitant with an increase in ethylene production, where the peak was found to be at day 4. These findings suggested that the salak fruit might be classified as a climacteric fruit; however a further investigation is required to confirm this hyphothesis.

16.3 Changes in quality components during maturation

A combination of the day after pollination and the changes in the concentration of soluble solids, acidity, astringency, odours, skin and seed colours are used as the index for harvesting salak. In Thailand, it is recommended that Sala and Rakam are harvested at 37–39 and 28–30 weeks after pollination, respectively (Dangcham, 1999; Thangjatupon, 2000). Supriyadi *et al.* (2002) suggested that the optimum stage for the consumption of salak was 5.5 months after pollination, when the flesh showed high firmness, sugar content and aroma compounds.

16.3.1 Skin and flesh colours

Skin, flesh and seed colours are used as a maturity index for salak. Basically, salak are harvested when the skin colour has changed to blackish brown and seed colour has turned black or blackish brown (Sukewijaya *et al.*, 2009). At immature stages, the flesh colour is white, then it changes to yellowish white when the fruit ripens (Supriyadi *et al.*, 2002). Plate XXX in the colour section between pages 238 and 239 shows immature and mature Salak Pondoh fruit. In Thailand, the skin colour of Sala and Rakam is dark brown in the immature stages, and the colour changes to brownish orange or reddish brown as the maturation increases (Thangjatuporn, 2000), see Plate XXXI in the colour section. The flesh colour of the Thai Sala and Rakam are light yellowish-white in the immature stages, after which the flesh colour changes to creamy or yellowish orange with the increase in maturation (Dangcham, 1999; Thangjatuporn, 2000). The seed colour also changes from light brown in the immature stages to blackish brown or grey-brown when the fruit ripens (Thangjatuporn, 2000).

16.3.2 Soluble solids concentration and titratable acidity

The soluble solids concentration of the fruit increases continuously during maturation (Dangcham, 1999; Supriyadi *et al.*, 2002). Supriyadi *et al.* (2002) reported that the Salak Pondoh became sweet when the fruit was 4.5 months after pollination. The glucose and fructose contents of the fruit increased during maturation, whereas the sucrose content increased until 5 months after pollination and then decreased. Similarly, the soluble solids concentration of Thai Sala fruit increased until 37 weeks after pollination and it then slightly declined at 38 weeks (Dangcham, 1999). The reduction of the sucrose content might be associated with the increase in glucose and fructose content during fruit development (Supriyadi *et al.*, 2002), while titratable acidity in the fruit decreases during maturation (Dangcham, 1999; Surpriyadi, 2002; Thangjatuporn, 2000). Dangcham (1999) reported that the titratable acidity of the Thai Sala at 36 and 37 weeks after pollination was higher than that of the fruit at 38 weeks after pollination (Table 16.6).

Table 16.6 Firmness, soluble solids concentration and titratable acidity of Sala fruit during development

Weeks after pollination	Firmness (N)	Soluble solids concentration (°Brix)	Titratable acidity (%)
36	26.55	17.47	0.81
37	32.72	19.12	0.87
38	25.02	18.79	0.74

Modified from Dangcham (1999).

16.3.3 Firmness

Texture is universally known as a very important factor in evaluating the quality of fruit. During maturation, the firmness of the salak increases and it then declines at the later stages of maturation (Dangcham, 1999; Supriyadi *et al.*, 2002). It is widely accepted that the texture of the Salak Pondoh is firm and crunchy, while the texture of the Thai Sala and Rakam fruits is soft and juicy at full maturation stage. During maturation, the pulp firmness of the salak increased until fruit reached 5.5 months after pollination and by 6 months after pollination the firmness declined (Supriyadi *et al.*, 2002). Similarly, the firmness of the Thai Sala fruit at 37 weeks after pollination was higher than that of the fruit at 36 weeks and the firmness then decreased in the fruit at 38 weeks (Table 16.6). Mahendra and Janes (1993) reported that salak stored at 22–24 °C showed an increase in firmness at day 7 and then decreased throughout storage (it is normally recognized that the loss of firmness during fruit ripening is concomitant with the modification of the cell wall structure). However, Lestari *et al.* (2004) reported that even though there was a marked increase in the ratio of soluble pectin to insoluble pectin of the salak during ripening, a slight change in the fruit firmness occurred.

16.3.4 Volatile compounds

Aroma is widely known as an important factor affecting the quality of salak and reports have shown that methyl esters of short-chain carboxylic acids are the major volatile compounds in salak (Supriyadi *et al.*, 2002, 2003; Wijaya *et al.*, 2005). The volatile aroma compounds are responsible for the sweaty and fruity character of the fruit (Supriyadi *et al.*, 2002; Wijaya *et al.*, 2005). During maturation, the level of esters and carboxylic acid in the salak increased markedly throughout storage. At the first stage of maturation, methyl dihydrojasmonate and isoeugenol were identified as the key volatile compounds in the fruit (Wijaya *et al.*, 2005). Supriyadi *et al.* (2002) suggested that the unsaturated fatty acids in the salak were oxidized to yield methyl ester of short-chain carboxylic acids, of which the level of the compounds increased remarkably throughout maturation, especially in the fruit at 5 and 5.5 months after pollination. Moreover, Supriyadi *et al.* (2003) reported that the methyl ester formation in the salak during development was associated with the action of pectinmethylesterase providing methanol, which was transferred to Acyl-CoA.

16.3.5 Ascorbic acid content

Salak has moderate ascorbic acid content (about 0.73–2.4 mg $100\,g^{-1}$) (Aralas *et al.*, 2009; Leong and Shui, 2002) and the change in the ascorbic acid content in the Thai Sala fruit during storage at various temperatures was reported by Dangcham (1999). Ascorbic acid content in the Thai Sala was about 5.17–5.85 mg $100\,g^{-1}$ and, compared to the salak, the Thai Sala has higher ascorbic acid content. During storage, the ascorbic acid content of the Thai Sala declined remarkably and storage at lower temperatures could delay the reduction of the ascorbic acid content during storage (Dangcham, 1999).

16.4 Preharvest factors affecting fruit quality

Water and sunlight are environmental factors affecting the growth rate of the salak palm, as well as its pollination and fruit quality. The palm requires about 50–70% of full sunshine and an average rainfall of about 200–400 mm $month^{-1}$, or not less than 1500 mm $year^{-1}$ (Sukewijaya *et al.*, 2009; Thangjatuporn, 2000). Thangjatuporn (2000) suggested that the Thai Sala palm requires a good irrigation system, especially during pollination, as water deficiency causes the fruit to drop from the bunch during development, producing an undesirably low quality of the fruit.

16.5 Postharvest factors and physiological disorders affecting fruit quality

Storage temperature is widely recognized as a key factor affecting the quality of perishable crops, including the salak. Dangcham (1999) reported that the shelf life of the Thai Sala stored at room temperature (30 °C) was lower than that of the same fruit stored at cold temperatures (Dangcham, 1999; Mahendra and Janes, 1993). The storage at high temperature and low relative humidity results in dried skin, dark brown or brownish black skin colour, soft and brown flesh and an increasingly astringent taste (Dangcham, 1999). Moreover, high temperature increases the rate of fruit drop from the bunch during storage (Dangcham, 1999; Thangjatuporn, 2000). Even though cold storage is recommended to extend the shelf life and quality of the salak, chilling injury during storage must be considered. It is universally accepted that chilling injury is a normal physiological disorder of tropical and subtropical fruit stored at low temperature. The most common symptom of chilling injury occurring in the salak is skin pitting and dark or brownish black skin colour, and the pulp turning brown and soft (Dangcham, 1999; Mahendra and Janes, 1993). Mahendra and Janes (1993) suggested that the chilling injury symptoms of the salak stored at 3–5 °C exhibited after two days, while the chilling injury of the Thai Sala stored at 10 and 12 °C appeared at seven and 14 days, respectively. The symptoms became more severe with increasing storage time. It is recommended that the fruit is stored at a temperature above 15 °C to prevent chilling injury (Dangcham, 1999; Thangjatuporn, 2000). Mahendra and Janes (1993) reported that no chilling injury symptoms occurred on a salak stored at 15 °C.

Exogenous ethylene from the environment causes fruit to drop during storage. Dangcham (1999) reported that the percentage of fruit drop increased with the increase of ethephon concentration and that exogenous ethylene had an effect on the decrease in titratable acidity of the Thai Sala during storage, resulting in the increase in sugar acid ratio. Table 16.7 shows the effect of exogenous ethylene on fruit drop and certain qualities in the Thai Sala.

Table 16.7 The percentage of fruit drop and quality of Sala fruit treated with ethephon stored for three days

Ethephon (mg L^{-1})	Percentage of fruit drop	Soluble solids concentration, SSC (°Brix)	Titratable acidity, TA (%)	SSC/TA
0	17.11	19.10	0.79	24.18
500	95.36	17.52	0.47	37.81
1,000	100	18.04	0.59	31.30

Modified from Dangcham (1999).

16.6 Postharvest pathology and entomology

Fungi that attack the salak include *Fusarium* sp., *Aspergillus* sp. and *Certocystis paradoxa* (Sukewijaya *et al.*, 2009), while *Marasmius palmivorus* and *Thielaviopsis paradoxa* attack the Thai Sala and Rakam (Thangjatuporn, 2000). The disease spreads rapidly in the rainy season and infects immature fruit on the tree. The following are common symptoms caused by the fungi in mature fruit: a brownish-black or black, water-soaked area covered with white or pinkish-white mycelium forms on the skin and water-soaked on flesh, and the skin becomes very dry and hard, which causes problems in peeling (Thangjatuporn, 2000). Arbie (2010) had tested the effect of alpinia galangal rhizome as a natural antimicrobe on Salak Pondoh stored in a perforated polyethylene plastic bag sized 25 cm × 16 cm with a thickness of 40 μm. The result showed that immersion in 5% alpinia galangal extract for 30 s and storage at 15 °C (85–90% relative humidity (RH)) could extend the shelf life of the Salak Pondoh for 21 days, as compared to 14 days in control.

Good agricultural practices, fruit thinning, orchard hygiene, weed and undesired plant management are required to prevent the spread of the disease in the orchard. Fungicides such as thiabendazol and caboxin are also being used to control the disease. Normally, the fungicide is sprayed before the rainy season and the spraying of the fungicide is stopped about 15 days before harvest (Thangjatuporn, 2000).

Pests such as sugarcane white grub (*Lepidiota stigma* (Fabricius)) and *Salacca* beetle (*Rhynchophorus ferrugineus*) could affect the export of the Indonesian salak to China (Dimyati *et al.*, 2008). In order to export the Salak Pondoh to China, The Indonesian Agriculture Quarantine Agency (IAQA) sent a list of pests to the Ministry of Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) of China. AQSIQ then sent a team of entomologists to verify the condition of Yogyakarta. After the verification, the Memorandum of Understanding between IAQA and AQSIQ was signed to declare that the exportation of the salak fruit from Indonesia was permitted. Thus, good agricultural practice is crucial in exporting the salak.

16.7 Postharvest handling practices

16.7.1 Harvesting, cleaning and grading

Proper postharvest operations are important to maintain fruit quality and to avoid physical damages and diseases. It is recommended that salak fruit is harvested when the hairs on the skin surface disappear and the skin colour changes to blackish brown for the salak and to reddish-brown for the Thai Sala and Rakam; at maximum fruit size, seed colour turns to black or blackish-brown with a pleasant and aromatic taste (Sukewijaya *et al.*, 2009; Thangjatuporn, 2000). The fruit is harvested using a sharp knife or scissors. The salaks are delivered to the packinghouse immediately after the harvest and the fruit are cleaned by spraying clean water or chlorinated water (50–100 ppm hypochloride) to remove soil, insects and undesired matter (Thangjatuporn, 2000).

Salak fruit are classified as extra class, class I and class II. The extra class fruit must be of superior quality and free from defects with the exception of very slight superficial defects which do not affect the general appearance of the fruit. The class I fruit must be good quality and slight defects in shape, colour and skin should not exceed 5% of the total surface area. The quality of the fruit in class II satisfies the minimum requirements and the fruit may have defects in shape and colour, as well as skin defects, of which the total area of defect should not exceed 10% of the total surface area (Draft Asean Standard for Horticultural Produce, 2009). In Thailand, the Sala are classified into two classes for the domestic market which are class 1 (without physical damage and disease and no fruit drop from the bunch) and class 2 (with some physical damage and fruit drop from the bunch) (Thangjatuporn, 2000).

16.7.2 Ripening and senescence control

The salak does not go through the ripening process as it is eaten when the fruit matures, but a few studies have been carried out to control senescence by prolonging storage life. Trisnawati and Rubijo (2010) conducted a study using fruits, either detached from or still attached with their bunch, wrapped using paper and placed in a braided bamboo basket for 15 days. They found that there was a significant decrease in the vitamin C, total acid, pH and soluble solids concentration as storage duration progressed. In another study, the storage life of Salak Bali fruit coated with 10% beeswax and stored in a bamboo basket at 22–26 °C and 70–75% relative humidity could be extended from seven to 12 days, while qualities of the fruit such as vitamin C, tannin content, organic acids and the pH of the fruit could be retained (Wrasiatil *et al.*, 2001). Water loss or weight loss, and sugar degradation were inhibited, but microbiological decay and loss of firmness or texture still occurred even though the Salak Bali was coated with beeswax.

The astringent taste of the salak may cause an unpalatable sensation to new consumers. The tannin content of the Salak Bali cv 'Nangka' can be significantly reduced by applying 25, 50 and 75% ethanol, both in solution and vapour, in a plastic bag with a volume of 5 L for 24 h (Utama *et al.*, 2009). The efficiency of ethanol in removing the astringent taste is concentration dependent, with high ethanol concentration effective in short period of time and vice versa. In addition to this, soluble solids concentration increased while acidity decreased by treating the salak with ethanol.

16.7.3 Storage

In Thailand, it is recommended that Sala and Rakam fruits are stored at 15 °C (Dangcham, 1999; Thangjatuporn, 2000). Dangcham (1999) suggested that the shelf life of Sala fruit stored at 15 °C could last 28 days without chilling injury, while the fruit stored at 12.5 °C showed slight chilling injury symptoms after 14 days of storage. Mahendra and Janes (1993) reported that the shelf life of salak fruit stored at 3–5 and 7–10 °C would last 15 days, which was longer than that of the fruit stored at 15 °C; however, temperatures of 3–5 and 7–10 °C could cause moderate to severe chilling injury.

In Indonesia, waxing and wrapping the salak cv 'Suwaru' using perforated polyethylene plastic film and placing it either in a cardboard box or a bamboo basket at 15 °C could prolong the fruit shelf life for three weeks (Hubeis *et al.*, 1995). Even after 23 days of storage the fruit retained fairly good nutrient values, with a 20% deterioration level and 2.04% weight loss as compared to day 0.

16.8 Processing

16.8.1 Fresh-cut processing

Increasing working activities and salaries affect citizens' preferences, where consumers tend to prefer ready-to-eat fresh fruit or minimally processed fresh fruit. The salak fruit is one of the potential horticultural products for this kind of industry. Coating fresh-cut salak fruit using 1.05% kappa-carrageenan and 0.15% carboxymethylcellulose (CMC) could extend its shelf life by three days as compared to control (Niam, 2009). The processed fresh-peeled fruit could be stored for up to 15 days in 10 °C and 87% RH and up to 9 days in 22 °C and 65% RH. An organoleptic test showed that the panelist could accept the colour, texture, flavour, and taste of fresh cut fruit stored at day 12 in 10 °C and day 6 in 22 °C.

Another study using edible film made of a soya protein isolate and fatty acid showed that the combination of 0.5% soya protein isolate and 0.5% strearat-palmitat gave the lowest water vapour transmission rate to fresh-cut salak fruit (Widyasari, 2000). As a result of these coatings, the shelf life of fresh-peeled Salak Pondoh fruit could be prolonged by up to 10 days at 5 °C compared to only two days at room temperature.

16.8.2 Other processing practices

A number of value-added products are produced from the salak in Indonesia. During the peak season, fruit is processed in order to overcome a surplus of salak production. Processed fruit products include wine, pickle, dried fruit, juices, candy, dodol, chips or crackers and jam (Palupi *et al.*, 2009). Most of these products are processed on the scale of home industry, although some are in middle class industry, such as the production of chips by farmers in the Sleman Regency of Yogyakarta using a vacuum frying technology.

The advantage of the vacuum frying technique was that it resulted in there being little change in the texture, flavour and colour of fruit due to the lower temperature used (85–90 °C) compared to frying under atmospheric conditions that leads to the boiling of the oil at 180–200 °C. Sanjaya (2007) found that the spinner rotation time during the process of de-oiling in vacuum frying technology also played an important role in the rancidity of salak chips obtained and therefore affected their shelf life. The longer (90 as compared to 60 and 30 s) spinner rotation time during de-oiling resulted in the shelf life decreasing. This may be caused by crispy chips absorbing greater amounts of water from their surroundings, so their rancidity hydrolize process is activated sooner. The longer the spinner process, the longer the chips are in contact with metal, which would serve as a catalyst for rancidity. By also comparing the type of packages, the study showed that the shelf life of salak chips obtained by using 30 s rotation time during de-oiling was 107, 95 and 81 days, respectively, by using alumium foil and oriented polypropylene packages.

The quality of salak juice was studied by adding pectin and CMC in different concentrations of water (Christandy, 1999) and the result showed that the titrable acidity of the juice increased from 10.7 to 13.5% during storage, while the pH decreased from 4.26 to 4.10. The viscosity of the juice also increased from 0.43 to 0.57 cp. An organoleptic test showed that the panelist prefered the salak juice prepared by addition of 0.45% pectin, 0.45% CMC and two volumes of water. According to the microbiological standard, the juice became unconsumable six weeks after storage at room temperature. The panelist could accept the product after four weeks of storage with organoleptic scores as follows: taste (3.1), colour (2.9) and smell/flavour (3.7).

16.9 Conclusions

The Indo-Malaysian region is very rich in salak germplasm, where traditionally the fruit had been grown for more than 150 years in these countries. However, economically it was still considered to be a minor fruit. With the demand from China, Europe and United States, salak fruit became an important commercial fruit in the Indo-Malaysian region, especially in Indonesia and Thailand. However, there is little information on postharvest technology for the fruit. More studies are needed in order to achieve a better understanding of the postharvest biology and physiology and to develop postharvest technology for this unique fruit.

16.10 References

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