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Durian for Hawai'i

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Introduction

The durian, often called the King of Fruit, is one of the most beloved, most hated, and least understood of the fruits of Southeast Asia. The edible fleshy part is the aril that surrounds the seed and is enclosed in a hard thorny rind. The seeds are also roasted and eaten. It gets its reputation from its strong, pervasive odor, deemed nauseating by durian haters but so delicious by durian devotees that the durian has an almost cult-like fan-base, with clubs dedicated to "durian hunting" in Indonesia, Malaysia, and Thailand and a growing international agrotourism industry that offers durian-eating travel packages (Figure 1). In famous durian-eating locales like Penang, Malaysia, and Chanthaburi, Thailand, Chinese and local tourists comprise the largest percentage of "durian tourists."

The Latin name *Durio zibethinus* was given by Linnaeus, sight-unseen, based on Rumphius's description in the 1741 classical work on Indonesian flora, which stated that the fruit was used to bait the Indian civet cat. The name was not given because the fruit smelled like the civet cat, as is sometimes assumed. Another point of confusion, which arose in the 1800s, is the authority for the name. It is sometimes assigned to the Swedish editor and botanist Johan Andreas Murray, who published a German translation of Linnaeus's 13th edition of the *Systema Naturae* in 1774. His name later appears in several major taxonomic works as the author. However, Linnaeus is the correct authority for *Durio zibethinus*, not Murray (Brown 1997).

First encounters in botanical literature varied between love and hate. The earliest explorers to reach Malaysia, from the fleet of the Chinese Admiral Zheng around 1407, noted, "They have a kind of foul-smelling fruit, of which the foreign name is *tu-erh-wu*; it resembles the 'water-fowl head' of the Central Country; it is eight or

Figure 1. Durian fanciers often travel in tour groups to sample the wide range of flavors and aromas found throughout Southeast Asia.

nine *ts'un* long [around 9 inches]; on the skin grow sharp prickles; when ripe, it splits open into five or six sections; the foul smell resembles that of putrid beef; [and] inside there are fourteen or fifteen lumps, as big as chestnuts, of milk-white flesh, very sweet and delicious to eat; moreover, all the [lumps] have seeds inside them, [and the seeds,] when roasted and eaten, taste like chestnuts."

Early European explorers, particularly the Portuguese, were more enthusiastic. In 1583, the Portuguese Garcia da Orta claimed that "the durians of Malacca are the most excellent fruits in the Orient." The Italian merchant, Francesco Carletti described durian as "delightful" in 1599, saying that "no other natural, simple food contains as complex and as sophisticated a variety of odors and flavors." Linschoten, a Dutch botanist, wrote in 1599 that the durian "surpasses in flavor all the other fruits of the world."

Later botanists found that it took a few attempts with durian to develop a taste for it, but they eventually became established aficionados. Alfred Russel Wallace (1823–1913) a British naturalist and the recognized father of biogeography, wrote in 1856 that "to eat durian is a new sensation worth a voyage to the East to experience" and "the more you eat of it, the less you feel inclined to stop." David Fairchild, whose home in Florida eventually became the Fairchild Tropical Botanic Garden, also succumbed to durian's haunting taste. While in Indonesia, he slipped away one Sunday afternoon to a "native village" to try it. He said, "the flavor being indescribably rich and sweet, … I enjoyed it at the moment but… its odor returned to plague me." Later that day, Fairchild recounts, when his benefactor Barbour Lathrop returned to their hotel, he shouted, "Fairy, you've been eating durian! I smell it! You get out of here and don't come near me until that stench has worn off." Many hotels and public transport systems today ban durian because of its characteristic pungent smell, as well as other strong-smelling fruits (Figure 2).

Hawai'i's King David Kalākaua (1836–1891) is believed to have been the first to have brought durian to Hawai'i following his stop in Bangkok, Thailand, in 1881 during his circumnavigation of the world. As a sign of good-will, King Chalalongkorn (1853–1910) had the ship's lockers filled with mangosteens, coconuts, and durians. The seeds were later planted on George N. Wilcox's property, The Grove Homestead, on Kaua'i. The last surviving tree was lost to Hurricane Iniki in 1992.

Figure 2. Some hotels and public transport, including airlines, prohibit durian because of its smell.

Common Names in Other Languages

The word "durian" comes from the Bahasa Melayu word for thorn, "duri." It is used in Malaysia and Indonesia, although whether the emphasis falls on the front or end of the word varies. In Thailand, the fruit is called "tu-rien," in Vietnamese "sau rieng" and in Mandarin "liu-lian guo." The Dutch refer to it as "stinkvrucht," literally "stink fruit."

Scientific Names

Durio zibethinus Linn., syn. *Durio acuminatissima* Merr.

Taxonomists originally placed the genus *Durio* in the family Bombacaceae. Molecular data has led to its being placed in the expanded Malvaceae family, which includes the former members of the Bombacaceae (Bayer et al. 1999).

Origin

The genus *Durio* is native to Southeast Asia and is thought to have evolved on the ancient combined island of Borneo and Peninsular Malaysia. It is closely related to *Boschia* and *Cullenia* fruits. Fossil evidence of pollens shows that all three may have originated from an ancestor on the Indian subcontinent when it was part of Gondwanaland, and that following India's separation the durian subsequently went extinct in India. Another possibility is that *Durio* and its relatives may have migrated to Southeast Asia from the Indian subcontinent after

India collided with Asia.

The largest diversity of durian species appears to be on the island of Borneo and in Peninsular Malaysia. The fruit is widely cultivated throughout Malaysia, Thailand, Cambodia, Myanmar, Vietnam, and Indonesia, and to a lesser extent in the southern Philippines. The Portuguese were responsible for distributing durian to Sri Lanka, India, and Zanzibar in Tanzania, where it can still be found growing commercially today. A small industry exists in northern Australia.

The British brought durian seeds to most of their colonies, including Jamaica and the West Indies; however, it did not become popular. In the Western Hemisphere, durian is cultivated on a limited scale in Hawai'i, Panama, Brazil, Ecuador, and Costa Rica, where its popularity is growing into a small industry. Until 2018's Hurricane Maria, it was also cultivated commercially in Puerto Rico, but few trees survived the storm.

Cultivars

There are 34 species belonging to the genus *Durio* (Lamb 2018). Four have been seldom photgraphed or documented (*Durio bruneinsis*, *D. lissocarpus*, *D. purpureous, Durio wyatt-smithii*). Twelve are considered edible, but only six are commonly consumed by locals, and only one, *Durio zibethinus*, is grown on a commercial scale for export.

Each species of *Durio* has a different morphology. *Durio zibethinus* is among the tallest trees, and *Durio testudinarum* among the shortest. When the durian tree is young, it grows tall with a thin trunk, but as it matures the trunk thickens, developing buttresses by the time the tree is around 50–60 years old. Seedling *Durio zibethinus* trees can exceed 150 feet tall (45 m), with the first branch 60 feet high (18 m).

In Asia, durians are very micro-regional, and the species and varieties of durian grown vary wildly between different areas. Some species readily hybridize, resulting in a lot of diversity in the durians available in different areas. Current commercial varieties have changed over time, as have consumer preferences (Table 1). New varieties are being developed and evaluated in different regions.

The main commercial durian, *Durio zibethinus*, has more than 500 documented clonal varieties that are grown for commercial purposes on farms in Thailand, Malaysia, Indonesia, Sri Lanka, Cambodia, Vietnam, Philippines, Hawai'i, and Papua New Guinea. Each country has its own varieties that are suited to local tastes and market needs (Table 2). The varieties selected and developed vary widely in fruit shape, size, and color, with the fleshy aril varying from white to orange with different textures and aroma and aroma intensity. Many of Singapore's varieties were lost following the forced relocation of agriculture in the 1980s.

Table 1. Selected durian varieties commonly grown (as of 2018) in various ASEAN countries

Country	Varieties
Indonesia	'Othong', 'Bawor', 'Matahari', 'Petruk', 'Sunan'
Malaysia	'Musang King' (D197), D24, 'Golden Phoenix' (D198), 'Red Prawn' (D175), D101, and D13
Philippines	'Puyat', 'Arancillo', 'Duyaya', GD-69, 'Alcon Fancy', D101
Thailand	'Monthong', 'Chanee', 'Ganyao', 'Kradumthong', 'Puangmanee'

Thailand, currently the largest producer and exporter of durian, produced 600 million kg (656,777 tons) in 2016, with 63% being exported. An estimated 90% of durians produced are of the cultivar 'Monthong', which produces a large, fleshy fruit with about 35% aril-to-seed ratio. It was selected as export-quality because its longer storage life and low respiration rate make it suitable for shipping fresh overland to China. 'Monthong' fruit are also used for making local products like durian chips, cooked durian paste, freeze-dried durian, and seedless flesh for bakeries.

The other common varieties in Thailand are 'Chanee', 'Ganyao', 'Nokrachip', and 'Puangmanee'. 'Ganyao' is the most expensive of the varieties. 'Puangmanee' is a relative newcomer on the market but is quickly becoming popular for its small fruit size, bright orange flesh, and buttery texture.

Since 2010, Malaysia has begun exporting durian, and the industry has seen rapid development, particularly of the export-grade registered cultivar D197, or 'Musang King'. 'Musang King' originated

Table 2. Characteristics of some durian cultivars described for some ASEAN countries

Cultivar	Fruit Characteristics
Indonesia	
‘Ajimah’	Fruit weighs 1.5–3 kg and is globose, greyish-green, with large, sharp, widely spaced spines. The rind is thin. The aril is large, thick, pale yellow, dry, slightly fibrous, sweet and somewhat bitter, and the seeds are small. Fruit exhibits uniform ripening.
‘Aspar’	Fruit weighs 6–8 kg and is ellipsoid, light brown with short, conical, widely spaced spines. The fruit can easily be opened. The rind is 1–1.5 cm thick. The flesh weight is 2.5–3.75 kg, and the aril is golden yellow, fine textured, dry, sweet, delicious, and aromatic.
‘Bokor’	Fruit weighs up to 4 kg and is oblong, yellowish-green, with medium-thick rind (3–5 mm) and large, conical, widely spaced spines. The pulp is pale yellow, fine textured, smooth, of medium thickness, sweet, and odorous. Tolerant to *Phytophthora* but susceptible to fruit borers.
‘Bubur	Fruit weighs 4–5 kg and is oblong to cylindrical, greenish-yellow, distinctly lobed, with pointed, closely spaced spines and small seeds. It yields 300–400 fruit/tree/year.
‘Gandaria’	Fruit weighs 4–7 kg and is elongated, brownish-green, with short, widely spaced spines. The rind is thin and can be easily opened. There are 4–5 arils per locule. The pulp is cream colored, slightly fibrous, sweet, with an alcoholic taste. The seeds are shrunken and flat.
‘Kamun’	Fruit weighs 2–3.5 kg and is an elongated ellipsoid, yellowish-green, with sparse, conical spines and a rind of 1–1.3 cm that can be opened with ease. The flesh is golden yellow, 1.5–2.5 cm thick, fine textured, dry, delicious, sweet, and aromatic. All seeds are shrunken.
‘Mansau’	Fruit weighs 0.9–1.5 kg and is ellipsoid, yellow, with small sharp, conical, dense spines. The rind is thin, 0.9 cm, and opens easily. There are 5 locules with 14–17 arils. Flesh weighs 277–460 g and is dark red, 0.5–1 cm thick, fine textured, dry, sweet, and odorless. The tree is resistant to fruit borers and root rot.
‘Perwira’	Fruit weighs 2–3 kg and is round, with a thin green rind and large, conical, dense spines. The thick, yellow flesh is dry, sweet, and strongly odorous. The variety is resistant to *Phytophthora* and fruit borer.
‘Petruk’	Fruit weighs 1.0–1.5 kg and is egg shaped with a yellowish-green skin and small, closely spaced spines and yellow flesh. Fruit are not easily opened. The variety is resistant to *Phytophthora* and fruit borer.
‘Si Dodol’	Fruit weighs 1.5–2.5 kg and is round, five-lobed, yellowish-green, with blunt, conical, dense spines. The fruit is easy to open. The flesh is thick, golden-yellow, soft, fine-textured, sweet, and delicious. The variety is resistant to *Phytophthora* and fruit borer.
‘Si Hijau’	Fruit weighs 2–2.5 kg and is round, green, five-lobed, with sharp, conical, dense spines. The fruit is easy to open. The golden-yellow flesh is soft, fine-textured, sweet, delicious, and aromatic. The variety is resistant to *Phytophthora* and fruit borer.

Notes: The varieties described give a general idea of the range of varieties that have been selected and grown in various countries. Malaysia has a durian registry that is prefixed by the letter “D” that includes varieties selected or developed in Malaysia and others that have been introduced. Table modified from Nanthachai (1994), Lim and Luders (1997), and Ketsa et al. (2019). Fruit weights are given in kilograms (kg); 1 kg = 2.24 pounds, 1 pound = 446 grams. For length, 30 centimeters (cm) = 1 foot.

Table 2. Characteristics of some durian cultivars described for some ASEAN countries, cont'd.

Cultivar	Fruit Characteristics
Indonesia, cont'd.	
'Si Japang'	Fruit weighs 1.5–2.5 kg and is an elongated oblong, five-lobed, greenish-yellow, with widely spaced, conical spines. The flesh is yellow-ivory, dry, smooth, and creamy, and it has a coconut taste. It is sweet and high in alcohol content and strongly odorous. Resistant to *Phytophthora* and fruit borer.
'Si Mas'	Fruit weighs 1.5–2.0 kg and is oblong in shape, with reddish-yellow skin and spines that are close together. The skin is intermediate in thickness and not easily opened. The flesh is bright yellow. Resistant to *Phytophthora* but susceptible to fruit borer.
'Sitokong'	Fruit weighs 2.0–2.5 kg and is long, not round, with yellowish-green skin and small, closely spaced spines. The skin is intermediate in thickness and difficult to open. The flesh is bright yellow. The cultivar is resistant to *Phytophthora* but not to fruit borers.
'Sukun'	Fruit weighs 2.5–3.0 kg and is long and round with yellowish skin and small spines that are close together. The fruit has a thick skin but is easily opened. The flesh is yellowish-white. Resistant to *Phytophthora* and fruit borers.
'Sunan'	Fruit weighs 1.5–2.5 kg and is reverse egg-shaped, with brownish-green skin and small, widely spaced spines. It has a thin skin that can be easily opened and cream-colored flesh. Resistant to *Phytophthora* and fruit borers.
Malaysia	
D2, 'Dato Nina'	Fruit weighs 1.3–1.8 kg and is often kidney shaped. The fruit is difficult to open although the valves are thin, with small sharp spines. The aril is thick, copper yellow in color, and firm. The aril flesh quality is excellent. Good tolerance to *Phytophthora* stem canker.
D10, 'Hijau'	Fruit weighs 1.0–1.7 kg and is round to oval. The fruit has poor keeping quality and tends to split easily. The skin is medium thick and yellowish-green in color. The aril is thick, bright yellow, and sweet and nutty. The aril quality is considered very good. Sensitive to *Phytophthora* stem canker. This is now considered a very rare cultivar and is not recommended any longer.
D13	Fruit have deep burnt-orange flesh that is sweet, less fibrous than most durians, and not very strong in taste. Seeds are large.
D24, 'Sultan Durian', 'Sultan King', 'XO'	Fruit weighs 1.0–1.8 kg and is round to oval shaped with a thick light green rind. Each locule contains 1–4 large arils arranged in single rows. The aril is thick and light yellow in color and has a firm and fine texture. The taste is sweet and nutty with slightly bitter undertones. Extremely susceptible to *Phytophthora* stem canker. From Perak, it was the leading commercial durian clone in Malaysia in the 1980s and 1990s but is now surpassed by 'Musang King'.
D101 (D168), 'Durian Mas', 'Johor Mas'	Fruit weighs 1.4–1.6 kg and is round, brownish-green, with a short peduncle. The fruit is easily opened. The pulp is orange-yellow, firm, sweet, and creamy. Some of the seeds are small and shrunken. This variety has a long shelf life and is very popular in Malaysia.
D105, 'Ganja', 'Taiping 3'	Fruit weighs 2–2.5 kg and is ellipsoid, tapering slightly towards polar ends, brownish-yellow when ripe, with straight, short spines that are widely spaced apart. The rind is thick. Usually there are 3 arils per locule, with creamy, firm yellow flesh.

Table 2. Characteristics of some durian cultivars described for some ASEAN countries, cont'd.

Cultivar	Fruit Characteristics
Malaysia, cont'd.	
D123, 'Chanee'	Fruit weighs 2 to 4 kg and is large, elongated, brownish-green, with a moderately thick rind and rough spines, brown at the tips. Peduncle short and thick. The flesh is creamy, firm, sweet, and golden-yellow, with a strong aroma. Durian varietyctahrocsg117 ctcc cccccc from Thailand; possibly a seedling, as it varies somewhat from the variety also called 'Chanee' that is very common in Malaysia.
D132, 'Eddie's Special'	Small fruit with white flesh and a mild aroma. Rare, possibly only now found in Hawai‘i.
D145, 'Tuan Mek', 'Hijau Beserah'	Fruit weighs 1.3–1.5 kg and is round to oval. The fruit rind is moderately thick and encloses 1–4 arils/locule in a single row. The flesh is thick, bright yellow, fine-textured, sweet, and nutty, with a good aroma. Rarely found outside of the Kuantan area of Pahang.
D146, 'Lepur Mas'	Fruit weighs 1–3 kg and is ellipsoid in shape and dark green. The aril is large, with yellowish, sweet, delicious flesh.
D148, 'Paduka'	Fruit is moderately large, round, with delicate spines. The sweet yellow flesh is of moderate quality.
D150, 'Empring Emas'	Fruit is elongated, tapering at the apical end and brownish-green, with a moderately long, 9 cm peduncle. The aril is thick and large with fine-textured yellow flesh.
D158, 'Kan Yau', 'Tangkai Panjang'	Fruit is round or globose, brownish-yellow, with a moderately thick rind and sharp, straight, dense spines. The flesh is thick, creamy, firm, sweet, golden-yellow, with a pleasant aroma that is not strong.
D159, 'Bantal Mas', 'Golden Pillow', 'Monthong', 'Ganja'	Fruit weighs 4–6 kg and is a large, elongated oval with a tapered apex. The thick yellow flesh has a fine texture, sweet creamy flavor, and little aroma. Originated in Thailand.
D160, 'Buluh Bawah'	Fruit weighs about 3 kg and is oval to ellipsoid, green and rough, with short, widely spaced spines. The thin rind can be easily opened. The large aril has thick, firm, brownish-yellow, creamy sweet flesh of excellent quality.
D162, 'Tawa'	Fruit is medium large, elongated, and yellowish-green. The aril is medium large with firm, yellow-white pulp of excellent bitter yet creamy sweet taste.
D163, 'Hortor', 'Labu'	Fruit is oval, cylindrical, medium sized, with a thick rind and short peduncle. The spines are closely spaced and of medium length. The arils are moderately thick and yellow colored, and the flesh is smooth, creamy sweet, and of excellent quality. From the Penang area, this variety prefers drier weather.
D164, 'Kun Poh Ang Bak', 'Isi Merah'	Fruit is medium size, elongated to ellipsoid with medium-length sharp, conical, densely spaced spines; medium-thick rind and short peduncle. The flesh is moderately thick, orange-yellow, fine-textured, creamy sweet, and of excellent quality, with a strong coffee-like bitterness. The fruit has a limited postharvest life.
D165, 'Cheh Chee'	Fruit is medium size, ellipsoid to round with large, long, densely spaced spines. The large aril has cream-colored, medium-thick, smooth, creamy, excellent-quality flesh. This variety is a second-generation selection out of 'Chanee'.

Table 2. Characteristics of some durian cultivars described for some ASEAN countries, cont'd.

Cultivar	Fruit Characteristics
Malaysia, cont'd.	
D166, 'Balik Pulau 604'	The fruit is medium large, oval, green, with large, short, sharp, and widely spaced spines. The aril is moderately thick and the flesh is yellow, sweet, and of good quality. The tree yields well.
D168, 'Durian Mas', 'Hasmah Mas', 'Muar', 'Muar Gold'	Fruit weighs 1.4–1.6 kg and is round, brownish-green, with a short peduncle. The fruit is easily opened. The pulp is orange-yellow, firm, sweet, and creamy. Some of the seeds are small and shrunken.
D175, 'Udang Merah', 'Red Prawn' ('Hong Xia')	Fruit weighs 1.5–3 kg and is elongate-ellipsoid with a brownish-green rind and small spines. The flesh is creamy sweet, thick, soft, fine, and yellow. One of the top five cultivars grown in Malaysia, this cultivar is originally from Penang and common in Johor.
D176, 'Durian Kuning'	Fruit is round, copper-green, with a short peduncle. The rind is easy to open. The flesh is sweet, soft, fibrous, slightly thick, and creamy yellow.
D188 (MDUR 78) D10 x D24 (male))	Fruit weighs 1.5–1.8 kg and is round to oval in shape with a yellowish–light-green rind. The aril is thick and orangish-yellow, with fine texture and a sweet and nutty flavor. It has good keeping quality, with a natural storage life of about 70 h. It is resistant to *Phytophthora* stem canker and fruit borer.
D189 (MDUR 79) (D24 x D10 (male))	Fruit weighs 1.0–1.6 kg and is roundish oval with a dark green rind. The aril is thick and orange-yellow, with a fine texture and a sweet and nutty flavor. The fruit is easily split open. It has a relatively short storage life of only 27 hours. It is resistant to *Phytophthora* stem canker and fruit borer.
D190 (MDUR 88) (D24 x D10 (male))	Fruit weighs 1.5–2.0 kg and is round to oval in shape with a yellowish-green rind. The aril is very thick and golden yellow, slightly dry, fine textured, and sweet and nutty. The fruit has a relatively long storage life, 78–86 hours. The variety is resistant to *Phytophthora* and fruit borer.
D197, 'Raja Kunyit', 'Musang King', 'Cat Mountain King' ('Mao Shan Wang')	Fruit weighs 2–2.5 kg. Flesh is thick, smooth, buttery, and bright yellow. The tast is slightly bitter. This is the leading commercial clone.
D198, 'Golden Phoenix', 'Jin Feng'	Fruit has thin and spiky spines. Flesh is slightly light yellow and not very firm.
D200, 'Black Thorn', 'Durian Hitam', 'Ochee'	Fruit is round. Arils are average size, with thick flesh. Flesh is reddish-orange, creamy, sweet, with a bitter taste. It is fine textured with little fiber and moderate aroma.
Philippines	
'Alcon'	Possibly a seedling from the Thai variety 'Kradum Thong'. The fruit has small thorns and green color, with a bright, canary yellow aril. Its taste has no bitterness. This is a very popular cultivar.
DES 806	Fruit weighs 2–4 kg and is ellipsoid, yellowish-green, with a thick rind, medium-length, densely spaced spines, and a short stalk. The flesh is yellow, sweet, and very glutinous, with a slightly bitter taste. The fruit has 25% recovery edible portion.
ACC 1497, 'Arancillo'	Fruit weighs ~1.5 kg and is ovoid, brownish-green, with firm, creamy, mimosa-yellow flesh. It has a mild aroma and excellent eating quality. The tree bears off-season fruits.

Table 2. Characteristics of some durian cultivars described for some ASEAN countries, cont'd.

Cultivar	Fruit Characteristics
Philippines, cont'd.	
DES 916, 'Mamer'	Fruit weighs 2–4 kg and is ellipsoid, greenish-brown, with long, sharp, dense spines. The yellow flesh is sweet and glutinous and makes up about 25% edible portion. This is a selected local variety, uncommon.
CA3266	Fruit weighs 1.5–2.5 kg and is globose and greenish-yellow. It has pale yellow sweet flesh. The recovery ratio is about 25% edible portion. The variety is from Indonesia.
'Duyaya'	The bright-yellow fruit is possibly the heftiest durian, with one of the highest flesh-to-seed ratios of all varieties. Some estimate up to 55% flesh to seed, although it is probably in the 40% range.
D101	This Malaysian durian variety is common in the Philippines.
GD69 ('Galang Durian 69')	A selection from the Thai variety 'Monthong', this cultivar is used widely to produce durian products. Its flesh is sweet and fibrous, and it has a high flesh to seed ratio. Sometimes this variety exhibits uneven ripening and wet core.
'Puyat'	This is a main commercial variety. Possibly a seedling of 'Chanee', it is more pear shaped and has browner thorns than that variety. The flesh has a strong, sweet flavor, with relatively little bitterness.
'Umali'	Fruit weighs 2–3 kg and is globose to elongated, yellowish-brown, with golden-yellow flesh. The recovery ratio is about 32%.
Thailand	
'Chanee'	Fruit weighs 2–4.5kg and is oval to broadly cylindrical, lobed, and greyish-brown. The rind is brownish-yellow, thin, with blunt, large, widely spaced spines. The bright yellow pulp is thick, fine textured, firm, creamy smooth, sweet, and of excellent taste. The flesh exhibits uniform ripening. The inferior qualities include high flesh fiber, frequent physiological disorders, wateriness at full ripening stage, poor fruit setting, and susceptibility to *Phytophthora* and fruit borer.
'Kampan'	Fruit is medium to large and rather round with the shoulder enlarged, tapering toward the apex. The fruit has 5 lobes, and the rind is greenish-brown with reddish-brown depressions. The spines are thick, short, straight, and angled, greenish-brown in color. The aril is thick, pale yellow to white in color, with a very fine texture and strong aroma; very sweet.
'Kan Yao'	Fruit weighs 2–4.5 kg and is lychee shaped to globose, greyish-brown, rough, with a moderately thick rind bearing short, sharp, straight, moderately dense spines. The cultivar is characterized by a long, thick peduncle of 10–14 cm. The flesh is golden-yellow, smooth, creamy, sweet, with a pleasant aroma. The inferior fruit characteristics include the large seed and the high number of seeds per fruit, high incidence of wet core and branch dieback, low *Phytophthora* resistance, and poor processing properties.
'Kradumthong'	Fruit weighs 2–4 kg and is oval and symmetrically or uniformly distinctly lobed. The rind is brownish-green, thin, and bears short, sharp, densely packed spines. The fruit peduncle is moderately long. There are 3–4 large, thick arils per locule with yellow flesh.
'Monthong'	Fruit weighs 2–6 kg and is elongated, oval-cylindrical, tapering at the stylar end. This large fruit has a pronounced beak and is lobed, with a yellowish-brown rind that is thick and covered with small, sharp, pointed, conical, densely packed spines. The peduncle is thick and moderately long. Each fruit has 10–15 arils and many small, shrunken (aborted) seeds. Each locule usually has 3 large, thick, creamy, smooth, pale yellow arils. The pulp has a mild odor and is of excellent quality, constituting more than 30% edible portion, and has few physiological disorders. This cultivar is extremely amenable to processing of preserved frozen pulp. It is susceptible to *Phytophthora* and fruit borer.

Table 2. Characteristics of some durian cultivars described for some ASEAN countries, cont'd.

Cultivar	Fruit Characteristics
Thailand, cont'd.	
'Nockrachip' ('Small Bird')	Fruit is small and round, weighing 1–1.5 kg, with a yellow aril with creamy, smooth, bitter and sweet taste. The seeds are small and flattened.
'Puang Manee', 'Phuang Mani'	Fruit is small, about 1.2 kg, although with good fertilizer management larger sizes up to 3 kg have been reported. The aril is sweet, creamy, with coffee undertones, yellow-orange when mature changing to deep golden-orange when fully ripe. Seeds are large, with one to two per locule, which creates a lower aril-to-seed ratio. This variety is reportedly sold in Malaysia under different names that garner the highest prices.
'Tongyoi'	Fruit weighs 2–3 kg and is heart shaped or lychee shaped, with a brownish-grey-green thin rind that bears small, sharp, dense spines. The peduncle is very short and thick. The arils are pale yellow and thick.
'Tubtim'	Fruit is large and round fruit, with dark yellow flesh with a fatty flavour. Fruit has a high flesh-to-seed ratio.
Vietnam	
'Com Vang', 'Sua Hat Lep'	Fruit weighs 2.5–2.7 kg and is round. The aril is yellow, soft, fine, and non-fibrous, with a high edible portion (26–30%); the taste is sweet and creamy, with an attractive aroma; seeds are small.
'Hat Lep', 'Dong Nai'	Fruit weighs 1.5–1.8 kg and is elliptical; the aril is yellow, firm, fine, dry, and non-fibrous, with a high edible portion (29.6%). Taste is sweet and creamy, with an attractive aroma.
'Kho Qua Xanh'	Fruit weighs 1.5–1.8 kg and is elliptical. The flesh is light yellow, soft, and fibrous; it has a medium edible portion (15–17%). The taste is sweet, fat, and bitter, with an attractive aroma; high yield.

Figure 3. Two other edible species of durian may be grown and sold in markets, though rarely: *Durio dulcis*, left, and *Durio testudinarum*, right.

in Kelantan and was registered with the Malaysian Department of Agriculture and assigned the number D 197 in 1993. It is famous for its dark yellow flesh and a dry texture that makes it suitable for freezing and shipping. 'Musang King' has had its genome fully sequenced, and the results were published in 2017. The genome highlighted the evolutionary increase in the number of genes associated with production of the smelly sulphur-containing volatiles. The previous popular commercial variety, D24, is now primarily used as paste in baked goods.

The most expensive variety in Malaysia is D200, known as 'Ocee' or 'Black Thorn', which sold in China for 65–115 RMB ($9.50–16.70) per kilo (2.2 pounds) in 2018 (Win 2017). The price varies with seasonal availability and quality. Currently the availability of 'Black Thorn' in the market is limited, and its high price has inspired rapid spread and cultivation in Malaysia, Indonesia, and southern Thailand. It is predicted that by 2020 cultivation will have tripled or quadrupled. Unfortunately, this variety is considered of poor quality until the tree has reached 15 or 20 years old.

Many varieties in Malaysia were previously introduced from Thailand as seedlings, and this has led to some confusion in the literature as to their origins. D99 ('Kop Kecil') appears to be a seedling of 'Kradumthong'. 'Ganja' (D159) is a seedling of 'Ganyao'. 'Chanee' has taken numerous forms, including D123 or D15, and its seedlings have spawned Penang's famous 'Green Skin' and 'Gold Fish'. The latter should not to be confused with D118, also known locally as 'Gold Fish' or 'Ikan Mas'.

Many varieties previously documented as recommended commercial grade have largely been lost or forgotten, such as D7, D10, 'Sukun', 'Rebok', 'Mas Parang', and 'Bakul'. The trees are often still alive, but their identity is no longer known by farmers. D10 is also no longer used for improving cross-pollination in Malaysia.

The durian industry in Indonesia and the Philippines is also seeing rapid development. Indonesians are primarily planting Malaysian cultivars 'Musang King' and 'Black Thorn'. Several Philippine growers began exporting their 'Puyat' cultivar in 2015, primarily to Japan, Korea, and Singapore, and export to the US is planned for 2019.

In Hawai'i, several durian cultivars are grown around the islands, primarily on the Big Island but also on Kaua'i, O'ahu, and Maui. Most durian varieties were imported from Thailand in the late 1970s and '80s, and their identities and source have been lost or confused. Two Hawai'i selections from these introductions are gaining some recognition, in particular 'Kilauea' and 'Pohokalani'. Other more recently introduced varieties include 'Red Prawn' (D175, 'Udang Merah'), D101, and 'Musang King' (D197, 'Raja Kunyit', 'Mau Shan Wang' (Cat Mountain King)) from Malaysia and 'Puangmanee' from Thailand. Several people are growing other *Durio* species as well, including *Durio dulcis*, *D. oxleyanus*, *D. graveolens*, and *D. kutejensis*.

Figure 4. Durian are most often propagated by grafting, as it is an out-crossing species. On the left a grower is seeding durian trees for grafting, and on the right is a grafted tree, of which the rootstock is growing much slower than the scion.

Other Species Found in Markets

Other species commonly consumed in Southeast Asia by locals include *Durio graveolens*, *D. kutejensis*, *D. oxleyanus*, and *D. lowianus*. Each species has various local names specific to region and indigenous language, which can make their identification tricky.

Durio graveolens can be found in three different forms (with red, orange, and yellow flesh), each form specific to a different region. The red-flesh form is most often found in Sabah, where it is known as "durian darah" (blood durian) or "durian merah" (red durian). The orange-flesh form is the most widespread, known as "dalit" in Sabah, "durian kuning" in Sarawak, "lalit" in the Bisaya language, and "isu" in the Iban language. The yellow-flesh form is most easily found south of Sibu. Of the three forms, the red fleshed has the mildest flavor and the yellow fleshed the strongest. In 2018, the growing international demand for durian encouraged some Malaysian companies to begin exporting red- and orange-fleshed *D. graveolens*, primarily to China but also to Europe. In Brunei and northern Sarawak, the most expensive and popular is the red-and-orange durian otak udang gala, which appears to be a grafted cultivar that is a hybrid of red- and orange-fleshed forms of *D. graveolens*. Several *D. graveolens* x *zibethinus* grafted cultivars exist, including 'Tenom Beauty', 'Suluk', 'Si-unggung', and 'Surut'.

D. kutejensis is most commonly found in northern Sarawak between Brunei and Sibu. It comes into season slightly after *D. graveolens* and is well known for a very sweet and slightly waxy orange flesh with an odor not unlike pineapple or jackfruit. The local names include "durian polo" and "durian lai." In Saratok, Sarawak, it is sold unripe and cooked in stir-fries.

D. oxleyanus is found on Peninsular Malaysia as well as in the cooler, more mountainous climates of Sabah. Common names include "sukang" and "isu." *Durio lowianus* is endemic to Peninsular Malaysia and can have white or yellow flesh. It is known as "durian daun" or "durian pekan." This variety also hybridizes readily with *D. zibethinus*.

Occasionally *D. dulcis* and *D. testudinarum* are consumed (Figure 3). *D. dulcis*, which has bright red skin like an oversized rambutan, is considered the smelliest of the durians. One of the rarest durians, it is known by a variety of local names, including "durian api," "durian merah," "durian tahis," "durian merangong," and "durian lahong." *D. testudinarum* ("kura kura" or tortoise durian), with its juicy, slightly crunchy texture and sweetened cabbage-like flavor, is consumed almost exclusively in

Figure 5. Durian being grown on a Tatura trellis. The trees require frequent pruning and training, with the advantages that the trellis offers wind resistance and all operations can be carried out from the ground.

Limbang and Brunei.

D. kinabaluensis ("durian tupuloh") is exclusively grown by locals in the Malaysian Crocker Mountain Range, while *D. grandiflorus*, the "ghost" known as "durian hantu" for its pearly grey-green skin, is almost unknown and is not commonly consumed, though edible.

Environment

Each durian species has particular environmental needs to thrive. In general, the trees thrive in ultra-tropical warm and humid frost-free climates at elevations below 3,000 feet (914 m) in Southeast Asia, although *Durio kinabaluensis* has been reported growing up to 4,500 feet (1371 m). In Hawai'i, there is one tree producing at 1,500 feet (457 m). Durian trees prefer humidity between 70 and 85% and daytime temperatures around 85°F (29°C). *D. zibethinus* has survived temperatures down to 45°F (7°C), but it will lose its leaves and struggle to survive.

Durio zibethinus can be grown at sea level, although it particularly likes steep hillsides. However, the tree is prone to falling over. It grows in a variety of well-drained soils with a pH between 5 and 7.5. *Durio graveolens* appears to have a higher tolerance for boggy clay soils. The trees do not do well in exposed locations with strong drying winds (like O'ahu's trade winds) and need irrigation in times of drought in order to produce fruit.

The regions dedicated to commercial durian farming have abundant rainfall of 100 inches (2,540 mm) to 150 inches (3,810 mm) spread more or less evenly throughout 9 months of the year. A dry period with little rain for 2–3 months period leads to flowering. Irrigation may be required during this dry period, as the trees will drop developing fruit and may be irreversibly damaged if the drought is prolonged. Areas with less rainfall, such as Davao, Philippines, struggle with losing trees to drought. Areas with more rainfall struggle with fungal and bacterial infections and flowers dropping without fruit set. Durian trees require a 7- to 14-day stress-period of drought to flower. In Thailand, this flower induction can be advanced by raking away the leaf litter from under the canopy. In Vietnam, where the land is flat, flower induction is sometimes produced by spreading plastic sheets around the base of the tree under the canopy where most of the feeder roots are found to induce water stress.

Propagation

The seeds germinate rapidly, within 10 days, and have about a 90% germination rate. The seeds cannot be dried but need to be kept moist after removal from the fruit, or they will quickly lose the ability to germinate. However, the seeds can survive several weeks in transit before losing viability if kept moist. Many seeds already show signs of germination when the fruit begins to ripening. During germination, the seedlings have their own unique growth pattern, in which the cotyledons remain hidden beneath the seed coat for several weeks as the fat hypocotyl grows. Typically, the seedling is already 8–10 inches tall before the seed coat is shed.

Young seedlings are susceptible to rats, fungi, and bacterial diseases, particularly *Rhizoctonia* and *Phytophthora*. Each durian cultivar has different susceptibilities

Figure 6. Durian flower buds on tree branches (left), a cluster of unopened and opened flowers (middle), and a fully opened flower releasing pollen next to a flower where petals and stamens have been shed and only the pistil remains (right). (Courtesy of Saichol Ketsa, Kasetsart University.)

to disease (Table 1). For example, 'Musang King' often develops *Rhizoctonia* (burnt leaf syndrome), while D24 is well known to be susceptible to *Phytophthora*. Young plants in the field are protected in wire cages from animals and from sunburn with 30–50% shade cloth or planting with other short-cycle crops such as bananas, papaya, cacao, or coffee.

Seeds are normally the result of out-crossing, and the offspring are rarely the same as the parent. For this reason, vegetative propagation is frequently used. In Thailand and Malaysia, young seedling trees are grafted when they reach 6 months to 1 year old or the height of about 2.5 feet, using the cleft graft or budding method. Hypocotyl grafting appears to be popular only in Hawai'i (Figure 4). Air-layering (marcotting) is still used in Indonesia, especially to clone very large and old trees, although it is not recommended as it makes the shallow-rooted durian trees unstable and prone to falling. Hormones can be added to make the young trees root faster. Root pruning is not widely used due to the potential infections with *Phytophthora palmivora*.

Figure 7. Durian aril color varies from white to yellow to orange to red, depending on cultivar and species.

Culture and Management

Durian trees prefer the thin soil of the tropical rainforest, with good drainage and a heavy layer of organic material (mulch) on the top of the soil under the canopy. Mulch should not touch the trunk. The trees are heavy feeders and particularly prefer additional supplementation of calcium and magnesium as liquid foliar fertilizers. In Asia, most farmers use a mixture of synthetic and organic fertilizers. The organic fertilizers provide bulk and reduce leaching during heavy rains. Foliar or liquid fertilizers are popular for the same reason, although foliar fertilizers are more common in Thailand where the trees are pruned to a smaller size and the land is flat. Foliar fertilizers are not common in Malaysia or Indonesia.

Commonly used organic fertilizers include seaweed; prawn shells; milled fish bones; and chicken, goat, or cow manure. In Thailand, fermented fruit compost teas are growing in popularity. As the trees' root systems are shallow, with 72–87% of root mass found in the top 18 inches (45cm), care must be taken when fertilizing with nitrogen foliar fertilizers as burning can occur (Masri, 1991).

The height of grafted trees varies depending on grafting method and pruning regimen, but often shorter trees are preferred. In Thailand, tree axial buds are topped to just 25–40 feet (7.5–12 m) and are pruned to a distinctive Christmas-tree shape with nearly horizontal lateral branches. Excessive branches are pruned off to improve light and air circulation, and lower branches are removed to reduce soil spatter during heavy rains that could introduce a *Phytophthora* infection.

Tree spacing varies in different orchard management systems due to differences in terrain and tree height. In Thailand and Vietnam, tighter tree spacing is practiced, typically 15–20 feet (4.5–6 m). In Malaysia, young trees are typically planted 25–35 feet (7.6–10.7 m) apart depending on whether the land is flat or hilly or if the trees are replacing palm oil terraces. On the hillside, they are often planted in a zig-zag formation. A new type of cultivation that utilizes the Open Tatura Trellis system is also gaining some popularity in areas subject to strong winds and where orchard management costs are higher. In this system, which originated in Australia, young trees are planted 12 feet apart (3.7 m) and pruned so their lateral branches grow horizontally along the trellis (Figure 5).

Fruiting branches are braced or otherwise supported to prevent the fragile wood from snapping under the weight of heavy fruit load. In Thailand, where trees are shorter, the branches are normally supported by bamboo or plastic poles. In Malaysia, branches are supported by tension, being tied with rope to the central trunk or

a larger branch. Diseased and dead branches should be removed regularly and the fruit thinned to increase uniformity in quality and size.

It is unknown how long a durian tree can live, but some reports on trees passed down from grandparents would place the trees at around 300 years old. The most common ways old trees die are by lightning strike and high winds. As grafting has only been popular for the last 50 years, it's unknown how long a grafted durian tree typically lives.

Pollination

In Asia, flowering typically occurs 2–3 times per year, but due to climate change flowering is now occurring irregularly, in some places constantly. A single tree can sometimes exhibit three or four different stages of fruit production at one time. Farmers are concerned that this puts undue stress on their trees and have begun to thin or prune fruit to prevent additional flowering.

Durian flowers are beautiful and showy (Figure 6). The flowers form from buds on the lateral branches and

Figure 8. Durian diseases and pests clockwise from top left: Phytophthora stem canker, squirrel damage, fruit rot, fruit rot though the stem, and larval damage of seed.

Table 3. Diseases and insect pests in Hawai'i

Diseases in Hawai'i	Condition	Pests in Hawai'i	Common Name
Phytophthora palmivora	dieback, foliar blight, patch canker	*Tenaphalara malayensis*	Leaf-sucking psyllid
Pythium vexans	root rot	*Coccus* spp.	scale
Corticium salmonicolor	pink disease	*Pseudococcus* spp.	mealy bug
Colletotrichum gloeosporioides	anthracnose	Stem-boring beetles	Unidentified species
Sclerotium rolfsii	fruit rot	Bark beetles	Unidentified species
Rhizoctonia solani	leaf spot		
Phomopsis spp	leaf and fruit spot		

occasionally the main trunk. A mature tree can produce up to 40,000 flower buds. The stigma is receptive as it grows through the top of the unopened petals before the pollen is released (Figure 6). The stigma can remain receptive after the petals and anthers have dropped (Honsho et al. 2007). The flowers are also self-incompatible and do not set fruit readily with pollen from the same trees. When open, the flowers produce copious nectar containing sucrose, fructose, and glucose. By the morning the petals and stamens drop, leaving only the pistil. In some places, it's common to eat the fallen flower stamens in stir-fry dishes and suck the drops of nectar from the fallen flower's crown.

Self-pollination is rare, so cross-pollination is almost always required, although not all varieties are compatible. Due to the requirement for cross-pollination and the lack of pollinators in some durian-growing areas, the use of artificial pollination is growing. Type A flowers (still closed but with the epicalyx or base of the flower bud already split) are less receptive to hand pollination than Type B flowers (stamens removed (emasculated) to free the stigma). If pollination is unsuccessful, the pistil will shrivel and fall off in 3 or 4 days.

Durian pollinators are not completely understood. The most important pollinator is thought to be the Asian giant honeybee (*Aphis dorsata*), which is active both during the day and at night. The *Pteropus* and *Acerdon* fruit bats are also effective pollinators (Aziz et al. 2017, Wayo et al. 2018). Other bees, which are only active in the daytime, probably play a very minor role in pollination.

The flowers are receptive to pollination in the early afternoon, and the pollen is shed in the late afternoon and early evening. This is not problematic in terms of hand pollination, however, because pollen is viable for about 24 hours and can be collected and refrigerated for

Figure 9. Durian approaching maturity may be tied to the branch so they do not fall to the ground.

dispersal the following day. This artificial pollination helps to increase fruit set and give uniform fruit with no empty segments (locules). Hand pollination is easily carried out. In Thailand, where it is widespread, it is usually accomplished with a feather-duster tied to a long stick that is run along the branches.

It's unclear how durians in Hawai'i are pollinated, and the unpredictability of flowering and pollination is a source of frustration to potential growers hoping to capitalize on the growing market. The seasons appear to be quite micro-regional, with the result that durian is available a large portion of the year, though the greatest production is at the start of the cool season and the mid-spring. It would be advisable to study durian pollinators to help the Hawaiian durian industry. Durian in Kona and Hilo areas can produce durian 6 months apart, sometimes 2 or 3 times a year.

Fruit

Durian has a hard, spiny shell that varies from pale grey-brown to dark green and can measure up to 18 inches (45 cm). It contains 5 or occasionally 6 segments, although often not all segments pollinate properly and may be empty. Each pollinated segment contains 2 to 10 seeds and weighs up to 20 lbs (9 kg). In *D. zibethinus*, the color of the arils (flesh, pulp) surrounding the seed varies from ivory to dark yellow to bright orange (Figure 7). The arils of other species can be dark orange or red. The texture and moisture content of the arils varies widely between different types, as do the sugar, fat, and fat ratios.

Although the tree will naturally abort fruit under stress, excessive flowering and fruit set can necessitate thinning young fruit to 1 or 2 per cluster on each branch. After flowering, the fruit matures within 85 to 150 days. When it is fully ripe, weakening parenchyma cells in the fruit's stem cause the durian to fall off the tree. Typically, a freshly fallen durian is difficult to open and requires a sharp knife. However, as the durian continues to ripen off the tree, it will slowly dehisce and crack open on its own. Fallen fruit are more likely to develop fruit rots, and high-quality fruit may be tied to the branch to keep them from falling and being mechanically injured.

The chemistry of the durian changes dramatically during the ripening process, impacting flavor, mouth-feel, and odor. Each culture has its own culinary preferences as to when in the ripening process a durian should be consumed. Many cultures prefer the flavor of freshly fallen durian, and the ability to open one is a badge of honor. In Thailand, durians are picked unripe and consumed while still firm and starchy, while in Indonesia, durians are typically consumed several days after falling when the fruit has become watery, the pH level (acidity) has dropped to around 5, and the durian has a strong, oniony flavor.

The fruit's noteworthy smell is caused by a complex concoction of over 140 aromatic volatiles, the occurrence of which varies by variety and species. In general, each durian type contains around 40 aromatic volatiles. The classic stinky durian aroma is typically caused by various sulfur-containing volatiles (thiols, disulphites, trisulphites) that are synthesized from the two sulfur-containing amino acids, cysteine and methionine, with methionine being the major contributor. Methionine is also connected with ethylene synthesis associated with fruit ripening. The fruit's sweeter fruity odor is due to another group of ester volatiles.

Diseases and Pests

The most serious disease of durian is caused by the fungus *Phytophthora palmivora*, which attacks the roots, branches, leaves, and fruit. When it attacks the branches, causing a condition known as canker branch that often targets trees just as they start fruiting, this often leads to leaf shedding and the death of the tree.

In Southeast Asia, squirrels and monkeys are a problem in eating the ripening fruit. Elephants are a problem for the same reason in some areas.

Borers and leaf-eating larva can be a problem. The area around the tree should be kept free of weeds, and no mulch should touch the trunk.

Harvesting

Harvest methods vary from country to country. In Malaysia and Indonesia, the fruit is often tied to the branch as it ripens in order to prevent its falling (Figure 9), or nets are spread beneath the tree to prevent the durian from breaking open upon hitting the ground. In Thailand and Vietnam, durians are typically cut off the tree 3–9 days before they would naturally fall. Practices in Philippines, Cambodia, and Myanmar vary.

Fruit allowed to fall naturally from the tree and collected from the ground after falling are more subject to disease and splitting, and they have a short storage life of just several hours to 2 to 3 days, depending on vari-

ety. 'Musang King' maintains quality for several days and even seems to be improved by being allowed to fall naturally, but 'Red Prawn' lasts for only a few hours. A common practice is to wrap the peduncle (stem) in plastic or a banana leaf to prevent breakage of the abscission zone, since such breakage gives consumers the impression that the fruit is old.

Maturity Index

In Hawai'i, uncertainty about when and how to harvest and serve durian has led to overripe and poor-quality fruit being sold in the local markets, reducing consumer acceptance and overall quality. At maturity, the fruit naturally falls (abscises) from the tree at the articulation of the fruit stem with the fruit, then ripens in 2 to 4 days, with the fruit normally splitting into segments of irregular width at the stylar end. Ripening results in an increase in sugars and a decrease in starch and pulp firmness, both processes which occur before natural fruit splitting starts.

A number of maturity indices have been developed for durian. These indices are either based on observable changes that occur during the change from immature fruit that has the potential to ripen to optimum quality to mature fruit. Days from flowering and tapping are regarded as the most reliable criteria for Thai varieties. Some of the indices given below are cultivar specific and are not generally good measures of maturity for other cultivars. Some indices require that the fruit be opened and the aril status tested.

Days from flowering

Days from flowering is a cultivar specific index as to when fruit is mature as commercial cultivars take about 85 to 155 days from full bloom to physiological maturity. However, maturity is also affected by the position of the fruit in the tree, cultural techniques and environmental conditions, and especially the ambient temperature while the fruit is growing. The index is used to give a general idea as to when harvesting should occur.

Tapping

Mature fruit when tapped give an audible dull hollow sound while immature fruit is a solid sound. Some growers will tap durian either before or after harvesting and can discern whether it is a mature and immature fruit. Usually they use a bamboo stick with rubber covering at the tip or the backs of their finger nails.

Rind color

The rind becomes light brown and yellowish-green when fruit approaches maturity, while the spine tips turn dark brown. It can be difficult to ascertain maturity based on rind color, as many durians are completely ripe when the rind is still a dark green color. However, once a durian has been harvested the rind color will lighten and turn to yellow or slightly orangey-brown, at which point the durian is likely no longer good for consumption.

Abscission layer

Mature fruit show a very distinct bulging or swelling at abscission zone on the fruit stem.

Table 4. Nutritive Food Value Per 100 g of Edible Portion (ranges from various samples)

Nutrients	Fresh Arils	Dried Arils
Calories	144–147	
Moisture	58–65 g	18 g
Protein	2.8 g	
Fat	1.2–3.9 g	3–6 g
Sugars	(approx.) 12 g	37–43 g
Starch	(approx.) 12 g	8–13 g
Total Carbohydrates	27–34 g	
Fiber	0.9–1.7 g	
Ash	0.8–1.2 g	3 g
Calcium	7.6–40 mg	
Phosphorus	38–56 mg	
Iron	0.73–1.9 mg	
Carotene	0.018 mg	
(as Vitamin A)	20–30 I.U., 90 mg	
Thiamine	0.24–0.35 mg	
Riboflavin	0.20–028 mg	
Niacin	0.68–1.1 mg	
Ascorbic Acid	24–44 mg	
Sodium	40 mg	
Potassium	70 mg	

Spine
Spine tips become slightly softer and more flexible. Spines of mature fruit are pliable when bent by hand, while spines of immature fruit resist being bent.

Fruit stalk
The fruit stalk of mature fruit may become more flexible as the fruit matures.

Grooves
The grooves between the spines expand and turn darker as fruit approaches maturity.

Fruit suture
The suture is the zone on a mature fruit where they will naturally splits (dehisces) becomes distinct and noticeable.

Sap
The sap from the cut surface of the mature fruit stem is clear and sweet, whereas in immature fruit, it is not clear, sticky, and not sweet.

Aroma
Unripe fruit do not produce a distinct aroma, while a perceptible aroma is emitted when fruit approaches maturity and begins to ripen. Electronic "noses" have potential for determining maturity.

Other non-destructive techniques
Near-infrared (NIR) spectroscopy is a non-destructive technique with high potential as a maturity index of the rind. The instrument can separate fruit into five maturity categories with 83% accuracy. Nondestructive vibration and ultrasonic methods give an accuracy of about 95% in sorting for fruit maturity.

Destructive techniques
Pulp dry matter can readily be correlated with fruit maturity, sweetness, nuttiness, off-flavor, and overall preferences. Dry-matter percentage is accepted by Thai growers as a reliable indicator of maturity, with 32% being the minimum for 'Monthong'. Other destructive measures include checking pulp and seed color and soluble solids (brix or %).

Postharvest Considerations

In Hawai'i, a mixture of tree-cut and tree-dropped durians is sold indiscriminately at local markets. Uncertainty about when to cut durian, combined with poor storage techniques, is also contributing to poor

Figure 10. Simple devices are often used to open fruit (left) to allow the aril and seed to be removed (right).

Figure 11. Durian and durian products (clockwise from top left): fresh durian arils in Styrofoam trays with plastic overwrap, with rolls of durian paste and whole fruit in the background; frozen durian; durian candy; durian jam; durian tarts; durian dip; freeze-dried durian pieces; and dried durian chips.

quality. Durian's storage life depends on whether or not it was allowed to fall naturally or cut off the tree early. If allowed to fall, it needs to be chilled to 59°F (15°C) but will still ripen very quickly, becoming overripe and smelly. Tree-cut durian can be stored for up to 10 or 15 days, although fungicides are commonly used when fruit are stored for more than 5 days.

While early harvesting allows durian to be kept for a longer time, care must be taken not to harvest fruit before the starch level has reached 70% of the dry matter. In Thailand, laws have been enacted to prevent immature durian from being harvested and sold in the export markets, due to concerns that the Thai exporters will get a bad reputation.

The Thai variety 'Chanee' takes 2–4 days to ripen after harvest, while 'Monthong' durian takes 4-6 days, depending maturity. Fruit at 85% maturity, based upon rind characteristics and days from anthesis, ripen to excellent quality in less than a week at 82 to 88°F (28 to 31°C). Ripening takes longer than a week at 72°F (22°C). Fruit that is 95% mature when harvested has already commenced ripening, while 75% mature fruit may ripen with an inferior quality.

Practices to prolong storage-life include reducing moisture loss by covering the stems, tying the shell closed with rubber bands to prevent it from cracking, protecting from bruising, and storing in a cool, shady area or under refrigeration. Recommended storage temperature is 59°F (15°C), at 85 to 95% relative humidity. Whole fruit stored at less than 59°F (15°C) develop chilling injury, shown by the rind turning black or dark brown starting at the groove between the splines. The pulp of chilling-injured fruit has little aroma, does not soften normally, and may develop sunken areas on the surface.

Fruit can be waxed to reduce water loss. The ethylene-receptor inhibitor 1-methylcyclopropene (1-MCP) can extend the storage life when stored at 59°F (15°C) from 18 to 30 days. Commercially, the storage-life of tree-dropped durian can be prolonged to up to 7 days by vacuum-sealing or replacing air in packaging with nitrogen gas, though this recommendation might vary with variety.

Uses, Packaging, Pricing, and Marketing

Sales of durian in Hawai'i's farmers' markets are extremely brisk, with fruit sometimes sold by size from

$20 to $50. Pricing at $5 to $8 per pound (approx. 500 g) has also been noted around the state. So far, due to the infamous odor, the fruit is usually only sold at farmers' markets in Hawai'i, where it is often the first fruit to sell out. On more than a few occasions bidding wars have taken place, with fruit going for as high as $75.00.

Durian is cholesterol free and contains high levels of mono-unsaturated fats. The aril contains up to 65% water, about 2.8% protein, 3.4% fat, 27.9% carbohydrate, and at least 24 mg/100 g Vitamin C (Table 3), as well as other vitamins in B-group, such as niacin, pyridoxine (B_6), riboflavin, and thiamin (B_1). It is a good source of potassium, copper, iron, magnesium and folic acid. It is also an excellent source of dietary fiber. In Chinese medicine it is regarded as a "warming" fruit.

The fruit is somewhat difficult to open, and often consumers do not want a whole large fruit, so sellers will open the fruit and remove the aril and seed (Figure 10). One or more arils with the seed is put on a styrofoam tray and covered with stretch wrap (Figure 11) to be sold.

Traditionally, in South East Asia, durian is cooked into a paste or jam that can be preserved for several months and eaten with sticky rice or on toast (Figure 11). The flesh, with the seed inside, is battered and deep fried, or sometimes the leftover seeds are roasted, boiled, or fried and eaten with salt or chili paste as a snack.

Overripe fruit can be mixed with salt into a fermented paste called tempoyak, which is then mixed with chilis and dried shrimp to make sambal or cooked into curry. Unripe durian flesh can be eaten raw in a salad, fried into chips, or cooked into curry like a buttery potato.

Durian is an extremely popular flavoring agent throughout Southeast Asia, with many cafes dedicated to all-things-durian popping up throughout Thailand, Indonesia, Malaysia, Vietnam, and the Philippines.

Today durian is frequently added to baked goods such as cakes, cookies, cream puffs, tarts, and other pastries, as well as to iced drinks, ice creams, popsicles, and even to iced coffees. McDonald's recently added Durian McFlurries to the menu in Malaysia and Thailand, and durian pizza can be purchased at Pizza Hut and other smaller pizza chains.

Other increasingly popular durian products include chocolate-covered freeze-dried durian, durian truffles, durian candies and gum, and durian powdered coffees. In Hawai'i, cookies and cakes as well as a durian soufflé have been found at farmers' markets. Durian jam and durian coffee are popular in the Philippines.

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http://www.prosea.lipi.go.id/

International Tropical Fruit Network
http://www.itfnet.org/

Fruits of Warm Climates by Julia F. Morton
http://www.hort.purdue.edu/newcrop/morton/index.html

Trade Winds Fruit
http://www.tradewindsfruit.com/