

The Distinct Aroma Characteristics Among Commercially Cultivated World Mango Varieties

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ABSTRACT

Mango ranks among the most widely consumed tropical fruits worldwide, following bananas, oranges, and pineapples. At present, more than 1,000 mango cultivars have been identified; however, only a limited number are cultivated on a commercial scale in the global market. Prominent examples include 'Alphonso' (India), 'Carabao' (the Philippines), 'Irwin' and 'Kent' (United States), 'Kensington Pride' (Australia), and 'Nam Dok Mai' (Thailand). These cultivars are generally characterized by a balanced sweet-sour flavor profile and relatively low fiber content, although such traits are not unique to them and can also be observed in other varieties. Consequently, distinct aroma attributes are likely a key determinant of consumer preference, as discussed in this review.

KEYWORDS: Ester, *Mangifera indica*, Polyembryony, Terpene

Fruits constitute a fundamental component of the human diet, ranking just after cereal crops in terms of global importance. Widely consumed fruits can generally be classified by their growing environments into temperate species such as apples and pears, and tropical species, including bananas, oranges, pineapples, and mangoes. With advances in cultivation practices, fruit production has expanded across diverse agroecological regions worldwide.

This report focuses on mango (*Mangifera indica* L.), a species extensively cultivated at multiple scales, ranging from small household gardens to intensive commercial plantations. Mango belongs to *Mangifera*, a genus comprising approximately 30 species within the family Anacardiaceae, widely recognized as the mango family. Several species within this genus yield edible fruit; however, the majority of cultivated trees commercially recognized as mangoes are attributed to *M. indica*. The remaining edible *Mangifera* species, which produce fruit of comparatively inferior quality, are collectively referred to as wild mangoes (Derese et al., 2017).

A key challenge in commercial mango production lies in varietal selection. In Thailand alone, more than 100 mango cultivars have been reported; however, only a limited number are commercially promoted, including ‘Nam Dok Mai’, ‘Kiew Sawoey’, ‘Nang Klang Wan’, ‘Maha Chanok’, and ‘Ok Rong’. Among these, ‘Nam Dok Mai’ is the predominant cultivar in export markets.

Globally, mango diversity exceeds 1,000 cultivars, yet only a small subset has achieved international commercial significance. Prominent examples include ‘Alphonso’ (India), ‘Carabao’ (the Philippines), ‘Irwin’ (USA), ‘Kent’ (USA), ‘Kensington Pride’ (Australia), and ‘Nam Dok Mai’ (Thailand). The successful penetration of these cultivars into

global markets suggests that they meet widely accepted consumer quality standards.

A critical determinant of mango marketability is fruit quality, particularly sensory attributes encompassing flavor, defined as the integration of taste and aroma. For instance, the Thai cultivar ‘Nam Dok Mai’ is characterized by a distinctive fragrance reminiscent of citrus and floral notes, combined with a balanced sweet–sour taste profile. Interestingly, this profile differs from local consumer preferences in Thailand, where ‘Ok Rong’—noted for its higher sweetness, lower aromatic intensity, and greater fiber content—is often favored.

These observations suggest that international consumers tend to prefer mangoes with a harmonious balance of sweetness and acidity, accompanied by low fiber content—traits shared across several globally traded cultivars. Nevertheless, the continued popularity of cultivars such as ‘Alphonso’, ‘Carabao’, ‘Irwin’, ‘Kent’, ‘Kensington Pride’, and ‘Nam Dok Mai’ indicates that aroma characteristics likely play a pivotal role in shaping consumer acceptance and preference in the global marketplace.

From a reproductive standpoint, mango cultivars are broadly categorized into two distinct groups according to their embryonic characteristics. Monoembryonic cultivars possess a single zygotic embryo and are predominantly associated with Indian and Burmese germplasm, whereas polyembryonic cultivars harbor multiple embryos that are largely nucellar in origin, a trait characteristic of Philippine and Southeast Asian types. In terms of seedling development, monoembryonic seeds give rise to a single offspring that is genetically distinct from either parent, while polyembryonic seeds simultaneously

Table 1 Flavor components of various commercially cultivated world mango varieties.

Cultivar name	Origin	Embryonic development	Taste		Major aroma components		Ref
			Sweet	Sour	Terpene	Ester	
'Alphonso'	India	Monoembryonic	++	++	β -Ocimene Linalool	Ethyl butanoate Ethyl hexanoate	1, 2
'Carabao'	The Philippines	Polyembryonic	+++	+++	α -Pinene Δ^3 -Carene γ -Terpinene α -Terpinolene Cadinene	Ethyl (Z)-5-octenoate	3, 4
'Irwin'	USA	Monoembryonic	++	+	α -Terpinolene δ -3-Carene	(Z)-3-hexen-1-yl acetate	4
'Kensington Pride'	Australia	Polyembryonic	++	++	α -Terpinolene	Ethyl butanoate Ethyl octanoate	5, 6
'Kent'	USA	Monoembryonic	++	++	Limonene α -Terpinolene	Violaxanthin dibutyrate	7
'Maha Chanok'	Thailand	Polyembryonic	++	++	α -Terpinolene δ -3-Carene Limonene	Ethyl butanoate Ethyl 3-methylbutanoate	8
'Nam Dok Mai'	Thailand	Polyembryonic	+++	++	β -Ocimene δ -3-Carene <i>O</i> -Cymene Caryophyllene Humulene Germacrene D	Not detected	9,10

References: 1. Idstein and Schreier (1985); 2. Kulkarni et al. (2012); 3. Naef et al. (2006); 4. Kuroki et al. (2021); 5. Lalel et al., (2003); 6. MacLeod et al. (1988); 7. Bonneau et al. (2016); 8. Laohaprasit et al. (2012); 9. Laohaprasit et al. (2011) 10. Tunsakul et al. (2021)

generate numerous seedlings, the majority of which are genetically identical to the mother plant –a property that makes them particularly well-suited for producing uniform rootstock populations. The two groups also differ markedly in their climatic adaptability. Monoembryonic cultivars demonstrate comparatively greater resilience to low-temperature conditions with respect to both vegetative growth and fruit set, whereas polyembryonic cultivars require warmer thermal regimes and exhibit heightened sensitivity to cool weather during critical reproductive stages. Prominent monoembryonic varieties in commercial production include 'Kent', and 'Irwin', while 'Nam Dok Mai' and 'Carabao' represent widely cultivated examples among polyembryonic types (Meurant et al., 1999; Ochoa et al., 2012; Ali et al., 2025).

Mango ranks among the most commercially significant tropical fruits globally, prized by consumers for its distinctive balance of sweetness and acidity, complemented by a characteristic aromatic profile. At full maturity, the fruit – typically medium in size– develops vivid yellow-orange pigmentation in both the peel and mesocarp, traits that substantially influence its market appeal and export value. To broaden our understanding of intraspecific diversity among elite commercial cultivars, the present review systematically characterizes information on two fundamental biological attributes: embryo type (monoembryonic versus polyembryonic) and volatile organic compound (VOC) composition. A comparative assessment of these parameters across globally traded mango varieties is presented in Table 1.

Among the monoembryonic cultivars examined, ‘Alphonso’, ‘Irwin’, and ‘Kent’ share a common volatile profile dominated by two principal chemical classes: terpenoids and esters. In ‘Alphonso’, the aroma complexity arises from the interplay of β -ocimene – a monoterpene responsible for fresh green nuances – with linalool, a terpenoid alcohol contributing distinct floral character, alongside the fruity ester fraction comprising ethyl butanoate (pineapple-like note) and ethyl hexanoate (reminiscent of fresh apple). The volatile profile of ‘Irwin’ is notably differentiated by α -terpinolene, imparting a resinous, pine-like quality, in combination with δ -3-carene, which confers an earthy undertone, and (Z)-3-hexen-1-yl acetate, associated with a crisp green apple character. In contrast, ‘Kent’ exhibits a comparatively simpler terpene-dominant bouquet, wherein limonene contributes citrus-orange nuances while α -terpinolene again provides a characteristic piney note, suggesting that this compound may serve as a shared aromatic marker across certain monoembryonic genotypes.

Within the polyembryonic cultivar group – which includes ‘Carabao’, ‘Kensington Pride’, ‘Nam Dok Mai’, and ‘Maha Chanok’ – two varieties have attained particularly widespread consumer acceptance across Asian markets: ‘Carabao’, originating from the Philippines, and ‘Nam Dok Mai’, a premium Thai cultivar. Despite sharing broadly comparable fruit morphology and external coloration, these two cultivars diverge substantially in their volatile composition and resulting aromatic profiles. The aroma of ‘Carabao’ is governed by a terpenoid–ester synergy, in which α -pinene and α -terpinolene collectively generate a resinous, pine-like character, γ -terpinene contributes a fresh citrus-lime quality, and an octanoate ester herbaceous green nuances and *p*-cymene providing

a lime-like freshness; notably, ester compounds are entirely absent from ‘Nam Dok Mai’ cultivar's volatile fraction, representing a chemotypic distinction that clearly differentiates it from its Philippine counterpart. The remaining two polyembryonic cultivars exhibit equally distinctive aromatic signatures. ‘Maha Chanok’, another commercially prominent Thai variety with a well-established presence in the Japanese export market, presents a terpene-dominant fragrance at the pre-ripe stage, wherein α -terpinolene confers a characteristic resinous, pine quality and limonene contributes bright citrus notes. Upon reaching full maturity, however, the volatile profile undergoes a marked compositional shift toward ester predominance, with ethyl butanoate and ethyl 3-methylbutanoate collectively generating a pronounced pineapple-like aroma – a ripening-associated transition that may hold practical relevance as a non-destructive maturity indicator. Similarly, ‘Kensington Pride’, a leading Australian export cultivar, is defined by a terpenoid–ester mosaic in which α -terpinolene again provides the foundational piney character, while ethyl butanoate introduces tropical pineapple nuances and ethyl octanoate imparts a distinctive peach-like facet, yielding a multi-layered aromatic complexity that likely underpins its strong international market performance. Terpenes are synthesized during mango fruit development, with their accumulation progressively increasing as the fruit advances toward maturity and ripening. These compounds are widely recognized as the primary contributors to the characteristic aroma of mango (MacLeod et al., 1988; Pandit et al., 2009). Notably, the composition of terpene compounds varies

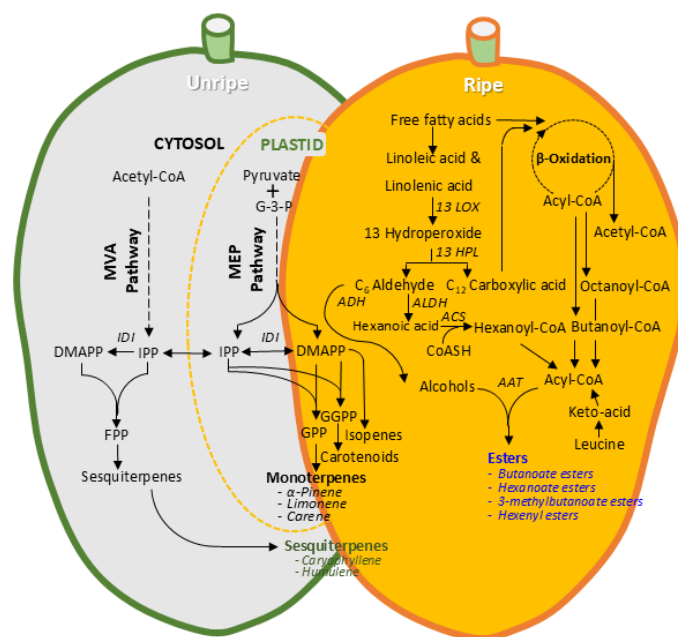


Figure 1 Putative pathways of terpenoid and ester biosyntheses in mangoes: 13-HPL (13-Hydroperoxidase lyase), 13-LOX (13-Lipoxygenase), AAT (Alcohol acyltransferase), ACS (Acyl-CoA synthase), ADH (Alcohol dehydrogenase), ALDH (Aldehyde dehydrogenase), DMAPP (Dimethylallyl diphosphate), FPP (Farnesyl diphosphate G-3-P (Glyceraldehyde-3-phosphate), GGPP (Geranyl geranyl diphosphate), GPP (Geranyl diphosphate), IDI (Isopentenyl-diphosphate delta-isomerase), and IPP (Isopentenyl diphosphate).

across different ripening stages. For instance, in ‘Kensington Pride’, limonene and *p*-cymene are predominantly present during the pre-climacteric phase, whereas α -terpinolene (a monoterpene) becomes more prominent during the climacteric stage. In addition, ester compounds such as ethyl octanoate are mainly detected at the fully ripe stage (Lalel et al., 2003).

In ‘Alphonso’, the volatile profile is dominated by mono- and sesquiterpenes, with *Z*- and *E*-ocimene identified as the principal constituents (Idstein and Schreier, 1985). In addition, compounds such as pentanoic acid and 5-hydroxy-2,4-di-tert-butylphenyl esters have also been reported (Tandel et al., 2023). A distinct lactonic note, attributed to 2,5-dimethyl-4-methoxy-3[2H]-furanone, has also been detected in ‘Alphonso’ (Hunter et al., 1974).

By contrast, the aroma profile of ‘Carabao’ is largely characterized by terpenoid compounds, including α -pinene, Δ^3 -carene, γ -terpinene, α -terpinolene, and cadinene, alongside ester groups such as

hexanoate and octanoate derivatives. This cultivar also exhibits a characteristic sulfurous nuance, primarily associated with the presence of 2-propanethiol (Naef et al., 2006). However, even within the same cultivar, aroma composition can vary depending on the country of cultivation, reflecting the strong influence of environmental factors such as climate and soil conditions on volatile compound expression (Kulkarni et al., 2012).

From a physio-biochemical perspective, monoterpenes are synthesized within plastids through the methylerythritol phosphate (MEP) pathway, utilizing pyruvate and glyceraldehyde-3-phosphate (G-3-P) as primary precursors (Figure 1). In contrast, sesquiterpenes are produced in the cytosol via the mevalonate (MVA) pathway, where acetyl-CoA serves as the initial substrate. Meanwhile, the majority of ester compounds identified in mango are short-chain esters, which originate predominantly from intermediates generated during fatty acid catabolism.

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