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A Comprehensive Review on Physicochemical Analysis and Quality Parameters of Various Mango Fruit Cultivars

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ABSTRACT : This review provides an exhaustive analysis of the physicochemical properties and quality parameters of various mango (*Mangifera indica*) cultivars, emphasizing their impact on consumer preference, agricultural practices, and the global mango market. Mangoes, being one of the most consumed tropical fruits worldwide, exhibit significant diversity in terms of size, shape, color, texture, sugar content, acidity, vitamin and mineral composition, and antioxidant presence. This review systematically explores these attributes across different cultivars, employing a comprehensive literature search and analysis methodology. The study identifies notable variations in size, weight, and external appearance among cultivars, with implications for consumer appeal and marketability. Textural properties, including firmness and pulp texture, are shown to significantly influence sensory evaluation and consumer preferences. Additionally, color analysis reveals correlations between skin and flesh color with maturity and ripeness, essential for determining optimal harvest times and post-harvest processing. Chemical composition analysis underscores the diversity in sugar types and concentrations, acid profiles, and pH levels, profoundly affecting flavor profiles and preservation qualities. A comparative analysis of vitamin content, especially Vitamin C, and the presence of various antioxidants, highlights the nutritional value and health benefits of different mango cultivars. Moreover, the review discusses the varying mineral content across cultivars, emphasizing its importance in consumer health and product marketing. The sensory evaluation section of the review reveals how aroma and flavor profiles, influenced by physicochemical properties, dictate consumer preferences and acceptance. It examines the correlation between these properties and consumer choices, providing critical insights for producers and marketers. The review also addresses the implications for producers and the mango industry. It highlights the role of physicochemical properties in the selection and breeding of cultivars, the development of new cultivars based on quality parameters, and the impact of these parameters on marketability and export potential. Looking ahead, the review identifies gaps in current knowledge and potential areas for further research. It emphasizes the need for advanced technologies in physicochemical analysis and the exploration of sustainable cultivation and processing methods. The review concludes by underscoring the importance of continued research for optimizing mango cultivation and enhancing its global market presence, thus sustaining its position as a key player in the fruit industry.

Keywords: Mangoes, Physicochemical, Nutrition, Antioxidants, Sustainability.

INTRODUCTION

Mangoes, belonging to the genus *Mangifera*, predominantly the species *Mangifera indica*, are believed to have originated in South Asia, with India being considered their primary center of diversity. From here, mangoes spread to Southeast Asia, East Africa, and subsequently to other tropical and subtropical regions globally (Bally & Dillon 2018). Mangoes are more than just a popular fruit; they hold significant economic and nutritional importance in many tropical and subtropical countries. As one of the major fruit crops globally, they contribute substantially to the agrarian economies of several developing countries (Jamnadass *et al*., 2011). The global trade of mangoes, including fresh and processed forms, has seen a steady increase, highlighting its importance in international markets (Briones, 2013). Mangoes are a source of essential nutrients and phytochemicals, contributing to food security and nutrition. The diversity of mango cultivars is vast, with over a thousand varieties recognized worldwide. Each cultivar varies significantly in terms of size, color, taste, texture, and shelf life, influenced by genetic factors and growing conditions (Hewett, 2006). Renowned cultivars include the 'Alphonso' from India, known for its rich flavor, the

'Tommy Atkins' from Florida, favored for its long shelf life, and the 'Ataulfo' from Mexico, noted for its creamy texture and sweet taste. This diversity underpins the versatile use of mangoes in various culinary and processing applications (Richard & Schaffer, 2023). Mango cultivation boasts a history exceeding 4,000 years, particularly flourishing in India where a remarkable genetic diversity is observed. Among the 111 mango-growing countries globally, India stands as the largest producer. The country dedicates about 2.516 million hectares to mango farming, yielding an impressive annual production of 18.431 million tonnes. This accounts for 3.3% of the total fruit cultivation area and 20.7% of the fruit production in India, achieving a productivity rate of 7.3 metric tonnes per hectare (Bora *et al*., 2015). The vast genetic variety found in Indian mangoes is largely due to cross-pollination and the diverse agro-climatic conditions across the country (Mukherjee, 1972). However, differentiating these cultivars based on morphological characteristics alone is often unreliable and imprecise, a challenge compounded by the perennial nature of this fruit crop. The application of biochemical and genetic markers has emerged as a more effective alternative for cultivar identification. Various techniques are now employed for analyzing genetic diversity in germplasm accessions, breeding lines, and populations. These techniques encompass a range of data, including pedigree, morphological, agronomic performance, biochemical, and, more recently, molecular (DNA-based) data (Mohammadi and Prassana 2003). Understanding the physicochemical properties of mangoes, such as sweetness (sugar content), acidity, texture, and nutritional value, is crucial in assessing fruit quality. These attributes directly influence consumer preference and market value. Physicochemical analysis provides objective data that can guide cultivar improvement, post-harvest handling, processing, and storage strategies. Moreover, such analyses are instrumental in standardizing quality parameters for international trade and ensuring consumer satisfaction (Florkowski *et al*., 2021). The diversity in mango cultivars significantly affects both consumers and producers, impacting choice, cultivation practices, marketability, and consumption patterns. For consumers, the choice of mango cultivar can influence taste preferences, nutritional intake, and usage in various culinary applications (Siddiqui *et al*., 2022). Different cultivars offer a range of flavors, textures, and aromas, catering to varied palates and cultural preferences. From a producer's perspective, understanding the distinct characteristics of each cultivar is vital for effective cultivation, harvest timing, post-harvest handling, and market targeting. Selecting the right cultivar can influence yield, disease resistance, and adaptability to specific climatic conditions, directly impacting economic returns (Tefera, 2012). Moreover, producers must align their choices with market demands and consumer preferences, which vary regionally and internationally. This review will focus on comprehensively examining the physicochemical properties and quality parameters of various mango cultivars. These include but are not limited to size, weight, skin and flesh color, texture, pulp-to-stone ratio, sugar content, acidity, vitamin content, and mineral composition. Understanding these properties is essential for evaluating fruit quality, shelf life, and suitability for different processing methods like drying, canning, and juicing. The review will encompass a diverse range of mango cultivars, selected based on their global significance, unique characteristics, and availability. Cultivars such as 'Alphonso', 'Tommy Atkins', 'Kent', 'Haden', 'Ataulfo', and 'Keitt' will be included due to their popularity, economic importance, and distinct qualities. This selection aims to provide a comprehensive understanding that reflects the diversity of mangoes consumed and produced worldwide.

METHODOLOGY

The literature for this review was selected based on specific criteria to ensure relevance and scientific rigor. Inclusion criteria involved studies published in peer-reviewed journals, focusing on physicochemical analysis and quality assessment of mango cultivars. Studies must have been published within the last 20 years, ensuring contemporary relevance. Exclusion criteria included non-peer-reviewed articles, studies not specifically addressing mango cultivars, or those focusing exclusively on genetic modification aspects. A comprehensive search was conducted using databases such as PubMed, Scopus, Web of Science, and Google Scholar. Keywords used in the search included “mango cultivars”, “physicochemical properties of mango”, “mango fruit quality”, and “mango cultivar comparison”. The search was limited to articles in English, published from 2003 to 2023. Reference lists of selected articles were also reviewed to identify additional relevant studies. Data extraction focused on key physicochemical parameters such as size, weight, sugar content, acidity, vitamin content, and mineral composition of different mango cultivars. A standardized data extraction form was used, which included study details (author, year), methodology, cultivar examined, and main findings related to physicochemical properties. This approach ensured a consistent and systematic review of the collected literature. The data synthesis involved a qualitative comparison and thematic analysis of the findings from the selected studies. Due to the variability in measurement methods and units across studies, a meta-analysis was not feasible. Instead, the review employed a narrative synthesis approach, identifying patterns and differences in physicochemical properties across the mango cultivars. This approach facilitated the identification of common trends and unique characteristics of different cultivars.

Physicochemical Properties of Mango Cultivars. The size and weight of mango fruits vary significantly across different cultivars. For instance, some cultivars like the 'Alphonso' are smaller and weigh less, while others like the 'Tommy Atkins' are larger and heavier (Yeshitela, 2006). These differences can be attributed to genetic factors and growing conditions. The size and weight of mangoes not only influence consumer preference but also affect the logistics of transportation

and marketing (Sivakumar *et al*., 2011). Mango cultivars exhibit a wide range of shapes, from oval and round to kidney-shaped and elongated. The skin texture can vary from smooth to rough, and the skin color may range from green, yellow, red, to purple, often depending on ripeness and cultivar (Ahmed *et al*., 2015). These physical attributes are crucial for consumer appeal and can also impact the choice of cultivar for specific processing methods, like canning or drying (Christofi *et al*., 2021).The textural properties of mango pulp, including firmness and internal texture, are key quality attributes that significantly differ among mango cultivars. For instance, the 'Kent' cultivar is known for its buttery and smooth texture, while the 'Haden' is more fibrous. These properties are determined by the fruit's cellular structure and composition, particularly the concentration and type of fibrous material and stone cells. Firmness, a crucial factor during grading and sorting processes, is commonly measured using penetrometers. Texture also greatly impacts consumer preferences and perceptions of quality. Smooth, creamy textures are typically favored for fresh consumption, while firmer textures are preferred for certain processing methods, like making dried mangoes. Consumer studies have highlighted that texture, along with flavor and sweetness, significantly influences satisfaction and repeat purchase behavior. Color variations in mango cultivars, both in skin and flesh, range from green, yellow, orange, to red and purple hues, with each cultivar exhibiting distinctive characteristics. The 'Ataulfo' mango, for example, is known for its bright yellow skin when ripe, whereas the 'Tommy Atkins' shows a vibrant red with green overtones. These color variations are primarily due to pigments like carotenoids and anthocyanins, influenced by genetic factors and growth conditions. Additionally, the change in color of mangoes is often an indicator of maturity and ripeness, with skin color transitions used commercially to determine optimal harvest times and assess ripeness during post-harvest handling (Singh *et al*., 2013). The pulp-to-stone ratio, another critical parameter, varies significantly among mango cultivars. Cultivars such as 'Alphonso' and 'Chaunsa' are valued for their high pulp yield compared to their relatively small stone, whereas others like 'Kent' may have a lower pulp-to-stone ratio. This ratio is essential for both fresh consumption and processing, as it directly impacts the quantity of edible fruit. In the commercial and processing sectors, the pulp-to-stone ratio is a vital factor in determining the economic efficiency and commercial value of mango cultivars, with higher pulp yields being more desirable for products like juices, purees, and dried mangoes, and also influencing consumer perception in fresh market sales.

Table 1: Physicochemical Properties and Quality Parameters of Various Mango (*Mangifera indica*) Cultivars (Liu *et al*., 2013; Jilani *et al*., 2010).

Cultivar Name	Size (Weight)	Shape	Skin Color	Pulp Color	Pulp Texture	Total Soluble Solids (°Brix)	Acidity (%)	Vitamin C Content (mg/100g)	Sugar Content (%)
Alphonso	Medium	Oval	Golden Yellow	Deep Orange	Smooth	18-23	0.2-0.3	28-46	16-18
Dasheri	Medium	Long Oval	Green to Yellow	Yellow	Soft	15-18	0.1-0.2	30-45	14-16
Haden	Large	Round to Oval	Red to Yellow	Bright Yellow	Fibrous	14-18	0.2-0.4	20-30	12-15
Kent	Large	Oval to Round	Green with Red Blush	Yellow	Juicy	18-22	0.3-0.5	25-35	15-17
Tommy Atkins	Large	Oval	Red with Green	Yellow	Fibrous	12-16	0.2-0.4	15-25	10-12
Kesar	Medium	Oval	Green to Yellow	Orange	Smooth	16-20	0.1-0.2	33-40	15-17
Chaunsa	Large	Oval to Round	Yellow to Green	Yellow	Smooth	18-22	0.2-0.3	25-30	15-18
Langra	Medium	Oblong	Green	Yellow	Fibrous	15-19	0.1-0.25	30-42	14-16

Chemical Composition and Nutritional Quality. Mango cultivars exhibit significant variations in sugar content and types, including glucose, fructose, and sucrose, with their ratios differing among cultivars. Some may have higher fructose levels, enhancing sweetness, while others with balanced glucose and fructose ratios offer less intense sweetness. This variation not only affects taste but also impacts the caloric value and nutritional profile. The sweetness level, a key determinant of consumer preferences and quality perception, varies regionally and culturally, influencing the popularity of specific cultivars. Sweeter mangoes are often perceived as higher quality in consumer surveys (Jenkins *et al*., 2018). Mangoes also vary in their acid profile and pH levels, containing acids like citric, malic, and tartaric acids, which influence tartness and tanginess. The acid profile and pH affect both sensory attributes and preservation, with lower pH levels enhancing stability and shelf life, important for processing (Martins *et al*., 2019). The balance between sweetness and acidity is crucial in defining the overall flavor profile, influencing consumer acceptance. In terms of nutritional content, mangoes are rich in vitamins and antioxidants. The Vitamin C content varies significantly among cultivars, influenced by factors like maturity at harvest and storage conditions. Mangoes also contain varying levels of Vitamin A and E. Additionally, their antioxidant profile, including compounds like carotenoids and flavonoids, varies among cultivars, impacting potential health benefits and

nutritional labeling. Mangoes are also a source of essential minerals like potassium, magnesium, and calcium, with variations across cultivars influenced by soil composition and farming practices (Maldonado-Celis *et al*., 2019). A comparative analysis of mineral content reveals differences in trace elements like zinc and selenium, affecting marketing and consumer choices, especially for those with specific nutritional needs.

Table 2: Chemical Composition and Nutritional Quality of Various Mango (*Mangifera indica*) Cultivars (Maldonado-Celis *et al*., 2019; Ubwa *et al*., 2014).

Cultivar Name	Moisture (%)	Protein (g/100g)	Fat (g/100g)	Carbohydrates (g/100g)	Fiber (g/100g)	Energy (kcal/100g)	Calcium (mg/100g)	Iron (mg/100g)	Potassium (mg/100g)	Phosphorus (mg/100g)
Alphonso	81.0	0.6	0.4	17.0	1.6	70	11	0.2	168	14
Dasheri	82.5	0.5	0.3	16.0	1.8	65	10	0.1	156	12
Haden	83.0	0.7	0.2	15.0	2.0	60	12	0.3	146	13
Kent	80.5	0.8	0.5	18.5	1.4	75	13	0.2	175	15
Tommy Atkins	82.0	0.6	0.3	16.5	1.9	67	11	0.2	158	14
Kesar	81.8	0.7	0.4	17.2	1.7	69	12	0.3	165	15
Chaunsa	83.2	0.5	0.3	16.0	2.1	62	10	0.2	150	13
Langra	82.8	0.6	0.2	16.3	1.8	64	11	0.3	160	14

Sensory Evaluation and Consumer Preferences. Mango cultivars are distinguished by their unique aroma and flavor profiles, significantly influencing consumer preferences. For example, the 'Alphonso' mango is celebrated for its sweet, tropical aroma and rich, creamy flavor, while the 'Kent' variety is known for its mild sweetness and fibrous texture (Dar *et al*., 2016). These differences are largely due to varying concentrations of volatile compounds and the sugar-acid ratios in each cultivar. Such sensory attributes are critically evaluated in food science research to gauge consumer appeal and assess market potential. The physicochemical properties of mangoes, like sugar content, acidity, and texture, play a significant role in shaping these sensory characteristics. Higher sugar content typically correlates with perceived sweetness, while acidity levels can alter the fruit's tartness. The texture, influenced by factors such as pulp fiber and firmness, affects the mouth feel, a crucial aspect of the eating experience (Teka, 2013). Understanding these relationships is essential for cultivar selection and breeding programs aimed at enhancing sensory appeal. Consumer preference studies, involving sensory evaluation panels or surveys, assess preferences regarding taste, texture, aroma, and appearance of different mango cultivars. These studies often reveal regional variations in preferences, indicating cultural inclinations towards specific flavors and textures. Moreover, research has found a significant correlation between the physicochemical properties of mangoes and consumer choices (Rojas-Rivas & Cuffia 2020). For instance, a study might demonstrate a regional preference for mangoes with higher sweetness and lower acidity, influencing the popularity of certain cultivars in that area. These insights are crucial for producers, retailers, and breeders to align their products with consumer demands and focus on desirable traits in new cultivar development.

Implications for Producers and the Mango Industry. The selection of mango cultivars by producers is heavily influenced by their physicochemical properties. Traits such as sugar content, acidity, pulp texture, and color significantly impact a cultivar's appeal and suitability for different markets. For example, cultivars with higher sugar content and firmer pulp may be preferred in regions where consumers favor sweet, less fibrous fruits (Ngamchuachit *et al*., 2015). Additionally, producers consider factors like yield, disease resistance, and climate adaptability, which are critical for sustainable cultivation. There is considerable potential in the mango industry for developing new cultivars through breeding programs that focus on specific quality parameters. By understanding consumer preferences and market trends, breeders can focus on enhancing certain physicochemical properties, such as developing cultivars with superior flavor profiles or improved nutritional content (Ekpa *et al*., 2018). Advances in genetic and agronomic research have opened new possibilities for cultivar innovation, targeting both local and global markets. The marketability of mango cultivars is largely determined by their quality parameters. Characteristics like size, appearance, shelf life, and taste significantly influence consumer buying decisions and, consequently, the success of a cultivar in the marketplace (Sivakumar *et al*., 2011). For instance, a cultivar known for its high antioxidant content can be marketed as a health-conscious choice. Developing strong narratives around the origin and cultural significance of certain cultivars can enhance their appeal in both domestic and international markets (Kaynak & Herbig 2014).

Future Research and Development. Despite extensive research on mango cultivars, there remain gaps in understanding their genetic diversity and how it relates to physicochemical properties. Further research is needed to comprehensively map the genetic makeup of lesser-known cultivars and their potential for cultivation in varying climatic conditions (Lalitha & Vinayan, 2019). Additionally, studies that link the phytochemical properties of mangoes to specific health benefits are still in nascent stages and require deeper investigation (Rodriguez-Concepcion *et al*., 2018).The development and application of emerging technologies, such as non-destructive imaging and molecular marker techniques, offer exciting opportunities for advanced physicochemical analysis of mango cultivars (Bureau, 2009). These technologies can provide more accurate and comprehensive data, aiding in the selection and breeding of superior cultivars. There is also a growing need to explore AI and machine learning applications in

analyzing large datasets related to mango cultivation and quality assessment (Dhiman *et al*., 2022). Understanding the physicochemical properties of mangoes is crucial for developing sustainable cultivation and processing practices. For instance, cultivars with longer shelf life or resistance to pests can reduce the need for chemical preservatives and pesticides, leading to more sustainable production methods. Research into drought-resistant and climate-adaptable cultivars can contribute significantly to sustainable mango farming in the face of global climate change (Legave *et al*., 2013). The mango industry can benefit from research into eco-friendly packaging solutions that extend shelf life and reduce waste. Innovations in biodegradable and recyclable materials, suited to the specific needs of different mango cultivars, are essential. Moreover, exploring efficient transportation methods that minimize carbon footprint and ensure the quality of the fruit during transit is another critical area for research, particularly for the export market.

CONCLUSIONS

This comprehensive review has elucidated the diverse physicochemical properties and quality parameters of various mango cultivars, highlighting their significance for consumers, producers, and the broader mango industry. We observed considerable variability in size, color, texture, and nutritional content across cultivars, underlining the importance of tailored cultivation and marketing strategies. The insights gained from sensory evaluation and consumer preference studies are invaluable for guiding cultivar selection and breeding programs. The potential for leveraging emerging technologies in cultivation and processing practices promises advancements in sustainability and efficiency. As we look to the future, continued research in this field is essential for optimizing the cultivation, processing, and marketing of mangoes, ensuring their enduring popularity and economic viability in the global market.

FUTURE SCOPE

Investigate newly developed mango varieties on physicochemical basis. Assess their physicochemical properties and discuss their potential impact on the market and agricultural practices. Conduct a thorough review of consumer preferences for various mango cultivars globally. Analyze sensory attributes and conduct sensory evaluations to understand how different physicochemical characteristics contribute to consumer liking or disliking. By this process branding could be done of good mango variety globally.

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