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REVIEW ARTICLE

Khirsapat (Himsagar) Mango: A Review of Its Nutritional, Agronomic and Export Importance from Chapai Nawabganj, Bangladesh

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ABSTRACT

Khirsapat, also known as Himsagar, is one of the most prized traditional mango varieties of Bangladesh, primarily cultivated in the northwestern region, including Chapai Nawabganj, Rajshahi, and Naogaon. Renowned for its fiberless, soft, and aromatic pulp, Khirsapat mango is highly valued for fresh consumption as well as processing into juices, jams, and other value-added products. This review provides a comprehensive synthesis of Khirsapat mango, covering its origin, botanical characteristics, agro-climatic requirements, cultivation practices, nutritional and phytochemical composition, sensory quality, post-harvest handling, processing, economic importance, and export potential. The fruit is rich in carbohydrates, vitamins, minerals, antioxidants, and bioactive compounds such as polyphenols, flavonoids, carotenoids, and mangiferin, offering numerous health benefits including immunity enhancement, eye health, antioxidant protection, and digestive support. Despite its economic and nutritional significance, Khirsapat mango faces challenges such as high post-harvest losses, pest infestations, limited cold storage, and climate change impacts. Future prospects include improved storage and transport systems, disease-resistant varieties, organic cultivation, and enhanced farmer training to boost production, quality, and export potential. This review emphasizes the cultural, economic, and nutritional importance of Khirsapat mango and highlights strategies for sustainable development and global recognition of this premium fruit.

Keywords: Khirsapat mango; kansant; Bangladesh; Nutritional composition; Mango Vaiya

1. Introduction

Mango (*Mangifera indica L.*), often referred to as the "King of Fruits," is one of the most popular and economically significant fruits in Bangladesh. It holds a unique position in the country's agriculture, culture, and food system, serving as a source of nutrition, income, and seasonal employment for millions of people. Mango is not only consumed as a fresh fruit but is also processed into a wide variety of value-added products including juice, nectar, pulp, pickles, chutney, jam, jelly, dried mango slices, and powder. Due to its high consumer demand, nutritional richness, and wide adaptability, mango cultivation contributes substantially to rural livelihoods and the national economy[1].

Bangladesh is among the leading mango-producing countries in South Asia, and its northwestern region

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is particularly famous for high-quality mango production. Among the mango-growing districts, Chapai Nawabganj is widely recognized as the "Mango Capital of Bangladesh" due to its long tradition of mango cultivation, favorable agro-climatic conditions, and production of premium varieties[2]. The region hosts the country's largest seasonal mango trading hub, the Kansat Mango Bazar, which plays a central role in the national mango market. Every year during the mango season (May–August), thousands of traders, farmers, wholesalers, and buyers gather at Kansat, making it the largest mango wholesale market in Bangladesh. This market not only facilitates nationwide distribution but also acts as a vital center for price determination and supply chain management for Bangladesh's mango industry[3].

Chapai Nawabganj is particularly renowned for its high-quality mango varieties such as Khirsapat (Himsagar), Langra, Fazli, and Gopalbhog. Among them, Khirsapat (Himsagar) stands out as one of the finest mango varieties due to its exceptional sweetness, rich flavor, fiberless texture, thin skin, and attractive golden-yellow pulp. Its pleasant aroma and high pulp content make it highly desirable both for fresh consumption and processing purposes. For these qualities, Khirsapat mango is often considered a premium fruit in domestic and international markets[4,5].

Khirsapat mango holds immense economic, cultural, and nutritional value. For farmers of Chapai Nawabganj, it is a major source of seasonal income and financial stability. Beyond its local importance, this variety has gradually gained international attention due to increasing export demand from Middle Eastern and European countries. Furthermore, the Khirsapat mango from Chapai Nawabganj has been awarded Geographical Indication (GI) recognition, which acknowledges its unique regional identity, quality, and traditional cultivation background, and strengthens its branding in both national and global markets[6].

Despite its popularity and significance, comprehensive scientific review articles focusing specifically on Khirsapat (Himsagar) mango are still limited. Existing research is scattered across different disciplines such as agronomy, food science, post-harvest technology, nutrition, and agricultural economics. The main aim of this review is to provide a comprehensive and integrated overview of the Khirsapat (Himsagar) mango of Chapai Nawabganj, with special emphasis on its nutritional value, agronomic characteristics, cultivation practices, sensory qualities, post-harvest management, economic importance, and export potential.

Figure 1. Khirsapat Mango (খিরসাপাত আম)

2. History Of Khirsapat (Himsagar) Mango

Khirsapat, widely known as Himsagar, is one of the most iconic and traditionally valued mango varieties of Bangladesh, with its strongest historical and commercial association rooted in the Chapai

Nawabganj region. The cultivation and popularity of this variety are deeply intertwined with the agro-cultural heritage of the greater Bengal delta, where mango has been grown and revered for centuries as a symbol of prosperity, hospitality, and seasonal celebration.

The origin of Khirsapat mango is believed to trace back to the pre-colonial era, although its wider recognition and organized cultivation expanded significantly during the British colonial period (18th–19th century). Historical accounts and regional oral traditions suggest that Khirsapat was initially cultivated extensively in the Malda district of present-day West Bengal, India, and gradually spread across the fertile northwestern belt of Bangladesh, particularly in Chapai Nawabganj, Rajshahi, and surrounding areas. The favorable agro-climatic conditions of this region—characterized by alluvial soil, warm temperatures, and distinct dry seasons—played a crucial role in shaping the superior quality of this cultivar[7].

During the Mughal and British periods, mango orchards flourished along the banks of the Ganges basin, supported by royal patronage, zamindari systems, and expanding rural horticulture. The term "Khirsapat" is believed to have originated from the Persian word *"Khir"* meaning creamy or milk-like substance, a direct reference to its exceptionally smooth, fiberless, and custard-like pulp texture. The alternative name "Himsagar" became popular across Bengal due to its refreshing sweetness, as *"Him"* implies coolness—symbolizing its soothing effect during the peak summer season when it matures[8].

In Bangladesh, Khirsapat attained large-scale cultivation and commercial dominance, particularly in Chapai Nawabganj, now widely recognized as the "Mango Capital of Bangladesh." Within this district, the famous Kansat Mango Bazaar has historically served as the central trading hub for Khirsapat and other premium mango varieties, acting as a crucial point of collection, wholesale marketing, and national distribution. Over generations, local farmers selectively propagated Khirsapat due to its high consumer demand, premium market price, excellent eating quality, and relatively favorable post-harvest characteristics compared to many local varieties[9].

Figure 2. Kansat-The largest mango market in Bangladesh

In recent decades, Khirsapat mango has gained increasing national and international attention due to its distinctive quality attributes, including its golden-yellow flesh, rich aroma, high sugar content, and superior

mouthfeel. In 2023, Khirsapat mango of Chapai Nawabganj was officially awarded the Geographical Indication (GI) tag by the Government of Bangladesh, recognizing its unique origin, historical authenticity, and regional identity. This GI certification has strengthened its branding value, protected its intellectual property rights, and enhanced its export potential, especially in Middle Eastern, European, and expatriate Bangladeshi markets[10].

Today, the Khirsapat (Himsagar) mango stands not only as a premium fruit variety but also as a living emblem of Bangladesh's agricultural heritage, rural livelihood, and cultural identity. It reflects the legacy of centuries-old horticultural practices, farmer innovation, and regional pride, making it one of the most treasured agricultural assets of the country.

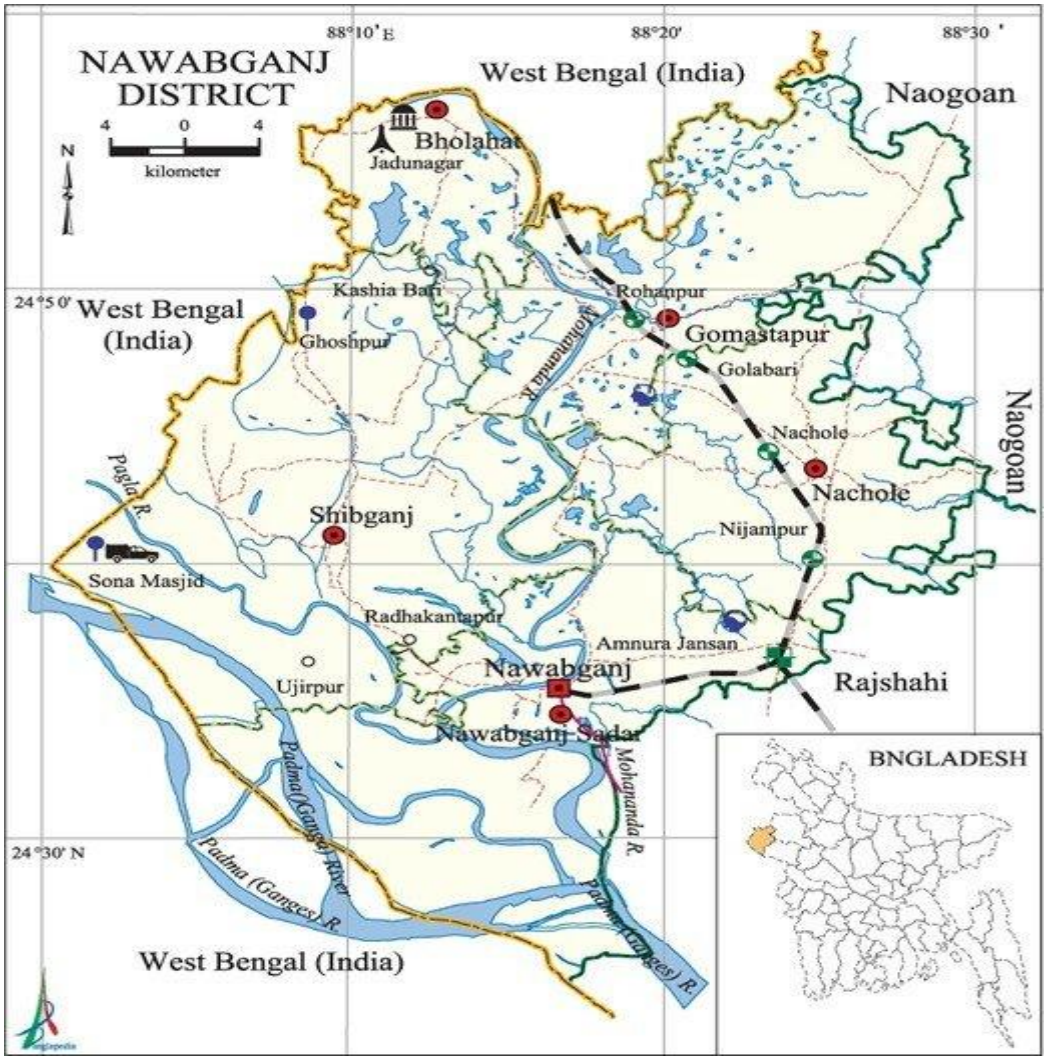

Figure 3. Map of Chapai Nawabganj District

3. Methodology

This review was conducted to provide a comprehensive overview of Khirsapat (Himsagar) mango, emphasizing its nutritional, agronomic, post-harvest, economic, and export aspects. The study integrates information from multiple sources and considers local cultivation practices. This review was carried out at the **Mango Vaiya Institute, Hazaredanga, Shibganj, Chapai Nawabganj**, an area renowned for producing high-quality mangoes and contributing significantly to national trade.

A systematic literature search was performed using Google Scholar, PubMed, Scopus, and ResearchGate, supplemented with official reports from FAO, BARI, and BBS. Keywords such as "Khirsapat mango," "Himsagar mango Bangladesh," "Mangifera indica nutrition," "Chapai Nawabganj mango," and "Mango production in Bangladesh" were used, with Boolean operators (AND, OR) applied to refine the results and ensure relevance. Articles published between 2005 and 2024 were considered, giving priority to peer-reviewed journals, conference papers, and institutional reports. Studies not related to Bangladesh mango varieties or lacking methodological rigor were excluded. From over 120 initially identified publications, 52 articles were selected after screening and full-text review. Relevant data on nutritional composition, phytochemical properties, agronomic practices, post-harvest management, sensory quality, economic importance, and export potential were extracted and organized thematically for analysis.

4. Origin and botanical description

The mango, scientifically known as Mangifera indica L., belongs to the family Anacardiaceae, which includes several economically important tropical and subtropical fruit-bearing trees. Among these, mango is considered the most significant due to its extensive cultivation, high nutritional and phytochemical value, and deep cultural and economic importance in South Asia. Within the numerous mango cultivars, Khirsapat, also referred to as Himsagar, stands out as one of the most esteemed traditional varieties of Bangladesh, prized for its unique sweetness, fiberless pulp, smooth texture, and rich aroma[11].

Origin and Distribution

Khirsapat mango is believed to have originated in the Indian subcontinent, with cultivation records tracing back several centuries in West Bengal (India) and adjacent areas of northwestern Bangladesh, particularly in Chapai Nawabganj, Rajshahi, and Naogaon districts. Chapai Nawabganj, often called the "Mango Capital of Bangladesh", provides ideal agro-climatic conditions for Khirsapat cultivation, including fertile alluvial soil, warm subtropical temperatures, and distinct dry and wet seasonal patterns. These conditions contribute to the development of its high sugar content, deep yellow color, and characteristic aroma. The region's famous Kansat Mango Bazar serves as a major hub for collection, marketing, and distribution of Khirsapat mango, linking local farmers to national and international markets.

Botanical Characteristics

Khirsapat mango trees are medium to large-sized, typically growing 10–20 meters in height, with a dense, spreading canopy that enhances fruit protection and photosynthetic efficiency. The leaves are long, leathery, and dark green, with young leaves often reddish-brown before maturing. The flowers are small, yellowish-white, and arranged in large, conical panicles that emerge from terminal and lateral branches. Flowering generally occurs from January to February, influenced by temperature and photoperiod. Pollination is largely cross-pollination, with bees and other insects playing a critical role in ensuring good fruit set and quality.

Fruit Characteristics

The fruit of Khirsapat is medium-sized, oval to slightly oblong, with smooth, thin skin that changes from green to golden-yellow upon ripening. Its flesh is deep yellow, soft, fiberless, and highly juicy, with a rich aroma that distinguishes it from many other local varieties. The seed is thin, small, and monoembryonic, which facilitates vegetative propagation through grafting, allowing farmers to maintain desirable fruit characteristics across generations. The high sugar content

(16–19%) and total soluble solids (20–26 °Brix) make it a favorite for fresh consumption, processing into juice, pulp, jams, and pickles, and export markets[12].

Phenology and Growth Cycle

The flowering period occurs in January–February, followed by fruit development through the pre-monsoon season. Fruit harvesting typically occurs between May and June, coinciding with the peak summer season. Optimal climatic conditions during flowering and fruiting contribute to uniform fruit size, high sugar content, and strong aroma, which are key quality determinants for consumers and exporters. The tree demonstrates vigorous growth and resilience to moderate drought conditions, with a dense canopy providing partial protection against sunburn and wind damage.

Propagation and Genetic Diversity

Khirsapat mango is predominantly propagated through grafting, which ensures the preservation of its elite traits, including fiberless pulp and aromatic flavor. Seed propagation is less common due to variability in offspring traits. The genetic diversity within Khirsapat populations is relatively high, reflecting traditional farmer-led selection and orchard management practices over generations. Conservation of local Khirsapat germplasm is critical to maintain its unique morphological, biochemical, and sensory traits, especially in the face of climate change and emerging pests and diseases.

Cultural and Economic Significance

Khirsapat mango is not only a premium fruit but also a symbol of Bangladesh's agricultural heritage. It is deeply integrated into local culture, festivals, and culinary practices. Its economic importance is substantial, as it contributes significantly to farmers' income, local trade, and export revenue, particularly through hubs like Kansat Mango Bazar. The variety has recently received a Geographical Indication (GI) tag, which formalizes its regional identity and protects it from imitation, further enhancing its marketability and global recognition.

Figure 4. Morphological Appearance of Khirsapat (Himsagar) Mango Tree

5. Agro-climatic requirements and cultivation practices

Khirsapat mango requires specific climatic, soil, and cultural conditions for optimal growth, flowering, fruiting, and fruit quality. Understanding these factors is essential for effective orchard management, maximizing yield, and maintaining the premium characteristics of this variety. The northwestern region of Bangladesh, particularly Chapai Nawabganj, provides ideal conditions for Khirsapat cultivation. Hazaredanga, Shibganj, is one of the prominent areas where the Mango Vaiya Institute operates, contributing significantly to high-quality mango production and marketing, while preserving traditional cultivation practices.

Climatic Requirements

Khirsapat mango thrives in subtropical to tropical climates with distinct dry and wet seasons. Temperature, rainfall, sunlight, humidity, and wind play critical roles in flowering, fruit set, and sugar accumulation. Optimal growth occurs at temperatures between 24–30°C. Temperatures above 35°C during flowering can reduce fruit set, whereas temperatures below 10°C may damage flowers and young fruits. Moderate rainfall of 750–2000 mm annually is ideal for vegetative growth, though excessive rainfall during flowering may lead to flower drop, fungal infection, and fruit deformities. Relative humidity of 50–70% supports healthy growth, while full sunlight for at least six hours per day enhances photosynthesis, sugar accumulation, fruit coloration, and aroma development, which are key quality traits of Khirsapat mango. Moderate wind facilitates air circulation and reduces humidity-related diseases, but strong winds may cause branch breakage or fruit drop[13].

Table 1. Climatic Requirements of Khirsapat Mango

Parameter	Requirement
Temperature	24–30°C (optimal)
Rainfall	750–2000 mm annually
Relative Humidity	50–70%
Sunlight	Full sunlight (≥6 hours/day)
Wind	Moderate; avoid strong winds

Soil Requirements

Soil type, fertility, and drainage significantly influence root development, tree vigor, and fruit quality. Khirsapat mango grows best in well-drained, fertile soils with good aeration. Sandy loam to loamy soils with a pH range of 5.5–7.5 provide optimal conditions. Well-drained soils prevent root rot and fungal diseases, which are common in waterlogged conditions, while sandy loam ensures adequate aeration and nutrient uptake, promoting vigorous growth. Incorporation of 1–3% organic matter through compost or manure improves soil structure, microbial activity, and water retention, contributing to sustainable orchard management. A soil depth of at least 1.5 meters is recommended for proper root development, and regular soil testing helps adjust fertilization according to tree requirements, preventing nutrient deficiencies or excesses[14].

Table 2. Soil Requirements of Khirsapat Mango

Soil Parameter	Requirement
Soil Type	Sandy loam to loamy soil
Soil pH	5.5–7.5
Drainage	Well-drained; avoid waterlogging
Organic Matter	1–3%
Soil Depth	≥ 1.5 m for proper root growth

Cultivation Zones

Khirsapat mango is predominantly cultivated in the northwestern region of Bangladesh, where fertile alluvial soils, moderate rainfall, and favorable temperatures support high-quality fruit production. The main cultivation districts include Chapai Nawabganj, Rajshahi, and Naogaon. These regions maintain traditional orchards while incorporating modern horticultural practices to preserve the fruit's genetic and sensory traits.

Table 3. Major Khirsapat Mango Cultivation Zones in Bangladesh

District	Area Cultivated (ha)
Chapai Nawabganj	12,000
Rajshahi	7,500
Naogaon	5,000

Cultivation Practices

Proper orchard management is essential to maintain tree health, maximize yield, and ensure superior fruit quality. Cultivation practices include pruning, irrigation, fertilization, pest and disease management, and weed control. Pruning is performed regularly to improve canopy ventilation, sunlight penetration, and fruit

quality while removing dead or diseased branches. Irrigation is critical during flowering and fruit-setting stages; drip irrigation is preferred for water efficiency and maintaining soil moisture. Fertilization involves application of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), and organic manure at pre-flowering, fruit set, and post-harvest stages to ensure optimal growth and nutrient balance. Pest management, including monitoring and controlling fruit flies, mealybugs, stem borers, and fungal infections, is implemented through integrated pest management (IPM) techniques. Weed control through mulching and manual removal reduces nutrient competition and helps maintain soil moisture[15].

Recommended Nutrient Application

Nutrient management is critical for optimal growth, fruit size, sugar content, and overall yield of Khirsapat mango. Fertilizer application is adjusted according to tree age, soil fertility, and growth stage. Balanced fertilization enhances flowering, fruit set, and premium quality while organic amendments improve soil fertility and sustainability of orchards.

Table 4. Recommended Fertilizer Application for Mature Khirsapat Mango Trees

Nutrient Type	Recommended Dose (per tree/year)	Application Time
Urea (N)	500–700 g	Pre-flowering and post-harvest
TSP (P2O5)	250–400 g	Early growth stage
MoP (K2O)	400–600 g	Fruit development stage
Organic Manure	20–30 kg	Pre-flowering

Balanced nutrient application, combined with regular monitoring of soil and plant health, ensures sustained orchard productivity, high-quality fruit, and maximizes the economic benefits of Khirsapat mango cultivation in Bangladesh.

6. Nutritional and phytochemical composition

Khirsapat mango is not only valued for its exceptional taste and aroma but also for its rich nutritional profile and bioactive compounds. The fresh pulp is a source of carbohydrates, vitamins, minerals, and antioxidants, making it an important fruit for human health and nutrition. The nutrient content of Khirsapat mango contributes to its high energy value and functional properties, supporting various physiological processes.

Macronutrients and Energy Content

The carbohydrate content of Khirsapat mango is relatively high, ranging from 14 to 18 g per 100 g of fresh pulp, which provides the primary source of energy. The fruit contains natural sugars, predominantly sucrose, glucose, and fructose, comprising approximately 16–19% of the pulp. Protein content is low, around 0.6–0.8 g per 100 g, while fat content is minimal (0.2–0.4 g per 100 g), making it a low-fat, energy-dense fruit. The total energy value ranges from 60 to 70 kcal per 100 g, which makes it an ideal natural snack for quick energy replenishment[16].

Table 5. Macronutrient Composition of Khirsapat Mango (per 100 g fresh pulp)

Component	Value
Carbohydrates	14–18 g
Total Sugar	16–19%
Protein	0.6–0.8 g
Fat	0.2–0.4 g
Energy	60–70 kcal

Vitamins and Minerals

Khirsapat mango is rich in essential vitamins, especially vitamin C, which ranges from 35 to 45 mg per 100 g of pulp. Vitamin C is a potent antioxidant that boosts immunity, supports collagen synthesis, and enhances skin health. The fruit is also an excellent source of provitamin A (β-carotene), ranging from 1200 to 1600 µg per 100 g, which supports vision, eye health, and overall growth and development. Minerals such as potassium, magnesium, calcium, and phosphorus are present in moderate amounts, contributing to electrolyte balance, bone health, and metabolic functions.

Table 6. Vitamin and Mineral Content of Khirsapat Mango[17]

Nutrient	Content
Vitamin C	35–45 mg
β-carotene	1200–1600 µg
Potassium	170–200 mg
Calcium	10–15 mg
Magnesium	12–18 mg
Phosphorus	9–12 mg

Phytochemical Composition

Khirsapat mango contains a range of bioactive compounds with antioxidant and health-promoting properties. Major phytochemicals include polyphenols, flavonoids, carotenoids, and mangiferin, which collectively contribute to its functional benefits. Polyphenols and flavonoids help scavenge free radicals, reducing oxidative stress and inflammation. Carotenoids, including β-carotene, have provitamin A activity and support vision and immune function. Mangiferin, a unique xanthonoid found in mangoes, exhibits anti-inflammatory, anti-diabetic, and cardioprotective properties[18].

Table 7. Key Phytochemicals in Khirsapat Mango (per 100 g fresh pulp)

Phytochemical	Major Functions
Polyphenols	Antioxidant, anti-inflammatory
Flavonoids	Anti-cancer, cardiovascular protection
Carotenoids	Provitamin A, supports vision and immunity
Mangiferin	Anti-diabetic, anti-inflammatory, antioxidant

Health Benefits

Regular consumption of Khirsapat mango provides a wide range of health benefits due to its rich nutritional and phytochemical composition. The high vitamin C content strengthens the immune system,

enhances resistance against infections, promotes collagen synthesis, and supports skin health by reducing signs of aging. The significant β-carotene content contributes to maintaining healthy vision, preventing night blindness, and reducing the risk of age-related macular degeneration. Dietary fiber present in the pulp aids in proper digestion, regulates bowel movements, and helps prevent constipation. The antioxidant compounds, including polyphenols, flavonoids, carotenoids, and mangiferin, play a crucial role in reducing oxidative stress, which is linked to chronic diseases such as cardiovascular disorders, diabetes, and certain types of cancer. Mangiferin, in particular, exhibits anti-inflammatory, anti-diabetic, anti-carcinogenic, and cardioprotective effects, helping to manage blood sugar levels, reduce systemic inflammation, and protect heart health[14].

Moreover, the bioactive compounds in Khirsapat mango have hepatoprotective properties, supporting liver function and detoxification processes. Regular intake of the fruit may also enhance cognitive function and mental health due to its neuroprotective antioxidant activity. The presence of essential minerals such as potassium, magnesium, and phosphorus supports electrolyte balance, cardiovascular health, muscle function, and bone strength. Khirsapat mango also promotes skin health by protecting against UV-induced damage and supporting a natural glow, thanks to its combination of vitamins, antioxidants, and polyphenols[17]. Its low fat and moderate energy content make it suitable for weight management, while the natural sugars provide quick energy for physical and mental performance. In addition, emerging studies suggest that regular consumption of mango may contribute to improving gut microbiota due to its prebiotic fibers, supporting a healthy digestive system and enhancing nutrient absorption. The fruit's rich nutrient and phytochemical profile make it not only a delicious summer fruit but also a functional food with potential therapeutic benefits, contributing to overall wellness and preventive health[19].

7. Sensory and quality characteristics

Khirsapat mango is renowned for its superior sensory and quality attributes, which distinguish it from other local and international mango varieties. One of the most striking features of this cultivar is its attractive golden-yellow color, which becomes more vibrant as the fruit ripens. The uniform and bright coloration not only appeals visually to consumers but also serves as an indicator of ripeness and high-quality fruit. The texture of Khirsapat mango is exceptionally smooth and fiberless, a key trait that makes it highly desirable for fresh consumption as well as for processing into juices, purees, jams, and other value-added products. The pulp is soft yet firm enough to maintain its shape, providing a pleasant mouthfeel that enhances the eating experience.

Taste is another defining feature of Khirsapat mango. The fruit is characterized by its remarkable sweetness, with total soluble solids (TSS) ranging from 20 to 26 °Brix, indicating a high sugar content. The sweetness is well balanced with low acidity, giving the mango a rich, mellow flavor that is both refreshing and indulgent. This delicate balance of sugar and acid contributes to its universal appeal among consumers of all ages. The aroma of Khirsapat mango is strong, distinctive, and highly pleasant, often described as floral and fruity, which enhances the overall sensory perception of the fruit[12]. This characteristic fragrance is a major factor in its market preference, as aroma is closely associated with ripeness and eating quality in mangoes. In addition to color, texture, taste, and aroma, the fruit's size and shape are also important quality traits. Khirsapat mangoes are generally medium-sized with an oval to slightly oblong shape, making them suitable for both local markets and export. The thin skin of the fruit facilitates easy peeling without affecting the flesh, further enhancing consumer convenience.

Table 8. Sensory and Quality Characteristics of Khirsapat Mango

Characteristic	Description
Color	Golden yellow, uniform and vibrant
Texture	Fiberless, smooth, soft yet firm
Taste	Highly sweet, well-balanced with low acidity
Aroma	Strong, floral-fruity, pleasant
Total Soluble Solids (TSS)	20–26 °Brix
Acidity	Low
Shape	Oval to slightly oblong
Size	Medium

These sensory and quality characteristics make Khirsapat mango not only a premium fruit in domestic markets but also highly competitive in international trade. Its combination of sweetness, aroma, fiberless pulp, and vibrant color enhances consumer acceptability and reinforces its high economic and cultural significance in Bangladesh.

8. Post-harvest handling and shelf life

Post-harvest handling of Khirsapat mango plays a critical role in maintaining fruit quality, extending shelf life, and minimizing losses during transportation, storage, and marketing. Improper handling after harvest can lead to mechanical damage, microbial spoilage, and reduction of sensory and nutritional quality, which ultimately affects both domestic consumption and export potential. Khirsapat mangoes are typically harvested at the mature green or partially ripened stage to ensure optimal shelf life and to reduce the risk of over-ripening during transportation. Harvesting is done manually using ladders or poles with soft hooks to avoid bruising and damage to the delicate fiberless pulp. Following harvest, fruits are sorted based on size, color, maturity, and absence of defects, which is critical for meeting market standards, especially for export-quality mangoes. Traditionally, mangoes are packed in bamboo baskets or wooden crates lined with straw to prevent physical injury[14]. However, modern post-harvest practices, particularly for international markets, employ plastic crates, corrugated cartons, and foam nets to provide cushioning and uniform ventilation. Packaging also allows stacking and efficient handling during transportation.

Table 9. Traditional and Modern Packaging Methods for Khirsapat Mango

Packaging Type	Description	Purpose
Bamboo Baskets	Handwoven baskets with straw lining	Protect fruits, traditional transport
Wooden Crates	Small wooden boxes with cushioning	Reduce bruising, local market use
Plastic Crates	Durable plastic containers with ventilation	Export markets, long-distance transport
Corrugated Cartons	Cardboard boxes with foam padding	International shipping, hygiene, reduced damage

Storage conditions significantly influence the shelf life of Khirsapat mango. At room temperature (around 25°C), mangoes can be stored for 5–7 days, which is suitable for local markets and immediate consumption. For longer storage or export purposes, cold storage at 12–13°C can extend shelf life to 15–20 days while maintaining firmness, color, flavor, and aroma. Advanced storage methods such as pre-cooling, controlled atmosphere (CA) storage, and modified atmosphere packaging (MAP) further prolong shelf life by reducing respiration rates, delaying ripening, and minimizing microbial growth. Proper hygiene during

handling, including cleaning of crates and careful fruit handling, is essential to prevent post-harvest losses and maintain fruit quality.

Table 10. Shelf Life of Khirsapat Mango under Different Storage Conditions

Storage Condition	Temperature	Relative Humidity	Approximate Shelf Life
Room Temperature	25°C	60–70%	5–7 days
Cold Storage	12–13°C	85–90%	15–20 days
Controlled Atmosphere	12°C, low O_2, high CO_2	85–90%	25–30 days

In addition to temperature and humidity, proper handling techniques during transportation are essential. Mangoes should be carefully loaded to avoid mechanical injury, and ventilation must be ensured to prevent heat buildup. Ethylene gas management is also important, as uncontrolled ethylene exposure can accelerate ripening, reduce shelf life, and deteriorate quality.

Table 11. Recommended Post-Harvest Practices for Khirsapat Mango

Post-Harvest Practice	Description	Benefits
Harvesting at Mature Green Stage	Picking mangoes before full ripening	Longer shelf life, reduced spoilage
Sorting and Grading	Separation based on size, color, and quality	Uniformity, market acceptability
Pre-Cooling	Cooling mangoes immediately after harvest	Reduces respiration, slows ripening
Packaging	Using plastic crates or corrugated cartons	Minimizes bruising, facilitates transport
Hygienic Handling	Cleaning tools, crates, and careful handling	Reduces microbial contamination, improves shelf life

Efficient post-harvest management ensures that Khirsapat mango maintains its sensory, nutritional, and market value from farm to consumer. Adoption of modern packaging, cold storage, and controlled atmosphere techniques is essential for meeting export standards and ensuring the fruit reaches international markets in premium condition. Proper post-harvest practices not only reduce losses but also enhance the economic returns for farmers and traders, reinforcing the significance of Khirsapat mango in Bangladesh's agricultural economy.

9. Processing and value addition

Khirsapat mango, with its fiberless pulp, rich flavor, and high sweetness, is ideally suited for various forms of processing and value-added product development. Processing not only enhances the shelf life of the fruit but also provides diversified income sources for farmers, processors, and entrepreneurs, while reducing post-harvest losses that often occur due to the short shelf life of fresh mangoes. The most common processed products from Khirsapat mango include mango pulp and puree, which are widely used as raw materials for juices, nectars, jams, and desserts. Mango pulp retains the natural sweetness, color, and aroma of the fresh fruit, making it a preferred ingredient in both domestic and international food industries. Mango juice and nectar are popular beverages that provide quick nutrition and can be enriched with additional vitamins or blended with other fruits for variety. Dried mango slices and mango powder are another important category of value-added products[17]. Dried mango slices are produced by controlled dehydration, which preserves the fruit's natural sweetness, flavor, and nutrients. Mango powder, or mango leather, is made by drying and grinding mango pulp, offering a convenient ingredient for smoothies, bakery products, and culinary uses. These products have extended shelf life and can be stored or exported without refrigeration. Traditional products such as pickles, chutneys, jams, and jellies are also prepared from Khirsapat mango. These products

are culturally significant and have high demand in local and regional markets. Pickles and chutneys combine mango pulp with spices and salt, providing unique flavors and extending shelf life. Jams and jellies made from Khirsapat mango pulp are rich in pectin and natural sugars, offering both nutritional and economic value.

Table 12. Common Processed Products from Khirsapat Mango and Their Uses

Product	Description	Uses/Benefits
Mango Pulp/Puree	Freshly extracted, fiberless pulp	Ingredient for juices, desserts, sauces, and bakery products
Mango Juice/Nectar	Liquid product from pulp, sometimes blended with water/sugar	Ready-to-drink beverage, enriched with vitamins
Dried Mango Slices	Dehydrated mango pieces	Snacks, export product, long shelf life
Mango Powder	Dried and powdered mango pulp	Ingredient for smoothies, culinary products, and desserts
Pickles/Chutney	Mango combined with spices, salt, and sugar	Traditional condiment, long shelf life, local markets
Jam/Jelly	Mango pulp cooked with sugar and pectin	Spreads, desserts, and processed food industries

Processing of Khirsapat mango adds significant economic value by converting perishable fruit into long-lasting products, which can be marketed domestically and internationally. Value addition also supports employment opportunities in rural areas, promotes agro-based industries, and increases the profitability of mango cultivation.

Table 13. Approximate Shelf Life of Khirsapat Mango Products

Product	Storage Condition	Shelf Life
Fresh Pulp	Cold storage 0–4°C	3–4 weeks
Mango Juice/Nectar	Pasteurized, refrigerated	6–8 weeks
Dried Mango	Room temperature, airtight	6–12 months
Mango Powder	Room temperature, airtight	12–18 months
Pickles/Chutney	Room temperature, sealed jars	6–12 months
Jam/Jelly	Sealed jars, refrigerated	12–18 months

The development of processed and value-added products not only helps in stabilizing the market price of Khirsapat mango but also ensures that excess production during peak season is effectively utilized. Technological interventions such as pasteurization, dehydration, vacuum packing, and hygienic processing further enhance product quality, safety, and export potential. By integrating modern processing technologies with traditional product development, Khirsapat mango can achieve higher market competitiveness and contribute significantly to Bangladesh's agro-industry and export economy. These strategies ensure that the premium qualities of Khirsapat mango, such as its fiberless pulp, sweetness, and aroma, are preserved and appreciated in both local and global markets[18].

10. Economic importance and export potential

Khirsapat mango holds a prominent position in the agricultural economy of Bangladesh, particularly in the northwestern region, where Chapai Nawabganj serves as the primary cultivation hub. The cultivation and marketing of Khirsapat mango significantly contribute to rural livelihoods, providing income, employment, and economic stability to thousands of farmers, laborers, and traders involved in the mango supply chain. Its high consumer demand, both domestically and internationally, ensures that farmers obtain favorable returns for their produce, enhancing the profitability of mango orchards.

Economic Importance:

The cultivation of Khirsapat mango generates substantial seasonal employment in activities such as orchard management, harvesting, grading, transportation, and processing. It also supports ancillary industries, including packaging, cold storage, and value-added product manufacturing. The fruit contributes notably to the national GDP through the horticultural and agro-processing sectors, and the premium pricing of Khirsapat mango compared to other varieties further strengthens its economic significance.

Table 14. Economic Contributions of Khirsapat Mango in Bangladesh

Aspect	Contribution
Farmer Income	Provides primary and supplementary income to thousands of households
Employment	Seasonal employment in cultivation, harvesting, packing, and processing
Agro-Industry	Supports value-added product industries such as pulp, juice, jams, and dried mango
National GDP	Significant contribution from the horticultural sector

Export Potential

Bangladesh has increasingly recognized the export potential of Khirsapat mango due to its premium quality, fiberless pulp, sweetness, and distinctive aroma. The fruit is exported to multiple countries, including the United Arab Emirates (UAE), the United Kingdom (UK), Saudi Arabia, Qatar, Italy, and Singapore. The international demand for high-quality mangoes has motivated improvements in post-harvest handling, packaging, cold storage, and logistics to meet export standards. The recent Geographical Indication (GI) recognition of Khirsapat mango further strengthens its branding and authenticity in global markets. This certification highlights the unique regional origin, superior quality, and cultural heritage of the fruit, enhancing consumer confidence and providing a competitive edge in international trade. GI recognition also helps in preventing imitation, ensuring that exported products retain their premium status and command higher prices.

Table 15. Key Export Destinations and Market Characteristics for Khirsapat Mango

Country	Export Volume (Approx., tons/year)	Market Demand Description
UAE	300–500	High, due to expatriate Bangladeshi and South Asian communities
UK	200–350	Steady demand for premium, fiberless mango varieties
Saudi Arabia	250–400	High demand during summer season
Qatar	150–250	Seasonal demand in urban centers
Italy	100–150	Niche market for tropical fruit enthusiasts
Singapore	50–100	Limited but growing demand for exotic mango varieties

In addition to direct export benefits, Khirsapat mango supports indirect economic growth by stimulating investments in cold storage infrastructure, transportation networks, and agro-processing industries. The combination of local consumption, processing, and export markets ensures year-round economic activity, reinforcing the importance of this cultivar to Bangladesh's agricultural and rural development[20]. The premium quality, high nutritional value, and GI recognition of Khirsapat mango position it as a flagship horticultural product, capable of enhancing the country's reputation in global fruit markets while providing sustainable income opportunities for farmers and stakeholders across the value chain.

Conclusion

Khirsapat (Himsagar) mango is one of the most valuable mango varieties of Bangladesh due to its superior nutritional quality, excellent taste, and high market demand. It plays a crucial role in the economy of Chapai Nawabganj and holds strong potential in the international market. However, addressing post-harvest losses, improving storage facilities, and adopting modern cultivation technologies are essential to fully utilize its economic and export potential. Future research and policy support can significantly enhance its global competitiveness.

Conflict of interest

The authors declare no conflict of interest

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