Review Article

Tamarind Cultivation, Value-Added Products and Their Health Benefits: A Review

ABSTRACT

Tamarind a highly versatile and underutilized crop, possesses immense potential as both a fruit and a condiment. Predominantly cultivated in peninsular India, its commercial growth remains limited to this region. Conversely, in other parts of the country, tamarind is commonly grown as an avenue tree or within homestead gardens. Unfortunately, its true value is often underestimated despite its delightful blend of sour and sweet flavors. Moreover, tamarind is a nutritional powerhouse, abundant in vitamins, minerals and antioxidants. Its climate-hardy nature allows it to thrive even in adverse environmental conditions and diverse soil types.Notably, tamarind trees exhibit unique flowering and fruiting patterns, with flowering occurring during the summer season and fruiting transpiring in either early summer or late winter. This distinctive growth cycle makes tamarind a valuable and consistent resource for various applications. Through meticulous processing, tamarind can be transformed into an array of valuable products such as jams, pickles candies and beverages. In the comprehensive review ahead, we intend to shed light on the significant aspects encompassing the importance, cultivation and extensive processing of tamarind, fostering a deeper understanding of its multifaceted potential and benefits.

Keywords: Tamarind, vitamins, candies, beverages, cultivation.

INTRODUCTION

Tamarind (*Tamarindus indica* L.) is a tropical fruit tree from the Fabaceae family, prevalent in warm-climate regions. Highly esteemed for culinary, cultural and medicinal purposes, tamarind has a rich history rooted in Africa and has spread across Asia, Latin America and the Caribbean due to its versatility and nutritional value.Cultivating tamarind involves systematic tree management to optimize fruit production and quality. Tamarind pods, housing the tangy edible pulp, are vital ingredients in global cuisines. Beyond culinary use, tamarind serves as a base for various value-added products like concentrates, pastes, sauces and supplements, minimizing waste and enhancing marketability (Neeta and Harish, 2016).Tamarind's nutritional profile, encompassing vitamins, minerals, fiber and antioxidants, underpins its potential health benefits. The pulp is rich in vitamin C, thiamine, iron, calcium, phosphorus and dietary fiber, complemented by natural bioactive compounds like polyphenols and flavonoids, conferring antioxidant and anti-inflammatory properties. These attributes support claims of tamarind aiding digestion, blood sugar management, heart health and possessing antimicrobial qualities.This review explores the interplay between tamarind cultivation, value-added product development and health benefits associated with tamarind-based products (Singh *et al.,* 2017). It seeks to offer a comprehensive understanding of agricultural practices, the expanding array of value-added products and the nutritional components that position tamarind as a valuable fruit in both traditional and contemporary contexts (Karthick *et al.,* 2013). Emphasizing the significance of scientific research and innovations, it advocates for harnessing tamarind's potential to advance human health and sustainable agricultural practices.

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NUTRITIONAL COMPOSITION OF TAMARIND

In 100 grams of tamarind pulp, there are 239 kcal of energy, 62.5 g of carbohydrates and 57.4 g of sugars. The protein content is 2.8 g, while fat is 0.6 g, with 0.2 g being saturated fat. Dietary fiber amounts to 5.1 g. Essential vitamins include 81 µg of Vitamin A, 3.5 mg of Vitamin C, 0.1 mg of Thiamine (Vitamin B1): 0.1 mg of Riboflavin (Vitamin B2): and 1.9 mg of Niacin (Vitamin B3). Additionally, there are 14 µg of Folate (Vitamin B9). The mineral content comprises 74 mg of Calcium, 2.8 mg of Iron, 92 mg of Magnesium, 113 mg of Phosphorus, 628 mg of Potassium and 28 mg of Sodium (Narina and Catanzaro, 2018).

BIOACTIVE COMPOUNDS:

- Tartaric acid: Provides the characteristic tangy flavor.
- Polyphenols: Including flavonoids, which possess antioxidant properties.
- Pectin: A soluble fiber that contributes to digestive health.
- Tannins: Compounds with potential anti-inflammatory and antimicrobial properties.

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HEALTH BENEFITS OF TAMARIND:

Antioxidant Properties: Tamarind contains various antioxidants, such as polyphenols, that help neutralize harmful free radicals in the body, potentially reducing the risk of chronic diseases.

Digestive Health: The dietary fiber and pectin in tamarind promote healthy digestion, alleviate constipation and support gastrointestinal health.

Anti-inflammatory Effects: Certain bioactive compounds in tamarind, including tannins, have been studied for their anti-inflammatory properties, which may aid in managing inflammatory conditions.

Blood Sugar Regulation: Tamarind may help regulate blood sugar levels due to its low glycemic index and ability to inhibit enzymes involved in carbohydrate digestion.

Heart Health: Potassium in tamarind supports heart health by regulating blood pressure and reducing the risk of cardiovascular diseases.

IMPORTANCE AND USES OF TAMARIND

Tamarind is a versatile and widely used fruit that has significant importance and various uses in culinary, medicinal and industrial applications (Begum *et al.*, 2016).

Importance of Tamarind:

a) Nutritional Value: Tamarind is rich in essential nutrients such as vitamins (A, C, E and K): minerals (potassium, iron, calcium): dietary fiber and antioxidants. These nutrients are crucial for maintaining overall health and well-being.
b) Souring Agent: Tamarind is a natural souring agent used in cooking to add a tangy flavor to a variety of dishes. It is a common ingredient in Asian, African, Indian and Latin American cuisines.
c) Culinary Versatility: Tamarind is used in a wide range of culinary applications, including sauces, chutneys, soups, stews, beverages, desserts and marinades. It enhances the taste and balances the flavors in many dishes.
d) Preservation and Fermentation: Tamarind paste or pulp is used in food preservation and fermentation due to its natural acidity. It helps extend the shelf life of certain foods and contributes to their flavor.
e) Traditional Medicine: In traditional medicine, tamarind is utilized for its potential health benefits. It is believed to aid digestion, alleviate constipation, improve heart health and boost the immune system. The fruit is also used in traditional remedies for various ailments.

f) Pharmaceutical and Cosmetics Industry: Tamarind extract is used in the pharmaceutical and cosmetics industries for its potential health and beauty benefits. It is incorporated into skin care products, lotions and shampoos (Havinga*et al.*, 2010).
g) Agricultural Applications: Tamarind trees help prevent soil erosion and can serve as windbreaks. Additionally, the leaves and bark of the tamarind tree are used for medicinal purposes and in making organic fertilizers.

USES OF TAMARIND

Tamarind is a versatile fruit that is widely used for culinary, medicinal, industrial and agricultural purposes (see table 1).

a) Tamarind Paste and Pulp: The pulp extracted from tamarind is used to make tamarind paste or concentrate, a fundamental ingredient in many recipes. It is used in curries, sauces, soups and marinades (Manjula *et al.*, 2017).
b) Beverages: Tamarind is used to make refreshing beverages like tamarind juice, tamarind tea, or aguade tamarindo, which is popular in various parts of the world.
c) Chutneys and Sauces: Tamarind chutney is a common condiment in Indian cuisine, often served with snacks like samosas or pakoras. Tamarind sauce is also used in Thai, Mexican and Middle Eastern cuisines.
d) Snacks and Candies: Tamarind is used to make a variety of candies, snacks and sweet treats. Tamarind balls, tamarind candyand tamarind-flavored lollipops are popular examples.
e) Traditional Medicines: Tamarind has a long history of use in traditional medicine for its potential digestive, anti-inflammatory and antibacterial properties. It's used in remedies for gastrointestinal issues and sore throats.
f) Beauty Products: Tamarind extract is used in the cosmetics industry, including in skincare products like facial masks and scrubs. It is believed to have skin-rejuvenating and moisturizing properties.
g) Industrial Applications: Tamarind seeds contain a polysaccharide called xyloglucan, which has various industrial applications. It is used in textile printing, paper making and in the production of adhesives and explosives (Roy *et al.*, 2013).

Table No. 1. List of the income-generating avenues associated with tamarind:

Sl. No.	**Income Generation Avenue**	**Description**
1.	Tamarind Fruit Sales	Selling fresh or dried tamarind fruit for consumption and processing purposes.
2.	Tamarind Seed Sales	Selling tamarind seeds, which are used for various purposes including cultivation
3.	Tamarind Pulp Production	Processing tamarind fruit to obtain pulp used in culinary and industrial uses.
4.	Tamarind Seed Powder	Grinding tamarind seeds to make powder used in various industrial applications.
5.	Tamarind Concentrate	Producing tamarind concentrate or paste used in food and beverage industries.
6.	Tamarind Candy Production	Manufacturing tamarind-based candies or snacks for retail sales.
7.	Tamarind Juice	Preparing tamarind juice or beverages for local or

		commercial sale.
8.	Tamarind-Based Sauces	Creating tamarind-based sauces or chutneys for sale in local markets.
9.	Tamarind Oil Extraction	Extracting tamarind oil for medicinal, culinary, or cosmetic applications.
10.	Tamarind Shell Byproducts	Utilizing tamarind shells to produce activated carbon or other byproducts.
11.	Tamarind Farming Consultation	Providing consultation services to farmers for tamarind cultivation techniques.

THE BOTANY OF TAMARIND

Tamarind is native to tropical Africa but has been widely distributed and cultivated throughout tropical regions globally due to its culinary, medicinal and ornamental uses Yahia and Salih, 2011).

Morphology:

1. Tree Structure:

- Tamarind is a medium to large-sized tree that can reach a height of up to 30 meters.
- The tree has a short, thick trunk with rough, dark-brown bark that becomes deeply furrowed as it ages.
- The canopy is broad and dense, with pinnate leaves providing ample shade.

2. Leaves:

- The leaves are compound, pinnately arranged and alternately positioned along the stem.
- Each leaf typically contains 10 to 12 pairs of oblong leaflets, each measuring about 2-3 cm in length.
- The leaflets are light green in color and turn yellow before shedding.

Comment [I 3]: green and turn

3. Flowers:

- The flowers are small, inconspicuous and typically pale yellow to cream in color.
- They are borne in clusters on long terminal inflorescences.

4. Fruits:

- The fruit is a pod-like legume, resembling a long, brown bean.
- It is characterized by a hard, brown outer shell covering a sweet, sour and sticky pulp.
- The pulp contains numerous seeds embedded in a fibrous matrix.

5. Seeds:

- Each pod contains several hard, shiny, brown seeds.
- The seeds are surrounded by a soft, edible pulp that is the prized part of the fruit.

6. Roots:

- Tamarind has a deep and extensive root system that helps anchor the tree and access water from deeper soil layers.

Habitat and Distribution:

- Tamarind trees thrive in tropical and subtropical regions with a hot, dry climate.
- They are well-adapted to a variety of soil types, including sandy, loamy and clayey soils.
- Tamarind trees are commonly found in countries across Asia, Africa and Central and South America.

CLIMATE AND SOIL FORTAMARIND

Climate: Tamarind trees thrive in hot, tropical climates with pronounced dry and wet seasons. They are well-adapted to regions with a monsoonal climate (Kakade, 2004). Ideal conditions for tamarind cultivation include:

a) Temperature: Tamarind trees prefer warm to hot temperatures year-round. They can tolerate a wide range of temperatures but thrive best in areas where the average annual temperature ranges between 25 to 35 degrees Celsius (77 to 95 degrees Fahrenheit).
b) Rainfall: Tamarind trees require a distinct dry season, as excessive rainfall can be detrimental to their growth and fruiting. The tree can withstand drought conditions and is adapted to areas with an annual rainfall ranging from 500 to 1,500 millimeters (20 to 60 inches).
c) Humidity: Tamarind trees can tolerate relatively high humidity levels, typical of tropical regions.

Soil: Tamarind trees can adapt to various soil types, but they prefer specific soil conditions for optimal growth and fruit production:

a) Well-Drained Soil: Tamarind trees thrive in well-drained soils that prevent waterlogging and root rot. Sandy or loamy soils are ideal for tamarind cultivation.
b) pH Range: Tamarind trees prefer slightly acidic to neutral soils, with a pH range of 5.5 to 7.5. They can tolerate a slightly broader pH range but do best in mildly acidic soils.
c) Soil Fertility: Tamarind trees are adaptable to a range of soil fertility levels, but they tend to thrive in moderately fertile soils. Adding organic matter or compost to the soil can improve its fertility and provide essential nutrients for the tree's growth.
d) Soil Composition: The soil should be loose and well-aerated to allow for proper root development. This aids in efficient nutrient absorption and contributes to the overall health of the tamarind tree.

VARIETIES GROWN IN INDIA

In India, a variety of tamarind cultivars are grown, each with its own unique characteristics and suitability for different regions. Here are some of the notable tamarind varieties cultivated in India:

Comment [l 4]: its unique

1. PKM-1:Clonal selection from seedling type, early fruiting, yielding about 263 kg pods per tree per year.
2. Urigam:Long pod size with sweet pulp.
3. Pratisthan:Developed in Maharashtra, characterized by acidic-sweet pulp.
4. Yogeshwari:High-yielding variety with red-colored pulp.
5. Raktichinch:Fruits have an absolute red-colored pulp.
6. Makhanwaan, Secthong, Manila sweet:Sweet varieties of tamarind.
7. Cumbum:High-yielding variety.
8. Jagdish:Sweet-sour high-yielding variety, originating from Maharashtra.
9. DTS I and DTS II:High-yielding regular varieties released from Dharwad, Karnataka.
10. Goma Prateek:Released from CIAH, with a short juvenile period of 3-4 years.

These varieties are cultivated across different regions in India, catering to various taste preferences and climatic conditions.

PROPAGATION AND NURSERY DEVELOPMENT TECHNIQUE

The techniques for cultivating Tamarind trees, beginning with seed collection in 2022-23, covering both seed and cutting propagation methods and various nursery development techniques. Here's a summarized version:

In 2022-23, the cultivation of Tamarind trees is explored, starting with seed propagation. Ripe Tamarind pods are harvested and seeds are carefully extracted. The seeds are treated by soaking, sowing in well-draining soil and then waiting for germination. When seedlings have 2-3 leaves, they are transplanted (Choudhary *et al.*, 2014).

Cutting propagation is another method, involving selecting healthy branches, preparing cuttings, using rooting medium, hormone and maintaining high humidity for successful rooting. The cuttings are eventually transplanted.

Comment [1 5]: arooting

Nursery development techniques include site selection in a sunny, well-drained area, raised nursery bed preparation, proper spacing, consistent watering, balanced fertilization, pest and disease management and weeding and mulching for a healthy nursery.

PLANTING

Cultivating tamarind trees in horticulture involves a critical transition from seedling to maturity, achievable through sexual or asexual propagation in 1-2 years. Transplanting depends on the mother plant's vitality and requires 7m × 7m or 10m × 10m pits, each measuring 60cm × 60cm × 100cm to accommodate saplings. Planting typically occurs during monsoon months, preferably July to August, but can extend to October for unprepared seedlings (Prasath *et al.,* 2019). Preparation involves pit filling with well-rotted FYM (15-20 kg): Single Super Phosphate (1 kg): and Furadon (100 g) per pit.

Establishing a robust irrigation system is crucial, with drip irrigation being the preferred method, ensuring steady water supply to saplings. The Ring method is an alternative. Diligent water management is essential to prevent water stagnation and its adverse effects (Singh, (2012).

Comment [1 6]: asteady

Staking young plants and pruning extra shoots and water suckers are vital during the slow-growing juvenile stage. After approximately 4-5 years, a significant growth spurt occurs, with an annual growth rate of about 60 cm. Tamarind trees can live up to 200 years, with improved growth and development after the initial lag phase. Early years require irrigation every 7-10 days for optimal cultivation.

FLOWERING AND FRUITING

Tamarind trees exhibit distinctive flowering and fruiting patterns. Flowers emerge annually from terminal shoots, typically after a prolonged juvenile phase of 8-10 years. In the southern part of India, flowering initiates in April and extends to July, peaking during May-June. The flowers adorned with yellow hues and reddish tinges, form racemes about 2-2.5 cm wide and typically possess five petals. Anthesis, the flowering process, primarily transpires in the early morning, reaching its peak around 6:30 am, influenced by prevailing weather conditions. The subsequent fruiting stage manifests as indehiscent legume pods, varying in size from 6-7 cm for the African type to 20-25 cm for certain Indian varieties (Divakara, 2008).). These pods feature a tough brown shell, encasing a fleshy, fibrous, juicy and acidulous pulp. Fruit maturity is marked by thickening fibers and a shift in pulp color to reddish-brown, occurring in different seasons across India. Fruits can remain on the tree for up to 6 months, achieving peak fruiting and optimal yield after 12-15 years of planting.

HARVESTING AND YIELD

The ideal time to harvest tamarind is when the outer shell of the pod starts drying and the fibers inside the pulp begin to harden, accompanied by a shift in pulp color to brownish-red. Tamarind pods should not be harvested until the outer shell is sufficiently dry and easily separated from the pulp. Harvesting primarily occurs in South India during January-February and in Eastern India between March 1st and April 30th due to slight delays in flowering and fruiting. The harvesting process involves plucking the fruits by pulling the pods against the direction of the stalk. Harvested fruits are stored in a clean place and sun-dried to obtain high-quality pulp. On average, a tamarind tree in India produces 175 kg of pods, yielding 70 kg of processed pulp per tree. A mature tree yields between 180-225 kg of fruit per seasonand

if the tree is large enough, harvesting is facilitated by shaking the branches (Buyinza *et al.*, 2010).

PESTS AND DISEASES

Several pests and diseases affect tamarind cultivation. The Fruit Borer, a lepidopteran pest, bores into ripened fruits, rendering them inedible. Management involves applying Polytrine (1ml) or Carbaryl (3g/L) at 10-day intervals. Mealy bug, a sucking pest, damages tender leaves and young fruits, leading to premature fruit drop. Spraying with imidacloprid (0.04%): chlorpyrifos (0.02%): or dichlorvos (0.05%) reduces infestation. Nematodes like Needle, Burrowing, Root-knot, Dagger and Sheathoid affect tamarind. Powdery mildew caused by Oidium sp. is common, managed with sulfur-based fungicide spraying. Leaf spot, caused by various fungi, presents as black lesions on leaves. Mancozeb (0.2%) spray at 15-day intervals effectively manages this foliar disease (Kenis *et al.*, 2009).

Comment [1 7]: spots

Comment [1 8]: present

PROCESSED AND VALUE-ADDED PRODUCTS OF TAMARIND FRUITS

Tamarind, a versatile fruit with a tangy and sweet flavor, can be transformed into a variety of processed and value-added products(see table 2).

Table No. 2. List of profitable business ideas related to tamarind in India:

Sl. No.	Business Idea	Description	Potential Profitability
1.	Tamarind Paste Manufacturing	Produce and package tamarind paste, a commonly used ingredient in Indian cuisine.	High
2.	Tamarind Concentrate Production	Extract and process tamarind concentrate, used in beverages, sauces, and snacks.	High
3.	Tamarind Seed Powder Production	Grind tamarind seeds to create powder for industrial uses like textile sizing and gum production.	Moderate to High
4.	Tamarind Juice Processing	Produce and package tamarind juice, a popular beverage with health benefits.	Moderate to High
5.	Tamarind Snack Manufacturing	Create a variety of tamarind-based snacks like candies, chutneys, and pickles for retail sale.	Moderate to High
6.	Tamarind Pulp Export/Trading	Source tamarind pulp locally and export it to international markets or supply to domestic retailers and wholesalers.	High (especially export)
7.	Tamarind Seed Oil Extraction	Extract oil from tamarind seeds for use in cosmetics, pharmaceuticals, and food products.	Moderate to High
8.	Tamarind Tree Plantation	Establish a tamarind plantation and sell tamarind fruit, seeds, or products derived from tamarind.	Moderate to High
9.	Tamarind Product Packaging	Offer specialized packaging services for tamarind-based products, ensuring quality and attractive presentation.	Moderate
10.	Tamarind-Flavored Beverages	Create and market tamarind-flavored beverages like sodas, teas, or energy drinks.	Moderate to High

Comment [1 9]: supplyit to

Highlighting the nutritional benefits and potential applications, explore the diverse array of processed and value-added products that can be prepared from tamarind fruits.These products include jellose, tamarind kernel powder (TKP): dried fruit blocks, toffees and candies, puree or paste, tamarind sauce, tamarind jam, tamarind pulp powder (TPP): tamarind pickle,

tamarind chutney, fruit juice concentrate, tamarind beverage, tamarind rice and tamarindade (Mehta, 2014).

Tamarind, a significant source of nutrients and medicinal properties, is rich in dietary antioxidants and total phenolics. To extend its shelf life beyond a month, optimal processing and value addition are essential. Value-added products such as concentrated pulp, juice, concentrate, powder, pickles and paste can be derived from tamarind (Singh *et al.*, 2007).

Jellose, an incomplete pectin extracted from tamarind seed, can be utilized as an industrial substitute for corn starch due to its 5% viscosity and slightly thicker consistency. Tamarind kernel powder (TKP) is obtained by crushing tamarind seeds and the resulting paste, when boiled with water, serves as a good adhesive with a decent shelf life.

To facilitate tamarind export and long-distance transport, dried fruit blocks are created by compressing dried tamarind pulp into convenient bars or blocks. Tamarind-based toffees and candies, known for their natural sour-sweet blend, are prepared by boiling tamarind pulp with sugar and minimal water. Tamarind puree or paste, tamarind sauce, tamarind jam and tamarind pulp powder (TPP) are other processed forms of tamarind with varying applications (Tripathi *et al.*, 2017).

Tamarind pickle is made from matured and ripened fruit, offering a hot, spicy, sour and sweet taste with a shelf life of 1-1.2 years. Tamarind chutney, cooked with spices and salt, is a quick processed product made from green immature fruits and is commonly consumed with South Indian dishes (Kolur *et al.*, 2012). Fruit juice concentrate and tamarind beverage are other forms of tamarind-based drinks.

Comment [10]: beverages

Tamarind rice is a flavourful dish made by boiling tamarind fruit extract with rice, pulses, spices and condiments. Tamarind, a refreshing liquid extract, is a simple beverage made by shaking tamarind juice and water.

CONCLUSION

There is promoting tamarind as a major crop is essential due to its high domestic and international demand, coupled with its versatility as both a fruit and condiment. Despite being underutilized, tamarind possesses a delightful sour-sweet taste and is abundant in vitamins, minerals and antioxidants. Its adaptability to various climates and soil types makes it a valuable asset in agriculture. In India, while it predominantly finds commercial cultivation in peninsular regions, it can thrive in other parts of the country as well, often grown in homestead gardens or as avenue trees. The flowering and fruiting patterns, typically occurring during summer and early summer or late winter, respectively, contribute to its potential for year-round cultivation. Moreover, tamarind lends itself to the production of diverse value-added products such as jams, pickles, candies and beverages. By shedding light on the significance, cultivation practices and processing options for tamarind, this review aims to encourage broader adoption of this valuable crop and capitalize on its numerous benefits.

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