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Psidium guajava. L Single Plant with Abundant Health Benefits – A Review

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Abstract

Guava (*Psidium guajava.* L) is a tropical fruit that can be grown with minimum attention and belongs to *Myrtaceae* family. Since ancient times guava and its several parts has been used to treat different ailments. This knowledge has made way to various innovations in nutraceuticals and functional foods which is in demand for a healthy lifestyle. The present review offers a brief overview in which data was searched and collected using precise key terms related to guava plant, seeds, leaves - its health benefits, pharmacological uses, as nutraceuticals and functional foods, toxicity, which were available in public domains and is presented. Currently, scientists are working to develop environmentally acceptable, cost-effective, alternative dyes for clothes and novel products in cosmetic industry using guava leaves. Thus, the present review confers about the different findings from various authors in connection to the importance of guava in different areas of research.

Keywords: Guava leaves, Fruits, seeds, Functional foods, Phytochemistry, Toxicity.

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Contents

Contribution of this paper to the literature
Recent research on guava has showed the presence of nutraceuticals and functional foods. This is not only created lot of demand in recent years but also paved the way to take up the present review. Value added products from fruits have been exhaustively reviewed in the present article.

1. Introduction

Guava is often promoted as a "super fruit" with seeds high in omega-3, omega-6, polyunsaturated fatty acids, dietary fiber, riboflavin, proteins and mineral salts, as well as significant nutritional value in terms of vitamin A and vitamin C. Guava is said to be the fourth most significant fruit in terms of area and output after mango, banana and citrus. India is the world's leading producer of guava. It has been grown in India since the early 17th century and has steadily grown in significance as a commercial crop. Guava is a tough plant that bears a lot of fruit and is quite profitable even without much attention. It is widely cultivated across the tropics, and subtropics, especially in India in states such as Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, West Bengal, Assam, Orissa, Karnataka, Kerala, Rajasthan, and many others. Allahabad Safeda, Lucknow 49, Chittidar, Nagpur Seedless, Dharwar, AkraMridula, ArkaAmulya, Harijha, Hafshi, Allahabad Surkha CISHG1, CISHG2, CISHG3 etc. are the main varieties produced in India [1].

With changing customer attitudes, expectations, and introduction of new market items it has become important for manufacturers to offer products that are both nutritious and healthy. Guava has great digestive and nutritional value as well as a pleasant flavour, excellent palatability and availability at reasonable price. Guava has a short shelf life and it is important to utilize it to a variety of goods in order to extend its availability and to constant the price during oversupply. Therefore, guava is processed into several value-added products like juice, nectar, dehydrated slices, pulp, jam, jelly and also as a flavour enhancer as an additive to the fruit juices or pulps [2]. Processed products are presently the focus of international commerce, with the United States, Japan and Europe importing majority of them [3].

Guava has been used to treat variety of ailments. Pharmacological research *in vitro* and *in vivo* has been widely used to demonstrate the potential of guava for different treatment of ailments with high prevalence around the world enhancing traditional medicines [4].

2. History

According to Ellshoff, et al. [5] in 1753 *P. guajava* was first named by Linnaeus. Guava fruits are eaten fresh or processed into other delicacies all over the world. It outperforms other tropical fruits in terms of productivity, hardiness, adaptability, and nutritional value, and provides providers with higher economic returns with lower inputs. Unfavorable weather conditions, such as high temperatures, low rainfall, marginal soils, waterlogging, and a scarcity of quality inputs such as irrigation water and fertilizers, have very little impact on guava production. To produce a productive and high-quality crop, however, precise management is needed [6].

Guava has been bred for so long that no one knows where it came from. It is known that, however, that the Egyptians cultivated it over a long period of time, and that it was possibly transported from Egypt to Palestine, and then widely spread in Asia and Africa. Years later, in the 15th century, European colonizers brought this fruit to the Bahamas and Bermuda, having acquired it in the East Indies and Guam. The guava was first discovered in Florida in the 18th century, and it is now distributed in the tropical and subtropical Americas [7].

Guava production has become a commercial preposition in recent years as a result of rising foreign demand for fresh and processed goods, which has a well-established market in over 60 countries. India is the world's largest producer of guava and China, Kenya, Thailand, Indonesia, Pakistan, Mexico, Brazil, Bangladesh, Nigeria, the Philippines, Vietnam, and Egypt are the other leading producers. Presently the fruit can be found growing over 60 countries including some Mediterranean regions [6].

Guava is known in different names in different parts of the world. The common names of the species *Psidium guajava* are:

The tree is called guayabo or guayavo in Spanish, while the fruit is called guayaba or guyava. The French call it goyave or goyavier; the Dutch, guyaba, goeajaaba; the Surinamese, guave or goejaba; Germany, Guavenbaum; Arabic,guwâfah and the Portuguese, goiaba or goaibeira. Hawaiians call it guava or kuaw; Chinese, fan shiliua; Brazil, araca; Thailand, farang; Cambodia, trapaeksruk. In Malaya, it is commonly known either as guava or jambu batu, the Philippines call it as bayabas [8].

3. Botany

Scientific Classification:
Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Rosidae
Order: Myrtales
Family: Myrtaceae
Subfamily: Myrtoideae
Genus: Psidium L.

The *Psidium guajava* L. belongs to the Myrtaceae family. *Psidium guajava* is the most popular fruit of the genus Psidium, which has around 150 species [9].

The guava tree is widely regarded as a drought-resistant plant and grows quickly and bear fruit between two and four years after seed germination (Figure 1a shows a guava tree). Trees aged 30-40 years have been discovered, but productivity begins to decline around the fifteenth year. Guava (*Psidium guajava* L.) is a small branched tree or shrub that grows to a height of 7–10 meters. The root system is superficial. After the trunk has grown to around 20 cm in diameter, it is woody and rough, with a distinctive smooth, pale mottled bark that peels off in thin flakes. Branches can be ascending, drooping, resulting in a variety of canopy forms [7].

Young twigs are quadrangular and downy with green leaves (Figure 1b depicts guava leaves). Variations in anthocyanin pigmentation, young leaves may be brownish-reddish. Mature leaves have prominent lateral veins on the underside, are aromatic, evergreen, sub-chartaceous, and opposite. Leaf shape ranges from elliptic to oblong-lanceolate, rarely rounded, 4-10 cm long and 2.5-6 cm wide, apex attenuate, apiculate, blunt but mostly obtuse or acute, broadly cuneate at the base, and short petioles 2-7mm long [9].

Guava fruit is classified as a berry. Fruits range in size from medium to large, weighing 100-250 g and measuring 5-10 cm in diameter, with four to five protruding floral remnants (sepals) at the apex. Fruit may be spherical, ovoid, or pyriform in shape, depending on the cultivar. The fruit's surface is rough to smooth and pubescent-free. Ripened fruit pulp is soft and juicy, with a white, pink, or salmon-red colour. Guava fruits have a strong, distinct, and alluring flavour and aroma due to esters and terpenes [10].

Immature and unripe fruit have a dark green skin that turns yellowish-green, light yellow, or yellow with a red flush on the shoulders when ripe, depending on the cultivar. The seed cavity in the center of the fruit will range in size from small to massive, containing a variety of hard to semi-hard seeds. Owing to the presence of stone cells (78 percent), which have heavily lignified cell walls, the outer mesocarp of guava fruit has a sandy or gritty appearance, while the endocarp tissue is abundant in parenchyma cells and few in stone cells. Thick pulp, few seeds and stone cells, high sugar concentrations and distinct aroma are the desirable fruit characteristics for table purposes [10].

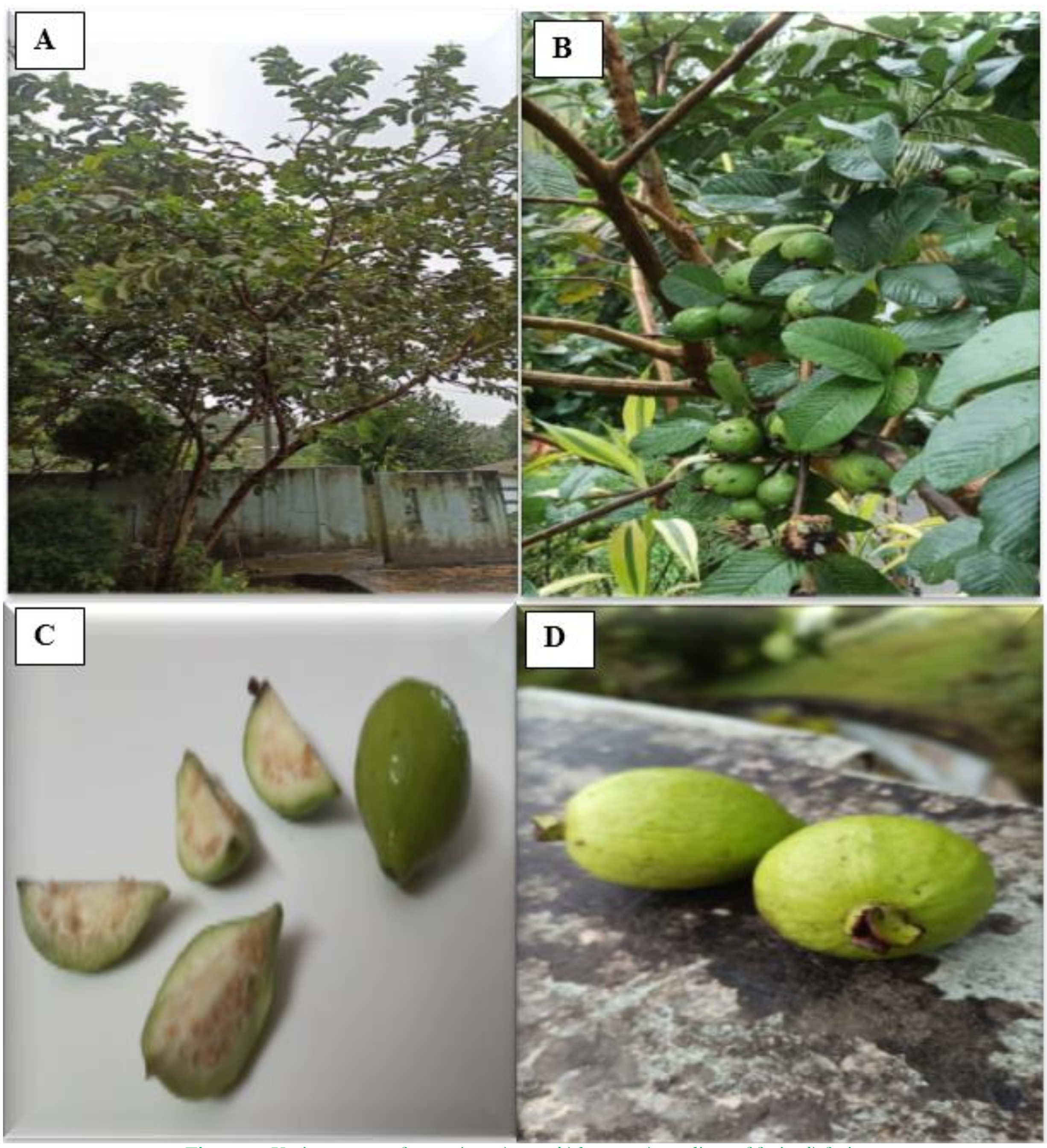

Figure 1. Various parts of *P.guajava* a) tree, b) leaves, c)cut slices of fruit, d) fruit.

Flowers are hermaphrodite, white-coloured, large, solitary or in clusters of two to three, and slightly fragrant. Flowers of four or five petals, but sometimes with ten petals arranged in two series of five. Petals are obovate, white, and pubescent, with a length of 1–2 cm. Pedicels pubescent, 1.5–2.5 cm long. Stamens are numerous, about 1 cm long, with a lot of pollen and pale-yellow anthers at the tips. Flowers can be produced on newly growing lateral shoots at any time of year, allowing for continuous flowering. As a result of a number of abiotic variables, blossom bud development and subsequent fruit set can be highly variable during the year and across years (Figure 1 c and 1 d shows guava fruits).

Psidium guajava spp. is mostly cultivated commercially. Other important *Psidium* species includes:

- *P. cattleianum*: It is an ornamental shrub which grows 7m high, bark smooth and young branches are cylindrical. Seeds are small and white, can be used as a substitute for coffee while roasting. It resembles strawberry with its sweet flavour and aroma. It is tolerant to lower temperature.
- *P. cattleianum f. lucidum*: It is found in Hawaii grows upto 12m height. The fruit is yellow in colour and it is propagated through seeds.
- *P. guineense Swartz*: It is a small tree which flowers throughout the year. The fruit flavour is sub acid and not musky like *P.guajava.*
- *P. friedrichsthalianum Berg*: It is a small tree which bears small sized sulphur yellow fruits. It is tolerant to guava wilt.
- *P. montanum Swartz*: It is found in the mountains of Jamaica called as mountain guava. It attains a height of 1.5m and fruits are of poor quality.
- *P. molle Bertd*: A small tree with obviate leaves which are pointed. Fruits are pale yellow with acidic white flesh.
- *P. pumilum*: A pyramidal shape tree with small leaves. It flowers twice in a year. It requires about 130 days before attaining maturity.
- *P. cujavilis*: The plant's growth characteristics and flowering habit are identical to those of *P. guineense.* The fruit is small to medium in size, weighing 30-50g on an average, and has a sour flavour.
- *P. policarpum*: Except for the pyriform shape of the fruits, the growth characteristics are identical to those of *P. guajava.* The average weight of the fruit is 200-250g.
- *P. araca Raddi*: It can be found in abundance in Brazil's uplands. It is typically a large shrub with hairy young growth; its leaves are large oblong-oval with soft velvety pubescence on top and thick pubescence on the bottom. When mature, the fruit is ovoid or oblong in shape, golden in colour and delicious [6].

4. Guavas Growth and Development

Guava flowers and fruits occur throughout the year in mild subtropical and tropical climates. It flowers in the summer, rainy and winter seasons in north India's subtropical climates, and thus bears fruit in the rainy, winter, and spring seasons, respectively. The growth period can be rapid phase extends for 45 to 60 days, or 30 to 60 days during which seeds mature fully, or it can be 30 to 60 days ends at fruit maturity. Fruit display the greatest improvement in weight and diameter during the final period of growth, as well as other improvements such as reduction in hardness, chlorophyll, and tannins. There is also an increase in soluble solid concentrations (SSC), titrable acidity and ascorbic acid [3, 11].

A study conducted by Ooi, et al. [12] examined the physiological and biochemical changes during fruit growth and development. According to the findings, RCG 1, RCG 2, and RCG 3 genotypes can be harvested after 105 days of fruit set, whereas the remaining genotypes can be picked after 120 days of fruit set to yield quality fruits.

The amount of chlorophyll in the fruit reduces as it ripens, while the amount of carotenoid in the fruit increases, allowing the skin colour to change from green to yellow. Depending on the cultivar, the flesh may be creamy white, purple, pink, or salmon red. Carotenoids are responsible for the guava fruit's flesh colour; the proportional quantities of various carotenoids decide the quality of the flesh colour. Total carotenoids concentrations rise during fruit ripening in general.

Guava fruit softening is caused by significant changes in cell wall carbohydrates during ripening. In general, total pectin content rises at first, and then drops as the fruit ripens. If the fruit ripens, the amount of soluble pectins increases. During fruit ripening, the concentrations of chelator-soluble polyuronides and carbohydrates also rise. The amount of aroma-volatile compounds rises during fruit ripening. It has a strong characteristic aroma due to esters and terpenes [13].

5. Nutritional Composition

Guava is the most delicious and nutritious fruits. Vitamin C (ascorbic acid), carotenoids, and polyphenols are abundantly present, making it an excellent source of antioxidants which are known to play an important role in the prevention of chronic and degenerative diseases. Vitamin C is necessary for immune system activation, connective tissue development. Polyphenols play a significant role in guava's higher antioxidant ability. Fruit skin contains more ascorbic acid and phenols than the rest of the fruit. Guava is a suitable option for ensuring proper bowel movements in parallel to preventive treatment for constipation because it contains a significant amount of dietary fiber. According to research the flavour of guava is due to the presence of hydrocarbons, alcohols, and carbonyls that form volatile compounds. Vitamin A, as well as dietary minerals like potassium, magnesium, phosphorus, and calcium, is found in good levels in guava [12, 14]. In general guava fruit, leaves and seeds contain the following nutrients as listed in Table 1.

Guava leaves (GLs) are high in micro-macro nutrients as well as bioactive compounds that promote good health. They have 82.47 per cent moisture, 3.64 per cent ash, 0.62 per cent fat, 18.53 per cent protein, 12.74 per cent carbs, 103 mg of ascorbic acid, and 1717 mg of gallic acid equivalents (GAE) per gram of total phenolic compounds. Polysaccharides are present in GLs which have antioxidant, anti-inflammatory, antidiabetic, immunomodulatory, and antitumor activities among other physicochemical, biological and pharmacological activities. Guava leaf polysaccharide (GLP) are water soluble, however it is not soluble in inorganic solvents such as ethanol, diethyl ether, ethyl acetate, acetone and chloroform. GLPs comprise 9.13 per cent uronic acid and 64.42 per cent total sugars, 2.24 per cent of which are reducing sugars. GLPs have been proven to help with diabetes mellitus. Type 2 diabetes is typically treated with acarbose (antidiabetic drug). It limits fast glucose release from complex carbohydrates by inhibiting glycoside hydrolases such as alpha-glucosidase and alpha-amylase [15].

Table 1. Nutritional composition of guava fruit, leaves and seeds (per 100g).

Constituents	Fruit [16]	Leaves [17]	Seeds [18]
Moisture (g)	80.80	82.47	6.68
Energy (kcal)	68	-	-
Carbohydrate (g)	14.32	0.007	3.08
Protein (g)	2.55	0.0168	11.19
Fiber (g)	5.4	-	61.8
Ash (g)	1.39	3.6	1.18
Calcium (mg)	18	1660.0	0.05
Iron (mg)	0.26	13.50	13.8
Magnesium (mg)	22	440	0.13
Phosphorus (mg)	40	1602	0.30
Potassium (mg)	417	360	0.20
Vitamin C (mg)	228.3	103.0	87.44

On a dry weight basis guava leaves contain 9.73 per cent protein. According to Lowry's and ninhydin techniques, guava leaves contain 16.8mg protein per 100g and 8 mg amino acids per 100g [17]. Calcium, potassium, sulphur, sodium, iron, boron, magnesium, manganese, and vitamins C and B are all abundant in guava leaves. According to the findings from the study of Thomas, et al. [17] Ca, P, K, Fe, Mg concentrations in guava leaf dry weight (DW) were 1660, 360, 1602, 13.50 and 440 mg per 100g respectively. Vitamin C and B concentrations were 103.0mg per 100g DW and 14.80mg per 100g DW respectively. Phenolic acids, flavonoids, triterpenoids, sesquiterpenes, glycosides, alkaloids, and saponins are among the secondary metabolites found in GLs. Phenolic compounds (PCs) are important bioactive compounds in GLs because they have antioxidant and hypoglycemic effects [15].

The chemical composition of guava powder, as well as the fatty acid profile and quantification of bioactive components was investigated [19]. It had varying amount of macro and micronutrients which are high in total dietary fiber (63.94g/100g), protein (11.19g/100g), iron (13.8mg/100g), zinc (3.31mg/100g) and have a low calorie content (182kcal/100g). The findings from the study concluded that guava powder was favourable for industrial use and using these seeds would prevent different illness and malnutrition as well as decrease the environmental effect of agricultural waste.

The effect of heat treatments (boiling/autoclaving) and germination times affect the nutritional composition and phytochemical content of guava seeds was studied by Chang, et al. [20]. The total dietary fiber, fat, protein and ash content of guava seeds were reported to be 618, 78, 72 and 5mg/g dry weight respectively. The overall dietary fiber and ash concentrations were unaffected by the heat treatments, while all other chemical components were decreased to varying degrees (15-91%). After 14 days of germination, there was a considerable decline in nutritent content ranging from 16 to 79 per cent. Guava seed may thus be used to change its chemical composition, allowing it to be used in food and feed industries.

El Anany [19] aimed to determine how roasting procedure affected the nutritional content of guava seeds, as well as antinutritional factors, bioactive compounds and antioxidant activity. During the roasting process, moisture content, crude protein, crude fiber, ash and mineral content, isoleucine, arginine, glutamic acid, total aromatic and sulphur amino acids, antinutritional factors (tannins and phytic acid), and flavonoids decreased, while oil content increased.

6. Phytochemistry

Tannins, phenols, triterpenes, flavonoids, essential oils, saponins, carotenoids, lectins, vitamins, fiber, and fatty acids are rich in guava. The following are the main plant chemicals found in guava: alanine, alpha-humulene, alpha-hydroxyursolic acid, alpha-linolenic acid, alpha-selinene, amritoside, araban, arabinose, arabopyranosides, arjunolic acid, aromadendrene, ascorbic acid, ascorbigen, asiatic acid, aspartic acid, avicularin, benzaldehyde, butanal, carotenoids, caryophyllene, catechol-tannins, D-galactose, D-galacturonic acid, ellagic acid, ethyl octanoate, essential oils, flavonoids, gallic acid, glutamic acid, goreishic acid, guafine, guavacoumaric acid, guaijavarin, guajiverine, guajivolic acid, guajavolide, guavenoic acid, guajavanoic acid, histidine, hyperin, ilelatifol D, isoneriucoumaric acid, isoquercetin, jacoumaric acid, lectins, leucocyanidins, limonene, linoleic acid, linolenic acid, lysine, mecocyanin, myricetin, myristic acid, nerolidiol, obtusinin, octanol, oleanolic acid, oleic acid, oxalic acid, palmitic acid, palmitoleic acid, pectin, polyphenols, psidiolic acid, quercetin, quercitrin, serine, sesquiguavene, tannins, terpenes, and ursolic acid [21].

The methanolic extract of guava had higher flavonoid content. Guava contains 41 hydrocarbons 25 esters, 13 alcohols and 9 aromatic compounds. Carbonyl compounds are responsible for the fruit's intense pleasant aroma. Guava fruit contains a lot of terpenes, caryophyllene oxide, and p-selinene, all of which have relaxing effects. The skin of fruit contains ascorbic acid in very high amount; however, it may be destroyed by heat [22, 23].

Leaves of guava are rich in flavonoids especially quercetin Begum, et al. [21]; Kamath, et al. [24]. Metwally, et al. [25] studied on *Psidium guajava* L. isolated five flavonoidal compounds quercetin, quercetin-3-O-α-L-arabinofuranoside, quercetin-3-O-β-Darabinopyranoside, quercetin-3-O-β-D-glucoside and quercetin-3-O- β-D-galactoside. For the first time from leaves quercetin -3-O-β-D-arabinopyranoside was isolated.

α-pinene, limonene, β-pinene, isopropyl alcohol, menthol, terpenyl acetate, caryophyllene, longicyclene and β-bisabolene are essential oils present in leaves. Oleanolic acid is also found in the guava leaves [26].

Ogunwande, et al. [27] reported that leaves have 42.1% of limonene and 21.3% of β -caryophellene of essential oils. According to the study carried out by Arain, et al. [28] β-caryophellene was dominant in leaves and has important medicinal value. Guajadial, a caryophyllene based meroterpenoid was isolated from the guava leaves [26] Phenolic compounds such as phenolic acids, flavonoids, triterpenoids, sesquiterpenes, glycosides, alkaloids, and saponins act as key bioactive compounds which play a major role in various metabolic activities in the human body. It modulate numerous physiological processes like cell proliferation, enzymatic activity, cellular redox potential, and signal transduction pathways to fight against chronic pathologies [29].

The bark contains 12–30 percent tannin and it contains 27.4 percent tannin, or polyphenols, resin, and calcium oxalate crystals. Tannin, leukocyanidins, gallic acid and sterols are present in roots [30]. Table 2 presents the phytochemicals which are extracted from various parts of guava tree.

Table 2. Phytochemical extracted from various parts of guava tree (*Psidium guajava* L.).

Compounds	Plant parts	References
Flavonoids	Fruit, seeds	Naseer, et al. [30]
Guaijavarin, Ascorbic acid, Oleanolic acid, Caryophyllene oxide, p-selinene, Quercetin, Saponins, Terpenes	Fruit	Naseer, et al. [30]; Anbuselvi and Rebecca [31]; Morais-Braga, et al. [32]; Kenneth, et al. [33]
Gallicacid, Tannin, Sterols, Leukocyanidins	Bark, stem, roots	Morais-Braga, et al. [32]; Naseer, et al. [30]; Kuber, et al. [34]
Catechin, Chlorogenic acid, Caffeic acid, Epicatechin Rutin, Ferulic acid, Terpenoids, Quercetin, Quercetin-3-O-α-L-arabinofuranoside, Quercetin-3-O-β-Darabinopyranoside, Quercetin-3-O-β-D-arabinopyranoside, Kaempfrol, Luteolin, α- pinene, limonene,β-pinene, isopropyl alcohol, menthol, terpenyl acetate, caryophyllene longicyclene, β-bisabolene, β-caryophyllene oxide	Leaves	Morais-Braga, et al. [32]; Chen and Yen [35]; Kenneth, et al. [33]; Metwally, et al. [25]; Begum, et al. [21]; Jun, et al. [36]

7. Pharmacological Uses of Guava

Guava (*Psidium guajava* L.) has traditionally been used to cure a number of ailments all over the world. The fruits, leaves, bark, and roots, have been utilized to cure stomach pains and diarrhoea in several countries [37].

Many studies have been conducted to clinically show the effectiveness of guava leaf treatment to cure a variety of diseases but the mechanism is still unknown. It is commonly used to treat diarrhoea, gastroenteritis and other digestive complaints. Certain findings showed that the flavonoids in guava leaf extract had antibacterial effects, while the antidiarrheal properties of guava leaf extract are due to the presence of quercetin. Quercetin has the ability to calm the smooth muscle of the intestine and prevent bowel contractions. *In-vitro* experiments using leukemia cells, guava leaves demonstrated antiproliferative activity. Its activity was 4.37 times greater than vincristine's activity. The polyphenol compounds in guava leaf extract can serve as an immunostimulant, causing the immune system to become more active [38].

The antibacterial activity of flavonoids from fresh and dried guava leaves was investigated by authors [39]. The most and least abundant were quercetin and morin-3-O-arabinoside respectively. Flavonoids inhibitory effects on spoilage and foodborne pathogenic bacteria were discovered to have a bacteriostatic mechanism of action against all spoilage and foodborne pathogenic bacteria examined.

The antibacterial activity of crude extract of leaves and bark of guava which demonstrated the effect against multidrug resistant *V.cholerae* O1 was studied [40]. The antibacterial activity of *P.guajava* remained persistent at 100°C for 15-20 minutes, suggesting that the active component is non protein. When 10 mg/ml(wt/mol) of crude aqueous mixture was premixed with rice oral dehydration saline (ORS) at a ratio of 1:7 (vol. extract/vol.ORS), *V.cholerae* development was totally supressed.

Decoction of leaves have been used to regulate menstrual cycle and as a douche for vaginal discharges, to tighten and tone up vaginal walls after labour in Africa. Guava leaves have traditionally been used to treat cough and respiratory disorders in Bolivia, Egypt and India. In China it is been used as an anti-inflammatory and haemostatic agent [33]. The anticancer mechanism of guava leaves components and lung cancer to develop a pharmacology network was studied by Jiang [41]. The disease genes were found in GeneCards database, whereas the potential targets of guava leaf components were found in the target databases. The most frequent targets of medication and disease targets were screened out. Triterpenoids, sesquiterpenes and flavonoids were investigated as potential targets of guava leaf components in this study. The findings stated that guava leaves had potential targets that interacted with different tumours, affecting the signal pathway using network pharmacology. This study established the pharmacological basis and mechanism of antitumour activity of guava leaves laying the groundwork for future research. According to Shabbir, et al. [42] polyphenols from the pulp of guava were effective against diabetes. The supplementation of polyphenol extract from guava pulp with a dosage of 250 mg/kg.bw as an alternative to diabetes drugs is suggested in this study.

The flowers have been used to cure bronchitis, eye sores and to cool the body, while the bark has been used as an astringent and to treat diarrhoea in children. Bark extracts are bactericidal against a range of diarrhoea-causing pathogens. Astringent, febrifuge, and antiseptic properties have been identified for the bark of *Psidium guajava*. The bark is used in the form of a decoction to cure ulcers and to regulate menstrual cycle. The bark tincture displayed fungicidal activity at various concentrations. In Africa and Asia, the plant has been used to prevent and cure scurvy [43-45]. The guava fruit has been used as a tonic, laxative, and to relieve bleeding gums. Guava fruit extract has been shown to effectively restore body weight loss and lower blood glucose levels in diabetic patients. Guava fruit extract reduces the depletion of insulin-positive beta cells and insulin release by protecting pancreatic tissues, including islet beta cells, from lipid peroxidation [46].

The methanolic root extract of *Psidium guajava* has been shown to have fungicidal properties due to the quercetin present in the root extract. *Clostridium prefringens* type A spore formation and development are inhibited by the aqueous and methanolic extracts. The methanolic root extracts yielded four antibacterial compounds, which were isolated using column chromatography. Three antibacterial substances, all of which are quercetin derivatives, have been identified in the leaves [47-49]. Table 3 gives the pharmacological uses of different parts of guava tree.

Table 3. Pharmacological uses of different part of guava tree (*P. guajava* L).

Different parts of the guava tree	Pharmacological uses	References
Leaves	Have antibacterial, antidiarrhoeal activity. Acts as immunostimulant. Possess anticancer activity.	Laily, et al. [38] Peng, et al. [50]
Fruit	Showed antioxidant activity. Used to relieve bleeding gums. Used as a laxative and for curing bleeding gums. Possess antidiabetic activity.	Martínez, et al. [51] Kumari, et al. [45] Huang, et al. [46]
Flowers	Used to cure bronchitis, eye sores and to cool the body.	Kumari, et al. [45]
Bark	Possess astringent, febrifuge, antiseptic properties. It is used for the treatment of ulcer. Acts as a bactericidal agent. Possess fungicidal activity.	Rishika and Sharma [44] Kumari, et al. [45] Dutta, et al. [43]
Root	Possess fungicidal activity.	Nair and Chanda [49]

Presence of arjunolic acid and flavonoids keeps lipid in normal range and act as a cardio protective agent. It can be used to treat dysmenorrhoea due to the estrogenic activity of flavonoids or the anti-inflammatory effects of guava leaves. *P.guajava* aqueous extracts have antioxidant or radical-scavenging properties. Polyphenols are responsible for most of the activity. The chemotherapeutic potential of leaf oil, guava seed, and whole plant extracts has been evaluated. It has been shown to have activity against various human cancer cell lines [41].

8. Post-Harvest Technology

Guava is a climacteric fruit, indicating it ripens quickly after being picked and loses its texture and quality in 3-4 days at room temperature. It contains a high proportion of water in its fresh weight and, as a result, has a high metabolic rate that persists until processing, making it a highly perishable product. Because of its fragile skin, it is prone to bruising and mechanical damage, and it cannot be kept for longer than a week, particularly in the winter [52].

According to the Ministry of Food Processing Industries, 2016 [53] of the Government of India, total postharvest losses of fruits and vegetables range from 4.5 to 15.8%, costing up to Rs. 40811 crore. Guava post-harvest handling is more important than other crops because it has a higher incidence of post-harvest losses. The susceptibility of fresh produce to post-harvest diseases and deterioration of quality attributes increases after harvest and during prolonged storage. According to Deepthi, et al. [54] under atmospheric conditions, found an increase in PLW (physiological loss in weight), TSS, and sensory rating, as well as a decrease in firmness, acidity and ascorbic acid. To prevent a glut and lower guava losses, it is essential to develop technologies that extend the fruit's shelf life by slowing the softening phase, which will increase the fruit's ability to be transported to distant markets [52].

Guavas are harvested when it reaches its maturity mostly it is assessed by its skin colour. When its colour changes from green to light green or slightly yellow, it is harvested [55]. It ripens quickly after achieving physiological maturity, in 1 or 2 days, resulting in early senescence of the fruit. According to a cross sectional study conducted by Katumbi, et al. [56] in two countries of Kenya it was observed that storage period was short and they practised limited post-harvest management in order to increase the shelf life of the fruit.

Increased shelf-life is beneficial in order to promote long-distance transportation, increase marketable time, and thereby boost fruit commercialization. Therefore, it is required to reduce the rate of physic chemical changes. Shelf life can be achieved by using low temperature storage, edible coating, packaging films, use of ethylene adsorbent, pre harvest treatment and post-harvest treatment with various chemicals. These chemicals include GA_3, NAA, salicylic acid, potassium permanganate, boric acid which is commercially acceptable and economically feasible [57].

Selenium helps in effective delaying senescence and some antioxidative losses due to enhanced activity of glutathione peroxidase. It has been effective in decreasing the production of ethylene. It is effective in plant protection against abiotic stress [52]. NAA (naphthalene acetic acid) and boric acid has positive effect to increase shelf life without losing the nutrients [57]. Gibberelins (GA_3) retards ripening and ageing of fruits. It delays chlorophyll degradation, fruit softening and reduces TSS. Salicylic acid inhibits ethylene biosynthesis [58]. Usage of potassium permanganate extends the storage period. It reduces ethylene by oxidizing carbon dioxide and water [58]. According to Singh, et al. [57] fruits were treated with boric acid (100ppm, 200ppm, 300ppm) and NAA (naphthalene acetic acid) (200ppm, 300ppm, 400ppm) at different concentrations for 1-2 minutes and observed that boric acid at 200ppm and 300 ppm were equally effective, similarly NAA at 300ppm and 400ppm were effective for quality retention in guava fruits.

The effects of different chelated glycine solutions (0, 0.02, 0.08 and 0.14 M) during ten minutes and stored for 20 days at 10°C and observed that application of calcium could maintain quality and firmness of fruit thus the ripening process was not affected [59].

According to the another study conducted by Tabasum, et al. [58] post-harvest treatment with Calcium chloride (1 and 2%), Calcium nitrate (0.5 and 1%) and Azadirachta decoction (10 and 20%) observed that while application of $Ca(NO3)_2$(1%) recorded a potential shelf life of 12 days under storage. Mature green stage fruits exhibited longer shelf life and better fruit quality with all the calcium treatments compared to other treatments during storage. In yet another study conducted by Choudhary and Jain [52] guava fruits were treated with selenium (0.01ppm, 0.02ppm, 0.03ppm, 0.04 ppm, 0.05ppm) for five minutes and observed that at lower concentration of selenium fruit storage affected positively. TSS was maintained at all stages during storage when treated with 0.02ppm. Tabasum, et al. [58] studied gibberellic acid (GA_3), calcium chloride ($CaCl_2$), salicylic acid and potassium permanganate at different combinations and individually concluded that salicylic acid were found to be effective in increasing shelf life and quality.

Guava fruits were chemically treated with $CaCl_2$ (1% and 2%), $CaNO_2$ (1% and 2%), naphthalene acetic acid (100 ppm and 200 ppm) and salicylic acid (100 ppm and 200ppm). $CaNO_2$ (2%) showed minimum physiological weight loss, maintained high palatability, maximum firmness, and ascorbic acid. Naphthalene acetic acid (200 ppm) was desirable to maintain higher total soluble solids. Salicylic acid (200 ppm) showed minimum decay of fruits [60]. Table 4 depicts different post-harvest treatments which are given to guavas.

Table 4. Different post-harvest treatment given to guavas.

Chemicals used	Keeping quality extended	References
Boric acid and NAA	Up to 9 days at ambient condition when treated with Boric acid or NAA.	Singh, et al. [57]
Chelated glycine solution	Applied to maintain quality and firmness of fruit without affecting the ripening process.	Alba-Jiménez, et al. [59]
Calcium chloride, calcium nitrate, azadirachta	Up to 12 days shelf life was achieved.	Tabasum, et al. [58]
Selenium	Selenium prevents softening of fruits during storage.	Choudhary and Jain [52]
Gibberellic acid, Calcium chloride, Salicylic acid and Potassium permanganate	Fruits had extended shelf life.	Tabasum, et al. [58]
Calcium chloride, calcium nitrate, naphthalene acetic acid and salicylic acid	It was found that shelf life of stored fruits was 10 days.	Kaur, et al. [60]

9. Toxicity Studies

Research on the therapeutic potential of plants over the years has demonstrated the tremendous capacity of plants in the treatment of a wide range of illnesses. All parts of the plant studied in the research, especially the leaves, have long been used to treat diarrhoea, dysentery, gastrointestinal issues, gastric pain, respiratory issues, obesity and hypertension. Guava is used as food and for many pharmacological uses. Plants must, however, be free of adverse side effects for the patient in addition to their potency, since the primary criteria for selecting medicinal plants is wellbeing. In order to ensure safety for humans and to develop new drugs it is required to collect toxicological data from guava [61]. Most of the toxicological effects may be due to excessive use of the products. Hepatic porphyria, haemorrhages of various organs, and damage that can impair the biochemical activity of the whole organism are possible side effects of such toxicity. Table 5 details the toxicological studies related to different parts of guava tree.

In a study conducted by Manekeng, et al. [62] reported that *Psidium guajava* bark extract is non-toxic but could exhibit mild organ toxicity while taking repeated administration. The findings from this study showed that a single dosage of 5000 mg/kg b.w. of this plant extract given orally is not harmful. The toxic effects found were sex specific after long-term treatment (28 days) at elevated doses (1000 mg/kg b.w.), and the plant might have certain hematological potency and hepatoprotective function with moderate organ toxicity.

In a study conducted in rats for 14 days evaluated toxicological effects on white, pink and red guava leaves and concluded that extract of guava leaves (white, pink and red) did not caused any deaths of rats used in the study. It did not show any toxicity signs and concluded that the leaves extract (white, pink and red) is safe at 5000 mg /kg BWT [62].

Prommaban, et al. [63] conducted a study using guava seed oil (GSO) which showed GSO to be nontoxic to normal hepatocytes and peripheral blood mononuclear cells, with mice receiving a median lethal dosage (LD50) > 10mg/kg for 14 days and rats for 90 days with a lethal dosage of (LD50). These findings showed that GSO, which is high in linoleic acid and antioxidants, can aid skin wound healing and prevent leukemic cell growth.

Table 5. Toxicological studies related to different parts of guava tree.

Different parts of guava tree	Studies related	References
Bark	Methanol extract showed moderate organ toxicity after long term treatment.	Manekeng, et al. [62]
Leaves	In rat's toxicity study conducted and results showed leaves are safe to use.	Babatola, et al. [64]
Seeds	Using GSO expand study concluded that it was not toxic.	Prommaban, et al. [63]

10. Guava Usage in Development of Foods - Functional Foods

The global market for functional foods has expanded in recent years, as there is consumer demand for a healthy lifestyle. Plants are a major natural source of a wide range of bioactive compounds. Since ancient times, a range of plant preparations have been used in folk medicine to treat a variety of illness and the cosmetic, pharmaceutical, and nutraceutical sectors are now paying increasing attention to plant preparations and pure phytochemicals. Plant leaves are largely responsible for the use of plant products in cosmetics, beverages, food and medicine. Leaves accumulate the bioactive compounds such as secondary metabolites, of all plant parts. Phytochemical profiles and biological activity of leaf extract have been described in various researches. Plant leaves, while being considered as agricultural waste, are a rich source of high nutraceutical compounds [15].

Guava leaves (GL) can be employed in the manufacture of functional foods and medicines because of their phytochemical profile and positive benefits. Numerous reports suggest the benefits of using GL extracts as a functional food ingredient because of the inclusion of a range of compounds such as rutin, naringenin, gallic acid, catechin, epicatechin, kaempferol, isoflavanoids, vitamins, citric acid, and flavonoids such as quercetin and guaijaverin, which are well known for their antimicrobial, antioxidant and anti-inflammatory properties. It does not alter the rheological and sensory characteristics of food when added a functional ingredient to foods [15].

In a study conducted by Kumar, et al. [15] guava leaf extract was used with pectin (1.5g), sugar (28g), and lemon juice (2ml) to make a jelly. The guava leaf extract jelly (GJ) and the control jelly (CJ, without extract) were subjected to proximate and textural tests in addition to assessing antioxidant and antibacterial characteristics. The textural studies of CJ and GJ revealed that both jellies had identical characteristics, indicating that the addition of guava leaf extract had no effect on the texture of guava jelly. The produced product, GJ has a higher nutritional content and adequate consumption of these jellies will benefit the consumer by decreasing high cholesterol levels and boosting immunity.

Guava leaf tea (GLT) which is a functional beverage commercially available in Japan, found no possible interactions between GLT and medications, indicating that GLT is safe in term of food drug interactions. Borderline diabetics, who are at high risk of developing diabetes, take GLT to prevent a fast rise in blood sugar levels after meals. GLT is made up of carbohydrate and polyphenols that bind to digestive enzymes and have been linked to poor dietary sugar or fat absorption [65].

A study on fresh pork sausage to determine antioxidant efficacy of guava leaf extract was carried out [66]. Natural antioxidants contained in GLs after fortification in fresh pork sausage were found to be beneficial in slowing down the oxidation of lipids in the fresh pork sausage.

In another study authors [67] investigated the antioxidant potential and functional value of guava powder in muscle foods. Guava powder was incorporated in sheep meat nuggets which increased the total phenolics, total dietary fibre (TDF), ash content and also the product redness value. It did not affect the sensory profile of the meat product.

Guava cheese was prepared by cold pulping, major ingredients were sugar and butter [68]. The guava cheese was made in such a way that the chemical analysis revealed that it has high levels of vitamin C and minerals. Furthermore, carbohydrate content was found to be greater, while fat content was found to be lower. The texture, colour, flavour of the prepared guava cheese was reported to be excellent.

A guava cheese (GC) which was developed as a semi solid concentrated fruit product that can be consumed as a snack. The hardness and phytochemical content were enhanced when pectin was added. Guava cheese's shelf-life stability and antioxidant potential were improved by pectin. The addition of alternative sweeteners and useful compounds, guava cheese can be used as a nutritious fruit snack [69].

Guava cheese with and without the addition of milk powder from the fruits of each type was developed [70]. The storage durability of guava cheese was tested for 150 days at room temperature (30°C +2, 90%RH). 200g of each product formulation was chopped into small pieces and wrapped with butter paper before putting into various packaging materials such as plastic containers, glass container and cardboard boxes. Guava cheese made from variety L-49 had the highest total reducing sugar and had superior storage durability. At both home and commercial level, the variety L-49 fared better for processing purposes.

Fortified wheat bread (GB10) and 20 per cent (GB20) by replacing wheat flour with guava powder as a source of fragrance and phenolic compounds was studied [71]. Control bread (CB) without guava powder and guava breads were tested for phenolic components, antioxidant capacity, volatile chemical profile and sensory acceptance. Adding guava powder to mix raised amount of phenolic compounds in the mix by around 2-3 times. Breads containing guava powder had a more complex volatile profile than those containing CB, owing to the presence of terpenes. GB enhanced the bread's fragrance profile. Aroma chemicals and phenolic antioxidants were added by guava powder which appeared as an innovative way to boost bread bioactivity and appeal.

Guava powder was used to replace commercial ascorbic acid as a natural improver in bread manufacturing and provided better or comparable results. When compared to bread produced from wheat flour or wheat flour with commercial ascorbic acid, guava powder bread had a greater bread specific volume. Sensory assessment revealed that samples containing commercial ascorbic acid were more acceptable than ones including guava. The bread with guava powder added to it on the other hand had a superior flavour [72].

11. Value Added Products of Guava

Guava grown in various parts of India is available in rainy and winter seasons. Due to improper handling, shipping and processing 20-25 per cent of guava fruit is ruined before it reaches the consumer. As a result, improving low-cost guava processing technology is required to make use of surplus and prevent it from spoiling. From the time the guava fruit is picked until it is consumed, around 10-15% of the overall crop is lost. Processing and storing the seasonal surplus of guava fruit into different value added products such as guava juice, pulp, nectar, jam, jelly, wine and toffee and being used as an addition to other fruit juices or pulps helps prevent these losses. Food items with added value or pre-processed commodities whose value has been enhanced by the inclusion of substances or processes that make them more appealing to buyers or used by the consumers. The fresh fruit has a short shelf life therefore, it is important to use it to make a variety of goods in order to expand its availability throughout time and keep price stable during glut season. These items have a lot of potential for both internal as well as external trade. Fruit and vegetable processed goods have a lot of export potential. An export of jams, jellies of guava worth 5,373.21 lakhs was exported in 2020-2021 [53]. The global trade in processed guava products was expected to grow steadily and significantly [73].

11.1. Guava Pulp

Guava fruits may be processed and stored as pulps, which then can be used to make juice, ready-to-serve beverages and nectar. Bons and Dhawan [74] prepared guava pulp and preserved with potassium metabisulphite. It was kept for three months in food grade plastic jars at a low temperature (2-5° C).

The optimum preservation methods and varieties for guava pulp preservation was studied [75]. The pulp of two guava cultivars (L-49 and Lalit) was preserved using nine different treatments for this purpose. The findings of the study showed that low temperature (-20°C) storage was superior in terms of TSS, sugars, ascorbic acid, pH and colour quality whereas non enzymatic browning (NEB), microbial population were lower. Furthermore, potassium meta bisulphite 0.1 per cent were efficient in the storage of guava pulp at ambient temperatures. During the whole storage time Lalit possess minimal NEB, L-color value, microbial count as compared to L-49 guava cultivars (upto 90 days).

Peng, et al. [76] studied the purpose of guava pulp (GP) to protect mice from cholestatic liver damage and the QBC939 cholangiocarcinoma cell line against interleukin-6(IL-6) mediated proliferation. In this method left and median bile duct ligation (LMBDL) surgery was used to produce cholestatic liver injury in mice, which were then treated with GP. The findings showed that GP extracts inhibited IL-6 induced QBC939 cell proliferation, p- ERK, and c- Myc expressions. GP might offer a fresh approach to the treatment of cholestatic liver damage.

11.2. Guava Juice

Fresh guava fruits or preserved pulp can be used to make juice. Squeezing guava slices through a hydraulic filter press extracts juice from fresh fruit. Pulp can be turned into juice by diluting it with water and filtering it. Fruit juices are generally cloudy suspensions of colloidal particles. It is tough to make clear juice from guava and other tropical fruits. Flavour compounds and natural antioxidants are carried by the colloidal particles that produce turbidity in juices. Carotenoids are abundant in the fruits, which are maintained in the structural tissue during pressing. In order to achieve greater yields, increase filtration rate, and create clear liquids of high quality, pectin enzymes in combination with fining agents must be used in fruit processing [73].

The post-harvest losses (PHL) management of guava fruit in rural regions which have no access to modern energy using small scale juice production was examined by authors [77]. Fruit processing utilizing locally developed solar technology was proven in this study to improve PHL management of fruits and vegetables. During the experiment, evenly cut fruits were disinfected and softened by boiling for half an hour in a solar boiler. The boiled fruit was combined with preservatives, homogenized, filtered and hot-filled into a glass bottle. The juice was tested for TSS, and microbial load for every 30, 60, 90 days. With the help of this technology small farmers would be able to begin equitable agro processing.

Thongsombat, et al. [78] conducted a study on the production of guava juice fortified with soluble dietary fiber obtained from guava cake (pulp, seeds and peel). With the exception of turbidity and odour, there were no significant changes in perceived sensory ratings from all examined qualities when compared to guava juice without addition of crude pectin (control). This research implies that deodorization may be required for commercial guava pectin production and use in the future.

To use response surface technique to enhance clarifying process of guava juice was initiated [79]. The optimum conditions for clarifying guava juice were discovered using response surface and contour plots.

11.3. Ready- to-Serve Beverages

Guava is used to prepare RTS beverages and it blends with other fruit pulp and dairy products. Bhuvaneswari and Tiwari [80] conducted pilot scale studies on RTS beverage on red flesh guava were prepared using 100kg of fruit. RTS beverage was made by combining fruit pulp and syrup to get desired level of acidity and sugar on a laboratory scale. Using a colloidal mill to blend RTS beverage increased the colour, consistency and overall quality. Pink varieties are ideal for beverage preparation because of their appealing colour.

A study to standardize the appropriate blending of guava and barbados cherry fruit pulps, as well as alternative blending ratios and recipes for the preparation of high quality blended ready-to-serve beverages, and to assess their storage stability at room temperature has been carried out. The organoleptic quality of the blended RTS was assessed using a 9 - point Hedonic rating scale. At monthly intervals, the chemical changes in blended RTS kept in glass bottles were assessed. TSS and acidity were constant for the first three months, and then gradually rose until the end of storage. The blended RTS was determined to be acceptable up to five months of storage at ambient temperature with satisfactory appearance, flavour, taste, and overall acceptability according to the organoleptic score [81].

A study to determine the physico-chemical properties of RTS guava, including TSS, acidity, total sugars, microbiological count as well as organoleptic qualities was studied. The results showed that the physico-chemical changes were minimal and sensory characteristics reduced with storage time [82].

The preparation of guava-lime-ginger RTS beverage was evaluated [83]. During storage acidity increased and sugar levels reduced along with reduction of TSS, pH, total sugar and ascorbic acid.

11.4. Guava Nectar and Guava Jelly

The juice from the guava fruit is guava nectar. It is generally produced from the crushed fresh guava fruits and utilizing the resultant guava pulp to make a flavourful thick juice. Guava nectar may be used in variety of ways, from mixed beverages to pure ingestion and this is especially popular in tropical areas. It is available in market places, usually in pasteurized and stable forms [73].

Bal, et al. [84] conducted a research for the preparation of nectar using guava with respect to the pulp percentage and TSS (^{0}Brix) and the processed nectar was analyzed in CRD (Completely Randomized Design). The findings of the study revealed minimum changes in biochemical parameters of guava nectar.

Guava jelly is a sweet, semisolid and rather durable spread or preserve prepared from fruit juice and sugar that has been cooked to a thick consistency [85]. Fresh guava fruits that are slightly under ripe are utilized to make the jelly Kumari, et al. [73]. Hossen, et al. [86] investigated the making of jelly from guava juice at various stages of extraction. The jellies sensory qualities and preservation studies were assessed. Based on sensory examination of guava jellies made from various juice extractions, including smell, taste, colour, texture and overall acceptability, the jelly made from a composite of the first and second juice extractions was found to be the most acceptable. Upto 210 days, the colour and flavour of jellies had altered due to fungal development and incipient deterioration.

Guava jelly bar which showed physico-chemical properties increased like TSS and total sugars while acidity, pectin content, ascorbic acid and organoleptic scores reduced in the jelly bar stored in ambient condition was studied by Kuchi, et al. [87]. The changes in the jelly bar under refrigerated storage were insignificant. It was observed the jelly bar wrapped in laminated aluminium foil and kept refrigerated had a higher quality till it is consumed.

11.5. Toffee

Fruit toffees are inherently high in nutrients because they include the majority of the nutrients found in the fruit from which they are made. Kohinkar, et al. [88] conducted a study to create a technique for making mixed fruit toffee using fig and fruit pulp, as well as to assess the quality of the toffees for 180 days of storage under ambient and refrigerated conditions. Toffee made from 75:25 w/w (fig:guava) ratios was shown to be superior to toffee made from different combinations of fig and guava fruit pulp.

Study was carried on toffee prepared by blending noni pulp with papaya and guava pulp. Toffee comprising 90% noni pulp and 10% papaya pulp, as well as 93 per cent noni pulp and 7% guava pulp, was shown to have considerably greater overall organoleptic acceptance Jadhav, et al. [89]. Khapre [90] made guava soy toffee by combining guava pulp with soya slurry to create a protein rich snack. As the amount of soya in the completed product increased, while the amount of sugars in the final product reduced. Added guava increased ascorbic acid, fiber, calcium and phosphorus to the mix. However, the product with 85 per cent fruit pulp and 15 per cent soya slurry received the best score in sensory characteristics, indicating that it is more acceptable to consumers. Thus, guava fruit is perishable and low in protein and fat may be used to make a healthy product by mixing it with soyabean products. A method for making mixed toffee from guava and strawberry pulp as well as to investigate how toffee's chemical composition and sensory characteristics changed while stored at room temperature and in the refrigerator was studied by authors [91]. Even after 90 days of storage at ambient and refrigerated temperatures, toffees were determined to be satisfactory.

11.6. Guava Wine

Guava wine has the potential to be a high quality wine with alcohol (stimulant) and high levels of phenols and ascorbic acid (antioxidants) as well as improving the economic position of farmers, particularly when there is surplus. As a result, creating a technology for the manufacture of guava wine may be beneficial [92].

A study to see if guava wine could be made with or without the inclusion of grape-grown yeast was carried out [93]. It was also noted that guava fruit may be turned into good quality wine. During fermentation, TSS, reducing sugars, and total sugars reduced as sugars were converted to alcohol and carbon dioxide while alcohol, total acidity, fixed acidity, and volatile acidity increased and pH fell as different acids were produced as by-products.

Dhakane, et al. [94] studied the effects of temperature and yeast count on fermentation kinetics as well as the chemical characteristics of guava fruits to make a low alcoholic beverage. Temperatures at 22, 27, 32°C as well as yeast concentrations of 1, 2, 3% were used to optimize fermentations. The findings reported that at high temperature (32°C) and at yeast count of 3% gave optimum parameters for low alcoholic beverage.

To develop a natural sparkling wine using the champenoise method and characterize its physicochemical and volatile properties was researched by Bertagnolli, et al. [95]. The fruity and flowery aroma in the sparkling wine was complex. Furthermore, by applying champenoise process which is typically applied to grapes, a natural sparkling wine with physicochemical properties comparable to sparkling wines manufactured from grapes was developed.

11.7. Guava Dehydrated Slices and Guava Leather

From firm and ripe guava fruits, ready-to-use dehydrated guava products like dehydrated guava slices can be prepared. Guava slices were osmo-dried after being sliced into 1.5 cm thick slices, cored, and dipped in various concentrations of sugar syrup solution containing 0.05 per cent potassium meta bisulphate (KMS) and 0.1 per cent citric acid for 6 hours at various temperatures. Without affecting the colour, texture, or natural flavour of the slices, osmotic drying significantly boosted sugar content and decreased acidity [96].

Fruits are used to make a variety of goods, but leathers are particularly popular due to their ease of handling and transportation. Dehydrating fruit puree into a leathery sheet is how guava leather is made. Leathers can be eaten as a dessert or cooked to a sauce. The chemical and organoleptic characteristics of guava and pawpaw leathers were examined in studies [73].

Verma and Bisen [97] carried out an investigation on the organoleptic and nutritive value of guava leather by using various amount of sugar levels with constant pulp and citric acid. The findings from the study indicated that there was a gradual reduction in the organoleptic properties over the storage period.

11.8. Guava Jam

Jam is a significant fruit product in the industry; it is built on the idea of high solids- high acid content. These preserved fruits have a lot of nutritional value in addition to their pleasant taste. Fruit jams are more stable than fruit juices, squashes, nectar and drinks because of high sugar content and low pH, which provide an unfavourable environment for microbial development. Guava jam is made by combining with edible portion of the guava fruit with water, sugar, pH, adjusters, jellifying agents, and other ingredients to make a product. It is heated until its right consistency, and then packed for storage [98].

A study was carried out to investigate how different processing and combining ingredient procedures affected the storage stability and customer acceptance of guava jam. According to the study turning guava fruit into jam can reduce losses. It also suggested that using a double jacketed steam kettle rather than an open kettle could reduce vitamin C, antioxidant and total phenolic content losses during processing [98].

A research on the development of zero sugar guava jam where two formulations of guava jam were prepared was studied [99]. One with standard formulations which contained sucrose and the other with the replacement of sucrose by a mix of sweeteners Lowçucar Brand® i.e., Zero Sugar Formulation (ZSF). The substitution of sweetener for sucrose in ZSF resulted in a reduction of roughly 40% in the reducing sugar concentration which is a positive result. But the Paired Test results indicated no significant difference in the approval of (Sugar Formulation) SF jam and ZSF jam by the untrained panelists.

Rahman, et al. [100] studied the storage stability of guava fruit jam and its shelf life at room temperature. The study focused on the influence of pectin on textural quality and storage stability. Storage intervals and treatments have a substantial impact on the colour of jam during storage period.

The microbial properties of bacteria, yeast, moulds for the prepared jam product was carried out [101]. The study revealed that the product was safe to ingest within 4 month microbial investigation.

In another study the authors [102] attempted to determine the feasibility of combining guava, carrot and tulsi leaves to make jam, therefore using a significant amount of marketable surplus of guava. To make the blended jam, guava, carrot and tulsi leaves extract were mixed in the following ratios: 50:50:0 (T1 control), 55:45:5 (T2), 45:50:5 (T3), 40:60:5 (T4). T2 which consisted of 55g guava pulp, 45g carrot pulp, 5ml tulsi leaves, had a brighter red colour. It may be viable on a pilot or commercial scale.

To find out the feasibility of blending guava and sapota for preparing jam was carried out by Sawant and Patil [103]. To make the blended jam, guava and sapota was in the ratios of 100:0, 90:10, 80:20, 70:30, 60:40 respectively. Among the blended jams 60% guava pulp and 40% had highest scores in colour, flavour, texture, taste and overall acceptability. Figure 2 provides the value-added products from guava.

12. Guava Waste Utilization

Commercially guava is utilized to make juice, jams, jellies, beverages, canned slices and other products which results massive volumes of guava waste in the form of peels, leaves, bark, seeds, pomace. However, research on waste utilization has shown that guava waste may be a significant source for the manufacture of a variety of high value-goods [104].

Rhizopus oligosporus was tested for its ability to produce higher quantities of free phenolics from guava residue combined with soy flour as a nitrogen source. Crude extracts were tested for β-glucosidase activity and antioxidant activity [105]. The use of *R. oligosporus* to bioconvert soy flour supplemented guava residue provides a unique method for increasing the phenolic antioxidant content and potential economic value of guava wastes.

Souza, et al. [106] studied to create nutrient budgets and diagnose nutrient balances in soil, foliar, and fruit in guava plantations treated using guava waste. In an eight-year-old guava orchard, a 6 year experiment was undertaken using 0–9–18–27–36 Mg ha^{-1}guava waste (dry mass basis) and locally prescribed mineral fertilizer. Balance sheets were created for nutrient budgets. During 6 years of research, fertilization treatments with guava waste resulted in a cumulative K deficit. Guava waste could be recycled in guava orchards at parsimonious dosage to minimize long term N and P excess, and supplied with K to avoid K shortage.

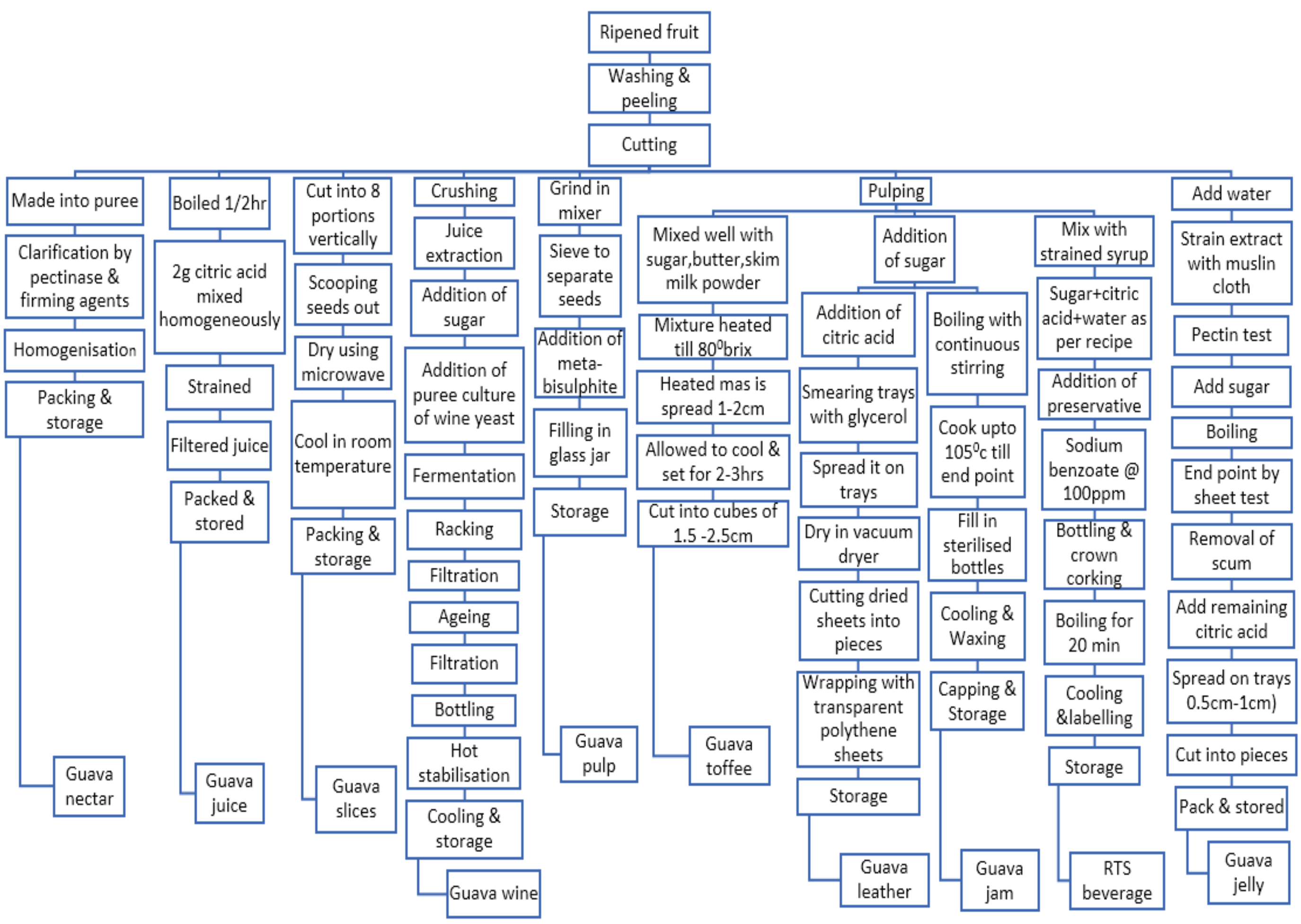

Figure 2. Flowchart of preparation of value-added products.

Note: Guava nectar [107] guava juice [77] guava slices [108] guava wine [94] guava pulp [97] guava toffee [91] guava leather [101] guava jam [101] RTS beverage [82] guava jelly [87].

The authors [109] in their study added dried guava waste (GW) in Ossimi lambs diet affected the growth, apparent diet digestibility, carcass traits and economic efficiency. Eighteen Ossimi lambs were split into three experimental groups (6 lambs each). The findings showed that GW may be used successfully in the diet of Ossimi lambs at a level of 20% without affecting performance, digestibility, carcass characteristics or health parameters.

In another study the growth performance and meat quality of lambs (40 animals) were assessed by giving increasing quantities of guava agroindustrial waste (GAW) (0, 7.5, 15.0, 22.5 and 30.0 percent) [110]. The amount of GAW added had no effect on growth parameters. Incorporating GAW into a lamb's finishing diet enhanced intramuscular fat. The addition of GAW to the finishing diet of lamb had no effect on sensory characteristics. As a result, GAW can be used upto 30% in lamb feed without affecting physico-chemical and sensory properties of meat.

The phytochemical composition (total phenolics, flavonoids, flavanols and condensed tannins), phenolic profile and antioxidant activity of guava pulp and waste extracts (GPE and GWE) made from guava pulp and waste powders (GPP and GWP) were studied [111]. The findings revealed that guava pulp and waste are a rich source of phenolic compounds and might be employed as a functional food component.

Lira, et al. [112] studied to evaluate the effect of guava waste in the diet on the performance and carcass output of broiler chickens. In a randomized full design with five levels of waste and five replications, 300 male Cobb strain chicks were used in an experiment. From the study it was observed that guava waste in the feed increases performance and carcass output similar to that obtained from corn and soybean meal based feed thus, this agro-industrial product may be utilized at up to 12% in broiler chicken feeds.

13. Other Applications of Guava

13.1. Textile Industry

Textiles are known to be prone to microbial assault due to their vast surface area and ability to absorb moisture, both of which can encourage microbial development. Several antimicrobial methods have been developed to protect various textile fabrics from microbial degradation and to prevent infectious disease cross-transmission by direct touch [113]. Currently, technological innovation is being utilized to generate novel textile goods such as fragrances, dyes, insect repellants, phase-change materials, antimicrobial agents and fire retardants to make functional textiles. Consumers are more aware of product safety as a result there is a need to produce microbe-resistant textiles as textile substrates find variety of applications, including masks, hospital covers, surgical gowns apart from conventional apparel usage. Natural extracts for finished fabrics are being explored as an antibacterial option [114].

Large amounts of aqueous wastes and dye effluents are generated in the textile industries which are being discarded. Majority of these dye wastes are toxic and may cause cancer. Elizalde-González and Hernández-Montoya [115] conducted a study on guava seed SEGUVE which was utilized as a carbon precursor or as a possible adsorbent for acid dye removal. The raw material's adsorption effectiveness on eight acid dyes was superior to that of the carbon samples, although the adsorbed quantity increased as the carbonization temperature rose from 600 to 1000°C.

The use of guava leaf extract to naturally colour hanji cotton textiles was studied [116]. The dyeing temperature and duration were 40°C and 90°C for eighty minutes. With a level of 4-5, the drying cleaning fastness was likewise very good. The materials rubbing fastness was better in dry rubbing than wet rubbing. In terms of light fastness, all dyed textiles had a poor rating. The coloured textiles with guava leaf extract exhibited 99.9% of high antibacterial activity. In the state of raw fabric, Hanji fabric cotton maintained a certain level of deodorization. The UV protection rate of all coloured fabrics was higher than that of control fabric.

Raja [117] used guava leaf powder as an adsorbent to remove Coomassie Brilliant Blue, a synthetic dye. From the findings of the study, it was clear that guava leaf powder can be utilized as an adsorbent to remove Coomassie Brilliant Blue from waste water. The influence of pH and temperature on each other is demonstrated and the role of pH is significant in adsorption process. The per cent dye removal is increased when the pH is low, the adsorbent dose and temperature is high.

Dyed cotton fabric which was used to test the dye capability of the colorants extracted from guava leaves was studied [118]. To enhance the dye ability of cotton fabric using natural dyes, bio mordanting was carried by utilizing several biopolymers and mordant before dyeing. From the study it was found that there was good light fastness, wash fastness, rubbing fastness and perspiration fastness. From an environmental standpoint, dyeing cotton fabric using natural dye and bio mordanting may be a preferable option to chemical mordanting.

An antibacterial cotton fabric by encapsulating *Psidium guajava* Linn. leaf extract in microcapsules was developed [114]. In situ polymerization with urea and formaldehyde was used to prepare microcapsules containing *Psidium guajava* Linn. leaf extract. Direct printing with a binder was used to apply *Psidium guajava* Linn. leaf extract and microcapsules containing *P.guajava* leaf extract to cotton fabric. The fabric was tested qualitatively for antibacterial properties using Escherichia coli and Staphylococcus aureus as test organisms. The cotton fabric treated with microcapsules containing *Psidium guajava* Linn. extract demonstrated antibacterial action against *Staphylococcus aureus*, but not against *Escherichia coli* according to antibacterial tests.

A unique eco-friendly technique introducing multifunctional cotton gauze textiles using guava powder extract was developed [119]. The objective of using natural ingredients in medical textiles for multifunctional applications while avoiding adverse effects is highly inspiring. The antibacterial activity of the produced cotton guaza was tested against *E.coli*, a gram negative bacteria and *S.aureus*, a gram positive harmful bacteria using the agar diffusion and bacterial counting techniques. The antibacterial, antioxidant, UV shielding, and wound healing activities of the treated cotton guaze were outstanding. As a result, the current work provides a new easy approach to create smart cotton gauze for multifunctional medical and healthcare applications using bioactive extract from sustainable plant waste.

13.2. Cosmetic Industry

Guava is a potential source of antioxidants that may be employed in the development of innovative cosmetic and dermatological formulations. The application of antioxidants on the skin is another essential approach for preventing oxidative stress [120]. Industry interest in incorporating natural ingredients in commercial cosmetic formulations has grown as concerns about health safety, social impacts, fair trade have risen. Plant extracts are now the subject of several investigations, however tropical fruits such as guava remain undiscovered and hence under used [121].

Lee, et al. [122] findings shed light on the therapeutic potential of guava in the treatment of melasma and the prevention of UV-induced melanogenesis, both direct and indirect. Many whitening agents target tyrosinase through diverse methods, like direct interference with tyrosinase catalytic activity or suppression of tyrosinase mRNA expression. This study identified the antimelanogenesis agents which can inhibit tyrosinase and ORAI1 channel (associated with UV-induced melanogenesis) from the methanolic extract of guava leaves.

The potential of guava fruit extract as a photoprotective ingredient in sun cream formulas was evaluated [121]. The presence of flavonoids and tannins, as well as the lack of coumarins, were discovered during the phytochemical screening. Sun cream using guava fruit extract has the ability to reduce the threat of synthetic agent toxicity while lowering the cost of sunscreen production by 65.8%.

13.3. Mouth Rinse and Soap

Control of biofilm adhesion on the tooth surface has long been a critical component of periodontal therapy. However, the high frequency of gingivitis suggests that self-promoted oral hygiene procedures are insufficient and that an adjunctive assistance for mechanical plaque reduction is required. Oral rinses contain chlorohexdin has been widely used, although they have certain drawbacks. Herbal products have been widely utilized demonstrating their effectiveness as a supplementary and alternative medicine. As a result, the goal of this study was to assess the antibacterial and antioxidant effectiveness of a guava leaf extract – based mouth rinse as an addition to oral prophylaxis in individuals with chronic generalized gingitivitis [123].

Guava leaf extract mouth rinse could be used as an adjunct to professional oral prophylaxis was studied [123]. Despite being less effective than the chemical ingredient (0.2 percent chlorohexidine mouthrinse) guava mouth rinse outperformed the placebo group in terms of antimicrobial activity. As a result, guava mouth rinse could be added to the list of phytotherapeutic options for ensuring healthy gingiva. However, further randomized clinical trials need to be conducted over a longer length of time to confirm its long term effects.

To determine and compare intraorally the effects of 0.5 per cent *Camilia sinesis* extract, 0.5 per cent guava leaf extract, and 0.2 per cent sodium fluoride solution on the quantity of *Streptococcus mutans* and *Lactobacillus* spp. in the oral cavity was studied [124]. Green tea extract was more efficient than guava extract on *Streptococcus mutans* in plaque compared to fluoride *in vivo* research, whereas guava extract was more effective on *lactobacilli* in saliva compared to fluoride.

Tiwari [125] conducted a study on 10 distinct herbal soaps utilizing guava and neem extract and five different types of oil (coconut, teel, mustard, olive and sunflower). Turmeric, indigo, milk powder henna and coffee powder was used as colouring agents while lemon grass was employed as a flavouring ingredient. Following the production of soaps, several characteristics of soap were examined including foaming capacity, yield percentage, lathering power, cleansing power, hardness, and moisture content of samples. On the basis of the analysis it was determined that the soap made with coconut oil is the best, while the soap made with sunflower oil is of inferior quality. It was also discovered that soap made from guava extract maybe utilized for washing wounds due to antibacterial properties.

14. Different Drying Methods Used in Guava

The term "drying" refers to the act of removing moisture from a solid utilizing heat as source of energy. It is a process that involves both heat and mass transfer and, in most situations, alters characteristics of products. Drying is used in range of industries, agricultural and food processing industries. Many technologies, such as hot air drying, vacuum drying, and freeze drying have been developed to get greatest results [126].

The effects of carbon dioxide and nitrogen on guava and papaya was studied. Normal air HPD (heat pump dryer), vacuum dryer and freeze dryer were used to examine the drying kinetics and quality of these dried fruits. The finished products showed reduced browning, quicker rehydration, and higher vitamin C retention. All these indicates the enormous potential of modified atmosphere heat pump dryer in the food drying sector [126].

The influence of different drying techniques and the inclusion of drying aids on physic chemical properties and sensory qualities of dehydrated guava concentrate was investigated [127]. Dehydrating concentrated guava juice using freeze drying, spray drying and tunnel drying methods yielded instant guava drink powder samples. From the study it was observed that the freeze dried product had superior nutritional and sensory characteristics while spray dried product was more stable and cost effective for producing free-flowing stable guava powder.

Patil et al [128] used spray drying for development of guava powder. Response surface methodology (RSM) was used to optimise spray drying. Different degrees of inlet air temperature and maltodextrin content served as independent variables. Moisture, solubility, dispersibility, and vitamin C were the responses. When compared to commercial fruit juice powders, spray dried guava powder contained more vitamin C and is found to be flowing with no physical changes such as caking, stickiness, collapse or crystallization.

Chemical composition of oven and freeze dried guava powders for future usage as an antioxidant rich flavour enhancers was studied [129]. Terpenes predominated among the thirty-one volatiles found in guava powders, even after both drying procedures. Although both drying methods reduced antioxidant content, guava powders had comparable antioxidant capacity to other tropical fruit powders. Our findings showed that oven drying might be a viable alternative for producing a functional component that would increase the phenolic content of cereal meals while providing a pleasant guava powder.

The effect of drying methods on the antioxidant activity of guava fruit was explored [130]. Guava was air dried using a 45ºC air dryer, a freeze dryer and osmotic drying methods. Fresh guava extracts (FGE), freeze dried guava extracts (FDGE), oven dried guava extracts (ODGE), and osmotic dehydrated guava extracts (ODGE) were analyzed for total polyphenols (TP), flavonoids, antioxidant potential by 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), oxygen radical absorbance capacity (ORAC), and trolox equivalent antioxidant (TEA) (OS).

The effects of various drying methods on ascorbic acid concentration and guava colour quality, including direct sunlight, freezing, convection oven (50,60,70,80,90ºC) and microwave oven (100, 250, 400, 600 and 1000 watts) was conducted [131]. When dried guava slices were compared to fresh guava slices, the amounts of ascorbic acid were significantly different. When the temperature and power of conventional and microwave ovens were increased, the colour of guava slices turned yellowish. In terms of ascorbic acid and natural colour retention, it was found that freeze drying was the optimum approach for dehydrating guava.

The effect of drying procedures and maltodextrin concentrations on the physicochemical properties of pink guava powder was investigated [132]. Pink guava puree was freeze dried at -110ºC and 0.001mbar, spray dried at 170ºC inlet air temperature and 350ml/hr feed flow rate with a 10-20% maltodextrin concentration (MDC). Powder characteristics were significantly affected by the drying techniques and MDC. Spray drying was more successful in lowering moisture content and water activity to 2.86 % and 0.377%, respectively whereas, freeze drying was better at retaining colour, lycopene and vitamin C. When compared to freeze drying, spray drying was the most cost effective option. Overall, spray dried pink guava powder made with 20% MDC outperformed freeze-dried powder in terms of lowest moisture content (2.17%), lowest water activity (0.33), greatest glass transition (215°C) reduced electricity and time consumption, moderate lycopene and vitamin C retention.

Phenolic compounds in fresh guava and newly generated small molecular phenolic compounds in dried guava, as well to assess the influence of various drying techniques on the major phenolic compounds and antioxidant properties of guava was studied [133]. Catechin and its derivatives were degraded as a result of drying procedures. Procyanidin trimers were found to be more abundant after drying treatments. The production of cinnamic acid dihexose was enhanced by drying procedures, most likely due to lignin or phenolics carbohydrates complex formation. Freeze drying and hot air drying were shown to be superior performance in terms of total phenolic content (TPC) retention and antioxidant activity (AA).

The effects of different drying techniques on the chemical composition and antioxidant activities in white and red guava fruits using freeze drying (FD), vacuum drying (VD), and hot air oven drying (OD) was investigated by Tan, et al. [133]. For the first time five to ten compounds were found in the guava fruit. The red guava powder had higher total polyphenols and antioxidant activity than the white guava powder dried under the same conditions.

15. Conclusion

Guava, a plant with numerous benefits has an advantage where backyard plots are tiny and/or scarce. Guava is easily propagated and thrives in all climatic conditions and it is widely available for medicinal and commercial purposes. Guava has been widely investigated for its pharmacological characteristics, since it has been proven to have numerous therapeutic benefits. Guava extract with its various mechanisms of action, may help to prevent the emergence of medication resistance to common infectious illness which are widespread in communities. As a result, guava extract, which has wide range of therapeutic qualities, needs to be further researched for use in the treatment of both communicable and non-communicable illnesses.

Phenolics, flavonoids, and carotenoids have been discovered in guava as medicinally significant phytoconstituents. Numerous pharmacological studies have shown that this plant has antimicrobial, antidiabetic, cardioprotective, neuroprotective, hepatoprotective, antioxidant and anticancer properties validating its traditional usage. Many chemically produced drugs are extremely effective in generating many harmful effects in people, therefore many studies on the therapeutic use of plant extracts are necessary in the recent time. The phytochemical and pharmacological studies on guava confirm the plant's tremendous potential in the treatment of a variety of illnesses. Additional study is required for compound isolation and identification in order to develop products from *P.guajava* in the future. Every therapeutic property of many medicinal plants must be determined.

With guava as a potential raw material for cosmetic and dermatological applications, a comprehensive description of the extract's components, particularly the non-volatile components, is critical for future research and the creation of new products based on consolidated composition data. Currently research is focused on finding eco-friendly, cost effective, alternative dyes for clothing. Synthetic dyes were used commercially for appealing colours; however, they are harmful to the skin and the environment. Thus, authors have developed colours using plant extracts. Therefore, the present review covers most of the usage of guava in various aspects.

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