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Ajay Gavhane
School of Agriculture,
Lovely Professional University,
Phagwara, Punjab, India

Sanket Chopade
School of Agriculture,
Lovely Professional University,
Phagwara, Punjab, India

Pratik Dighe
School of Agriculture,
Lovely Professional University,
Phagwara, Punjab, India

Arishdeep Kour
School of Agriculture,
Lovely Professional University,
Phagwara, Punjab, India

Corresponding Author
Ajay Gavhane
School of Agriculture,
Lovely Professional University,
Phagwara, Punjab, India

The nutritional and bioactive potential of guava and possibilities for its commercial application in value-added products

Ajay Gavhane, Sanket Chopade, Pratik Dighe and Arishdeep Kour

Abstract
Guava (*Psidium guajava* L.) is a tropical and subtropical fruit crop widely used in diet and traditional medicine. Guava is scientifically known as *Psidium guajava* L. which belongs to the Myrtaceae family. There are around 150 species of guava available globally, the most prominent of which are common guava, cattley guava, peer guava, and apple guava. Guava output in the world was expected to be at 500,000 metric tonnes, with South American countries such as Brazil, Colombia, and Mexico producing considerable amounts of the fruit. It is rich in certain nutrients like protein, carbs, vitamins, and minerals, which work as health boosters for the human body, according to its nutritional composition. Some of the commercial products manufactured by using guava such as guava pulp, blended ready-to-serve beverages, guava leathers, guava juice and nectars, guava wine, guava dehydrated slices, etc. Guava has found pharmacological potentials such as antioxidants, anti-inflammatory, antiviral, antiparasitic, antibacterial, wound healer and anticancer activity.

Keywords: *Psidium guajava* L., bioactive potential, production, varieties, products, nutrients, etc.

1. Introduction
Fruits are a rich source of vitamins and minerals. India is 2nd largest producer of fruits with an annual production of about 45 MT. Among all fruits, guava is an important fruit crop cultivated widely. It is considered one of the richest sources of vitamin C. It is available during the rainy and winter season. Due to inappropriate handling, transportation and processing, 20 – 25% of guava fruit is spoiled before reaching the consumer. Guava is considered the "apple of the poor" due to its low cost. It originated in the southern part of Mexico and Central America (Kumari *et al.*, 2017) [15].

The scientific name of guava is *Psidium guajava* L. There are about 150 species of guava available worldwide, out of the common guava, cattley guava, peer guava, and apple guava are the most important species. In Pakistan, the species of common guava (*Psidium guajava* L.) yield about 100 – 300 fruits per tree and is widely cultivated due to its sweetness. Guava is climatic fruit that ripens fast and considered as most perishable fruit. So, the shelf life of guava fruit is about 2 – 3 days at room temperature. This fruit has come in various shapes, sizes and flavours depending upon variety. Guava fruit has a different musky flavour, which gets reduced when applying any processing. (Kanwal *et al.*, 2016) [14]. The average weight of guava fruit varies from 150 – 250g (Bal and Daliwal, 2004) [2]. The fruit is usually in round shape with 3 – 10 cm in diameter. It is a very productive and highly profitable fruit crop (Hassan *et al.*, 2012) [7].

Owing to its nutritional composition, it has rich in dietary fibres, vitamin A and C, folic acid, minerals such as potassium, copper, manganese, etc (Prabhudesai *et al.*, 2019) [20]. Guava is widely cultivated in all tropical and subtropical regions including India. It has been cultivated in the 17th century in India. There are many varieties such as Allahabad Safeda, Lucknow-49, Chittidar, Nagapur seedless, Banglore, Dharwar, Hafshi, ArkaAmulya, Harija, etc are cultivated in different states of India (Kadam *et al.*, 2012) [12]. Many guava products are available in the market such as jellies, juices, ice cream, yogurt and nectars, squashes, etc. It is also eaten raw and can also be consumed as a sweet meal such as guava cheese or paste (Patel *et al.*, 2016) [19].

2. Botanical Description

Guava is a small tree that belongs to the family Myrtaceae. This tree can be cultivated in any soil type and climatic condition. The guava fruit is usually 4 to 12cm long and contained round or oval shapes depending upon variety. The fruit is green in colour which turns yellow when it gets ripened. Apple guava is the most common variety of guava available in the market (Kafle *et al.,* 2018) [13]. Botanical classification is shown below in table no. 1.

Table 1: Botanical classification of *Psidium guajava.*

Botanical Classification	
Kingdom	Plantae – Plants
Subkingdom	Tracheobionta Vascular plants
Division	Magnoliophyta Flower plants
Class	Magnoliopsida Dicotyledonous
Subclass	Rosidae
Order	Myrtales
Family	Myrtaceae
Subfamily	Myrtoideae
Gender	Psidium
Species	*Psidium guajava*

Source: Kafle *et al.,* (2018) [13]

3. Production of guava fruit

Guava fruit has been considered an important tropical fruit and is mostly consumed fruit. It has considered a berry that consists of fleshy pulp and numerous small seeds. According to Jimenez – Escerg *et al.,* (2001) described that the world production of guava was estimated at 5,00,000 metric tonnes in South American countries, Brazil, Colombia, and Mexico, these countries produced significant quantities of guava fruit. Kanwal *et al.,* (2016) [14] reported that guava was one of the major fruit of Pakistan grown throughout the country. The cultivation area for guavas was 62.3 thousand hectares giving 512.3 thousand tons of total annual production and 8223 kg per hectare yield.

In India, 8 – 10 years old trees from seedlings may produce 400 – 500 fruits per year while grafted trees at the same age may produce 1000 – 2000 fruits. It could be harvested throughout the year (Prabhudesai *et al.,* 2019) [20]. As per the study by Kadam *et al.,* (2012) [12], guava fruit is cultivated in both tropical and subtropical regions in India *viz*, Uttar Pradesh, Bihar, Madhya Pradesh, Maharastra, Andhra Pradesh, Tamilnadu, West Bengal, Assam, Odissa, Karnataka, Kerela, Rajasthan and many more states. According to Omayio *et al.,* (2019) [18] revealed that the production of guava fruit in Kenya had increased in the year 2014 – 2016 from about 9800 – 11,327 tons in the 1260 – 1806 hectares.

4. Nutritional composition of guava

Guava is an excellent source of protein, carbohydrates, vitamins, minerals other major and micronutrients are known as health boosters. The nutritional value per 100g of guava has shown in table 2.

Table 2: Nutritional composition of *Psidium guajava* L.

Sr. no.	Components	Amount	References
Macronutrients			
1.	Calories	77 – 86 kcal	Uzzaman *et al.,* (2018) [27]
2.	Moisture	80 – 86 g	Omayio *et al.,* (2019) [18]
3.	Crude fibre	0.9 – 1 g	Uzzaman *et al.,* (2018) [27]
4.	Protein	0.1 – 2.55 g	
5.	Fat	0.43 – 0.7 g	
6.	Ash	9.5 – 10 g	
7.	Carbohydrates	9.1 – 17 g	
8.	Total sugars	8.92 g	Omayio *et al.,* (2019) [18]
Micronutrients			
Minerals			
9.	Iron	0.26 mg	Kafle *et al.,* (2018) [13]
10.	Magnesium	20 mg	
11.	Manganese	0.15 mg	
12.	Phosphorous	40 mg	
13.	Potassium	417 mg	
14.	Sodium	2 mg	
15.	Zinc	0.23 mg	
16.	Lycopene	5204 µg	
Vitamins			
17.	Ascorbic acid	56 – 500 mg	Patel *et al.,* (2016) [19]
18.	Thiamin	0.067 mg	Omayio *et al.,* (2019) [18]
19.	Riboflavin	0.04 mg	
20.	Niacin	1.084 mg	
21.	Vitamin B6	0.11 mg	

Guava fruit is considered the richest source of vitamin C and other nutrients such as vitamin A, phosphorous, iron and calcium. It also contained polyphenols, flavonoids, saponin, etc (Prabhudesai *et al.,* 2019) [20]. Owing to its nutritional properties such as protein (0.1 – 0.5g), fat (0.43 – 0.7g), carbohydrate (9.1 – 17g), crude fibre (0.9 – 1g) and calories (77 – 86g) (Uzzaman *et al.,* (2018) [27]. Omayio *et al.,* (2019) [18] described that the total sugar content of guava fruit was 8.92g. Also described about vitamin such as Thiamin (0.067mg), Riboflavin (0.04mg), Niacin (1.084mg), vitamin B6 (0.11mg). Minerals present in guava fruit were studied by Kafle *et al.,* (2018) [13] such as iron (0.26mg), magnesium (22mg), manganese (0.15mg), phosphorous (40mg), potassium (417mg), sodium (2mg), zinc (0.23mg), lycopene (5204µg).

5. Commercial products from guava fruit

5.1 Guava pulp

Guava pulp processing is a convenient way to preserve guava fruits. To avoid nutritional breakdown, add potassium metabisulphite at low concentrations (0.005 - 0.2%) to the guava pulp and store it at low temperatures (2-5°C). The pulp can be easily processed into different goods such as juices, ready-to-drink beverages, guava nectars, and guava leather, and can be stored at 2-5°C for up to 90 days. The procedure of extracting the fruit pulp is crucial because it impacts the end product's quality and yield. Pulp extraction can be done using either cold or hot procedures. Hot methods require a preheating step in which the fruits are blanched before being extracted with hot water or steam. On the other hand, cold methods involve pulping of clean fruits without preheating resulting in higher quality pulp although lower yields compared to the hot methods (Omayio *et al.,* 2019) [18].

5.2 Blended ready-to-serve beverages

Guava fruit pulp has been utilised in the manufacture of several blended, ready-to-drink beverages by combining it with other fruits such as anola, papaya, and pineapples in varying ratios (Sarkar and Bulo, 2017) [22]. According to Jakhar *et al*., (2013) [9] were described that blending guava pulp with other fruit pulps has been found to increase product appearance, nutritional content, and flavour.

5.3 Guava leathers

According to Kanwal *et al.,* (2016) [14] studied that guava leather is prepared by dehydrating fruit puree into a leathery sheet. Leathers can be eaten as a dessert or cooked into a sauce. In the tropics, there is a scarcity of information on the chemical and organoleptic qualities of guava leathers. Ashaye *et al.,* (2005) [1] prepared guava and pawpaw leathers and evaluated their chemical and organoleptic properties. Guava leather has a higher protein and fat content. This was also seen in the ash content, with pawpaw leather having (2.67%) and guava leather having (2.67%), (2.87%). According to studies, guava leather has a significantly higher fruitiness smell and overall acceptability, as well as better compositional attributes.

5.4 Guava Shrikhand

Sharma and Borah, (2021) [24] discussed that the current consumer preference for reduced or low-fat products that aid in the prevention of chronic degenerative diseases has prompted the development of probiotic low-fat foods such as shrikhand, a semisolid light, sweetish sour fermented dairy product. It is a popular delicacy in Gujarat, Maharashtra, and Karnataka. Shrikhand was made by heating skim milk, cooling it in a batch pasteurizer at 30 °C, adding lactic acid bacteria (LAB) starter culture, and thoroughly mixing it with a mixer. During the incubation period, which lasted 8 to 12 hours, the temperature of the pre-sterilized storage vat was kept at 37 °C. The curd was transferred to another vessel using a clean, moist muslin cloth after it had properly set. Sugar and guava powder have been added to this chakka and thoroughly mixed to a homogeneous consistency, either manually or mechanically. It is typically packaged in polystyrene cups and stored in a refrigerator.

5.5 Guava juice and nectars

Omayio *et al.,* (2019) [18] discussed that guava juice is made from either fresh fruits or guava pulp. The juice is extracted by squeezing the guava fruits through a hydraulic filter press or by dilution with water and subsequent filtration of the pulp. The juice is usually milky and requires the use of pectic enzymes to produce clearer, easily filtered juice. Imungi, (2005) discovered that the optimal conditions for extracting guava juice using proteolytic enzymes from Kenyan guavas were 400ppm of the enzyme at 45-50°C for 90 minutes.

5.6 Guava wine

It was discovered that guava fruit can also be converted into high-quality wine. Wine from 1:4 dilutions with DAHP was found to be the best treatment and was graded as fair, but its quality was lower than that of standard grape wine (Shankar *et al.,* 2006) [23].

5.7 Guava dehydrated slices

Dehydrated guava products like dehydrated guava slices can be made from firm and ripe guava fruits. The Osmo-dried guava slices were made by cutting guava fruits into 1.5 cm thick slices, coring them, and dipping them in different concentrations of sugar syrup solution containing 0.05% KMS and 0.10% citric acid for varying periods and temperatures. The results showed that as sugar concentrations and solution temperatures increased during the osmosis process, so did water loss and solid gain. In 60°B sugar solution at 60 °C temperature, the best solid gain (13.1%), water loss (34.2%), and mass reduction (21.1%) were observed in slices. Osmotic drying significantly increased sugar content and decreased acidity without affecting the colour, texture, or original flavour of the slices (Kumari *et al.,* 2017) [15].

5.8 Guava Pomace

Guava pomace is a representation of prepared waste delivered after the manufacturing process, and it can account for up to 15% of the first natural fruit (Denny *et al.,* 2013). Guava fruits were used to extract the juice. For drying guava pomace, a cabinet tray dryer was used, which could accurately control the ideal drying temperature between 20 and 150 °C. The guava pomace, which has a high moisture content, can be dried at a temperature of 65 °C, as previously proposed for drying carrot pomace (Tangirala *et al.,* 2012).

6. Pharmacological benefits of guava

Guava has been shown to have the ability to treat a wide range of disorders by several different specialists in various diseases. In ethnopharmacological evaluations, research centres, and clinical preliminary studies, guava has been proven to be useful in the treatment of several disorders. Furthermore, harmful quality evaluations of the plant's roots, bark, leaves, natural items, blooms, and seeds have been deemed safe for therapeutic applications, both for oral and effective usage, when used in blends and development structures (Gupta *et al*., 2020) [6].

6.1 Antioxidant activity

According to Fasola *et al.,* (2011) [5], *Psidium guajava* is a major source of phytochemical antioxidants. Guava is an excellent antioxidant and a strong source of vitamin C. Guava has antioxidant properties due to the polyphenols contained in its leaves. Guava leaf extracts and essential oil from the stem and bark will scavenge free hydrogen peroxide and superoxide anion radicals, and prevent hydroxyl radical formation. The antioxidant properties of guava can be due to quercetin, carotenoids, vitamin C, and polyphenols (Dakappa

et al., 2013) [3].

6.2 Antiparasitic activity
Lee *et al.,* (2013) [16] reported that antiparasitic medications are used to treat infections caused by ectoparasites, protozoa, parasitic fungi, and helminths, among other things. Guava leaf essential oil performed effectively as a host for Toxoplasma gondii in an *in vitro* antiparasitic experiment. The potential therapeutic action of guava leaf essential oil may have resulted in the *in vitro* decrease of free extremists associated with toxoplasmosis pathogenesis.

6.3 Antibacterial
Guava extracts have antibacterial properties against both Grampositive and Gramnegative microorganisms. An aqueous combination and a water-soluble methanol extract from guava leaves and bark have shown high antibacterial effectiveness against multidrug-resistant Vibrio cholera *in vitro* (Shu *et al.*, 2011) [25].

6.4 Anti-inflammatory activity
Guava extract in ethyl acetate has been found to inhibit germ contamination and thymus formation. It has the capability of acting as an antiviral agent. It can boost the expression of mRNA. The heme oxygenase-1 protein may be affected by guava. As a result, it can be used as a topical anti-inflammatory medication (Jang *et al.,* 2014) [10].

6.5 Wound healer
Ravi and Divyashree, (2014) [21] described that collagen fibres make up the gingival and periodontal ligaments. The most frequent cell type seen in periodontal connective tissue is fibroblasts. Vitamin C is necessary for the periodontium's general health. Vitamin C (ascorbic acid) is abundant in guava. Ascorbic acid can influence the expression of the procollagen gene, causing collagen organisation and altering fibroblast separation via its effects on the extracellular matrix. A mouthwash made from the root bark is recommended for sore gums, and a gargle made from leaves is recommended for swollen, bleeding gums (Mittal *et al.,* 2010) [17].

6.6 Guava for cough and cold
According to Kafle *et al.,* (2018) [13] revealed that guava leaves are effective in treating colds and coughs. Guava is rich in ascorbic acid and iron, which aid to reduce lung inflammation and mucus production while also keeping infections out of the respiratory tract. Many Indian villages used roasted ripe guava as a home cure for severe cough, cold, and congestion. Another study discovered that as compared to a control, a hydro extract of *Psidium guajava* leaves dramatically reduced coughing frequency caused by capsaicin aerosol within 15 minutes of treatment.

6.7 Anticancer activity
Lycopene, an antioxidant found in Guava, plays a vital role in cancer prevention and treatment. Breast cancer and prostate cancer respond the best of all. When guavas are sliced, the red flesh contains more lycopene than the other varieties. Lycopene works by scavenging free radicals while also preventing new ones from forming. Many studies have found that an aqueous extract of guava-developing leaves has anti-prostate cancer activity in a cell line model, indicating that it could be a viable anti-androgen-sensitive prostate cancer agent. Guava also has a high content of carotene, which is considered to prevent lung and oral malignancies (Kafle *et al.,* 2018) [13].

7. Conclusion
Guava (*Psidium guajava* L.) is well known around the world for its food and nutritional benefits. Guavas were also included in the list of super fruits because of their high levels of folic acid, dietary fibre, potassium, and minerals. Some post-harvest losses occurred due to improper handling, transportation and processing 20 – 25% of guava spoiled before reaching the consumer. Guava products such as RTS, nectar, guava leather and many more are quite important. The developed products had a great taste, were high in nutritional value, kept the original fruit flavour, and were safe to eat. Guava has some pharmacological benefits also and it has been proven to be useful in the treatment of several disorders. It has powerful antioxidant, antiparasitic, antibacterial, anti-inflammatory, wound healer and antimicrobial properties, according to numerous studies and published literature.

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