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A Comprehenssive Review On Guava Plant; Nutritional Composition , Potential Pharmacological Activities

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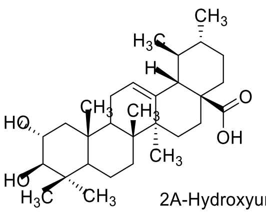
ABSTRACT
In countries that are tropical or subtropical, a common food crop and medicinal plant,Psidium guajava is also utilised in traditional medicine all around the world. This seeks to provide thorough understanding of the pharmacological, clinical, and chemical components. A wide range of in vivo and in vitro models have been employed for pharmacological investigations. Important phyto-constituents for medicine have also been found. Several metabolites in good yield, primarily from the phenolic, flavonid, carotenoid, terpenoid, and triterpene groups, have been demonstrated to have beneficial biological actions. This plant's metabolites and extracts, especially those derived from the leaves and fruits, have beneficial pharmacological properties. Because of its antispasmodic and antibacterial properties, P. guajava is mostly used to treat diarrhoea and dysentery, according to a review of the literature. has also been used extensively as a hypoglycemic agent. Numerous pharmacological studies have demonstrated the antioxidant, hepatoprotective, anti-allergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, vigorous, cough suppressant, antidiabetic, anti-inflammatory, and antinociceptive qualities of this plant, thereby substantiating its traditional uses. Provide a variety of clinical uses for the treatment of diabetes, diarrhoea, and infantile rotaviralenteritis.

Keywords: *Guava seeds* **,** *Bioactive compounds* **,** *pharmacological activities* **,** *Functional food properties* **,** *commercial applications* .

1. INTRODUCTION

A member of the Myrtaceae family, guava (Psidium guajava L.) is referred to as the tropical fruit of the tropics. Approximately 55.85 million tonnes of guavas were produced globally in 2019 [1,2]. South America, Bangladesh, Indonesia, India, Pakistan, and a few additional tropical and subtropical places of the world all grow this well-liked fruit. In 2020, China was a large importer of guavas, while Thailand was the top exporter (15.25%) [3,4]. About $3.74 billion USD is exported. The seeds of guava fruits account about 4% of their weight. They are an inexpensive and plentiful agricultural waste that is easily accessible in big amounts.



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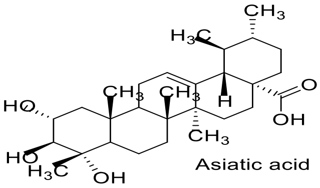

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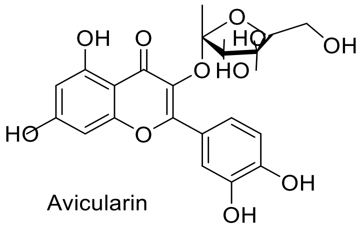

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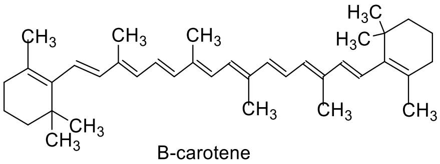

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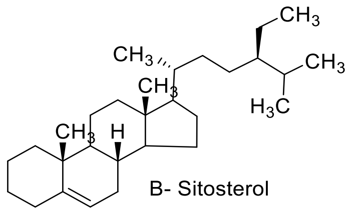

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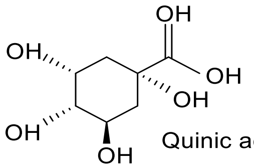

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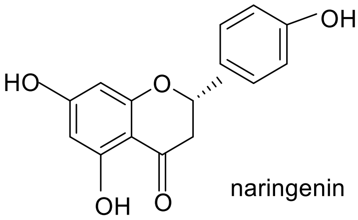

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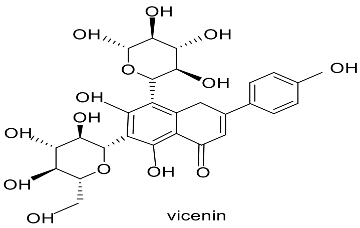

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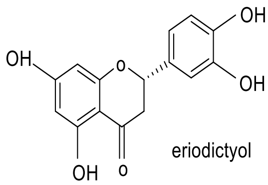

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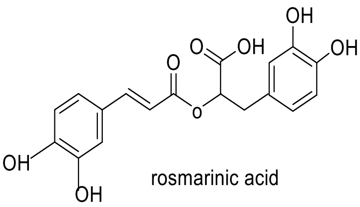

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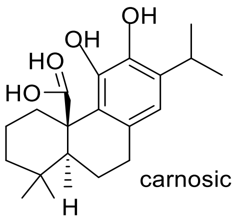

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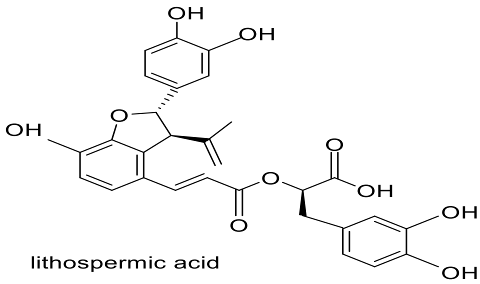

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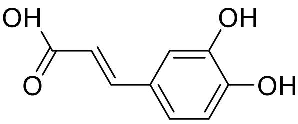

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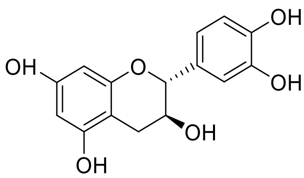

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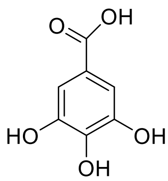

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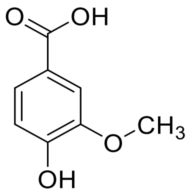

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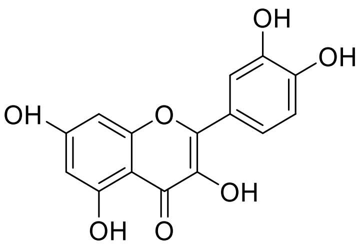

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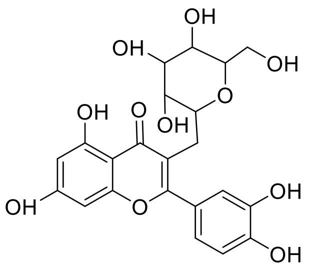

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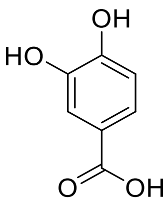

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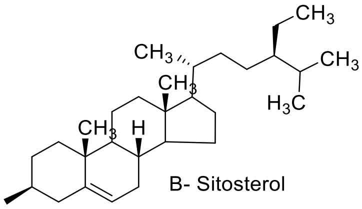
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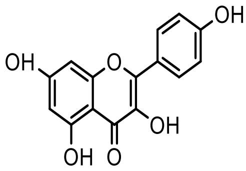
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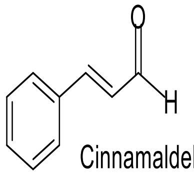
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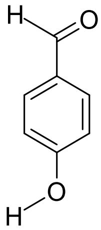
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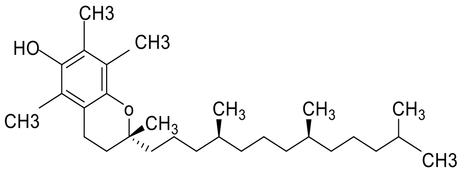
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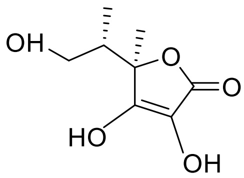
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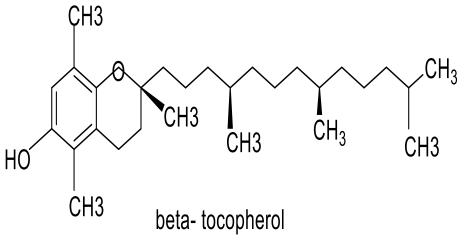
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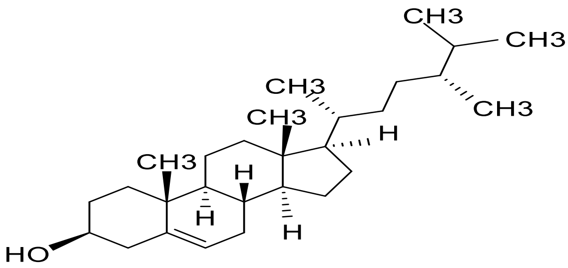
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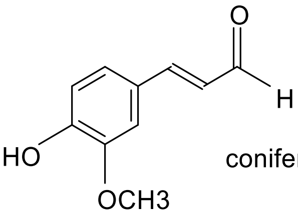
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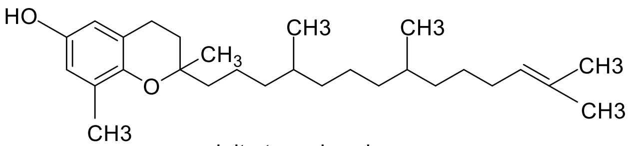
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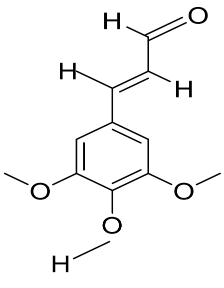
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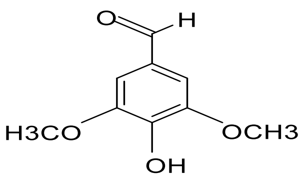
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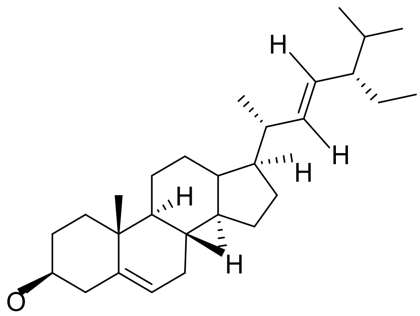
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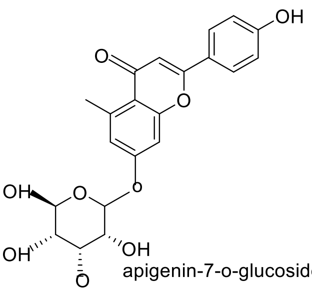
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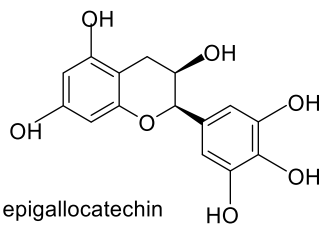
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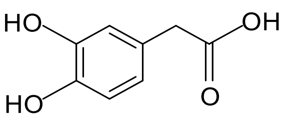
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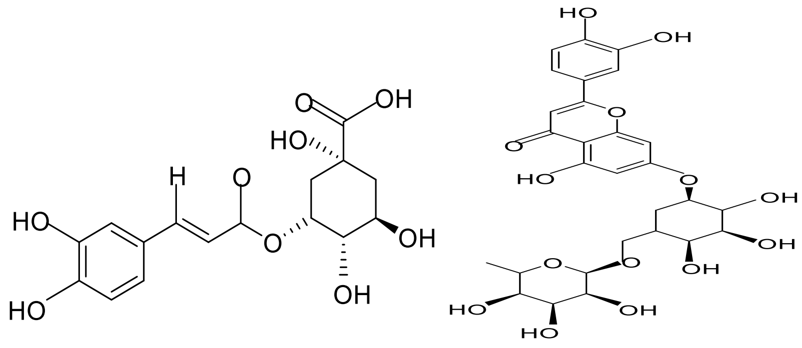


neochlorogenic acid luteolin-7-rutinoside

Fig-1 structure of phytochemical that are present in Guava plant.

The nutritious composition, agreeable flavour, gritty sweet taste, and medicinal qualities of this fruit have made it popular with consumers [5,6].

Guava is naturally rich in a variety of beneficial compounds, including minerals, dietary fibre, ascorbic acid, total phenols, and total carotenoids[7]. The fruit is used to make a number of high-value products, such as juice, jam, jelly, fruit butter, nectars, and syrups, in addition to being eaten raw[8].Guava's delicate peel limits its shelf life as a table fruit, leaving it vulnerable to microbial spoilage, low storage temperatures, and damage [7]. This promotes guava processing into a variety of goods, increasing its shelf life for export requirements. Europe, Japan, and the US are the three primary importers and consumers of processed goods made from guavas. Guava seeds are produced in vast quantities as leftovers of the large-scale processing of guava into different products, which leads to waste disposal issues. Specifically, about 80 kg of waste is produced during the preparation of one metric tonne of guava fruits [9].

Guava seeds are used because of their neutraceutical properties. Along with a wide spectrum of bioactivity and functional qualities, guava seeds are a plentiful supply of different nutritional componentssuch as dietary fibre, phenolics, carotenoids, minerals, vitamins, protein, lipids, and polysaccharides. The bioactivities and characteristics of guava seed and extract may be advantageous to the biomedical and culinary sectors. However, guava seeds' use in the food business is restricted by certain antinutritional factors (ANFs). Numerous research have examined the potential applications of guava seeds in the food and other industries [7, 10]. Recent evaluations have focused on fruit and vegetable processing waste, such as seeds, pomace, leaves, and peels [11,12,13,14]. A comprehensive evaluation of the research on guava seeds' bioactive profile, health effects, and other subjects has not yet included them. This review emphasises the nutritional value, phytochemical composition, and therapeutic potential of guava seed extracts (GSEs).

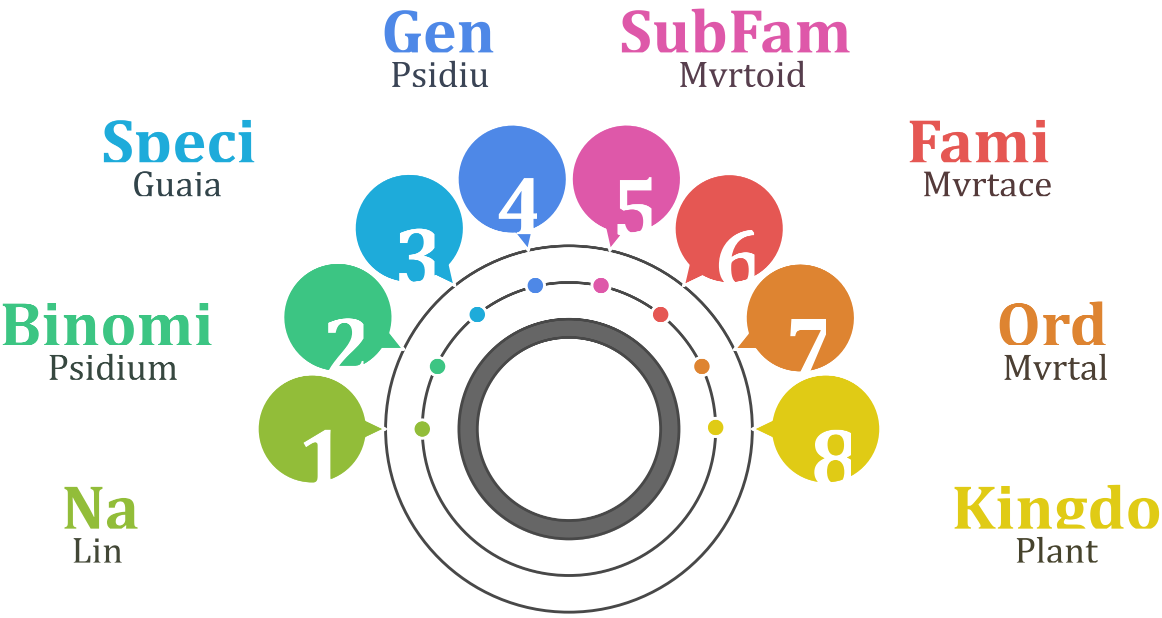
Additionally, this review suggests potential paths and applications for guava seeds in the food sectors. The purpose of this review is to assist the waste management, food processing, pharmaceutical, and nutraceutical businesses in making money out of the waste from guava seeds.

Cultivation of guava

In both tropical and subtropical regions, guavas can be grown up to 1500 meters above mean sea level.In the summer months in northern India, it can withstand high temperatures and drought [15]. The temperature range that guavas can withstand is 15 to 45 °C (59 to 113 °F).and they are mostly planted in tropical regions [16]. Established plants can tolerate short-term temperatures of -3 to -2°C (27 to 28°F), but they may cease to bear fruit if the temperature drops below 15°C (60°F).Guavas thrive best around 23 to 28°C (73 to 82°F). However, it is susceptible to severe frost, which can kill recently sprouted plants.An yearly rainfall of roughly 100 cm is necessary during the rainy season, which runs from July to September. Rainfall during harvest season degrades fruit quality. Guavas can withstand alkaline soils up to 8.5 pH, but they prefer a pH of 4.5 to 7. Numerous soil types, including as sandy, rocky, and loam soils, are suitable for their growth [17].Compared to most tropical fruits, guavas can withstand extended droughts by stopping their vegetative growth before the weather improves. River basins are used to raise high-quality guavas. For the crop, water logging is an issue [18]. Planting occurs throughout the rainy season. India is the biggest in the universe producer of guava, with about 40 hectares of agricultural area dedicated to guava cultivation. Various guava cultivars have been cultivated nationwide, with claimed production levels of 15.3 MT/Ha. With 928.44 tonnes of guava produced in 2017–2018, Uttar Pradesh leads the world in guava production.

Guava taxonomy

The guava plant (Psidium guajava L.) belongs to the Myrtaceae family. The most important fruit among the roughly 150 species in the genus Psidium is Psidium guajava. The guava is said to have originated in an area that spanned from Central America to southern Mexico [19]. Guava is grown and renowned all over the world [20].



Sr. no.	Production (tonnes)	States	Varieties grown
1	928.44	U.P	Apple Colour, Chittidar, Red Fleshed, Allahabad Surkha, Sardar, Mirzapuri Seedless, L-49, Allahabad Safeda, Lucknow Safeda, First, second, and third CISH-G
2	686.70	M.P	Hafshi, Seedless Chittidar, Gwalior-27, Allahabad Safeda, L-49.
3	427.61	Bihar	Apple Colour, Chittidar, Hafshi, Harijha, Sardar, Allahabad Safeda, and Selection-8.
4	229.78	A.P	Anakapalli, Banarasi, Chittidar, Hafshi, Sardar, Smooth Green, Safed Jam, Arka Mridula, Allahabad Safeda, Lucknow 49.
5	215.20	West Bengal	L-49, Allahabad Safeda, Gole Khaja, Kabli, Baruipur, Chittidar, Harijha, Sardar.
6	197.18	Chattisgarh	Allahabadi Safeda' and 'lalit'
7	195.60	Punjab	Punjab Pink, Allahbad Safeda, Arka Amulya, Sardar, Punjab Safeda, Punjab Kiran, Shweta, Nigiski, Punjab Soft, Allahabad Surkha, Apple guava, Chittidar.
8	169.57	Gujarat	Nagpur seedless, Dharwar, Dholka, Kothrud, L-24, L-49, Nasik, Sindh.
9	155.06	Tamil Nadu	Banarasi, Bangalore, Chittidar, Hafshi, Nagpur Seedless, Smooth Green.
10	140.23	Karnataka	Allahabad Safeda, L-49, Araka Mridula, Araka Amulya, Bangalore.

Utilisation of various guava parts

A wide range of processed foods and drinks, syrup, ice cream, jams, jellies, toffee, juice, and canned and dried goods all include guava.Additionally, there are other medicinal uses for different parts of guava.

Food utilization

Due to its high nutrient content, ease of development, and ability to be processed into a wide range of consumer goods, guavas have enormous potential for widespread commercial application [21]. Guava processing can provide a variety of products, including spray-soluble guava extracts with high antioxidant concentrations and wine, chocolate, guava jam, juice, pulp and guava powder, which is frequently used to make yoghurt [22].

Table 2: food utilization of different parts of guava

Sr. no	Parts of guava	Utilization	Purpose or activity	References
1	Fruit	Jams	Utilized solely for commercial purposes	[23]
2	Fruit	Jellie	Different treatment combinations.	[24-25]
3	Fruit	Wine	Commercial purpose	[26]
4	Guava	Leathers	Higher protein and fat content was found in guava leather	[27]
5	Leaf	Tea	Evaluation of food–drug interaction	[28]
6	Leaf	Fine Powder	Can be used as an adsorbent, experimental studies were carried out to investigate the potential of NGLP to remove phenol from aqueous solutions.	[29]
7	Seed	Fine Powder	alternative to prevent various diseases and malnutrition	[30]
8	Guava Seed Powder Fortified Biscuits	Fine Powder	Antioxidant activity	[31]
9	Fruit	Fresh Juice	nutritional and economic potential	[32]
10	Fruit	Nectar	of anti-inflammatory and analgesic bioactives	[33]
11	Guava	Guava-pomace and pulse	utilized up to the level of 10% to in Ready to Eat Snacks.	[34]

2. Nutritional characteristics of guava seeds

Because of their nutritional and functional qualities, seeds that are abandoned from the industries that process fruits and Vegetables include a lot of valuable and economically viable reusable components. Numerous prior studies have quantitatively assessed the usage of fruit waste for specific industrial uses. These include employing tamarind seeds as a source of polysaccharides to create biopolymers that improve the gelling and emulsifying properties of food, durian seeds as a source of starch and dietary fibre, and jackfruit seed flour for baking and cereal products.[35, 36, 37], and mangosteen seed for pectin. Guava is the most processed crop in the beverage sector, with a significant market share in pulp that is pure and ready to eat (RTS), nectar, and concentrates[38]. This is because of its pleasant flavour and high output. After processing, guava crops have a 30% waste index, mostly made up of highly nutritious seeds, according to [39]. With levels of 67.7%, 11.7%, 7.6%, 6.1%, and 1.20 percent, respectively, lipids, proteins, carbs, and ash are the main constituents of guava seed meal that have been documented [40].

Lipid profile

Guava is the most processed crop in the beverage industry, accounting for a sizeable portion of the market for concentrates, pure pulp, and nectar. This is due to its high output and pleasing flavour. Guava crops have a 30% waste index after processing, primarily composed of extremely nutrient-dense seeds [39,40].The triacylglycerol chain's middle sn2 position contains 90% linoleic acid, according to the fatty acid distribution pattern in GSO. These important fatty acids are more accessible to the human organism due to their central placement than fatty acids at the sn1 and sn3 locations [49]. Additionally, some uncommon lipids have been discovered in GSO by [50], including xestoaminol C, eschscholtzxanthin, sphingofungin B, 4-hexyl-decanoic acid, sphinganine, didrovaltratum, and 5S-hydroxyeicosatetraenoyl diendoperoxide. Because GSO contains linoleic acid (Omega 6), it has a high nutritional value and can be blended with highly saturated oils to create a well-rounded product. Numerous health benefits, including wound healing, anti-aging, and protection against atherosclerosis and coronary heart disease, have been demonstrated for oils high in linoleic acid [51, 52].

As is now common in modern diets, eating more n-6 than n-3, has been demonstrated to have detrimental health consequences and may be a contributing factor to the onset of many chronic inflammatory disorders, even though PUFAs are essential for basic bodily functions,

cardiovascular diseases, platelet aggregation, vasoconstriction, and some types of cancer. This is because inflammation is the primary cause of most chronic diseases linked to modern diets [53,54]. Therefore, to prevent the harmful effects of too much omega-6 on human health, oils should be blended to maintain an optimal (n-6): (n-3) ratio. Because of its low peroxide (0.2–5.6 meq kg 1) and acid values that indicate fewer free fatty acids, GSO is comparatively stable. Several studies indicated that GSO was classified as semidrying oil because its iodine number ranged from 100 to 143 [55, 56, 57]. Because GSO contains a higher proportion of triacylglycerides, which have an average molecular mass, it has a higher density and viscosity than other fruit seed oils, such as passion fruit seed oil [58].

However, because of its high PUFA content, which causes fatty acid double bonds to behave fluidly rather than rigidly and fixedly, its rheological characteristics exhibit Newtonian fluid behaviour [56]. The properties of methyl ester combinations derived from GSO were comparable to those of soybean oil, which is currently utilised in Brazil for the generation of commercial biodiesel [59]. However, consumers should be aware of the hazards connected with excessive consumption of n-6 PUFAs because some studies have demonstrated detrimental effects on human health.

Guava seed ethanolic extract is rich in flavonoids and antioxidant phenolics [60]. Toxicological investigations have demonstrated that GSO does not affect human peripheral blood mononuclear cells or mouse hepatocytes, making it safe for human consumption [61]. It has been demonstrated that linoleic acid has both pro- and anti-inflammatory qualities both in vitro and in vivo [61,62,63,64]. demonstrated that linoleic acid hindered leukemic cell proliferation and further suggested that linoleic acid in GSO may have proinflammatory effects on skin by causing proinflammatory cytokines to be secreted by leucocytes. Likewise, [63]discovered that linoleic acid can speed up the healing of wounds by increasing the mass and total protein content of leucocytes, vascular endothelial growth factor-alpha, and IL-1β. Regarding its ability to reduce inflammation, [64] showed that skin epidermal lipoxygenase hydrolysed linoleic acid to create 13S-hydroxyoctadecadienoic acid (13S-HODE). 13S-HODE-substituted diacylglycerol was subsequently produced by the hydrolytic cleavage of membrane inositol phospholipids. Similarly, [62] showed that linoleic acid-rich vegetable oil increased the number of immune cells that entered the injured area and stopped the release of the proinflammatory cytokines TNF-α and IL-6 by RAW 264.7 macrophage cells [lipopolysaccharide (LPS)-stimulated cells]. All of these findings support the potential cutaneous applications of linoleic acid and confirm its capacity to accelerate wound healing [65].

Numerous health benefits, such as anticancer, antioxidant, antiatherogenic, antiulcer, and anti-inflammatory properties, have been linked to plant sterols. [50, 66] further demonstrated that GSO might assist regulate serum fatty acid levels and reduce plasma triglyceride levels in rats. Tocopherols, a family of antioxidant vitamins with superior free radical scavenging capabilities, are abundant in GSO [49, 56, 67]. Subsequent tocopherol fractionation revealed that 83% of GSO is made up of γ-tocopherols, which are superior antioxidants to α- and β-tocopherols and give the oil protection oxidative stability [68].

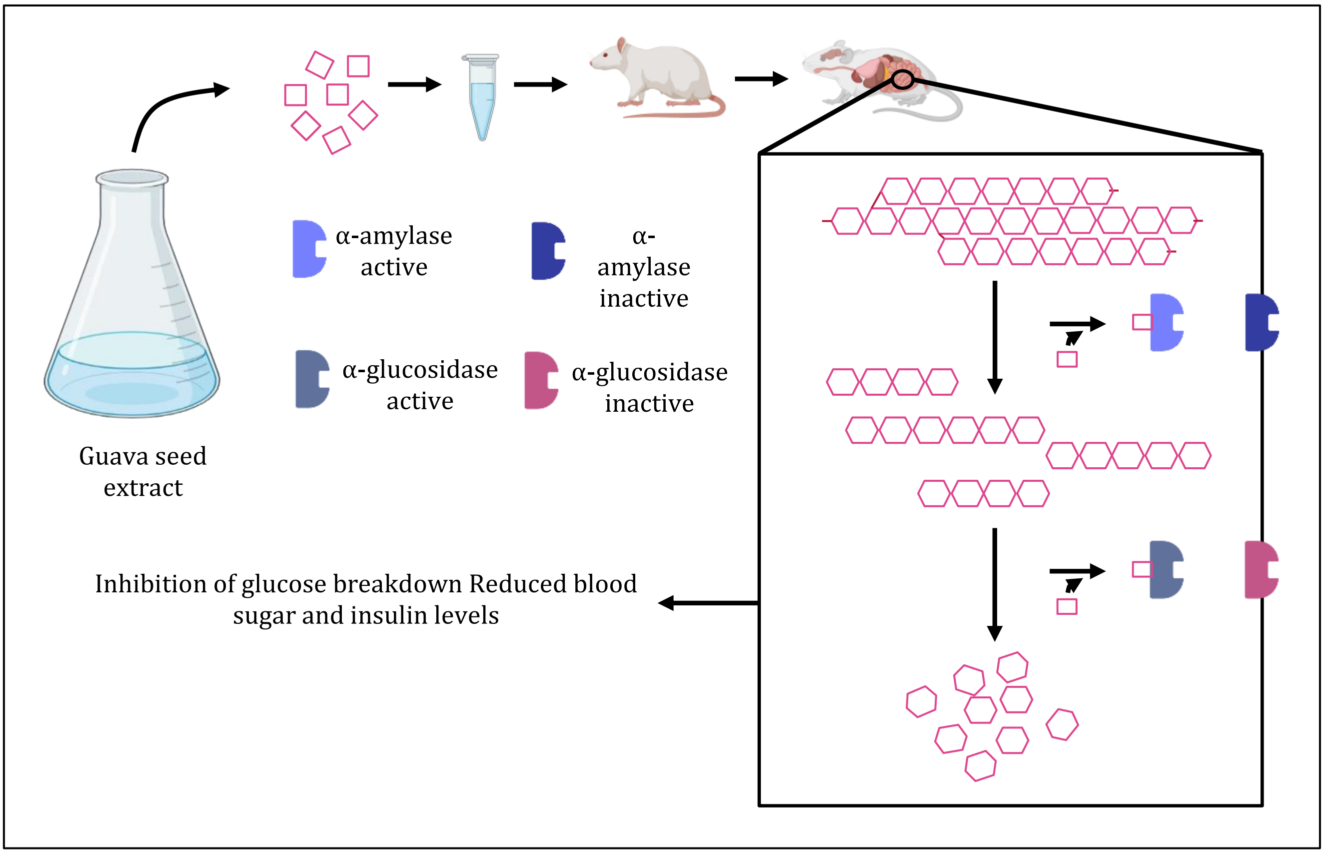
Mi*nerals, vitamins and antinutritional factors*

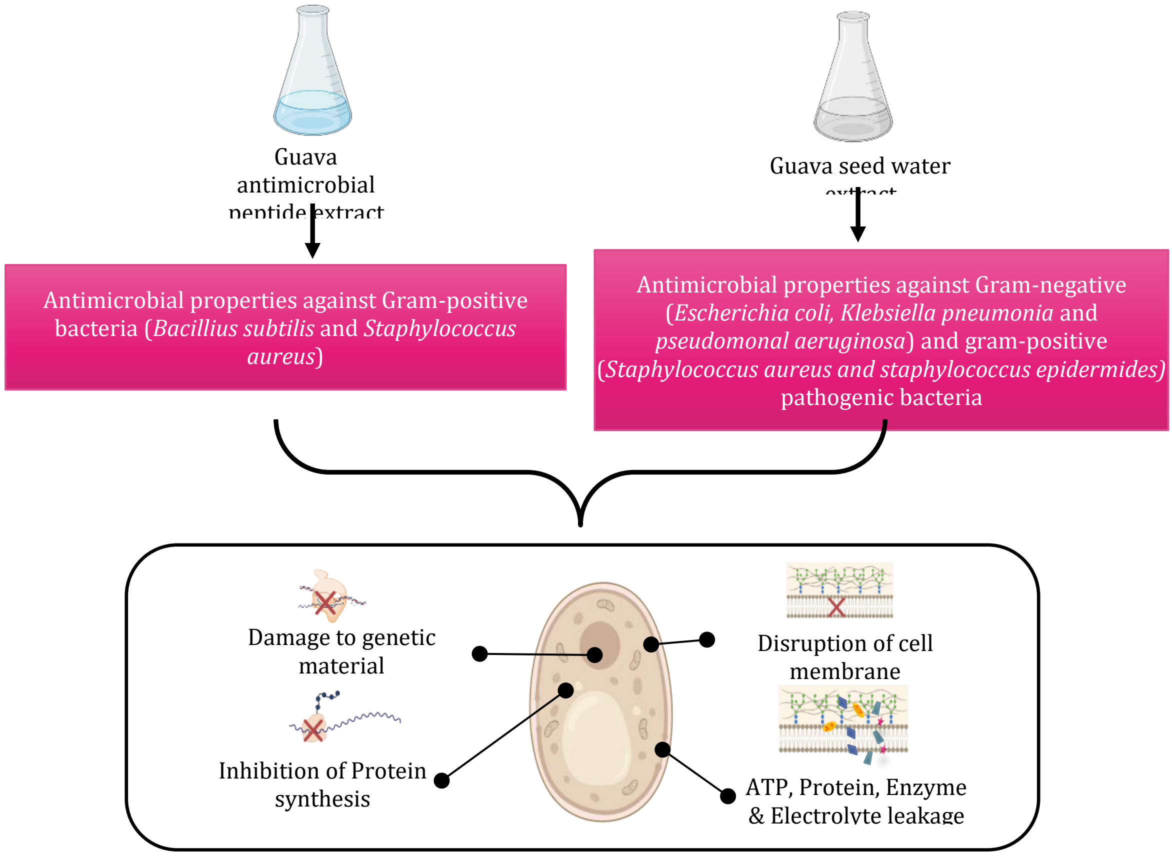
According to research by [69], guava seeds are primarily high in potassium [566.01 mg/100 g dry weight basis (DWB)], followed by sodium (328.81 mg/100 g DWB), phosphorus (215.14 mg/100 g DWB), calcium (146.37 mg/100 g DWB), and magnesium (119.72 mg/100 g DWB), along with trace amounts of zinc, iron, copper, and manganese. The authors also found that guava seeds' mineral concentration significantly dropped after toasting. Conversely, [65] discovered that iron and zinc were the primary elements in guava seeds, with sodium being present in smaller amounts (0.05 mg/100 g). GSM was found to contain 87.44 mg/100 g of vitamin C, despite the fact that the vitamin value of guava seeds has not been revealed.According to their structures, ANFs are secondary metabolites from plants that have particular biological activity. They can lower nutrient bioavailability and interfere with normal human growth, reproduction, and health [70]. Guava seeds were discovered to contain some ANFs, including phytic acid and tannins [69].

Roasting can reduce the tannins in these ANFs, but because phytic acid is heatstable, it takes a greater temperature and more time to deactivate. Guava seeds' phytic acid concentration was shown to decrease by 91% when autoclaved, whereas it decreased by 90% after 14 days of germination [71]. Overall, because guava seed waste is rich in macronutrients, especially protein and fat, it can be used in a variety of ways. Guava seed protein isolates have the potential to be a valuable addition for culinary or medicinal uses, but their low yield makes commercial extraction difficult. It's interesting to note that guava seeds' lipid profile and polysaccharides both provide anti-inflammatory effects in some cancer cell lines and skincare products; as a result, they can be utilised as substitute ingredients in pharmaceutical products. After refinement, the culinary qualities of guava seed oil might be investigated further for usage as a blending oil in domestic settings.

Medicinal importance of guava

In subtropical regions of the world, Psidium guajava L. is used as a food source and traditional medicine because of its pharmacologic properties [72]. Therapeutic herbs hold great significance in medical systems across the globe. These findings are consistent with what is generally believed. Around the world, guava is widely used to treat a variety of illnesses, including diarrhoea, which lowers fever, dysentery, gastroenteritis, diabetes, hypertension, dental cavities, discomfort, and wounds. In countries like Mexico, Africa, Asia, and Central America that have a long tradition of using medical herbs, guava is also utilised extensively. In addition to its medical applications, it is utilised as food and to produce food items. It is also utilised in the construction of toys and constructions. Among the many chemical and inorganic substances found in guava are secondary metabolites including polyphenols, antioxidants, and antiviral and anti-inflammatory components. Numerous substances found in guava have anti-cancer properties. It has extra vitamins and minerals. Flavonoids and other phenolic chemicals are abundant in guava. Flavonoids and lycopene are significant antioxidants. They aid in the treatment of malignant cells and stop the skin from ageing too quickly [73]. Guava may have an impact on cardiac inotropism. After 21 days of treatment, guava skin extract can lessen the severity of diabetes [74].





Antimicrobial activity

Guava has potent antimicrobial qualities. Guava leaf extract has anti-cough qualities that help reduce the intensity of coughing. Some bacteria can be inhibited from growing by leaf extracts in methanol, chloroform, and water [75]. Guava leaf extracts contain potent antibacterial qualities that can inhibit the growth of S. aureus. Strong antibacterial qualities can be found in methanolic extracts of the leaves and bark of the P. guajava plant. These extracts have the ability to inhibit Salmonella and Bacillus bacteria [76]. Guava extract in methanol has strong antibacterial properties. These formulations have the ability to suppress Salmonella and Bacillus bacteria. Because it includes active flavonoid components, it also possesses anti-plaque properties [77].

It is possible to separate the guava's flavonoid components and their derivatives. In varying dilutions, these substances can prevent the growth of certain bacteria [78,79].

Both ethanol and aqueous extracts have less antibacterial activity when the methanol extract has a high minimum inhibitory concentration (MIC). Methanolic extract has high activity, which makes it effective.Because it has efficacy against haemolysis, this extract also demonstrates anti-hemolytic potential [80]. Guava has modest antibacterial action against gramme negative bacterial strains and significant antibacterial activity against gramme positive bacteria [81, 82]. Guava also has antioxidant and anticancer properties. Guava peels, seeds, and pulp are rich in cyanidin 3-glucoside, kaempferol, galangin, gallic acid, and homogentisic acid, among other compounds.However, it is unexpected that seeds and skin contain more of these chemicals than pulp. Guava's nutritional value increases as a result of these chemicals [83]. It is evident that guava leaf extracts, both aqueous and methanolic, can create an impressive zone of inhibition and prevent bacterial growth.

While ethanol extract exhibits the least amount of antifungal activity, methanol and water extracts have the greatest MIC. Guava's pulp, leaves, seeds, and skin all have exceptional antibacterial properties, to summarise [84]. Alcohol-based fruit extracts from guava (Psidium guajava) were evaluated for their antibacterial properties in comparison to pineapple (Ananas comosus) and apple (Malus pumila). Enterococcus faecalis, Enterobacter cloacae, Shigella flexineri, Pseudomonas aeruginosa, Klebsiella, Enterotoxigenic E. coli (ETEC), Enteroaggregative E. coli (EAEC), and Staphylococcus aureus were the eight bacterial strains used for antimicrobial studies. Similar to other well-known fruits with similar qualities, such pomegranates, which have been shown to have strong antibacterial qualities, guavas also contain antibacterial capabilities [85]. Using both in-vitro agar diffusion and in-situ techniques, pomegranate fruit peel extracts were evaluated for their antibacterial activity against a few food-borne pathogens. Peel 80% methanolic extract was reported to be a potent inhibitor of Yersinia enterocolitica, Staphylococcus aureus, Escherichia coli, and Listeria monocytogenes. Peels also include strong substances known as flavonoids and phenolics, which function as strong inhibitors, according to a phytochemical analysis

[86, 87, 88, 89].

Antidiarrheal activity

One of the most prevalent and well-known health issues, diarrhoea affects people all around the world. About 2.2 million people are thought to die from diarrhoea each year, with children and newborns accounting for the majority of these deaths [90]. One can separate quercetin from guava leaves, as well as quercetin-3-arabinoside. A substance that functions similarly to morphine is found in its leaves. Muscle tone is controlled by it. Quercetin inhibited intestinal contraction, which was aided by increased calcium absorption. Quercetin affects the ileum strongly. The spasmolytic action of guava leaves is believed to be caused by quercetin. A guava's cytotoxicity is high [91].Guava can be used to treat diarrhoea brought on by toxins from S. aureus or E. coli [92]. Acetylcholine and/or KCl solution diminish the separated guinea-pig ileum by more than 70% when Psidium guajava is extracted in ethanolic and aqueous form at a concentration of 80 g/ml in an organ bath. To assess the anti-diarrheal properties of the aqueous extracts of Psidium guajava leaf, the rates of impulsion in the small intestine into male Sprague Dawley rats were measured using morphine as the reference standard [93]. It has been shown that guava fruit ethyl acetate extract enhances locomotor coordination [94]. In mice with water-induced diarrhoea, the anti-diarrheal effects of guava leaf extract were examined.

This extract gives rats and mice significant protection against diarrhoea caused by castor oil. Rats' intestinal transit is inhibited by it. This extract has dose-dependent action. Diarrhoea brought on by castor oil is prevented by atropine's strong anti-motility effects. The onset of diarrhoea caused by castor oil is considerably postponed by a dose of loperamide. There is a noticeable decrease in intestinal fluid output as compared to other animals. Due to its anti-diarrheal properties, guava extract can be used to both prevent and cure diarrhoea [95]. Significant antidiabetic and antidiarrheal properties are found in ethanolic extracts of guava [96,97].

Anti-inflammatory activity

When combined with ethyl acetate, guava extract can stop bacteria and thymus from growing. There are antiviral qualities to it. The expression of mRNA can be enhanced by it. Guava has the power to alter the heme oxygenase-1 protein's activity. Because of this, it can be used as an anti-inflammatory for the skin. Ethanol with guava extract stops LPS from generating nitric oxide. It suppresses the expression of E2. This is how it works as an anti-inflammatory medication [98]. Ethyl acetate extract can lower the antigen. It can stop β-hexosaminidase and histamine from being released by RBL-2H3 cells. Consequently, TNF-α and IL-4 mRNA stop arising.The antigen inhibits and spoils IκB-α in this way. Both benzophenone and flavonoids are significant components of guava. They inhibit histamine and generate nitric acid [99]. Guava extract contains anti-nociceptive qualities as well. It happened because of the production of acetic acid. Phenol, an important compound found in guava, is known to have anti-inflammatory and anti-allergic effects [100]. Inflammation and serum production linked to liver injury can be decreased with the use of guava extracts [101].

Antioxidant activity

Chemicals known as antioxidants slow down oxidation. Free radicals can harm cells by starting a number of chain reactions. They are produced by oxidation events. Cell damage from free radicals is the cause of cancer and many other disorders. Antioxidants eradicate free radicals and stop chain reactions. Examples of antioxidants include beta-carotene, lycopene, and vitamins C, E, and A. The oxidative process is a necessary destructive process. The harm that free radicals inflict to humans includes mental disorders, viral infections, inflammation, and disputes. When medications are metabolised in the body, free radicals are produced. Guavas are rich in antioxidants and nutrients that help control the actions of free radicals. These nutrients are essential for survival. It also contains a variety of phytochemicals that are beneficial to human health, including diabetes, obesity, and high blood pressure. Free radicals are neutralised by antioxidants utilising the widely used DPPH and FRAP tests. The oxidation process can be stopped by the several antioxidants included in guava extracts in water and organic solvents. These compounds have increasing concentrations as concentration increases [103]. The antioxidant activity of pink guava is also strong [104].

Antioxidant-rich guava can help lower the incidence of degenerative diseases such cancer, heart disease, arthritis, inflammation, arterioclerosis, and cognitive decline [105]. The two most common oxidants in fruits are polyphenols and ascorbic acid. Polyphenols are mostly flavonoids, with the most prevalent forms being glycosides and ester forms [106]. Myricetin and apigenin glycosides, as well as free elagic acid, have been found to be present in guava [107]. Leaf excess of the essential antioxidant ascorbic acid [108,109]. Significant antioxidants found in large quantities in guavas include quercetin, ferulic acid, ascorbic acid, gallic acid, and caffeic acid. Various solvent extracts have shown that phenolic compounds, not flavonoids, are responsible for the antioxidant action of guava.Aqueous extraction and methanol exhibit the highest activity [110–111]. The DPPH and FRAP experiments, among other antioxidant tests, show that guava ethanol extract is not very effective [112]. The antioxidant properties of guava can help manage diabetes. It shows a significant control of diabetes in mice [113]. Morin, quercetin, and quercetin-3-O-glucopyranoside can be extracted from leaves. These compounds have been shown to have antioxidant properties. Quercetin has the ability to balance free radicals. Its reducing power is significantly higher than that of any other chemical. [114,115] It is considered the most powerful and strong antioxidant found in guava leaves.

Immunomodulatory activity

Leaf extract from Psidium guajava exhibited immunomodulatory activity. Using the murine monocyte cell line J774, it has been demonstrated that guava leaf decoction activates macrophages to eliminate the E. coli strain, which produces heat-stable toxins [116]. It has been demonstrated that the guava leaf ethyl acetate fraction inhibits FceRI-mediated signalling, cytokine release, degranulation, and COX2 expression in antigen-stimulated mast cells. Using Labeo rohita head renal macrophages as an in vitro model system, it has been demonstrated that a flavonoid fraction of guava leaf extract regulates the activation of the nuclear factor KB [117].

Antiparasitic Activity

Antiparasitic drugs are used to treat infections caused by organisms such as parasitic fungi, helminths, protozoa, and ectoparasites. In an in vitro study targeting *Toxoplasma gondii*, guava leaf essential oil demonstrated promising antiparasitic activity. Its potential therapeutic effects may be linked to its ability to reduce free radicals, which are associated with the pathogenesis of toxoplasmosis [118].

Wound healer

Collagen forms the structural fibers of the gingival and periodontal ligaments, with fibroblasts being the most prevalent cell type in the connective tissue of the periodontium. Vitamin C is essential for maintaining the structural integrity of the periodontium [119]. Guavas are a rich source of vitamin C (ascorbic acid), which plays a key role in modulating the extracellular matrix. It influences fibroblast activity by regulating the expression of procollagen genes, thereby promoting proper collagen formation. Traditionally, a decoction of guava root bark is used as a mouthwash for relieving sore gums, while a leaf decoction is commonly used as a gargle to treat swollen and bleeding gums [120].

Antibacterial

Guava extracts have been shown to exhibit antibacterial action against both Gram-positive and Gram-negative bacteria.According to in vitro experiments, guava leaves and bark methanol extract and an aqueous combination shown significant antibacterial activity against multidrug-resistant bacteria. [122, 123, 124, 125].

Guava for Cold and Cough

Research suggests that guava leaves may help treat coughs and colds. Guava reduces lung irritation and mucus production and helps prevent respiratory infections due to its high iron and ascorbic acid content. Fruit is an excellent remedy for colds and coughs, particularly Unprocessed fruit or a medicinal infusion (decoction) prepared from Fresh-picked fruit leaves. Its astringent qualities help to minimise mucus intake, alleviate coughing, stop existing microbial activity, and hinder the growth of germs in the mouth, lungs, and respiratory tract. Guavas are high in vitamin C and have been proved to help treat viral and bacterial coughs and colds. A common home cure for coughs, congestion, and bad colds in many parts of India is roasted ripe guava. Another study reported that a hydroalcoholic extract of *Psidium guajava* leaves significantly reduced the incidence of capsaicin-induced coughing within 15 minutes of administration, compared to the control group [126].

Hematological activity

The methanolic extract of *Psidium guajava* bark shows promise as a natural remedy to boost blood levels, potentially helping people with anaemia or even serving as a preventive approach. In the study, a dose of 200 mg/kg was found to support the body’s blood-forming process, known as haemopoiesis. While researchers didn’t pinpoint the exact way the extract improved blood parameters, it’s believed that its effects are linked to how it interacts with the body’s system responsible for producing blood cells [127].

Acne lesions

Acne vulgaris is a chronic inflammatory disease linked to neutrophil and lymphocyte activation as well as Propionibacterium acnes colonisation. Evidence suggests that the pathogenesis of inflammatory acne may involve both immune responses against Propionibacterium acnes that are dependent on the antigen and those that are not. Additionally, it has been suggested that epidermal keratinocytes contribute to the onset and progression of cutaneous inflammation. Due to their potent antibacterial activity against Propionibacterium acnes, Psidium guajava leaf extracts may be helpful in treating acne due of their well-known anti-inflammatory qualities [128].

Effect on dental plaque

Dental plaque is formed in part by the adherence of early dental plaque settlers to the tooth surface. The bacterial cell wall structure's hydrophobic surface properties are indirectly responsible for the bacterial cell's adherence to the acquired pellicle on the tooth surfaces.One of the best methods for preventing plaque buildup is brushing your teeth. Plaque accumulation on the surfaces of teeth can be decreased by using chemical treatments. When Psidium guajava leaf aqueous extract (1 mg/ml) was applied to early plaque settlers, the cell-surface hydrophobicity of Actinomyces sp., Staphylococcus mitis, and

Staphylococcus sanguinis decreased by 40.6%, 49.9%, and 54.1%, respectively. These results provide some scientific support for its use in treating dental disorders and suggest that extracts from guava leaves may shield teeth from cavities caused by Streptococcus, which could be beneficial for dental treatment [129].

Antimalarial effects

Extracts from Psidium guajava were examined for their antimalarial properties in this study. Researchers from all around the world are becoming more interested in finding new plant-derived medications that could counteract the threat of cancer, tumours, and drug-resistant pathogenic bacteria. It was discovered through antimalarial activity testing that methanolic extract possesses strong antimalarial properties [130].

Scientists are investigating the effects of guava leaf extracts on the production of β-hematin, a material linked to malaria, both from guava-infused water and a water-ethanol mixture. Even at low concentrations (1 to 0.4 mg/ml), the 35% ethanol extract outperformed the water-only extract and performed as well as the reference treatment in laboratory testing. The extract contained a number of advantageous plant substances called flavonoid glycosides, including ellagic acid, derivatives of quercetin, and derivatives of morin.This implies that complexation with the free heme is more promising than β-hematin production [131].

Antigenotoxic and antimutagenic effects

Guava leaf (Psidium guajava) extracts were separated using several organic solvents, including petroleum ether, benzene, ethyl acetate, ethanol, and methanol. The extracts' capacity to prevent genetic damage and mutations was examined. Utilising techniques that gauge their ability to decrease certain metals, such iron and copper, their antioxidant strength was also evaluated.DPPH free radical scavenging, and other tests showed that the methanolic fraction had the highest antioxidant activity, which was on par with that of butylated hydroxyl toluene (BHT) and ascorbic acid. Researchers used the Ames test with various toxic compounds, including as sodium azide, MMS, 2-aminofluorene, and benzo(a)pyrene, to assess the guava leaf extract's capacity to prevent mutations. At a dose of 80 µg/ml, the methanol-based extract was able to prevent over 70% of the impacts that caused the mutation. [132].

Another study verified guava's antimutagenic properties by in vivo testing using L. sativa meristematic cells. The antimutagenic qualities of three guava cultivars—Peter Sato, Paluma, and Roxa—were assessed. Guava infusions at a concentration of 2.5 $g \cdot L^{-1}$ were employed in the antimutagenic procedures. A method that combined the guava infusion with the mutagenic chemical methyl methanesulfonate (MMS) showed the antimutagenic potential of the infusion. The percentage of damage brought on by MMS exposure dropped for all three cultivars. The processes that produced this antimutagenic impact were discussed. L. sativa is a useful model for assessing the antimutagenic potential of natural compounds [133].

Effect on muscular system

In this investigation, A humanized mouse model mimicking steroid-induced muscle degeneration model was used to test the hypothesis that guava leaf might slow down the breakdown of proteins. DEX injection was used to cause muscle atrophy in 7-week-old male ICR mice for 28 days. Then, for 21 days, oral gavage was used to supplement with one of two GL extracts: low-dose (LGL, 200 mg/kg) or high-dose (HGL, 500 mg/kg). Body composition, calf thickness, and muscle strength were examined. Using haematoxylin and eosin staining, histopathological alterations in the gastrocnemius muscle were investigated, and western blots were used to analyse molecular pathways associated with muscle deterioration. In mice with muscle loss caused by dexamethasone, GLE treatment—regardless of the dose—helped improve muscle strength and also blocked the cellular pathway involved in muscle breakdown. Additionally, a high dose of GLE treatment enhanced apoptosis and the ubiquitin proteasome system in animals with DEX-induced muscle atrophy. This work suggests that by regulating the ubiquitin–proteasome system, autophagy, and apoptosis—all of which contribute to muscle deterioration—GLE may help to maintain muscle health and lower proteolysis. In conclusion, GLE might be a helpful nutraceutical to prevent muscle atrophy. [134]

Toxicology

To determine their toxicity, rats were administered extracts of white, red, and pink guava leaves during a 14-day period in these studies. The extract was given orally at doses of 50, 500, and 5000 mg/kg of body weight, and the subjects were closely monitored for any signs of toxicity—hourly throughout the experiment and especially during the first six hours after treatment.The experimental period involved the examination of biochemical markers, mortality, body weight differences, and clinical signs. No deaths or clinical symptoms were seen during the treatment, and the rats' body weight increased somewhat. Malondialdehyde (MDA) levels in rat tissue and serum levels of renal marker enzymes (creatinine, urea, uric acid, and blood urea nitrogen (BUN)), as well as liver indicator enzymes (aspartate aminotransferase (AST), alkaline phosphate (ALP), and alanine aminotransferase (ALT), bilirubin, and bilirubin were not significantly different from the control group. The extract of white, red, and pink guava leaves has NOAEL (no observable adverse effect level) estimations ranging from 50 to 5000 mg/kg. [135].

Anti-allergic effects

In this study, interviews were conducted with 102 allergy sufferers. 72.5% of them were female, and their average age was 34±18. Atopic dermatitis (19.6%), allergic rhinitis (24.5%), and bronchial asthma (16.7%) were the most common main diagnoses. The most often used herbal medicines were Nigella sativa (19.6%) and Pimpinella anisum (12.7%), with almost 60% of individuals reporting using them. Other commonly used herbs were Olive (Olea europaea, 8.8%), Thyme (Thymus vulgaris, 5.9%), Chamomile (Matricaria chamomilla, 4.9%), Peppermint (Mentha piperita, 4.9%), Fennel (Foeniculum vulgare, 9.8%), Guava (Psidium guajava, 9.8%), Boswellia sacra (11.8%), and Clove (Syzygium aromaticum, 4.9%).Sixty-three percent reported subjective improvement in their symptoms. It was discovered that using herbal remedies was substantially linked to asthma (p=0.001). [136]

Conclusion and future direction

Guava plants are rich in both primary and secondary metabolites and serve as an excellent source of protein, minerals (including potassium, sodium, phosphorus, calcium, and magnesium), fatty acids (such as linoleic, palmitic, and oleic acids), and vitamin C. Guava seeds also contain various polyphenolic compounds, including vanillin and vanillic acid. The diverse range of metabolites found in guava seeds has demonstrated numerous bioactivities, including anti-inflammatory, neuroprotective, antidiabetic, antioxidant, and anticancer effects. However, clinical studies are still needed to fully validate the therapeutic potential of the guava plant.Guava also shows promise in food functionalization, influencing properties such as lipid reduction, foaming and emulsion stability, water retention, and solubility. Beyond the food industry, guava seeds are gaining recognition for their applications in veterinary, medical, and cosmetic fields. To fully explore the guava plant's potential, the development of advanced extraction methods—utilizing various techniques, solvents, and predictive models is essential. These approaches will help isolate valuable bioactive compounds, fatty acids, polysaccharides, and proteins for use across the food, nutraceutical, pharmaceutical, agricultural, and cosmetic industries.

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