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Guava (*Psidium guavaja)* – Properties and Trend in Functional Foods

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Abstract

Guava (*Psidium gujava*) is a popular tropical fruit, native to South America. Brazil is the top most producer of this fruit packed with promising chemical and biological features. Guava leaves are rich in phenolic compounds, isoflavonoids, gallic acid, catechin, epicathechin, rutin, naringenin, kaempferol. The pulp contains ascorbic acid, carotenoids (lycopene, β-carotene and β-cryptoxanthin). The seeds, skin and barks are rich in glycosides, carotenoids and phenolic compounds. Hepatoprotective, antioxidant, anti-inflammatory, antispasmodic, anti-cancer, antimicrobial, anti-hyperglycemic, analgesic, endothelial progenitor cells, anti-stomachache and anti-diarrheal are the biological properties which are reflected by different plant parts of Guava. Guava, inspite of having such promising features, has limitations for usage because of its highly perishable nature. So, many attempts have been taken for making food products using different parts of guava fruit with focus toward enhancing the shelf life also. The aim of this review is to discuss the physicochemical, phytochemical properties and recent functional foods made from guava fruits.

Keywords: Guava, fruit, functional food, processing, diabetes, antioxidant

Guava (*Psidium Gujava*) is a popular fruit of tropical and subtropical countries. It belongs to Myrtaceae family. Generally, the guava fruits are planted in the tropical or sub-tropical area of America, Asia and Africa . In Malaysia, guava fruit is an important tropical fruit due to its high commercial and nutritional values, and there are various types of guava fruit, such as Gu4, Gu5, Gu7, Jambu Biji, Laknaw, Hongkong pink, Red Malaysian, Taiwan and Vietnamese . All those species have a small size of 2.4 cm to 3.35 cm radius and have a thin mesocarp with 9 to 15 mm. In contrast, the Vietnamese guava fruit has a larger radius and mesocarp thickness of 5 cm to 5.5 cm and 19 mm to 25 mm respectively. The mesocarp colour of guava fruit can be either white or pink colour. The average vitamin C content of the fruits is around 40.1 mg g-1 to 180.5 mg 100 g-1. In the last decade, the importance of guava fruit was improved from neglected fruit to one grown largely for processing. The fruits are generally juicy and sweet in taste, with red or yellow flesh pulp and many seeds within. The fruit contains 80% moisture 20% dry matter, 1% ash, 0.7% fat and 1.5% protein (Chin and Yong, 1980). Guava is highly rich source of ascorbic acid (vitamin C) and contains other nutritional components namely, vitamin A (beta-carotene), vitamin (B1) thiamin, (B2) riboflavin, niacin and pantothenic acid. In addition, it also contains a fair amount of phosphorous, calcium, iron, potassium and sodium (Lim and Khoo, 1990). The

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high level of antioxidants pigments like carotenoids and polyphenols present in guava increases its dietary value (Imungi *et al*. 1994). These various bioactive nutrients play significant role in traditional therapies for various health problems related to lifestyle diseases like diabetes (type 2) and obesity (P′erez *et al.* 2008). Although guava poses enormous health benefits still a major drive in the research and development of guava as functional fruit is far behind the other exotic fruits (Heinrich *et al.* 1998). The fresh fruit is preferred for consumption but its seasonal availability limits the availability of fruit throughout the year. Hence processed products such as puree, paste, canned slices in syrup or nectar are developed and marketed. Guava juice is a health drink used by the population worldwide and manufacture of instant guava powder available for formulated drinks, baby foods and other confectionary products are gaining popularity. The utility of guava as functional foods are increasing day by day and the main traditional use preferred is as an anti-diarrhoeal include gastroenteritis, dysentery, stomach, antibacterial colic pathogenic germs of the intestine and other medicinal properties involve treatment of diabetes, hypertension, inflammation (Mejıa and Rengifo, 2000; Mitchell and Ahmad, 2006a,b).

Bio defensive properties of guava

The guava fruits are characterized by high water content (84.9%) and low content of carbohydrates (13.2%), fats (0.53%), and proteins (0.88%) (Medina and Pagano 2003). Proximate composition is given in Table 1 (Conway, 2002; Iwu, 1993; Fujita *et al.* 1985; Hernandez, 1971; Conway, 2002). Beside this many other important compounds such as hexanal (65.9%), γ-butyrolactone (7.6%), (E)-2-hexenal (7.4%), (E, E)-2,4-hexadienal (2.2%), (Z)-3-hexenal (2%), (Z)- 2-hexenal (1%), (Z)-3-hexenyl acetate (1.3%) and phenol (1.6%) were reported from fresh guava fruit extract. Certain essential oils extracted from guava are 3-caryophyllene (24.1%), nerolidol (17.3%), 3-phenylpropyl acetate (5.3%) and caryophyllene oxide (5.1%) (Paniandy *et al.* 2000), and few active aromatic constituents from pink guava fruit such as 3-penten-2-ol and 2-butenyl acetate were isolated (Jordan *et al.* 2003). Ascorbic acid is the main constituent of guava as antioxidant (Charles *et al.* 2006). The genus citrus is well known for its pharmaceutical importance. The peel extracts of Dargiling Orange (C8), South African Malta (C5), Kagja Lemon (C2), Batabi Lemon (C4), Elachi Lemon (C3), Kagja Lemon (C2) and Kagji Lemon (C1) show excellent antimicrobial potential against various bacterial strains e.g., B. cereus, S. aureus etc. (Afroja *et al.* 2017). The strong odour of the fruit is attributed to its carbonyl compounds (Dweck, 2001). There is a growing trend to use the medicinal plants as the natural resources in order to develop new drugs. The natural products are applied to treat various viral, fungal and bacterial diseases. The antimicrobial activities of alcohol fruit extracts from guava (*Psidium guajava*) were compared to those of pineapple (*Ananas comosus*) and apple (*Malus pumila*). Eight bacterial strains including *Pseudomonas aeruginosa*, *Klebsiella*, *Enterococcus faecalis*, *Shigella flexineri, Enterobacter cloacae, Enterotoxigenic E.coli* (ETEC), *Enteroaggregative E. coli* (EAEC) and Staphylococcus aureus were used for antimicrobial evaluations. The fresh fruits of the above mentioned plants were purchased from the market; then they were cut into small cubes and finally dried over 4–5 days in sun to a crisp. The pieces were blended to the fine powder; finally methanol extracts were obtained by passing 75 g of each powder through a Soxhlet apparatus having 250 ml of 99% methanol. The same process was performed with 250 ml of ethanol to produce a methanolic crude extract. The sample extracts were evaluated using agar well diffusion method. Norfloxacin and water were used as positive and as negative controls, respectively. The extracts caused the inhibition of microbes; the zones of inhibition were measured and an activity index was calculated from the mean zone sizes. It was concluded that all the fruits possess some antimicrobial potential; the highest activity index (2.6) was observed from pineapple extracts against EAEC. The pineapple fruit displayed strong potential against all the bacteria. The guava extracts possessed the antimicrobial potential against all the microbes with the exception

Table 1

Parts	Constituents	References
Fruit	Vitamin C, vitamin A, iron, calcium, Manganese, phosphoric, oxalic and malic acids, saponin combined with oleanolic acid. Morin-3-O-α-L-lyxopyranoside and morin-3-O-α-L arabopyranoside, flavonoids, guaijavarin, Quercetin. Essential oil contains hexanal, -2-hexenal, 2,4-hexadienal, 3-hexenal, 2-hexenal, 3- hexenyl acetate and phenol, while β-caryophyllene, nerolidol, 3-phenylpropyl acetate, caryophyllene oxide, pentane-2-thiol, 3-penten-2-ol and 2-butenyl acetate, 3-hydroxy-2-butano3-methyl-1-butanol, 2,3- butanediol, 3-methylbutanoic acid, (Z)-3-hexen-1-ol, 6-methyl-5-hepten-2-one, limonene, octanol, ethyl octanoate (pink guava fruit).	Hernandez *et al.* 1971; Iwu, 1993; Burkill, 1997; Nadkarni and Nadkarni, 1999; Bassols, Demole, 1994; Paniandy *et al.* 2000
Leaves	α-pinene, β-pinene, limonene, menthol, terpenyl acetate, isopropyl alcohol, longicyclene, caryophyllene, βbisabolene, caryophyllene oxide, β-copanene, farnesene, humulene, selinene, cardinene and curcumene, mallic acids, nerolidiol, β-sitosterol, ursolic, crategolic, and guayavolic acids, cineol, quercetin, 3-L-4-4arabinofuranoside (avicularin) and its 3-L-4-pyranoside (Essential oil), resin, tannin, eugenol, caryophyllene (1a α-, 4a α-, 7 α-, 7a β-, 7b α-)]-deca hydro-1H-cycloprop[e] azulene, Guajavolide (2α-,3 β-,6 β-,23-tetrahydroxyurs-12-en-28,20 β-olide; 1) and guavenoic acid (2 α-,3 β-,6 β-,23-tetrahydroxyurs-12,20(30)-dien-28-oic acid, triterpene oleanolic acid,triterpenoids, flavinone-2 2′-ene, prenol, dihydrobenzophenanthridine and cryptonine.	Zakaria *et al.* 1994; Iwu, 1993, Nadkarni and Nadkarni, 1999; Oliver-Bever, 1986; Begum *et al.* 2002; Wyk *et al.* 1997; Joseph *et al.* 2010
Bark	Polyphenols, resin and crystals of calcium oxalate	Burkill, 1997; Nadkarni and Nadkarni, 1999
Root	Tannin, leukocyanidins, sterols, gallic acid, carbohydrates, salts, tannic acid	Iwu 1993, Quisumbing, 1978
Seed	Proteins, starch, oils, phenolic, flavonoid compounds, flavonol glycoside, quercetin-3-O-β-D-(2″ Ogalloylglucoside)- 4′-O-vinylpropionate	Michel *et al.* 2002; Burkill, 1997
Twigs	Calcium, magnesium, phosphorous, potassium, sodium, fluoride, copper, iron, zinc, manganese, and lead	Okwu and Ekeke, 2003

of ETEC. The methanolic and ethanolic extracts of apple were found active only against EAEC and Staph. Aureus. The methanolic extracts of guava and apple were found active as compared to the ethanolic extracts while the ethanolic extracts of pineapple showed slightly larger inhibition zones. The results of this investigation show great promise for potential antimicrobial drugs (Samiha Kabir *et al.* 2017). Table 1 details the phyto constituents on different parts of guava.

Therapeutic potential of guava

Guava (*Psidium gujava*) has a long history to be used in treatment of different ailments e.g. anti-inflammatory, diabetes, hypertension, caries, wounds, pain relief and reducing fever in traditional and folk medicines (reference would be appreciable). However, the therapeutic significance of guava for disease curing has gain attention over last decade. The guava fruits are observed to have fungicidal action against *Arthrinium sacchari* M001 and antimicrobial activity against *Chaetomium funicola* M002 strains (Sato *et al.* 2000). Similarly, the ethanolic extract from the shell of ripe fruit presenting activity on *Streptococcus mutans* and *Escherichia coli* (Neira and Ramirez, 2005). Guava was also found resistance against malarial infection. An *in vitro* study of antiplasmodial assay carried out on malarial parasite, *Plasmodium falciparum* strain D10 showed antigiardiasic activity with trophozoite mortality (87%±1.0), intending the anti malarial effect (Nundkumar & Ojewole, 2002). The important therapeutic properties of guava against metabolic disorder, diabetes, obesity and antioxidant are discussed.

Prevention of diarrhea and metabolic disorders

Diarrhea has long been recognized as one of the most important health problems faced globally particularly by the population of developing countries. Each year diarrhea is estimated to kill about 2.2 million people globally, the majority of whom are infants and children below the age of 5 years (Venkatesan *et al.* 2005). Ethanol and aqueous fruit extracts of guavaat a concentration of (80 μg/ml) in an organ bath exhibited more than 70% inhibition of acetylcholine and/or KCl solution-induced contractions of isolated guinea pig ileum (reference). The antidiarrhoeal action may be due to the inhibition of the increased watery secretions that occur commonly in all acute diarrhoeal diseases. The Quercetin present in guava is significant for anti-diarrhoeal activity on the contraction of guinea pig ileum *in vitro* and the peristaltic motion of mouse small intestine, and reduced the permeability of abdominal capillaries (Heinrich, 1998; Zhang *et al.* 2003). In addition, galactose-specific lectin presents in ripened guava fruit also resist the adhesion of *Escherichia coli* to the intestinal walls, inhibiting prolonged diarrhea infection (Coutino *et al.* 2001).

Prevention of diabetes and obesity

The occurrence of obesity and diabetes is rapidly increasing; the two diseases are seen in relation to irregular lifestyle and unbalanced dietary intake. Overweight or Obesity is defined as higher body mass index (BMI) and significantly associated with increased predisposition of extra fat which leads to hyperlipidemia, hyperglycemia, insulin resistance other cardiovascular disorders (Lois & Kumar 2009). Diabetic nephropathy is prominent factor responsible for oxidative injury, inflammatory stress and overproduction of advanced glycation end products (AGE). The interaction between AGE and RAGE (receptor for advanced glycation end products) induces activation of oxidative stress and stimulates the production and release of cytokines, thus amplifying the tissue damage (Gravis *et al.* 2008). Complications and side effects associated with diabetes and obesity, and failure of existing appropriate treatments are forcing researchers to come up with long term and sustainable solutions for the management of diabetes and obesity. Conceptually it has been proven that drugs produce their effect by acting through nutrition dynamics at molecular level (Lin *et al.* 2011).

The effect of ripened guava fruitaqueous decoctions at concentrations of 0.01–0.625 mg/ml was seen as anti-LDL (low density lipoprotein) glycative agent (Hsieh *et al.* 2005). However, the effective dosages for longer duration are still not standardized. The

Table 2: Worldwide Ethnomedical uses of Guava (Kamanth *et al.* 2008)

Country	Usage
Amazonia	For diarrhea, dysentery, menstrual disorders, stomachache, vertigo
Brazil	For anorexia, cholera, diarrhea, digestive problems, dysentery, gastric insufficiency, inflamed mucous membranes, laryngitis, mouth (swelling), skin problems, sore throat, ulcers, vaginal discharge
Cuba	For colds, dysentery, dyspepsia
Ghana	Coughs, diarrhea, dysentery, toothache
Haiti	For dysentery, diarrhea, epilepsy, itch, piles, scabies, skin sores, sore throat, stomachache, wounds and as an antiseptic and astringent
India	For anorexia, cerebral ailments, childbirth, chorea, convulsions, epilepsy, nephritis, jaundice
Malaya	For dermatitis, diarrhea, epilepsy, hysteria, menstrual disorders
Mexico	For deafness, diarrhea, itch, scabies, stomachache, swelling, ulcer, worms, wounds
Peru	For conjunctivitis, cough, diarrhea, digestive problems, dysentery, edema, gout, hemorrhages, gastroenteritis, gastritis, lung problems, PMS, shock, vaginal discharge, vertigo, vomiting, worms
Philippines	For sores, wounds and as an astringent

study on intravenous administration of fruit juice produced significant reductions in systemic arterial blood pressures and heart rates of hypertensive patients (Cheng and Yang, 1983). Other reports for the hypoglycemic components in guava fruit states some involvement of ursolic acid, oleanolic acid, arjunolic acid and glucuronic acid (Chang, 1982). The antiglycation activities of guava fruit is related to its polyphenolic content (extractable polyphenols 2.62–7.79%), still the mechanism of action of guava fruit components needs more specific observations and research to reveal the anti-LDL glycative association for obesity and diabetic diseases (Hsieh *et al.* 2007). The study based on randomized, single-blind, clinical trial suggests that by adding moderate amounts of guava fruit to the diet, changes in dietary fatty acids and carbohydrates may decrease lipoprotein metabolism and blood pressure. Two groups of patients (N= 120) were assessed over 12 weeks. Each group received ripe guava fruit, preferably before meals. At the end of the period, approximately half of the patients had a net decrease in serum total cholesterol, triglycerides, and blood pressure with a net increase in high-density lipoprotein (HDL) cholesterol (Singh *et al.* 1992). Another experiment on observation of single-blind, randomized, controlled trial of 145 hypertensive patients found similar results (Singh *et al.* 1993). Clinical study on consumption of guava fruit (400 g/day) on 122 people examined the effects on total antioxidant status and lipid profile (total cholesterol, triglycerides, low-density lipoprotein LDL and HDL cholesterol which reduced oxidative stress and blood cholesterol levels. Thus, it could also reduce the risk of disease caused by free radical activities and high cholesterol in the blood (Rahmat *et al.* 2004). In various other studies in addition of guava fruit, leaf decoction was also used for diabetes management (Cheng and Yang, 1983). Guava contains high levels of dietary fiber, the oral administration of capsules containing 500 mg of *Psidium guajava* fruit in 40 patients showed a reduction in blood glucose level in consecutive weeks. The study provided an inclusion of guava as supplementation diet of 0.517 g/day could reduce fasting blood glucose level (Yusof and Said, 2004).

Antioxidant and free radical scavenger action

The cellular damage or oxidative injury caused due to free radicals or reactive oxygen species (ROS) now appears to be the fundamental mechanism underlying a number of human neurodegenerative disorders, diabetes, inflammation, viral infections, autoimmune pathologies and digestive system disorders (reference). Free radicals are generated through normal metabolism of drugs, environmental chemicals and other endogenous chemicals, especially stress hormones (adrenalin and noradrenalin) (Masuda *et al.* 2003). The prevention of free radical damage has often been attributed to the consumption of antioxidants such as vitamins C and E, and carotenoids, such as lycopene, phenolic acids, and flavonoids present in fruits and vegetables (Michels *et al.* 2005; Rouphael *et al.* 2010). There are a lot of compounds like Gallic acid, galangin, kaempferol, homogentisic acid and cyanidin 3-glucoside which are found in peels, seeds and pulp of guava. But it is surprising that the amount of these compounds is high in seeds and skin as compared to the pulp. Due to the presence of these compounds guava's food importance becomes high (Chen *et al.* 2015). The antioxidant properties of guava from high ascorbic acid content are associated with its phenolic compounds such as protocatechuic acid, ferulic acid, quercetin and guavin B, quercetin, gallic aci and caffeic acid (Thaipong *et al.* 2005; Abreu *et al.* 2006). The alleged health-promoting properties of guava also could include prebiotic activity, which encompasses the cell protective effects of particular antioxidants that can be liberated in the colon after fermentation by gut flora (Ferguson *et al.* 2003, 2005). The various antioxidant compounds concentrated to produce dietary supplements for human use. However, the additive and synergistic effects of food constituents and their value added products are frequently ignored (Hodek *et al.* 2009; Rajoria *et al.* 2010). The antioxidative potential of guava extracts has rendered a new therapeutic path against the various complications and diseases. Further investigations are required in this regard to find the actual mechanism involved in antioxidant and other pharmacological activities of guava (Manikandan *et al.* 2015).

Trends in guava functional and fermented foods

Guava fruit is frequently used in various indigenous medicinal practices in different countries. The preparations of guava extract traditionally are in the form of infusion, decoctions, and tinctures in order to increase the level of guava as dietary supplement. To combat the scarcity researches have focused in the development of different formulations by preserving the nutraceutical properties of guava for fortification like milkshakes, curd and other low fat calorie products (Menezes *et al.* 2012). The popular products of guava as jellies and preserves are saturated in the market. However retaining the functional characteristics is an important factor while preparing new formulations (Gonzalez *et al.* 2011; Rajoria *et al.* 2013). In the development of a new product, with addition of concentrated fruit juice, the determination of its rheological parameters is an essential aspect, as the use of pre-existing parameters in industry could easily include some process errors while designing the processes such as pumping, stirring and transport in pipelines (Branco *et al.* 2005).

The most efficient method of production of guava fruit powder can be attained through heat infusion, spray drying, freeze drying (Chauhan *et al.* 2013). Since guava juice is very delicate in flavor and usually pink or yellow in colour according to the variety used therefore drying operations need to be carefully designed to preserve the quality and colour. Several methods are used for production of guava powder, but the most successful methods include freeze drying, foam mat drying and spray drying. Although the freeze drying process was successful to convert guava juice into powder the production cost are high (Chopda and Banrett 2004). Hence, spray drying techniques have been applied for producing guava powder Drying by spray drying is cheaper than freeze drying, and the spray dryer capacity is also higher than freeze dryer (Tashtoush *et al.* 2007). The spray drying is one step process having short dehydration time and controlled pressure in comparison to freeze drying, vacuum drying and tunnel drying which minimizes heat damage (Bhandari *et al.* 1993). The thermal sensitivity and hygroscopic nature of fruit components gives rise to wall deposition problems and hinders handling procedures. A suitable carrier such as maltodextrin or glucose syrups facilitate drying of fruits like orange, lemon, apricot and mango juices (Ahlawat *et al.* 2009). This micro-encapsulation of carrier agents provides longer shelf life and protect against light, oxygen and other type of environmental degradation. It also increases solubility, and improves the handling and flow properties of the core material. Micro-encapsulation has to be optimized several times so that it does not affect the rheological properties or operational events of manufacturing fruit powder (Jafari *et al.* 2008). However productions of fruit powders by spray drying sustain problems in their functional properties such as stickiness and solubility (Bhandari *et al*. 1997). Studies suggest that oven drying is a viable option for the production of a functional ingredient that would improve the phenolic content of cereal foods while adding desirable guava flavor (Juliana *et al.*). More research work is required to overcome the technical difficulties for food processing.

After processing guava remains good source of vitamin C, lipid, ash content and dietary fiber ingredients useful for food industry (De Costa *et al.* 2009), Products like guava enriched cookies prepared from high fiber obtained from guava waste pulp for ready to product are also equally nutritious (Fátima *et al.* 2005). Other symbiotic food products guava mousse formed by addition of prebiotic guava fruit and probiotics *Lactobacillus acidophilus* increases the nutrients of functional foods (Flavia *et al.* 2010). Consumer awareness is the most important factor determining demand for such type of food products. Sensory analysis and likeability of products increases the market demand. Functional foods offer potential health benefits. Studies aimed at understanding consumers' needs for functional foods in relation to their traditional diets or special dietary needs are also recommended.

Guava in dairy fermented functional foods

Guava in combination with probiotic fermented dairy food like yoghurt, curd and *shrikhand* will develop high value commodities to increase application of guava in the area of functional foods (Chauhan *et al.* 2015). Dairy products such as fermented milks are most popular food of probiotics. They are live microorganisms which when administered in adequate amount confer health benefits. The most common strains of probiotics bacteria are from genus *Lactobacillus* and *Bifidobacterium* which are tailored into dietary formulations at global level (Ram *et al.* 2002). While transferring the probiotics the emphasis for prolonged survival of probiotics in the food matrix is priority. Probiotic bacteria must remain viable in the food carriers and survive the harsh condition of GI tract, with a minimum count of 10^6CFU/ g^{-1} (Kumar *et al.* 2003). The traditional dairy foods like yoghurt, curd, milk beverages and many more are innovated and manufactured as new probiotic dairy products (Singh, 2001).

Guava in non-dairy functional fermented foods

Dairy products have been traditionally considered as the best carriers for probiotic bacteria. In recent years, non-dairy probiotic foods have been attracting more attention due to consumer demands. Therefore, in order to alleviate the drawbacks of dairy based probiotics, the development of non-dairy probiotic products, including food matrices from fruit, vegetables, and cereals has a promising future.

Guava (*Psidium guajava*) pulp was fermented with *Lactobacillus plantarum* WU-P19 to a product rich in microbially produced vitamin B12 and conjugated linoleic acid (Palachum *et al.* 2020). In a work by Buriti *et al.* (2011) pilot-scale mousse were produced and supplemented with *Lactobacillus acidophilus* La-5 probiotic culture with frozen guava pulp (GP) and prebiotic inulin. Nausheen *et al.* (2018) reported Guava juice blended with honey and fermentation by different yeasts studied for bioenrichment of guava juice. The results revealed that the guava juice blended with honey as prebiotic and fermented by probiotics of yeast *Saccharomyces boulardii* showed enriched nutritional. The results concluded that the combined fermentation of guava juice blended with 4 percent honey could be bio-enriched product from guava juice and it will be new product in the food industry.

CONCLUSION

Psidium guajava is a well-known tropical fruit used in various indigenous systems of medicinal purposes. The multiple disease ameliorating properties of guava, has been discussed in this review. Such properties have been further explained by several studies detailing the specific bioactivity of individual phytochemicals extracted from guava including clinical studies. The ripe guava fruit is a very useful nutraceutical with important properties that can affect the maintenance of health and prevention of many diseases (Hwang *et al.* 2002). The fruit juices have been proven to prevent diabetes and other metabolic disorders and a potent antioxidant essential for health and well being. Interestingly, this ends pharmacological credence to the implication of designing value added products. Further research is required for characterization and exploitation to innovate guava enriched functional foods.

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