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Palmyrah fruit (*Borassus flabellifer* L.): Source of immunity and healthy food: A review

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Abstract
The palmyrah fruit is natural and nutritionally rich, it can be considered as a potential source of various value-added products. Palmyrah pulp obtained from the ripe fruit is used in many traditional food items and its juice is a seasonal and low priced drinking juice due to lack of mechanisation and value addition. The fruit pulp helps to cure skin inflammations. It is used to treat nausea and vomiting as well as worm infestation. It is used as an expectorant and also as a liver tonic. A thin layer of sugar palm fruit jelly applied on the affected area has a soothing effect and immediately alleviates the itchiness associated with prickly heat. Being rich in minerals and vitamins, sugar palm fruits are a healthy option for people on diet or suffering from diabetes. It is a rich source of vitamins such as B, C and rich in minerals such as iron, zinc, potassium, calcium, phosphorus, thiamine, and riboflavin. Palmyrah fruit has anti-inflammatory and antioxidant properties. The antioxidant activity could be attributed due to the presence of high content of crude flavonoids, saponins, and phenolic compounds. It is also being used in folk medicine to cure various diseases. It contained pectin as well as contain an appreciable amount of saponin because of that fruit pulp having important medicinal properties. Although palmyrah fruits are seasonal they have excellent chemical and physical properties for the development of food and beverages. There is a demand for palmyrah ready to serve the beverage.

Keywords: Palmyrah fruit, fruit pulp, pulp extraction, medicinal properties

Introduction
India is the center of origin for many tropical fruit tree species, most of which are not commercially cultivated but provides a significant source of livelihood support for many rural communities. Besides their importance for their nutritional value and as a source of household income, this fruit diversity also has a cultural and social value and contributes to the stability of ecosystems(reference). Many tropical fruits are labeled as “underutilized species”, which are characterized by the fact that they are i) locally abundant, but restricted in their geographical dispersion and have a high use value, ii) there is a lack of scientific knowledge about them and iii) that their current use is limited relative to their economic potential(reference).

History and origin
Borassus flabellifer, commonly known as palmyrah palm, tala palm, toddy palm, wine palm, sugar palm, or ice apple is a large fan palm of Arecaceae / Palmae (Palm family). The plant is native to the Indian subcontinent and Southeast Asia, including Nepal, India, Bangladesh, Sri Lanka, Cambodia, Laos, Burma, Thailand, Vietnam, Malaysia, Indonesia, and the Philippines. It is supposedly naturalized in Pakistan, Socotra, and parts of China (Morton, 1988) [10]. The palmyrah palm has enormous economic potential, and every component of the palm may be used in some way. Palmyrah palm serves as food as well as building material (Waziri *et al.*, 2010), also used in the pharmacopeia (Sanakaralingam *et al.* 1999, Hiralal, 2017) [20, 5]. India ranks first in the world in terms of its wealth of palmyrah palms with a population of nearly 122 million palms (Anonyms 2015). The palm is found growing in Andhra Pradesh, Tamil Nadu, Bihar, and Orissa and a greater number of the palms were found in southern states of India (reference).

Palmyrah fruit
Palmyrah (*Borassus flabellifer* L) is an indigenous fruit of India. It grows throughout the Indian Peninsula as well as in Sri Lanka, Pakistan, Bangladesh, Burma, Thailand, and most of the southeastern Asian countries. It is a very hardy subtropical, deciduous tree that can thrive

well in various soil-climatic conditions (from swampy to dry soils) and can tolerate alkaline soil, and is not injured by low temperatures. There is no organized orcharding of this fruit in India. Its cultivation is scarce, and it now grows mainly wild or along the bunds and wastelands. In the excellent flavor and nutritive and therapeutic values of the palmyrah fruit lies an untapped potentiality for processing. In most countries, fresh fruit pulp is used as animal feed (Theivendrarajah, 2008) [25]. The palmyrah fruit is nutritionally rich, pulp obtained from the ripe fruit is used in many traditional food items and its juice is a low-priced seasonal drinking juice with commercial and medicinal value (Nguyen *et al.* 2019) [11]. Carbohydrates, pro-vitamin-A, vitamin-C, minerals, and lycopene are abundant in palmyrah fruit; hence it is a promising raw material for the production of industrially viable products (Kurian *et al*., 2017) [8]. During July/August, the fruits mature, and the ripened fruits fall off the tree between August and October, about 150-200 fruits (Fig.1) may be found on each female palm every year. India has the potential to produce more than 20,000 metric tonnes of palmyrah fruit pulp every year (Sivaganeshan, 1994). In Andhra Pradesh, 15 to 20 million palm trees are available from which 3,000 metric tonnes of the pulp can be extracted every year. Uluwadge *et al.* (2007) [26] reported that the Pinattu, prepared by drying the palmyrah fruit pulp reduced serum glucose levels of mild type-II diabetic patients. Palmyrah palm juice is a seasonal and low priced drinking juice. This juice has commercial and medicinal value. (Nguyen *et al.* 2019) [11]. Palmyrah fruit is mostly used as fresh fruit, because of its perishable nature it is traditionally preserved as dried fruit pulp called fruit leather. It contained pectin as well as contain an appreciable amount of saponin because of that fruit pulp having important medicinal properties (Srishankar *et al.* 2017) [24]. Although palmyrah fruits are seasonal they have excellent chemical and physical properties for the development of food and beverages. Though there is a demand for palmyrah ready to serve the beverage, existing commercial products are failed due to their poor quality (Nithiyananthan *et al.* 2018) [13].

A. B. C.

Fig 1: Palmyrah fruit and pulp availability in nature. (a) Bunch of Palmyrah fruits to tree; (b) Palmyrah fruits; (c) Palmyrah pulp;

Vengaiah *et al.* (2021) [21] investigated some physical properties of palmyrah fruit. The average values of major, medium, minor, and geometric mean diameters of fresh whole palmyrah fruit were 11.54,10.45, 9.85, and 10.64 cm respectively at 47.34% (w.b) moisture content whereas that of palmyrah nut were 8.59, 7.35, 4.99, and 6.79 cm respectively at 8% (w.b) moisture content. Sphericity, surface area, and aspect ratio were found to be 91.94%, 359.17 cm^2, and 0.90 for fruit and whereas that of nut were 79.19%, 145.16 cm^2 and 0.86 respectively. The average mass of the individual palmyrah fruit and nut was 927.78 and 248.10 g whereas bulk density was 525.92 and 693.0 kg/m^3 respectively. The coefficient of static friction on mild steel, glass, and plywood surfaces were 0.27, 0.21, and 0.25 for palmyrah fruit and 0.36, 0.28, and 0.27 for nut respectively. The angle of repose of palmyrah fruit and nut were 30.77 and 44.03 respectively.

Benefits of palmyrah fruit pulp

The fruit pulp helps to cure skin inflammations. It is used to treat nausea and vomiting as well as worm infestation. It is used as an expectorant and also as a liver tonic. A thin layer of sugar palm fruit jelly applied on the affected area has a soothing effect and immediately alleviates the itchiness associated with prickly heat. Being rich in minerals and vitamins, sugar palm fruits are a healthy option for people on diet or suffering from diabetes. It is a rich source of vitamins such as B, C and rich in minerals such as iron, zinc, potassium, calcium, phosphorus, thiamine, and riboflavin. Palm fruit has anti-inflammatory and antioxidant properties. The antioxidant activity could be attributed due to the presence of high content of crude flavonoids, saponins, and phenolic compounds (Pramod *et al*., 2017) [16]. It is also being used in folk medicine to cure various diseases *(*Kurian *et al 2017)* [8]. The Pinattu, prepared by drying the Palmyrah fruit pulp could reduce serum glucose levels of mild Type-11 diabetic patients (Uluwadge *et al.* 2007) [26]. The fruit pulp has been used in traditional dishes and herbal medicine due to its pharmacological values along with sweeteners for diabetic patients (Vedapriya *et al*., 2016) [27]. The fruit pulp showed to have a significant hypocholesterolemic effect in ICR mice. Beta-sitosterol, the parent sterol of flabelliferins, is known to reduce cholesterol uptake (Pathberiya *et al* 2015). It has also been reported to possess immune suppressant properties (Revesz *et al*., 1999) [17]. It is also being used in folk medicine to cure various diseases. It contained pectin as well as contain an appreciable amount of saponin because of that fruit pulp having important medicinal properties (Kapoor, 2000) [7]

Fruit Pulp Extraction

Georges and Simard (1992) [2] developed an efficient process for the extraction of juice from palmyrah fruits using a pectinase (Pectinex Ultra SP-L) enzyme at a concentration of

0.6 mg/kg, and temperatures of 45 °C with 120 min time which gives the highest juice yield (73.14%). Colour parameters L, a, b fluctuated in intensity between batches of rehydrated material. Juice consistency was found to be stable at 45 ºC at the enzyme concentrations used. There was a slight variation in pH among the different treatments. In general, the yield and quality of the juice obtained were affected by treatment temperature, enzyme concentration, and maceration time. Mahendran *et al.* (1993) [9] developed a mechanical device for palmyrah fruit pulp extraction which had square blades fitted at an angle to the vertical shaft through rods. The shaft was operated through a 0.75 horsepower motor and a gearbox was used to regulate the rpm. Using this device, pulp from palmyrah fruit was extracted and compared with the manual and mechanical extraction. The manual extraction of fruit pulp taken time 11.9 min fruit^{-1} and while mechanical extraction is only 0.48 min fruit^{-1} and cost also 3 times more in manual as compared to mechanical device. The amount of pulp extracted per fruit by manual and mechanical processes was 0.63 kg with 11–13% Brix and 0.84 kg with 9–10% Brix respectively. Even though there is a 2% difference in the Brix content of the pulp obtained by the two processes, the soluble solids separated per fruit are the same (0.08 kg fruit^{-1}) in both processes.

Fruit and pulp characterization

The fresh pulp contains carotenoids (609.10 mg per kg of pulp), vitamin C (461.40 mg per kg of pulp), polyphenols (270 mg per kg of pulp), and anthocyanin (53.90 mg per kg of pulp). Free radical scavenging activity of the dried pulp (water content of 11.60%) was 93.4% (Herianus *et al*., 2000). Several techniques including fermentation, sodium carbonate, and PEG treatment have been successfully developed to reduce the bitterness of the pulp without significantly reducing its antioxidant activities. Food products (chips, stick crackers, and jelly sweet) have then been developed and have got a positive response from the panelist. The fresh pulp contains a moisture content of 74.5% with ash and fat contents (wet matter basis) were 1.2% and 0.8% respectively. The protein and carbohydrate contents were 1.25% and 22.5% respectively. The pH value of pulp was 5.5. The values give significant values which can be utilized directly or combined with other pulps for the preparation of foods (Vengaiah *et al.* 2015) [28].

The total phenolic content of the pulp extracts of fruits showed the highest value (9.297 ±0.018 mg GAE/mg extract). DPPH Radical scavenging activity was seen highest in the Anamaduwa samples (3.065 ±0.176 mg ml^{-1}) and lowest in Batticalo sample (7.466 ±0.156 mg ml^{-1}). The total antioxidant capacity based on the Phosphomolybdenum assay also indicated the highest value in the Anamaduwa sample (68.171± 2.068 mg AE/g extract) and lower value in the Batticalo sample (31.134 ±0.470 mg AE/g extract) (Kurian *et al.*, 2017) [8].

Srishankar *et al.* (2017) [24] identified and evaluated the phytochemical constituents of solvent extracts of pinattu. Samples were collected from the three different branches of the Palmyrah Development Board. Pinattu contains 16.6±0.08 g/100g of moisture, 2.23±0.062 g/100g of protein, 0.08±0.001g/100g of Fat, 0.04±0.001g/100g of Ash, 5.06±0.01 g/100g of crude fiber, and 75.91±0.61 g/100g of carbohydrate respectively. There was a significant difference between each sample for all the nutrient content except moisture content. More recently the Palmyrah Development Board in an effort to popularize fruit pulp converted the pulp into several edible products such as fruit drinks, cordials, jams, concentrated pulp, fruit bread, chocolates, pulp mellows, and pulp delight. The fruit has a characteristic bitterness which is a drawback in efforts to popularize the product or even export it. Hence, it is important to debitter the pulp. The technique of bioconversion for debittering with Naringinase has been successful (Jansz *et al*., 1994) [6].

According to Ariyasena *et al*., (2002), FII was suspected to reduce weight gain in ICR mice when the administration of F-II (1mg/mouse) extracted from Palmyrah fruit pulp, can significantly inhibit the increase in blood glucose after a glucose challenge. So it suggests that F-II of the pulp can inhibit the intestinal glucose uptake. This study also indicated that inhibition of Na^+/ K^+ ATP ase activity could be a mechanism by which F-II mediates its inhibitory action on the intestinal glucose uptake in mice. Shirisha *et al. (2018)* [22] studied photochemical screening and identified albuminoids, fats and the fresh pulp is reportedly rich in vitamins A and C. It also contains a bitter compound called flabelliferrins; these are steroidal saponins. 28 chemical constituents are present they are 2-Furanmethanol, Propane, 1-(1-methylethoxy), 2-Cyclopenten-1-one, 2- hydroxy-, 2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, Glycerin, 1,3-Propanediamine, 1,2-Propanediol 2- acetate, Butane, 1-(ethenyloxy)-3-methyl-, Propane, 1,1-diethoxy-,1H-Imidazole-4-carboxamide, 5-amino-, 4H- Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-, Resorcinol, Phenol, 2,6-dimethoxy-,6H-Purin-6-one, 2-amino1,7-dihydro-,6H-Purin-6-one, 2-amino-1,7-dihydro-, 1,4-Benzenediol, 2-methoxy-, Phenol, 3,4-dimethoxy-, Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-, Phenol, 4-92-(dimethylamino)ethyl0-, 1-Butanol, 2-amino-, 3-Hydroxy-4-methoxy benzoic acid, Phenol, 3,4,5-trimethoxy-, Phenol, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, (R)-, 7H-Furo[3,2-g] benzopyran-7-one, n-Hexadecanoic acid, Pentanoic acid, 10-undecenyl ester, Octadecanoic acid.

Palmyrah Fruit Pulp (PFP) storage

Fruits of Palmyrah palm are seasonal; therefore their Palmyrah fruit pulp (PFP) is extracted with water and should be preserved with lengthened shelf life to ensure its availability in the local and international market throughout the year. Therefore, a study on preservation of PFP was carried out by Robika *et al.* (2000) with or without various concentrations of preservatives, Sodium benzoate (SB), Sodium metabisulphite (SMS), and combinations of the both at different ratios and pH of the PFP were adjusted to 3.8 with citric acid along with heating in a water bath at 90ºC for 20 Sec. The bottled pulp was heated at 80ºC for 30 min in a thermostatic water bath and kept at room temperature (30ºC) for 180 days for shelf-life study, and at 30days intervals were analyzed for microbial, physicochemical, and sensory characteristics. From the results, it was observed that PFP alone (without preservatives) was spoiled with increasing pH by showing adverse characteristics (unacceptable odor) before 24hours of storage. All the treatments showed a significant increase in total soluble solid (10.82-13.10º Brix) and decline in pH (4.42 - 4.14) was observed with a proportional increase in the acidity (0.71- 0.91%) up to 180 days. But no colony (Total Plate Count) was observed in the pulp treated with SMS and with the combination of SMS & SB at various concentrations up to 120 days of storage. Among all treatments, the pulp treated with SB was found to be inferior in both colour and flavor characteristics. Even though it was

found that PFP treated with SMS, could be stored for an extended period of 180 days without any major changes in chemical, microbiological, and sensory characteristics, whereas SMS,0.4g/l was selected as the best treatment based on the overall acceptability. Sobini *et al.* (2018) [23] conducted research on clarification to obtain quality Palmyrah fruit juice by using pectinase treatment and optimum condition was found that 1% pectinase enzyme, at 40 ºC incubation temperature and 1 hour incubation time.

Drying of fruit pulp

Nguyen *et al.* (2019) [11] studied the feasibility of spray drying of palmyrah palm juice. Various characteristics of spray-dried fruit juice powders are well affected by spray-drying conditions including inlet air temperature, outlet air temperature, feed flow rate, drying carrier agent. Results revealed that inlet/ outlet spray drying temperature (140º C: 85º C), speed flow rate (12 ml/ min), arabic: maltodextrin (5: 5% w/v) were appropriated for spray drying of dried palmyrah palm powder from its juice. The spray-dried product of Arabic gum-maltodextrin-palmyrah palm juice was considered to be a good technique to dry palmyrah palmyarh juice on the result of phytochemical determination, physical and chemical properties, and antioxidant activity. Value addition of palmyrah palm juice has been created by changing in the physical form of the agricultural produce which leads to its greater acceptability, extended availability, enhanced market viability and increased cost to benefit ratio for the grower of the palmyrah palm produce

Wijewardana *et al.* (2016) [30] evaluated the effect of various dehydration techniques such as sun drying, solar drying, drying after freezing (freezing for one hour followed by mechanical drying at 55°C), vacuum drying and drying using lab-scale air oven on proximate composition and retention of antioxidants in fruit powder prepared from palmyrah. Among different drying treatments, the highest fat percentage was recorded by the solar dried palmyrah fruit powder. Higher concentrations of β-carotene and total phenolic content were recorded in vacuum dried samples. Vacuum dried fruit powder of palmyrah gave the highest radical scavenging activity. Therefore, vacuum drying was found as the most effective drying method to protect chemical characteristics and retention of antioxidant properties of fruit powders.

Value added products

Sangeeta *et al.* (2014) [19] conducted research on processing palmyrah fruit pulp into a value-added product to broaden the utilization of palmyrah fruit pulp. Set, swiss-style, jelly, and pulp preserve yogurts incorporated with palmyrah fruit pulp were developed. Control yogurt and plain yogurt for other preparations were prepared with 13% sugar, 1% gelatin, 12% skim milk powder and lactic acid bacteria culture following the household method. The fresh pulp was kept at – 25 ºC for 48 hours and heated up to 85 ºC for 30 minutes with 5% cane sugar, 0.6% tartaric acid, 1% ascorbic acid, and 0.13% sodium chloride. The treated pulp was added at 5%, 7.5%, 10%, 12.5% and 15% into both set and swiss-style yoghurts. Fruit jelly was prepared with sugar, gelatin, sodium citrate, citric acid, and 20% pulp. It was then incorporated into yogurt at 5% and 6%. Palmyrah fruit pulp preserve was prepared by heating sugar, pectin, and pulp (45. 8%) until its Brix reached 68.5º and it was topped on set yogurt at 5%, 7.5%, and 10%. Sensory evaluation for color, odor, appearance, mouthfeel, and texture was conducted with 21 untrained panelists using 5 points hedonic scale, and the optimized pulp concentrations for the set, swiss-style, jelly and preserve yogurt were 5%, 7.5%, 6%, and 10% respectively ($p< 0.05$). The overall sensory qualities of all palmyrah fruit yogurts were rated as good to very good. There were no significant changes in sensory attributes, Brix, and pH in storage at 4 ºC. Shelf life was 18 days for all products at 4 ºC without any preservatives except set yogurt as it showed separation of water from the third day of the preparation. Nutritional and microbiological qualities of the products were investigated and compared with control yogurt. Protein was higher in swiss style (6.12%) and jelly (7.77%) yogurts. Carbohydrate was higher in swiss style yogurt (36.87%) and preserve yogurt contained highest fat content (2.57%).

Saranya and Vijayakumar (2015) [21] developed ready-to-serve beverage from palmyra palm fruit pulp by optimizing the level of palmyra fruit pulp (PFP) and sugar through central composite rotatable design in response surface methodology. The responses for optimization were acidity, pH, total soluble solids, total sugar, reducing sugar, non-reducing sugar, color, flavor, and taste. A second-order quadratic polynomial regression equation was fitted to the data for all responses to predict the level of PFP and sugar concentration. The optimum level of PFP and sugar for the preparation of 100 mL of RTS beverage determined as per the set goals of 0.3% as maximum titrable acidity, 10% as minimum total soluble solid, 10% as minimum fruit pulp level with desirability of 0.713 was 13.71 and 18 g, respectively.

Nilugin and Mahendran (2011) [12] conducted a study to develop a ready-to-serve (RTS) beverage using palmyrah fruit pulp at different concentrations of 8, 10, 12, 14, and 16% with sugar, citric acid, distilled water, and potassium metabisulphite, considering the recommendations of Sri Lanka standards for RTS fruit beverages. The results of Physico-chemical analysis revealed that titrable acidity, ascorbic acid, and total sugar increased while the pH decreased and total soluble solids remained the same as 15º Brix with an increase in the pulp concentration from 8 to 16%. The findings of microbial studies showed no total plate counts in the formulated beverages. Samples subjected to sensory evaluation showed that there were significant differences between treatments with respect to color, aroma, taste, consistency, and overall acceptability. From the results of quality assessments, the formulated beverage with 12% of pulp concentration was found to be superior in quality and could be stored at 30±2 °C for a minimum period of six months without any significant changes in quality

Nithiyananthan *et al.* (2018) [13] conducted a study to improve the quality of palmyrah ready-to-serve beverages by reformulation and modification of the process. Pectin and citric acid were selected as stabilizers and acidulants through the ranking test with 11 semi-trained panelists. Using general full factorial design, 18 treatments were carried out to optimize the levels of fruit (5 -12%), sugar (10-15%), and pH (3.5-4.0) in the final formula. The final formulation was evaluated through 31 sensory panelists using 9 points hedonic scale. The formulated beverage contained 12% fruit pulp, 12.5% sugar, and pH of 4.0. The level of pectin was adjusted to 0.66% and the fruit pulp was subjected to homogenization (30000 rpm for 5 min). Chemical and nutrient analysis of the reformulated product revealed that the product was significantly better than the existing product in nutrients. It contained 0.14% crude protein, 0.78% crude fat, 0.41% crude fibre, 0.17% ash and 11.97% total sugar. Total antioxidant

capacity, total phenolic content, and inhibition of DPPH radical scavenging activity of prepared product was 4044.00 Ascorbic acid equivalent (AAE) mg/L, 137.57 gallic acid equivalent (GAE) mg/L, and 12.43% respectively. The developed product did not show any growth of yeast and mold and bacterial count during 10 weeks. Hence the developed palmyrah fruit ready-to-serve drink showed better quality in the analyzed properties compared with commercially available products.

Guberan, *et al.* (2016) [3] developed a palmyrah fruit pulp (PFP) flavored pasteurized milk toned with soy milk (Glycine max) using different percentages of PFP and soy milk sweetened with 7.5% (w/v) sugar based on the recommendations of Sri Lankan Standard Institute (SLSI). Flavored milk samples were prepared by adding 2, 4, 6, 8, and 10% of PFP (v/v) to cow milk and subjected to sensory evaluation. Subsequently, after the 6% of PFP added flavored milk was preferred; 10, 20, 30, and 40% of soy milk were used in the preparation of flavored milk. Flavored milk prepared using vanilla was used as a control. Based on the results obtained from sensory evaluation, selected samples and control were analysed for nutritional and microbial quality. Milk prepared by adding 6% of PFP and 10% of soy milk resulted in superior sensory and nutritional qualities compared to control sample.

Pagthinathan *et al.* (2016) [14] developed palmyrah fruit pulp added yogurt and determined the effects of Physico-chemical attributes of yogurt during storage. It was revealed that the Physico-chemical attributes like ash, dry matter, total sugar, reducing sugar, pH, and titratable acidity significantly ($p< 0.05$) changed. The concentration of 2.5% PFP added yogurt had the highest overall acceptability compared to other all types of yogurt.

Conclusion

It appears that palmyrah fruit is wild and one of the most nutritious fruits of India; its therapeutic and medicinal properties have long been known. The palmyrah palm is very hardy and can grow under adverse agroclimatic conditions, unlike other delicate fruit trees. No attempt has been made to utilize or preserve the ripe palmyrah fruits. Few techniques for the extraction of palmyrah fruit pulp have been developed by the authors. The addition of an equal amount of water gives about 125 percent yield of pulp which has the consistency of mango pulp. This is highly important economically for no other fruit will give such a high yield of pulp ready for processing, because the total solid content of the palmyrah fruit is nearly double that of other common fruits. The investigation has indicated that several acceptable products can be prepared from palmyrah fruit pulp. Such preparations have to be standardized, and storage requirements also are formulated to enable commercial exploitation of this fruit. Further, the palmyrah fruit flavor is entirely unknown in the export market and a good range of products that have been developed retained fully the natural flavor. Present studies also point out the possibilities of popularizing the cultivation of the undomesticated fruit exclusively for the processing industry.

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