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Review Article

EXPLORING KAMALAM FRUIT (*HYLOCEREUS* SPP.): CULTIVATION, NUTRITIONAL VALUE, AND HEALTH BENEFITS. A REVIEW

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ABSTRACT

This review aims to cover the cultivation techniques, nutritional content, and health advantages of Kamalam fruit. Kamalam fruit plants exhibit remarkable adaptability and thrive in slightly heavy-textured soils. Typically, these plants are propagated through stem cuttings. After approximately 15–18 months of planting, flower buds emerge, taking about 28–30 days to bloom. Kamalam fruit is renowned for its nutritional richness, being a valuable source of minerals, glucose, fructose, dietary fiber, and various vitamins. It contributes to fortifying the human immune system and is utilized in managing conditions such as diabetes and heart disease, while also assisting in maintaining a healthy body weight. The yield and nutritional content of Kamalam fruit can fluctuate based on factors such as species, cultivation practices, geographic location, and harvest timing. Notably, the peel of Kamalam fruit shows significant potential as a natural dye. The number of commercial growers in various countries is steadily rising, driven by the attractive prices their products fetch in the market. At present, there is limited information available on the production aspects of Kamalam fruit. Research across different facets of cultivation and the health benefits of this fruit holds the promise of maximizing advantages for growers and consumers worldwide, thereby expanding the Kamalam fruit market.

Keywords: Cultural practices, Medicinal values, Nutrient content, Red Pitaya, Kamalam.

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INTRODUCTION

Kamalam fruit, scientifically classified as a vine cactus species within the *Cactaceae* family (Patwary *et al*., 2013), captivates with its exotic appearance (Liaotrakoon, 2013). In recent years, Kamalam fruit has been steadily gaining popularity for its remarkable nutritional and medicinal properties (Sonawane, 2017). This fruit has emerged as a significant economic commodity on a global scale, due to its exceptional nutritional value (Rifat *et al*., 2019). It is important to note that various factors can influence the bioactive compounds within Kamalam fruit, including the choice of cultivar, seasonal variations, climate conditions, cultural practices, water availability, transport, handling, and storage methods (Franke *et al*., 2004; Wall, 2006). Moreover, the Kamalam fruit stands out as a promising crop for Mediterranean growers, primarily due to its minimal water requirements and its remarkable adaptation to high-temperature environments (Trivellini *et al*., 2020). As Kamalam fruit ripens, the red-fleshed varieties undergo a pigmentation process, enhancing their visual appeal (Rahim *et al*., 2009). Beyond aesthetics, Kamalam fruit is cherished for its deliciously sweet taste and crispy texture (Rao and Sasanka, 2015). Notably, it is an edible fruit rich in water-soluble fiber, boasting a high concentration of essential nutrients such as Vitamin C and various antioxidants, including betalains, hydroxycinnamates, and flavonoids (Moshfeghi *et al*., 2013). This impressive nutritional profile underscores its significance as a wholesome dietary choice. Kamalam fruit, with its enticing taste and exceptional nutrient profile, offers a multitude of health benefits. It has gained recognition for its potential to aid in weight management, enhance digestion, reduce LDL cholesterol levels in the blood, and bolster the immune system. The presence of Hydroxycinnamates contributes to its cancer-preventive properties, while flavonoids, acting on brain cells and blood vessels, mitigate the risk of heart diseases. In addition, Kamalam fruit demonstrates antimicrobial properties, guarding against bacteria and fungi, and contributes to overall bodily functions (Verma *et al*., 2017). Originating in the tropical and sub-tropical forest regions of Mexico, Central, and South America, Kamalam fruit has spread to various parts of the world, including tropical and sub-tropical America, Asia, Australia, and the Middle East. It is now extensively cultivated in countries such as Australia, Cambodia, China, Israel, Japan, Nicaragua, Peru, the Philippines, Spain, Sri Lanka, Taiwan, Thailand, South-Western USA, Vietnam, and India (Mizrahi and Nerd, 1999; Nobel and De la Barrera, 2002). It is particularly popular in South-east Asia (Patwary *et al*., 2013). The cultivation of Kamalam fruit has been rapidly expanding in recent years due to its growing recognition for both health and economic benefits, with its potential to serve as a source of functional materials rich in phytochemicals with potent antioxidant properties (Parmar *et al*., 2019). Varieties like *Hylocereus undatus* are particularly noteworthy for their rich fiber content, vitamins, calcium, phosphorus, magnesium, phytochemicals, and antioxidants (Mahdi *et al*., 2018; Luo *et al*., 2014; Sushmitha and Sathyamurthy, 2018). Kamalam fruit's appeal in Asian countries is further amplified by its nutritional value, alluring features, and vibrant colors (Harivaindaran *et al*., 2008; Hoa *et al*., 2006). In India, the cultivation of Kamalam fruit has gained momentum due to the suitable tropical climate, seasonal rainfall, light intensity, and soil types. This expansion is aided by mass media, which has raised public awareness regarding Kamalam fruit cultivation, as well as its diverse health benefits and nutritional qualities. Crop management and multiple cropping schemes integrating Kamalam fruit to other crops in location-specific areas are still unavailable. Research and development activities on Kamalam fruit production were initiated at IIHR, Bengaluru. Karunakaran and Arivalagan 2019); however, despite its growing importance, there remains a dearth of comprehensive information on the production aspects of Kamalam fruit (Karunakaran and Arivalagan, 2019). This review endeavors to bridge this knowledge gap by offering insights into the cultivation, nutritional values, and health benefits of Kamalam fruit based on recent philanthropic efforts and research findings.

AN OVERVIEW OF KAMALAM FRUIT PLANT MORPHOLOGY

The Kamalam fruit plant, scientifically known as *Hylocereus* spp., is a remarkable and fast-growing evergreen cactus that possesses distinctive features. This cactus can reach a height of 1.5–2.5 m, sporting slender, leafless, and vine-like branches. It exhibits a fascinating duality by thriving as both a terrestrial and epiphytic cactus, boasting succulent

achieve remarkable results by adhering to a set of guidelines and techniques, ultimately contributing to higher yields and the best quality fruit. Fertilization for Fruitful Growth: To ensure vigorous growth and bountiful fruit production, it is recommended to provide each Kamalam fruit plant pit with specific quantities of key nutrients. This includes 40 kg of cow dung, 50 g of urea, 100 g of TSP (triple superphosphate), 100 g of MoP (muriate of potash), 100 g of gypsum, and 10 g of borax per plant (Rahim *et al.,* 2009). This nutrient regimen is crucial for fostering a thriving Kamalam fruit plant.

Structural support and irrigation

Kamalam fruit plants require sturdy vertical supports to hold their vines upward. A pillar with a frame attached at the top allows the plant to hang down, optimizing space and sunlight exposure. Regular irrigation is vital to build sufficient reserves and ensure the successful development of fruits. Under-tree sprinklers with a 1–1.5-m-diameter wetting area are suitable for concentrating water into the root zone (Perween *et al*., 2018).

Optimal harvest timing

Knowing the right time to harvest Kamalam fruit is crucial. It typically takes 28–30 days for Kamalam fruit to mature after flowering (To *et al*., 2002). The variety of Kamalam fruit and its flowering time have a significant influence on its physio-morphological traits (Mallik *et al*., 2018). For optimal fruit production, flower bud emergence typically occurs after 15–17 months of planting, with 28 days required for blooming. Ripened fruits can be harvested between 30 and 50 days after pollination (Nerd *et al*., 1999; Pushpakumara *et al*., 2005). Longevity and Preservation: Kamalam fruit plants are long-lived and can bear fruit for up to 25–30 years. In Bangladesh, they yield fruit between May and November each year, and the fruit can be preserved for at least 2 months. The best quality fruits are large, often exceeding 400 g and, in some cases, reaching up to 500 g in weight.

Variety matters

The choice of Kamalam fruit variety can significantly impact the outcome. For instance, the BAU Kamalam fruit-2 variety has displayed superior performance in terms of physio-morphological and chemical characteristics compared to BAU Kamalam fruit-1 (Mallik *et al*., 2018).

Post-harvest considerations

Kamalam fruit exhibits minimal changes in color, flavor, odor, total soluble solids (TSS), and pH during the first 4 months of storage at ambient temperatures (27–34°C), with only slight changes in pH observed after the 4th month (Islam *et al*., 2012). It is important to note that the fruit typically changes its peel color from green to red at the mature stage. The color of the fruit pulp varies depending on the variety, with some having red pulp and others white (Patwary *et al*., 2013).

Income generation and modern farming practices

Kamalam fruit is considered an attractive crop for income generation due to its early yielding ability (Thokchom *et al*., 2019). Adopting the latest farming management practices can significantly enhance the benefits for Kamalam fruit growers, further strengthening its appeal in the agricultural landscape.

In conclusion, Kamalam fruit cultivation represents a promising avenue for agricultural prosperity when guided by the right combination of fertilization, structural support, timing, variety selection, and post-harvest management practices. This versatile and nutritious fruit has the potential to serve as an economic boon for growers willing to embrace modern techniques and practices.

POTENTIAL PESTS AND DISEASES IN DRAGON FRUIT CULTIVATION

Kamalam fruit is a relatively low-maintenance crop with a natural resistance to many pests and diseases. Common insects such as ants, scale insects, and mealy bugs can be managed through the application of standard insecticides.

In India, Kamalam fruit cultivation is generally tolerant to major pests and diseases. However, there are a few noteworthy diseases that can affect the crop.

Anthracnose

This disease has been reported in India, specifically in the Andaman Islands, caused by the fungus *Colletotrichum siamense*. Symptoms include reddish or orangish-brown concentric lesions with ascervuli (black-colored pinheads). These lesions typically start near the ribs of the vine, often at points where spines emerge from the edge, and can also affect the fruit. Prevention involves regular sprays with chlorothalonil or mancozeb as a preventive measure and carbendazim for curative treatment.

Wilt disease

Some observations suggest the presence of wilt disease caused by *Fusarium* species. Symptoms include wilting and loss of turgidity.

Rotting diseases

Rotting diseases can be caused by various species of *Alternaria*, *Bipolaris*, *Rhizopus*, and *Dothirella*, although they have not been reported in India thus far.

Bacterial rot

Bacterial rot can be caused by *Xanthomonas campestris* and *Erwinia carotovora*. Excessive exposure to light, sunburn, and calcium deficiency can exacerbate the disease. Copper oxychloride, when applied at 0.2%, can be used to manage this bacterial rot.

It is worth noting that while there are reports of fruit flies, such as *Anastrepha* species, there is no recorded presence of this pest in India.

In summary, while dragon fruit is generally robust against many pests and diseases, it is essential for growers to monitor for potential issues such as anthracnose, wilt disease, rotting diseases, and bacterial rot. Appropriate preventive and curative measures can help ensure the health and vitality of dragon fruit crops in India Abirami *et al.* (2019).

KAMALAM FRUIT NUTRITIONAL INFORMATION: A CLOSER LOOK AT ITS HEALTH BENEFITS

The nutritional value of Kamalam fruit, also known as pitaya, is influenced by various factors, including the species, origin, and harvesting time, making it a fascinating subject of study (Liaotrakoon, 2013). Furthermore, the nutritional composition and phytochemical properties of red Kamalam fruit can significantly differ due to environmental conditions during growth (Nurul and Asmah, 2014). This variation in nutritional content adds to the intrigue surrounding this exotic fruit. Kamalam fruit stands out for its abundant mineral content, with substantial amounts of potassium, phosphorus, sodium, and magnesium. These levels surpass those found in other tropical fruits such as mangosteen, mango, and pineapple (Gunasena *et al*., 2007; Stintzing *et al*., 2003; To *et al*., 1999). It also boasts an impressive array of vitamins (Choo and Yong, 2011). The timing of flowering and fruit setting plays a pivotal role in determining the quality of Kamalam fruits, particularly their TSS contents (Mallik *et al*., 2018). Mature Kamalam fruits are known to have higher TSS, with autumn fruits containing more than their summer counterparts (Nomura *et al*., 2005). Kamalam fruit is a nutritional powerhouse, providing an array of essential nutrients. It is rich in minerals, glucose, fructose, dietary fiber, and vitamins (Rao and Sasanka, 2015). Notably, it is celebrated for its abundance of Vitamin C, phosphorus, and calcium, in addition to its antioxidant content (Morton, 1987). Fresh Kamalam fruit typically contains 82.5–83.0% moisture, 0.16–0.23% protein, and 0.21–0.61% fat. It also provides 0.7–0.9% dietary fiber. In every 100 g of fresh fruit pulp, you can find 6.3–8.8 mg of calcium, 30.2–36.1 mg of phosphorus, 0.5–0.61 mg of iron, and 8–9 mg of Vitamin C (TFIDRA, 2005). Betalains

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Table 1: Kamalam Fruit's Antioxidant Compounds and Essential Minerals: Their Health-Boosting Functions

Components	Amount	Functions
Flavonoids	Red-fleshed: 46.29±2.47 mg RE/100 g FW White-fleshed: 26.71±4.46 mg RE/100 g FW (Senadheera and Abeysinghe, 2015)	Flavonoids act on brain cells and blood vessels to reduce the risk of heart diseases (Verma *et al*., 2017). They minimize heart diseases and help maintain blood pressure (Patel and Ishnava, 2019).
Betalains	42.71±2.48 mg/100 g fresh pulp (Rodriguez *et al*., 2015)	Betalains combat oxidative stress, possess potential cancer-suppressing abilities, aid in weight loss, improve digestion, reduce LDL cholesterol in the blood, and strengthen the immune system (Verma *et al*., 2017).
Hydroxycinnamates	Minor amounts of hydroxycinnamic acids (Mahattanatawee *et al*., 2006)	Hydroxycinnamates help prevent cancer (Verma *et al*., 2017).
Carotenoids (Beta-carotene)	1.4 mg/100 g (Charoensiri *et al*., 2009)	Carotenoids, specifically beta-carotene, reduce the risk of cancer and cardiovascular diseases (Aghajanpour *et al*., 2017).
Lycopene	3.4 mg/100 g (Charoensiri *et al*., 2009)	Lycopene inhibits the growth of various human cancer cell lines (Levy *et al*., 1995).
Linoleic Acid and Linolenic Acid	Seeds are rich in these essential fatty acids (Sonawane, 2017)	Kamalam fruit seeds contain high levels of polyunsaturated fats, specifically omega-3 and omega-6 fatty acids, which reduce triglycerides and lower the risk of cardiovascular disorders (Sonawane, 2017).
Vitamin C	White-fleshed: 31.11±3.85 mg/100 g FW Red-fleshed: 20.00±1.33 mg/100 g FW (Senadheera and Abeysinghe, 2015)	Regular consumption of Kamalam fruit, rich in Vitamin C, aids in fighting cough and asthma, accelerates wound healing, enhances the immune system, and stimulates other antioxidants in the body (Cheah *et al*., 2016, Duarte and Lunec, 2005).
Phosphorus (P) and Calcium (Ca)	P 22.5 mg/100g and Ca 8.5 mg/100 g Thokchom *et al*., 2019)	Kamalam fruit's high levels of phosphorus and calcium reinforce bones, play a crucial role in tissue formation, and contribute to healthy teeth (Choo and Yong, 2011).
Iron	1.9 mg/100 g (Thokchom *et al*., 2019)	Red Kamalam fruit's iron content increases hemoglobin and erythrocyte levels in pregnant women (Nurliyana *et al*., 2010).

in Red Kamalam Fruit: The red-fleshed Kamalam fruit variety is especially noteworthy for its high Betalain content. This feature aligns with the growing demand for antioxidant products and natural food colorants (Perween *et al*., 2018). The red layer of Kamalam fruit, a visually striking part of the fruit, serves as a veritable reservoir of essential vitamins, including B1, B2, B3, and C, alongside an array of valuable minerals (Le Bellec *et al*., 2006). Beyond its vibrant appearance, this layer contributes significantly to the fruit's nutritional value. Kamalam fruit stands out for its relatively high antioxidant activity when compared to other subtropical fruits (Davis, 2007). This attribute makes it a favorable choice for those seeking to boost their antioxidant intake, which is known for its potential health benefits. The Kamalam fruit is a nutritional powerhouse, offering an impressive range of nutrients, including Vitamin B1, B2, B3, and C. It is also known for its high fiber content and a mineral trio comprising calcium (Ca), iron (Fe), and phosphorus (P). In addition, it is noteworthy for its minimal carbohydrate content and the absence of fats (Sonawane, 2017). The seeds of Kamalam fruit are not to be overlooked, as they contain approximately 50% of essential fatty acids, particularly linoleic acid and linolenic acid. These fatty acids are vital for various physiological functions (Sonawane, 2017). Interestingly, the premature stems of the Kamalam fruit are found to have higher levels of ascorbic acid (Vitamin C) in comparison to the fruit flesh. This elevated ascorbic acid content may play a role in preventing conditions such as scurvy, anemia, and weakness (Jaafar *et al*., 2009). It underscores the value of the entire plant in terms of nutritional benefits. Kamalam fruit could be a substantial source of pectin in fruit production (Tang *et al*., 2011). Pectin is a versatile natural substance used in various food products as a thickener, particularly in low-viscosity foods and beverages (Nur Izalin *et al*., 2016). This pectin source offers a unique dimension to the fruit's utility in the food industry. Kamalam fruits are recognized worldwide for their high content of polyphenolic components and their associated antioxidant properties. These compounds play a vital role in maintaining overall health and wellness (Ortiz-Hernández and Carrillo-Salazar, 2012). The extracts from both the pulp and peel of Kamalam fruit harbor phytochemical compounds with antimicrobial activity, underscoring their potential as natural antioxidants (Patel and Ishnava, 2019). These findings reinforce the notion that Kamalam fruit is not only nutritious but also possesses functional properties that can contribute to overall well-being.

THE IMPACT OF CONSUMING KAMALAM FRUIT: UNLOCKING THE NUTRITIONAL AND HEALTH BENEFITS

The worldwide surge in the popularity of fruits can be attributed to their captivating hues and their delightful, sweet, and juicy flavors (Minh *et al*., 2019). Among these fruits, Kamalam fruit stands out, not just for its delectable taste but also for its versatility in culinary and non-culinary applications. Kamalam fruit is best savored in its raw, fresh, or dried form, offering a burst of flavor and nutrition (Sonawane, 2017). Its vibrant hues have even made it a sought-after natural coloring agent in a wide array of beverages, giving them a visually appealing twist. Kamalam fruit is not limited to one culinary role; it plays multiple parts in the global culinary scene. It is not just a fruit but also a vegetable. The fruit, as well as its young stems, can be consumed as vegetables. In addition, dried Kamalam fruit components find their place in local medicinal practices. In Taiwan, dried Kamalam fruit flowers are an essential part of the cuisine and are consumed as vegetables. Moreover, Kamalam fruit can take on diverse culinary forms, such as juices, jams, preserves, and more, to cater to various tastes (Perween *et al.,* 2018). Both fresh and dried Kamalam fruit skins are remarkable for their pectin and Betalain content. This makes them valuable natural food thickeners and coloring agents, adding both substance and visual appeal to a variety of culinary creations (Sonawane, 2017). The culinary possibilities with Kamalam fruit are endless. Its juicy and flavorful flesh can be enjoyed as a raw fruit or processed into delectable treats such as ice cream, cookies, candies, and jam. It even finds its way into the world of beverages, featuring in shakes and special drinks. Moreover, it imparts its unique flavor to various recipes. The Kamalam fruit flower, often overlooked, is put to use in soups, lumpia, and Filipino viands, enhancing the taste and nutritional value of these dishes. The skin pulps of Kamalam fruit are transformed into embotido, pickles, jams, and even cleansing drinks. Such diverse culinary applications make Kamalam fruit a culinary gem (Pascua *et al*., 2015). The utility of Kamalam fruit transcends the kitchen. Its stems and skin pulps can be harnessed for beauty purposes, processed into invigorating soaps. This multifunctional approach to Kamalam fruit underscores its versatility and potential in various aspects of life (Pascua *et al*., 2015).

THE HEALTHFUL BOUNTY OF KAMALAM FRUIT: UNVEILING ITS NUTRITIONAL AND WELLNESS ADVANTAGES

As previously discussed, Kamalam fruit is a powerhouse of essential nutrients, including vitamins, minerals, complex carbohydrates, dietary fibers, and antioxidants. Its remarkable health benefits extend to promoting the growth of beneficial gut bacteria and harnessing the power of Betacyanin, a red or purple pigment known for its antioxidative properties (Liaotrakoon, 2013). Kamalam fruit is a boon for those seeking a health-conscious diet. It is low in calories and devoid of cholesterol, making it an ideal choice for those looking to maintain cardiovascular health and regulate blood pressure (Patel and Ishnava, 2019). One of Kamalam fruit's unique qualities is its capacity to promote the growth of healthy gut bacteria. Studies have shown that the fruit is rich in polysaccharides (Xu *et al*., 2016) and mixed oligosaccharides (Wichienchot *et al*., 2010), both of which act as stimulants for the growth of *Lactobacilli* and *Bifidobacteria*. These probiotic microorganisms play a crucial role in maintaining a healthy gastrointestinal system by suppressing the growth of harmful pathogens. In this sense, Kamalam fruit is not just a fruit but a natural probiotic (Sonawane, 2017). The juicy pulp of Kamalam fruit, adorned with numerous small black seeds, is a treasure trove of micronutrients and antioxidants (To *et al*., 1999; Mahattanatawee *et al*., 2006; Lim *et al*., 2007; Ariffin *et al*., 2009; Jaafar *et al*., 2009; Lim *et al*., 2010). These micronutrients and antioxidants play a vital role in supporting overall health and wellness. In essence, Kamalam fruit goes beyond its vibrant appearance and sweet taste. It is a nutritional ally that offers an array of health benefits, from promoting gut health to bolstering cardiovascular well-being and providing essential micronutrients. This multifaceted fruit is not just a culinary delight but a true asset to a balanced and health-conscious lifestyle.

Kamalam fruit, also known as pitaya, is a remarkable fruit that offers a multitude of health benefits. Its consumption has been associated with various positive effects on physical and mental health. Let's delve into the extensive array of advantages provided by this exotic fruit: Kamalam fruit promotes the healing of wounds and cuts, which can be attributed to its rich Vitamin C content. It accelerates the regeneration of damaged tissues, aiding in faster recovery. In additiom, it is known to improve appetite, eyesight, and memory, contributing to overall well-being (Rao and Sasanka, 2015). The fruit possesses properties that may retard the aging process (Lim *et al*., 2012; Zhuang *et al*., 2012). Kamalam fruit has been linked to cancer prevention (Yusof *et al*., 2012) and is believed to have positive effects on metabolism, digestion, the immune system, vision, and oxidative stress. It may help in managing diabetes and cardiovascular diseases, strengthening the immune system, and improving blood circulation. Kamalam fruit is packed with nutrients, including Vitamin C, phosphorus, calcium, fiber, and antioxidants. These components play a role in controlling diabetes and lowering cholesterol levels. The high iron content in red Kamalam fruit can increase hemoglobin levels in pregnant women (Nurliyana *et al*., 2010). Kamalam fruit peel contains pectins and betalains, making it a natural food thickener and coloring agent. Its use in creating "Kamalam Fruit Coloring Powder" (DFCP) is an innovative approach that preserves the fruit's natural benefits and can be employed in various culinary applications. Kamalam fruit seeds are rich in polyunsaturated fats, including omega-3 and omega-6 fatty acids, which help reduce triglycerides and lower the risk of cardiovascular disorders (Sonawane, 2017). The fruit's high phosphorus and calcium levels reinforce bones, support tissue formation, and contribute to healthy teeth (Choo and Yong, 2011). The abundance of Vitamin C in Kamalam fruit enhances the immune system and stimulates the activity of other antioxidants in the body. The polyphenolic compounds in Kamalam fruit act as excellent antioxidants, protecting human health and playing a role in disease prevention (Barros *et al*., 2015). The fruit's bioactive compounds boost immunity and improve physical and mental health (Jeronimo *et al.*, 2017).

CONCLUSION

This review paper aims to introduce the cultivation of Kamalam fruit in new geographical areas while considering its significance in terms of food production and economic value. Kamalam fruit, celebrated for its adaptability and global popularity, has gained recognition due to its nutritional richness and associated health benefits. This fruit can be cultivated year-round in subtropical and tropical regions, provided the soil is well-drained, ranging from moderately loose to slightly heavy in texture. Kamalam fruit is a valuable source of essential minerals, glucose, fructose, dietary fiber, and vitamins, which synergistically contribute to fortifying the human immune system. The flowering and fruit setting of Kamalam fruit are profoundly influenced by various environmental factors. Furthermore, the nutritional content of Kamalam fruit can vary depending on factors such as the species, cultivation area, and time of harvest. One intriguing potential application of Kamalam fruit lies in its peel, which holds promise as a natural dye. With the ongoing surge in its consumption, the fruit has a promising outlook in the global market. To tap into its full potential, it is crucial to intensify and extend research efforts, with a particular emphasis on understanding the value chain and optimizing production aspects for a sustainable and long-term perspective.

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