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A review on jackfruit and its by-products

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Abstract
The jackfruit, or *Artocarpus heterophyllus* Lam., is a tropical fruit from India's Western Ghats that is also widely grown in Asia, Africa, and some parts of South America. It is a member of the Moraceae family and is native to tropical climates. It is well known that it is the world's largest edible fruit. The jackfruit is full of vitamins, minerals, phytochemicals, carbs, proteins, and other nutrients. The jackfruit's meat and seeds are both eaten in curries and other cooked forms, but when the meat is fully ripe, it can be eaten like a fruit. Using pureed jackfruit, several nations have created a variety of food items, including jams, jellies, marmalades, and ice creams. Due to the jack tree's anticarcinogenic, antibacterial, antifungal, anti-inflammatory, wound-healing, and hypoglycemic properties, several of its parts, including fruits, leaves, and bark, have been extensively used in traditional medicine. However, despite all these advantages, commercial scale processing of the fruit is not utilised in the developing regions. The goal of this review's conclusion is to spread awareness of the jackfruit's nutritional and health benefits in order to promote its use in commercial food production.

Keywords: Jackfruit, physical properties, jackfruit powder, seeds

Introduction
The tropical fruit known as the jackfruit (*Artocarpus heterophyllus* Lam) is a member of the Moraceae family. It is native to the Western Ghats of India and is widely cultivated in Asia, Africa, and some regions of South America. (Ranasinghe *et al.*, 2019) [1]. About 25.71 t/ha of jackfruit are produced annually (Loizzo *et al*., 2010) [2]. Both the tree's main branch and its side branches bear fruit (Mushumbusi *et al*., 2015) [3]. Jackfruit constitute of 3major components: pulp (30- 32%), seeds (18%), and rind (5-55%).
Golden-yellow pulp is arranged in fleshy bulbs that account for 30–35% of the fruit's weight and each include a single seed inside (Swami *et al*. 2014) [4]. In addition to its pulp, the jackfruit's under-utilized sections like the seed and rind have been said to contain great nutritional qualities. Nutrients such as starch and dietary fiber are observed to be abundant in jackfruit seed and makeup to 22 & 3.19 percent of it. The major protein in jackfruit seed is jacalin which possesses immunological properties. Apart from that, jackfruit seed is said to be a rich source of lignins, isoflavones, saponins, all phytonutrients, and their health benefits are wide ranging from anti-cancer to antihypertensive, anti-aging, antioxidants, anti-ulcer and so on (Swami *et al*., 2012) [5]. Pectin is abundant in the slimy coating of jackfruit seeds, which has high antioxidant and phenolic characteristics (Kumar M *et al*., 2021) [6] its seed flour can result in culinary products with enhanced value (Kushwaha R *et al*., 2021) [7].
The strongest antioxidant ability is seen in jackfruit axis extract, which is more effective than vitamin C at preventing cytotoxicity brought on by alcohol. Through its phytonutrients, such as carotenoids, jackfruit demonstrates antioxidative action and protects tissues from oxidative damage (Ranasinghe *et al*., 2019) [1].
Perianth and seeds of jackfruit contains a high starch content, and the amount of dietary fiber and flesh varies with maturity, according to several chemical and histological investigations (Ranasinghe *et al*., 2019; Jagdale *et al*., 2021) [1, 8]. In addition to this, Jackfruit's rind also possesses antioxidant properties. Jackfruit's rind extracts are observed to contain more polyphenols and flavonoids compared to that of its spine and skin. Additionally, it was discovered that its rind had a higher polyphenol concentration than the fruit peels of pineapple, pomegranate, and orange. There are no changes in jackfruit fibre content according to the stage of ripeness; it ranges from 0.33 to 0.4% (Amadi *et al*., 2018) [9]. A study found that the fibre content of immature and ripe jackfruits was 2.6% and 0.8%, respectively.
The importance that nutrition plays in the prevention and treatment of many illnesses has gained widespread acceptance, and consumers, food industry and researchers have all shown

an increased interest in recent years in how food products might assist sustain health. This review's objective was to provide a summary of the jackfruit's physiological, therapeutic, and functional characteristics.

Nutritional composition

The jackfruit is a rich source of several high-value compounds that could have beneficial physiological effects. It is known for having anti-inflammatory, anti-bacterial, anti-antidiabetic, and antioxidant effects. The jackfruit tree yields the largest oval shaped-cylindrical edible ellipsoid shape, measuring 1-2 cm in diameter and 2-3 cm long, with a thin, white cotyledon coating with a light brown exterior layer. The ripe fruit bulbs are consumed in huge quantities; the seeds, on the other hand, are used occasionally as dessert, as minor ingredients in recipes, or as a snack after boiling, steaming, or roasting. Seeds are typically left untreated or thrown away as trash because of their unappealing flavour and texture.

The rind of the jackfruit has antioxidant qualities as well. Jackfruit rind extracts contain more polyphenols and flavonoids than extracts from the fruit's skin or spine. More polyphenols were also discovered in its skin compared to the fruit peels of orange, pomegranate, and pineapple. Amino acids present in jackfruit include cystine, arginine, leucine, histidine, lysine, threonine, methionine, and tryptophan (Khan *et al*., 2021; Haleel *et al*., 2018) [10, 11]. According to the level of maturity, the amount of fibre in jackfruit remains constant and can vary from 0.33 to 0.4% (Amadi *et al*., 2018) [9]. According to a study, ripe and immature jackfruits had fibre contents of 2.6% and 0.8%, respectively. Consumers, researchers, and the food industry have all recently demonstrated an increased interest in how food products might assist in sustaining health as the role that nutrition plays a role in the prevention and treatment of many illnesses and gained widespread acceptance (Vinuda-Martos and others 2010) [12]

Jackfruit bulbs

Jackfruit is hefty and dense and about 20% to 25% of its edible portions, or bulbs are really recovered. The edible section of Jackfruit which ranges from 20% to 25% of the overall weight and mass, is easily digestible but is also hefty and thick. Around 13.7 mg of vitamin C and 95 calories, making it a good source of antioxidants.

The fruits are also agg od source of potassium, calcium, iron, and vitamin B6. Ripe jackfruit' bulb is used in FRUI salads and eaten raw. It has a high nutritional value, 100 g of ripe fruit pulp includes 84 calories, 20 mg of calcium, 30 mg of phosphorus, 500 mg of iron, 540 IU of vitamin A, 30 mg of thiamine, 1.9 g of protein, 0.1 g of fat, 77% moisture, 1.1g of fibre, and 0.8 g of total mineral matter. The bulbs of the jackfruit contains beta- carotene which is necessacry antioxidant for human health (Shedge *et al*., 2022) [13]

Composition of jackfruit bulb; (100 g edible portion)

Composition				
Carbohydrates (g)	16.0- 25.4	18.9	7.74	9.4 - 11.5
Protein (%)	1.2-1.9	1.9g	10.6	2.0- 2.6
Fat(g)	0.1-0.4	0.1g	1.49	0.1- 0.6
Fiber(g)	1.0-1.5	1,1g	3.01	2.6- 3.6

Minerals and vitamins

Composition (mg)				
Calcium	20.0-37.0	20	0.03	30.0- 73.2
Magnesium	27.0	-	-	-
Phosphorus	38.0-41.0	30	-	20.- 57.2
Iron	0.5-1.1	500	21.50	0.4- 1.9
Vitamin C	7.0- 10.0	-	2.10	12.0- 14.0

(Shedge *et al*., 2022) [14], (Amadi *et al*., 2018) [9]

Jackfruit seed:

The jackfruit seeds, which constitute 10-12% of the weight of the fruit overall, which are rich in protein and carbohydrates. Every fruit contains 100 to 500 seeds. Seeds typically utilised in some regional cuisine or discarded, then steamed and consumed as a snack. Fresh seeds cannot be stored for an extended period of time; however, seed flour can be used as an alternative product in few food preparations. The jackfruit seeds include a healthy amount of dietary fiber (3.19%) and carbohydrates (22%) (Shedge *et al*., 2022) [14].

Composition of jackfruit seed; (100 g of edible portion)

Composition				
Carbohydrates	25.8-38.4	7.89	38.4	30.84
Protein	6.6 - 7.04	10.09	606	11.83
Fat	0.40 - 0.43	4.29	0.4	0.49
Fiber	1.0 - 1.5	3.92	1.5	0.94

Minerals and vitamins

Composition (mg)		
Calcium	50.5	0.03
Magnesium	54.0	-
Phosphorus	38.0-97.0	-
Iron	1.5	21.50
Vitamin C	11.0	2.10

(Gupta *et al*., 2011) [15], (Thatsanasuwan *et al*., 2022) [16]

Bioactive components and health benefits of jackfruit

Fruits can be eaten at all stages of growth as it can be baked, roasted, fried or steamed. The seed is also cooked and used for cooking. The bark and leaves are excellent cattle feed. The tree provides food, fodder, fuel wood, timber and 70% of timber, 90% of fuel wood and 48% sawn (Khan *et al*., 2020) [17].

The jackfruit has been used as traditional medicines. The plant has been used as anti-bacterial, anti-diabetic, antioxidant, anti-inflammatory (Hwang *et al*., 2017) [18]. It is

major source of carbohydrates, minerals and vitamins (Deivanai *et al*., 2010) [19]. The fruit contains lignins, flavones and saponins which have the properties of anti-aging (Gapasin *et al*., 2014) [20]

Bioactive components and health benefits of jackfruit

Bioactive compounds	Health benefits
Phytonutrients- Lignans, isoflavones, niacin & saponins	Cancer, Hypertensive, Ulcer, Aging, Nerve function, Asthma
Phenolic Compounds	Chronic diseases, hyperglycaemia
Antioxidants- Vit E, C, A, beta-carotene, selenium, alpha-lipoid acid and glutathione.	Coronary heart disease, Hypertension, Lungs & Prostate cancer.
Carotenoid- All-trans- beta, alpha, lutein, neoxanthin, 9-cis- violaxanthin carotene	Inflammation, cardiovascular diseases, cataract, age-related macular degeneration

(Swami *et al*., 2018) [21]

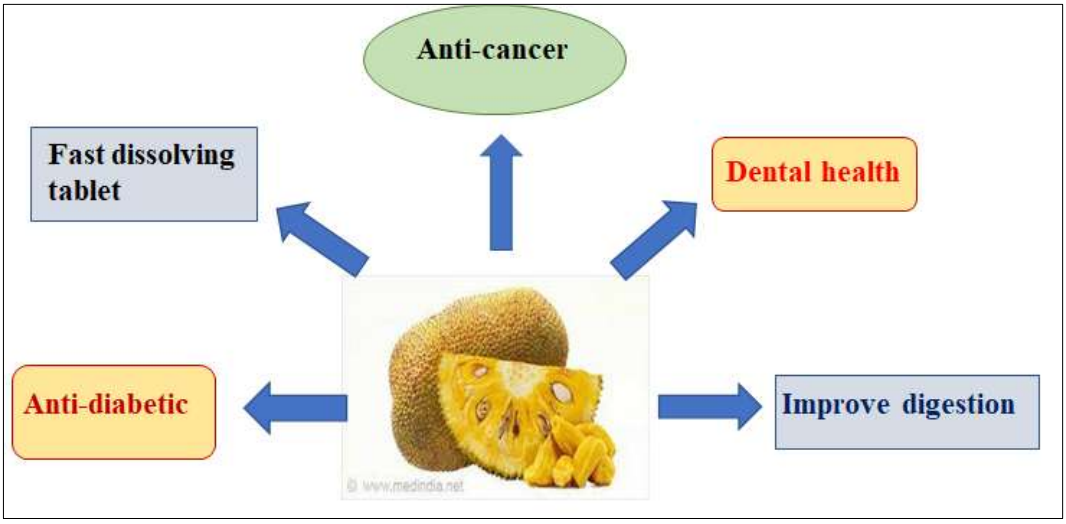

Fig 1: Health benefits of jackfruit

Anticancer

Recent studies have demonstrated the anticancer benefits of all phytonutrients found in jackfruit bulbs. These nutrients' primary function is to fend off dangerous free radicals, which have been linked to the development of cancer and numerous other serious disorders. The phytonutrients stop the creation of cancer cells from their very beginning. Additionally effective anticancer agents, saponins. A study found that saponins had the ability to prevent colon cancer. In the case of leukaemia cells, it has been discovered that these phytonutrients promote mitotic arrest. The study also discovered that it occasionally assisted in bringing about remission. According to Oktavia *et al*. (2017) [22], saponins have been observed to react with cancer cells' outer coats.

Isoflavones and lignans are two significant categories of phytoestrogens found in jackfruit pulp (Swami *et al*., 2012) [23]. These vitamins and minerals assist in lowering the risk of endometrial cancer. Fibre is abundant in jackfruit. Moreover, it has a distinct sticky form. These two qualities come together to make a powerful colon cleanser. It aids in cleansing your digestive system of impurities. Additionally, this lowers the risk of colon cancer.

Dental Health

When tested for antibacterial and antifungal capabilities, the jackfruit latex extracts, which are high in flavonoids and alkaloids, performed rather well and much better than typical antibacterial and antifungal medications. They came to the conclusion that this information reveals a number of significant uses of jackfruit latex or resin, or both, which can be used as a cementing medium, irrigation solution (washing a wound or cavity by a stream), denture cleaning solution, resin, and other potentially cost-effective dental filling material (Rao *et al*., 2014) [24].

Improve Digestion

High fibre content (3.6 g/100 g) found in jackfruit helps with smooth bowel movements and prevents constipation. By eliminating or driving away the carcinogenic, these fibres also provide protection for the colon mucosal membrane (Shedge *et al*., 2022) [13].

Antidiabetics

Hyperglycemia, a metabolic condition caused by abnormalities in insulin action, secretion, or both, characterises diabetes mellitus. kind 2 diabetes mellitus is the most prevalent kind of the condition, accounting for 85–95% of all cases and posing a serious public health issue (Cheplick *et al*., 2010) [25].

Fast-Dissolving Tablet

The main carbohydrate that plants use for storage is starch. Worldwide, more than 66.5 million tonnes of starch are produced each year. The starch and protein content of the cotyledons of the jackfruit seed is average. The starches derived from jackfruit seeds are utilised as super disintegrates when creating fast dissolving tablets, or FDT. According to the Food and Drug Administration (FDA), FDT formulations are "a solid dosage form from containing medical substance which disintegrates rapidly, typically within a second, when place upon tounge." Jackfruit can be viewed as a functional fruit since it has useful chemicals with functional and

therapeutic benefits in many regions of the fruit (Shedge *et al*., 2022) [13].

Product developments

Ripe jackfruit products

The by-products of jackfruit have a broad range of possible applications in the food industry. They are used in foods like bread, biscuits, cakes, cookies, and ice creams to boost the nutritional value of the items. Additionally, the by-products of jackfruit are used to extract useful molecules. Babu (2017) [26] discovered that the oil of jackfruit seeds was rich in linoleic and alpha-linolenic acids, two important fatty acids. Jackfruit seed flour has a lot of protein, per studies on its nutritional properties (Abedin *et al*., 2012) [27].

Starch of jackfruit seed contains a higher proportion of amylose, it could be used in place of modified starch. Jackfruit seeds have a high concentration of saponins and phytochemicals. Jackfruit seeds can be used as a medicine and pharmaceutical plant-based product since they have a high flavonoid concentration and reduction potential (Shanmugapriya *et al*., 2011) [28]. The sensory panel approved of dinner wine made from jackfruit byproducts including seed coat, pith, rags, peel and overripe pulp. After only two weeks of unrest, there is a good chance that wine-related accessories will arrive. Low-glycemic diets are frequently advised to the general populace and provide therapeutic benefits for diabetic individuals. Using jackfruit seeds in place of cocoa powder to create a low-glycaemic-index diet chocolate and get the positive outcomes. Meat alternative that is healthful using jackfruit by-products. Seed powder, cloths, and rinses were used. The produced meat analogue's nutritional makeup revealed high levels of protein and dietary fibre. According to research on the textural characteristics of meat analogues, chewiness and hardness significantly decreased as wheat gluten level was reduced (Hamid *et al*., 2020) [29].

Babu (2017) [26] conducted study on the traditional milling method of extracting oil from jackfruit seeds. It took about 6kg of the seeds to produce 2L of oil. He claimed that linoleic acid and alpha-linolenic acid, two essential fatty acids, were abundant in the oil of jackfruit seeds. They calculated the oil from jackfruit seeds to have 1.35g/100g free fatty acids.

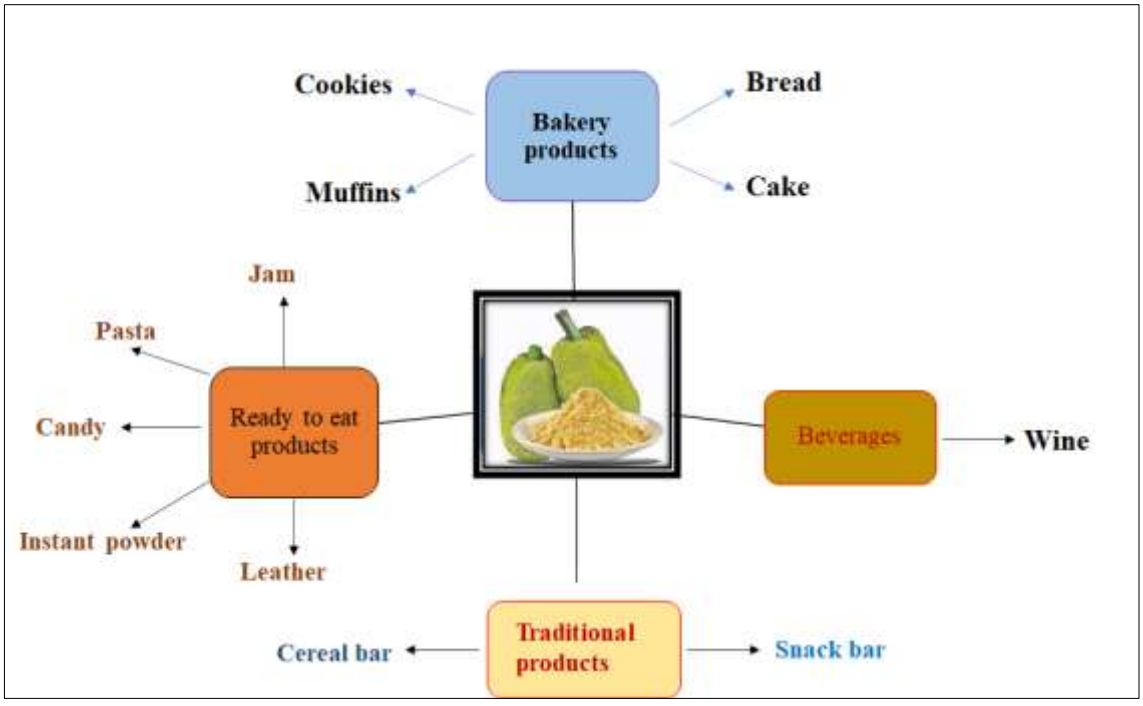

Fig 2: Utilization of Jackfruit and its by-products for development of food products

Preparation of products using jackfruit seeds and pulp:

Bakery product

In order to effectively distribute powerful ingredients with health advantages to people, bakery products are a good option. Recent research has shown that a variety of bakery goods, including biscuits, cookies, cakes, and muffins, have been created by adding jackfruit seed flour at varying quantities (Islam *et al*., 2015; Arpit & John, 2015; Siti Faridah & Noor Aziah, 2012) [[30], 31, 32].

Table 1: Baked products prepared by Jackfruit seed fortification in different forms and at different concentrations

Product	Amount of Supplementation (%)	Outcome	Reference
Bread	25	Increased crude fiber content	Butool & Butool (2015) [13]
Bread	25	Nutritionally higher carbohydrate, fat, protein, and crude fiber content	Hossain (2014) [14]
Biscuit	20	swelling power, percent solubility, flour dispersibility and viscosity	Butool & Butool (2015) [13]
Biscuit	10-40	Moisture, fat, crude fiber and ash content increased	Islam *et al*., (2015) [30]
Cake	5-15	Increase in protein and reduction in fat content	Arpit &John (2015) [31]
Cake	10-30	Better crumb, texture and nutritional characteristics	Khan *et al*., (2016)
Muffins	10-20	Specific gravity increased and viscosity decreased	Siti Faridah & Noor Aziah (2012) [32]

Bread and biscuits

The availability of jackfruit seed flour and its considerable nutritional and practical value have caught the interest of scientists and bakeries. In order to make bread and biscuits, Butool and Butool (2015) [33] successfully added flour made from jackfruit seeds. The colour and texture of bread and biscuit formulations with 10% and 20% jackfruit seed flour added an outstanding eating quality.

The products' crude fiber content was boosted by the addition of jackfruit seed flour. Biscuits made with jackfruit seed flour had slightly higher ash and crude fiber levels but lower carbohydrate levels. Hossain *et al*. (2014) [34] experimented with different ratios of jackfruit seed flour to wheat flour to determine the ideal mixture for making bread. The breads contained 25%, 35%, 45%, and 55% of jackfruit seed flour, respectively. According to their findings, the bread that included 25% jackfruit seed flour as a replacement was the most palatable in terms of its nutritional content and general appeal.

Cake

Khan *et al*. (2016) made cake by replacing 10%, 20%, and 30% of the wheat flour with jackfruit seed flour. In comparison to the other cakes, the specific volume of the cake for the 20% substitution was larger. However, the cake with a 10% addition of jackfruit seeds to the flour was the most well-liked by the panel. Because jackfruit seed flour was used, the crust and crumb qualities differed (Faridah and Aziah, 2012; Arpit and John, 2015) [32, 31].

The jackfruit seed also gave rise to other pastry goods, including biscuits, muffins, masala vada, flour, and chapathi. Pectin, which was taken out of the rind, is another excellent source (Swami *et al*., 2012) [5].

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Traditional products

The processed food industry is growing more and more interested in developing new products in order to attract customers. Traditional snacks and other products are included in Table 2, including Karasev, Jamun, cereal bars, chocolate milkshakes, and chapatti improved with jackfruit seed flour. According to Santos *et al*. (2011) [36], cereal bars made with 30% and 40% jackfruit seed meal exhibited high fibre contents, better sensory qualities, and nutritional values that were comparable to those of other bars available for purchase.

Table 2: Other products prepared by jackfruit seed fortification in different forms and at different concentrations.

Product	Amount of supplementation	Outcome	References
Cereal bar	30 & 40	high fiber content, better sensorial characteristic	Santos *et al*., 2011 [36]
Cereal bar	15	Preserved hardness and crispness	Torres *et al*., 2011
Snack bar	35- 45	increased protein content	Meethal *et al*., 2017

(Waghmare *et al*., 2019) [37]

Ready to eat products

Jackfruit Jam

Jam can be made using the pulp from the fruit. A synthetic flavouring ingredient, such as ethyl or n-butyl ester of 4-hydroxybutyric acid at 100 and 120 ppm, will greatly enhance the flavour of jackfruit products (Technical Manual for Small-Scale Fruit Processors, 2004).

The risk of developing diabetes is raised by the large amount of sugar that is added to many other fruit jams sold in shops. Instead, jackfruit jam is a great food source for losing weight because it is high in natural sugars and low in calories (Swami *et al*., 2012) [5].

Instant powder

Hema (2015) [38] explored how jackfruit seeds and bulbs may be combined to create a nutrient-rich quick dried powder. According to the study, adding more jackfruit seed powder to the mix made the instant powder's protein content higher and its moisture content lower.

Jackfruit Candy

The jackfruit was split in two along its length. The pulp of the fruit was removed after the core was cut out. The pulp was separated from the seeds. A brine solution comprising 15% sodium chloride (150g/L) and 1% calcium chloride (10g/L) was used to soak the pulp for two days. In order to eliminate the salt, the pulp was taken out of the brine, drained, and then washed with water. It was stored at room temperature (28.30C) for 24 hours after being boiled in 140 brix sugar syrup for 5 minutes. The pulp was taken out of the syrup and dried in a tray dryer for roughly a day (24 hours). Cardboard cartons were used to package the Jackfruit candies.

Jackfruit leather

The leather is made from of dried jackfruit pulp sheets. It tastes sweet and has a soft, rubbery feel. It can also be produced from a combination of fruits, and the flavour can be altered by adding sugar, chopped nuts, or spices. In place of a boiled sweet, it can be consumed as a snack item. Additionally, it can be used as a component in the creation of desserts like cakes and ice cream (International Centre for Underutilized Crops, UK, 2004).

Preparation of Jackfruit Beverage / Drink

Wine

The riped jackfruit has a sizable amount of fermented sugar that can be used to make vinegar and wine for sale. Jack wine had a maximum alcohol percentage of 10% (v/v) and utilised 14% of the total sugar solids. These first findings indicate that this fruit has potential for application in the creation of commercial wines. For jackfruit to be used in the creation of jackfruit wine, it must be at a specific stage of maturity and ripeness (29 to 30 Brix).

The jackfruit wine may offer protection from antioxidant and DNA damage and may prove to be a valuable source of nutraceuticals with a high concentration of antioxidants. Additionally, the wine can be a useful by-product for the jackfruit growers from a business perspective.

Conclusion

A great source of vitamins, minerals, dietary fibre, phytochemicals, proteins, and other nutrients is tropical trees

like the jackfruit. Jackfruit has a wide range of health advantages, including, antibacterial, antifungal, anti-inflammatory, and hypoglycemic characteristics. It is believed that this fruit is underutilised on a commercial scale, primarily due to the fruit's high proportion of edible parts, which leads to waste generation, difficulty peeling and separating the edible bulb from the rind, ignorance of proper postharvest procedures, and a lack of processing facilities in the regions where they are grown. Therefore, according to proper postharvest practises and turning jackfruit into minimally processed products, like precut jackfruit, might get more people to eat jackfruit and may aid in waste management. Only a small number of recent studies have focused on expanding the shelf life of jackfruit and generating value from waste by converting it into other products and renewable energy sources. In order to determine possible industrial applications for jackfruit and to figure out how to handle the trash generated during jackfruit processing, more research is needed.

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