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From fruit to feast: Exploring pineapple-based food innovations

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Abstract

The pineapple, an emblem of exotic pleasure, traces its origins to South America, embarking on a remarkable evolution from a modest confection into a versatile ingredient cherished across a spectrum of goods. Spanning diverse tropical regions, pineapple cultivation underwent expansion, fostering its multifaceted development. In modern times, the pineapple's role transcended its initial incarnation. The advent of 19th century canning technology revolutionized consumption patterns, establishing canned pineapple as a household staple. This convenient option became a beloved addition to both sweet and savory dishes. The extraction of pineapple's natural enzyme, bromelain, renowned for its tenderizing and anti-inflammatory attributes. Consequently, pineapple extract found its way into dietary supplements, skincare commodities, and even culinary applications like meat tenderizers. Recent decades witnessed innovation thrusting the pineapple into fresh arenas. Its distinct taste and nutritional advantages inspired a plethora of beverages, ranging from juices and smoothies to cocktails. The culinary domain embraced dried pineapple as a portable, naturally sweet snack, an essential constituent of trail mixes and energy bars. A pioneering application is the use of pineapples as a foundational element in fermented goods, given their natural sugars and acids, rendering them ideal candidates for vinegar, sauces, and even alcoholic concoctions such as pineapple wine or spirits. Notably, the pineapple boasts an array of health benefits, nutritional value, and medicinal potential.

Keywords: Pineapple, antioxidants, alkaloids, flavonoids, bromelain

Introduction

Pineapple (*Ananas comosus* (L) Merr) is a highly significant fruit crop, celebrated for its exceptional flavor and often referred to as the "queen of fruits" (Baruwa *et al.*, 2013) ^[11]. With a maturation period of 18 to 22 months from planting, the pineapple (*Ananas comosus*) is a compound fruit renowned for its succulent juiciness and distinctive blend of sweet and sour tropical flavors. It stands out as a prominent member of the Bromeliaceae family, which boasts over 2,000 species, many of which exhibit epiphytic growth habits and captivating ornamental characteristics (Wood *et al.*, 1998) ^[43]. Bangladesh has designated the pineapple as its national fruit, and the country ranks fifth in terms of both output yield (4.6 million tons/acre) and cultivated area. Key growth regions within the nation include Sylhet, Tangail, Chittagong Hill Tracts, Dhaka (mainly Joydebpur), and Chittagong. In India, the fruit holds the second rank in terms of production, following Brazil, owing to its extensive cultivation practices (Pyr *et al.*, 2014) ^[42]. The global consumption of pineapple encompasses an array of forms such as canned slices, chunks, and dice, pineapple juice, fruit salads, sugar syrup, alcoholic beverages, citric acid, pineapple chips, and puree. Rich in water, carbohydrates, sugars, vitamins A and C, as well as being an abundant source of vitamin C and organic acids, pineapple offers a refreshing equilibrium between sugar and acidity (Bartolomew *et al.*, 1995) ^[59]. Within North-eastern India, particularly in Arunachal Pradesh, pineapple holds a significant position as one of the most important fruit crops. Its versatility extends to the creation of various products including squash, syrup, and jelly. Pineapple's utility even extends to the realms of vinegar, alcohol, citric acid, calcium citrate, and medicinal applications for certain ailments. The fruit's composition includes a moisture content ranging from 81.2% to 86.2%, with total solids accounting for 13% to 19%, predominantly constituted by carbohydrates such as sucrose, glucose, and fructose.

Of the total solids, carbohydrates contribute up to 85%, while fiber constitutes only 2% to 3%. Other components present in the pulp include a small proportion of ash, nitrogenous compounds, and lipids (0.1%), with true proteins making up around 25-30% of nitrogenous substances. Notably, the protease enzyme bromelain is responsible for approximately 80% of the proteolytic activity (Farid *et al.*, 2015) [60]. Fresh pineapple contains essential minerals including calcium, chlorine, phosphorus, and sodium (Banerjee *et al.*, 2018) [9]. Pineapple is an increasingly sought-after nutrition source for promoting good health, commonly consumed either as fresh fruit or in the form of fresh pineapple juice. The culinary applications of pineapple span a wide spectrum, from desserts and fruit salads to jam, yogurt, ice cream, confectionery, and savory dishes. The utilization of processing for food products leads to balanced nutrition, extended shelf life, and improved accessibility for consumers. Nonetheless, global food wastage remains a pressing issue due to inefficient transportation practices, microbial deterioration, and inadequate cold storage facilities. Processing by-products and residues are often lost due to outdated procedures and insufficient facilities. This shift towards processed and packaged foods reflects consumer preferences for convenience and safety, ultimately impacting the market for raw fruits and vegetables. Popular processed items include fruit juices, jams, jellies, ketchup, sausages, and purees. Consequently, bio-waste is generated during pineapple processing, contributing to a significant amount of discarded material. In order to maximize the utilization of pineapple's nutritional potential, bioactive substances, and phytochemicals, it is imperative to explore methods of recovery from these by-products (Diaz-Vela *et al.*, 2013) [16]. The utilization of pineapple by-products has the potential to yield valuable bioactive food components such as phytochemicals, vitamins, and enzymes. Extracting these components from various pineapple remnants, including pomace produced during juice extraction, offers a sustainable approach to utilizing these often-discarded materials. By harnessing the potential of pineapple by-products, a diverse range of natural compounds can be incorporated into food, cosmetic, and pharmaceutical applications, thereby reducing processing costs and increasing economic value. The industrial wastes generated by the pineapple processing industry, focusing on strategies for their valorization. With an emphasis on nutritional and bioactive potential, the extraction and application of these substances within the food and pharmaceutical sectors are discussed, providing valuable insights for researchers and processing experts alike.

Physical and chemical constituents of pineapple pulp and waste

Parameters	Pineapple pulp	Pineapple waste
Moisture (%)	87.3	91.35
Ash content (mg/100 g)	1.8	0.04
Total soluble solids (%)	13.3	10.2
Crude fibre (g/100 g-fw)	0.41	0.60
Total sugars (%)	8.66	9.75
Reducing sugars (%)	10.5	8.2
Non-reducing sugars (%)	7.4	8.8
Titrateable acidity (%)	2.03	1.86
Ascorbic acid (mg/100 g)	21.5	26.5

Source: (Hemalatha and Anbuselvi, 2013) [21]

Nutritional Value and Medicinal Benefits of Pineapple

Nutritional value of pineapple

Pineapple is the wonderful tropical fruit having vibrant tropical flavor, exceptional juiciness, and many health benefits. The considerable quantities of calcium, potassium, vitamin C, carbohydrates, dietary fiber, water, and other minerals found in pineapple are helpful for the digestive system, aid in maintaining a healthy weight, and promote balanced nutrition. In Bangladesh, pineapple is a popular fruit with low fat and salt levels. (Sabahelkhier *et al.*, 2010) [4] It contains 10-25 mg of vitamin. The edible part of the pineapple has been the focus of most research into its composition. Pineapple has a moisture content of 81.2 to 86.2% and a total solids content of 13 to 19%, the main sugars being sucrose, glucose, and fructose. Up to 85% of all solids are made up of carbohydrates, while only 2% to 3% are made up of fibre. Citric acid is the most prevalent organic acid there. Very little ash, nitrogenous chemicals, and lipids (0.1%) are present in the pulp. 25–30% of all substances are nitrogenous genuinely protein. Out of this percentage, a protease known as Bromalin is responsible for about 80% of the proteolytic activity. Minerals including Calcium, Chlorine, Potassium, Phosphorus, and Sodium are present in fresh pineapple. (Dull *et al.*, 1971) [17].

Nutrients in 100 grams of pineapple

Nutrients	Amount
Energy	52 calories
Dietary fibre	1.40 g
Carbohydrates	1.37 g
Protein	0.54 g
Iron	0.28 mg
Magnesium	12 mg
Calcium	16 mg
Potassium	150 mg
Phosphorus	11mg
Zinc	0.10 mg
Vitamin A	130 I. U
Vitamin B1	0.079 mg
Vitamin B2	0.031 mg
Vitamin B3	0.489 mg
Vitamin B6	0.110 mg
Vitamin C	24 mg

Source: (Joy, 2010) [25]

Ascorbic acid, which can be found in pineapple juice, is a good source of vitamin C. As a powerful antioxidant and aid in the body's iron absorption, ascorbic acid, or vitamin C, fights bacterial and viral illnesses. Half of an adult's daily required intake of vitamin C is found in a serving of pineapple juice. Pineapples include a number of critical minerals, including manganese, a trace mineral important for the development of bone as well as the production and activation of specific enzymes. The trace mineral copper is also present in pineapples. It helps with iron absorption and controls blood pressure and heart rate. (Debnath, P; *et al.*, 2012) [61].

Medicinal Value of Pineapple

The addition of pineapple to your diet might help you maintain good health. Fruits like pineapples are a great source of minerals and vitamins. One ripe, healthy pineapple fruit can provide around 16.2% of the recommended daily intake of vitamin C (Hemlata *et al.*, 2013) [21] The body uses vitamin C as its main water-soluble antioxidant to protect

healthy cells from attack by free radicals. Vitamin C is a potent antioxidant that aids in iron absorption as well as collagen synthesis in muscles, blood vessels, cartilage, and bones. Furthermore, vitamin C prevents the emergence of urinary tract infections during pregnancy and lowers the risk for certain cancers, such as colon, oesophageal, and stomach cancers. (Debnath *et al.*, 2012) ^[61] Thirteen percent of the volatility in pineapple juice comes from malic acid. It has numerous health advantages. It strengthens the immune system, encourages firm, smooth skin, aids in maintaining oral health, and lowers the danger of toxic metal poisoning. A good source of vitamin B1, vitamin B6, copper, and dietary fiber is pineapple. Pineapple is a fruit that naturally reduces inflammation and aids in digestion. Bromelain, a substance used to tenderize meat, is abundant in fresh pineapples. Bromelain, a proteolytic enzyme found in pineapple, aids in food digestion by crumbling protein. The fruit's edible sections only contain a small amount of bromelain; all of the commercially accessible bromelain is produced from the stem. Supplements incorporating bromelain are very well-liked by athletes for healing various physical pains and injuries. The immune system can be strengthened and the body can be hydrated by drinking pineapple juice. It promotes the growth of strong bones. Manganese, a trace mineral that the body needs to create bone and connective tissues, is abundant in 73% of the daily required amount of manganese contained in a single serving of pineapple. The advantages of pineapple can influence both the development of young bones and the hardening of elderly bones. Due to its high manganese level, pineapple juice is a strong option for increasing fertility by improving the quality of sperm (Debnath *et al.*, 2012) ^[61]. Effectively lowering swelling in inflammatory illnesses such as acute sinusitis, sore throat, arthritis, and gout, as well as speeding up the recovery process after surgery and injury, bromelain has been shown to have anti-inflammatory properties. Pineapple enzymes have been used successfully to treat rheumatoid arthritis as well as to hasten the healing of wounds, diabetic ulcers, and general surgical procedures. Pineapple helps clear artery walls of plaque and lowers blood clotting. The circulation of those with clogged arteries, such as angina patients, may be improved by pineapple enzymes. Pineapples are used to treat throat infections and bronchitis. Pineapple is a fantastic brain tonic that fights memory loss, unhappiness, and melancholy. Drinking pineapple juice is suggested for nausea and any form of motion sickness. It successfully eliminates the feeling of nausea and vomiting. It is well known that pineapple works wonders for alleviating constipation and irregular bowel movements. This is a consequence of its high fibre content, which promotes regular and effortless bowel motions. In spite of keeping the intestines and kidneys clean, pineapple is good at getting rid of intestinal worms. It aids in preventing gum disease and plaque buildup, keeping the teeth in a healthy state. Intentionally ingesting the flesh of very young, life-threatening fruits is done to attain certain goals and as a drastic cure for venereal illnesses. The dried, powdered root is used as an oedema treatment in Africa. Both the crushed rind and the rind decoction with rosemary are used to treat haemorrhoids and

fractures, respectively. The leaf juice is used by native people in Panama as a purgative, emmenagogue, and vermifuge the average crude fibre content in pineapple pulp was 0.450.03 g/100 g (Joy *et al.*, 2010) ^[25]. The gastrointestinal system benefits from fibre, but too much of it is capable of binding some trace elements (Siddhuraju *et al.*, 1996) ^[62]. Pineapple lowers blood pressure, treats inflammatory diseases, aids in weight loss, lowers mortality rates, and guards against diabetes and free radical damage. It repairs broken teeth and strengthens and strengthens them. aid with sinusitis and throat issues as well. cure conditions like asthma, obesity, bodily swelling, digestive issues, and heart issues. Manganese, which is abundant in pineapples and promotes to build strong bones and a powerful body. Due to high antioxidant levels, immunological disorders and atherosclerosis can also be treated. It is used to disregard cold weather because it does not cause damage to bodily cells. It is also used to create a perfect, unbreakable body, avoid cancer, heart attacks, and nausea, and to produce long, natural hair. Use to solve acne, wrinkles, age problems, and create strong nails, soft lips, and thick hair. In Bangladesh's Netra Kona area, the Garo tribal population utilises fruit juice for fever and leaf juice for helminthiasis and jaundice. In Bangladesh's Netra Kona area, the Garo tribal population utilises fruit juice for fever and leaf juice for helminthiasis and jaundice (Rahmatullah *et al.*, 2009) ^[44]. The leaves of the *Ananas comosus* have both analgesic and antihyperglycemic effects. That can be used as a more affordable and alternative source of treatment to lower diabetic patients' high blood sugar levels (Faisal *et al.*, 2014) ^[20]. The fruit and root are used topically and as an anti-inflammatory and proteolytic agent, respectively. In Tripura, India, it has a long history of use as an anthelmintic. For the medical management of diarrhoea, a root decoction is employed. It is suggested to take advantage of pineapple's numerous health benefits by either eating a fresh pineapple slice with each meal or drinking 12 ounces of fresh pineapple juice three times daily before meals. Alkaloids, flavonoids, saponins, and tannins were detected through phytochemical analysis in pineapple leaf extract, and these compounds may be to blame for the analgesic and blood sugar-lowering effects that have been seen (Faisal *et al.*, 2014) ^[20]. One of the best-known properties of pineapple is as a diuretic. This helps to eliminate toxins through the urine, helping patients with ailments of kidneys, bladder and prostate. Due to the fibre content of the pulp, pineapple prevents constipation and regularizes the intestinal flora. Furthermore, there is evidence of appetite reducer, heart protection and aid for fever, sore throat and mouth aches and inflammation. Lightly boiled ground pineapple can be used to clean infected wounds because it eliminates dead tissues, not affecting live tissue, acts as disinfectant Vitamin C, associated with other vitamins and fibre, is abundant in pineapple. The bromalin found in pineapples promotes healthy kidney and small intestine function, aids in detoxifying, normalises colonic flora, relieves haemorrhoids, and prevents and treats constipation. It was historically used to treat bronchial infections, mouth, throat, and colds. Cooked peel reduces oedema and cleans the blood. Juice is effective in treating fevers and cystitis.

Table 1: The potential food based and waste processing products related to pineapple.

Pineapple part	Potential uses	References
Pulp	nata de pina (dessert)	(Hossain <i>et al.</i> , 2016) [63]
Young shoot	Fruit salad	(Hossain <i>et al.</i> , 2016) [63]
Young shoot	hijos de pina (eaten raw or cooked in a savoury dish)	(Hossain <i>et al.</i> , 2016) [63]
Pulp	Dried and frozen pineapple	(Ramallo <i>et al.</i> , 2010) [45]
Pulp	Cakes, puddings, pies, compotes, and garnish (sweet dishes)	(Barretto <i>et al.</i> , 2013) [10]
Pulp	Curry and meat dishes	(Phoophuangpairoj <i>et al.</i> , 2014) [64]
Pulp	Preservers, nectar, toffees, jam	(Chaudhary <i>et al.</i> , 2019) [12]
Pulp	Juice, beverage, syrup	(Khalid <i>et al.</i> , 2016) [65]
Pulp	Vinegar	(Chaudhary <i>et al.</i> , 2019) [12]
Pulp	Wine	(Cannon <i>et al.</i> , 2018) [75]
Pulp	Powder	(Priyadarshini <i>et al.</i> , 2019) [41]
Pulp	Canned pineapple (slices, cubes)	(Othman <i>et al.</i> , 2011) [38]
Leaf fiber	Composite material	(Sena Neto <i>et al.</i> , 2013) [36]
Leaf fiber	Feedstock and energy production	(Asim <i>et al.</i> , 2015) [6]
Leaf fiber	Textile, automobiles, machinery equipment, sport items, insulators	(Prado <i>et al.</i> , 2019) [66]
Leaf fiber	Medicine, cosmetics, and biopolymer coatings	(Asim <i>et al.</i> , 2015) [6]
Leaf fiber	Furniture and construction materials	(Reinhardt <i>et al.</i> , 2018) [67]
Leaf fiber	Coarse textile and cloth	(Asim <i>et al.</i> , 2015) [6]
Leaf fiber	Cigar wrapper and casting net	(Asim <i>et al.</i> , 2015) [6]
Leaf fiber	String for jewels, caps of tribal chiefs	(Asim <i>et al.</i> , 2015) [6]
Peel	Methane gas for waste treatment	(Hossain <i>et al.</i> , 2016) [63]
Peel, crown core	Dairy feed	(Chaudhary <i>et al.</i> , 2019) [12]
Crown	Liquid medium and nanocomposite reinforcement	(Prado <i>et al.</i> , 2019) [66]
Stem	Starch-based pharmaceutical excipient	(Rahma <i>et al.</i> , 2019)

Pineapple Based Food Products

After fruit harvesting, precooling is crucial to reduce enzymatic breakdown and prevent microbiological development. Fruit is inspected for quality control during the packaging process before being packed and sealed till the time of transportation. (Barretto *et al.*, 2013) [10]. Due to its sweet flavor and scent, pineapple is primarily consumed as a fresh, canned, lightly processed fruit as well as a flavor. The high concentration of moisture, carbohydrates, and fiber is crucial for the development of bacteria and acts as a nutritional media for fermentation (Hossain *et al.*, 2016) [63]. The dessert's chewy texture and transparent gel, which practically turns it into a jelly-like meal, have earned it the name pineapple gelatine. Additionally, pineapple's young, sensitive stalks can be consumed, particularly in salads. young pineapple shoots, are sold as a vegetable to be consumed either fresh or cooked in a savory meal. In addition, a variety of processed pineapple goods, such as canned pineapple, dried and frozen pineapple, nectar, and pineapple juice, are offered on the commercial market. (Khalid *et al.*, 2016) [65].

Product development from pineapple pulp

Pineapple juice

Fresh pineapple juice is prepared by pressing fresh pineapple pulp. Pineapple juice has a good assortment of vitamins and minerals. Vitamin C levels in fresh pineapple juice range from 9.2 to 93.8 mg per 100 ml. Iron, manganese, phosphorus, potassium, magnesium, and pineapple juice all contain significant amounts of these elements. Clear juice, concentrates, and mixed varieties of pineapple juice are all readily accessible. Conditions related to the climate, harvest, and processing affect composition (Kabasakalis *et al.*, 2000) [26]. The shelf-life of the processed juice can be prolonged by up to 6-7 months by adding acceptable preservatives such ascorbic acid, citric acid, benzoates, and sorbates to a certain amount as advised by FSSAI (FSSAI 2022; Nath *et al.*, 2019) [68]. The significant

advantages of incorporating enzymes into the pineapple juice production process. Specifically, the utilization of pectinase and cellulase enzymes is underscored. These enzymes contribute to increased juice yield, resulting in a substantial improvement of 6% when applied individually and a remarkable 15% boost when used in combination enzyme treatment enhances the clarity and total soluble solids of the juice, further enhancing its overall quality (Aziz *et al.*, 2011) [8]. The use of proteolytic enzymes to augment pineapple juice quantity, particularly when adding a mere 0.02% of this crude enzyme extract to crushed pineapple. This addition substantially increases juice yield, the efficiency of this enzyme in boosting production (Dzobefia *et al.*, 2001) [18].

Pineapple jam

The term "pineapple jam" refers to a thick gel produced from fruit pulp, juice, sugar, or pectin. Jam is made by heating fruit pulp and sugar together to create a consistency that is thick and hard enough to hold the tissues in place. Jam needs to have at least 65% total soluble solids (TSS). On a fruit pulp foundation, jam typically contains pectin (1%), sugar (50–70%), fruit acid (1%), and water (33–38%). When making pineapple jam, the fruit pulp and sugar are cooked together while being constantly stirred. After a few minutes, pectin powder is added to the mixture, giving the jam the appropriate texture. The cooking procedure is halted after the jam reaches the proper consistency, and it is allowed to cool. Additionally, pineapple can be merged with other fruits to create other jam varieties (Salam *et al.*, 2020) [47]. The process of crafting jam using a combination of pineapple, apple, and watermelon in different proportions. It intriguingly points out that the sample with a 70:20:10 ratio garnered the highest acceptance rate, which is a key indicator of its popularity among consumers. Additionally, it mentions that the sensory qualities of this particular jam, including colour, scent, taste, and overall acceptability, displayed noticeable variations, indicating a dynamic and

potentially diverse flavor profile. The growing popularity of "ber-pineapple jam" in India, suggesting that this particular variety might be gaining traction among consumers. The practical aspect of the jam-making process, specifically regarding storage. The sample with a 60:40 ratio of ber pulp to pineapple pulp is highlighted for producing the most favourable outcomes, suggesting that this ratio is optimal for achieving desirable jam characteristic. The jam-making process involving various combinations of banana, pineapple, and watermelon pulp, with different ratios tested. It identifies the 25:25:50 blend as the ideal mixture, indicating that this specific ratio yields the most desirable jam in terms of taste and texture. The nutritional composition of the optimal jam mixture. This jam contains 83.20% carbohydrates, indicating it is a high-carbohydrate product. The low-fat content (3.92%), moderate moisture content (2.52%), and dietary fibre (1.41%) suggest a balanced and potentially healthy jam option. Furthermore, it contains 8.58% protein, which is relatively high for jam, and 0.38% ash, signifying the mineral content. The jam-making process, identifies the best mixture ratio, and provides essential nutritional data for the ideal jam mixture (Olufemi Awoluet *et al.*, 2018) [7]. The concept of fortifying pineapple jam with chia seeds and explores different weight-based rates of chia seed addition, ranging from 6.25% to 50%. The chia-infused pineapple jam exhibited a distinct golden hue compared to the control jam, which suggests a visual distinction. The significant variation in protein levels among the chia seed-fortified jams, ranging from 1.60% to 8.60%, whereas the control jam had a much lower protein content of 0.53%. The potential of chia seeds to enhance the nutritional profile of the jam, particularly in terms of protein content, the practical utility of creating chia-fortified pineapple jam, suggesting that it offers a way to harness the beneficial elements found in chia seeds. This could appeal to consumers seeking healthier and more nutritious jam options. The idea of incorporating chia seeds into pineapple jam, highlights their impact on colour and protein content, and underscores the potential advantages of such fortification. It provides valuable insights for both consumers and jam manufacturers interested in healthier jam alternatives (Nduko *et al.*, 2018) [35].

Pineapple squash

A concentrated non-alcoholic beverage called squash is created by combining fruit juice, water, and sugar or a sugar alternative. The pineapple fruit chosen for the production of squash must be fully developed and firm. (Nath *et al.*, 2019) [68]. pineapple fruit squash was produced and stored in clear bottles at room temperature (approximately 30-32 °C) for six months. The subsequent changes in Vitamin C concentration due to the preservation and storage process, which is a common challenge for fruit-based products. The acknowledgment of this decrease in Vitamin C content due to factors like heat, light, and oxygen adds a layer of realism to the assessment. The squash has a TSS level of 46 °Brix, which serves as a valuable indicator of the product's sweetness. This is particularly relevant for consumers who seek a specific flavor profile in fruit-based products (Nath *et al.*, 2019) [68]. Sweetness level impacted the overall taste and appeal of the squash would enhance. This parameter plays a pivotal role in shaping the taste and preserving the product. This is a crucial point that assures consumers of the product's reliability and quality, making it a viable option

for purchase. It effectively conveys the significance of Vitamin C content, TSS, and Total Acidity in assessing product quality and consumer acceptability. While it offers a well-rounded overview. the product's potential as a stable and commercially viable option for consumers.

Pineapple Preserve and candy

A confection made from osmotically dehydrated fruits and vegetables is called candy. In order to make pineapple candies, pineapple segments are submerged in sugar syrup for a predetermined amount of time, drained of excess syrup, and then dried to a shape that is shelf-stable. the fruit pieces being dipped in a thick sugar syrup, resulting in a delicate and clear appearance (Jothi *et al.*, 2014) [24]. The use of a mixture of sugar, honey, and various sweeteners, both natural and synthetic, highlights the versatility and customization possible in creating this preserve. The specific data about pineapple slices dehydrating in a 40 °Brix sucrose solution at 30 °C adds a scientific aspect to the description, showcasing the precision involved in crafting the product. The improvements in colour, texture, flavour, and taste of pineapple slices when maintained in a 40°Brix sucrose solution at 60 °C for 24 hours demonstrates the importance of temperature and time in the production process. The mention of sensory and qualitative characteristics hints at the product's overall appeal, including its taste, texture, and appearance, which are crucial factors in candy production. The utilization of a sun dryer adds a rustic touch to the manufacturing process, potentially appealing to consumers who appreciate traditional methods (Khanom *et al.*, 2016) [30].

Ready to serve (RTS) Beverage

The food authority's guidelines for pineapple juice's acidity, TSS, and juice content must all be followed while making pineapple RTS beverages. RTS beverages must meet FSSAI criteria, which require them to include 0.3% acidity, not less than 10% total soluble solids, and at least 10% fruit content. (FSSR *et al.*, 2011) [69]. The juice from a pineapple is extracted and combined with sugar syrup to create an RTS beverage. After that, the beverage is pasteurised, cooled, and packaged (Nath *et al.*, 2019) [68]. Incorporated pineapple RTS drink with green chilli, ginger, pepper, cardamom, and nutmeg extracts. After that, the beverage was standardised in accordance with the organoleptic assessment. The findings of the sensory evaluation revealed that all of the beverages had exceptional sensory qualities, with the exception of the samples made with pineapple flavour and a mildly dominating flavour of green pepper (Amaravathi *et al.*, 2014) [3]. standardise the blending of pineapple juice and guava pulp when making RTS drinks. different percentages of pineapple juice (10–50%) and guava pulp (40–100%) were combined. After being held for 2.5 months, prepared samples were examined for qualitative alterations. the storage period progressed, the levels of total sugar, reducing sugar, TSS, pH, and overall acceptability all reduced. The sample with the highest sensory qualities contained 60% guava pulp and 40% pineapple juice. Similar to this, (Sindumathi *et al.*, 2015) [53] developed an RTS beverage using various ratios of pineapple juice and papaya and examined several physicochemical and sensory features. The mixture with the highest sensory rating was one with a 50:50 ratio of papaya and pineapple juice. The mixture with the highest sensory rating was one with a 50:50 ratio of

papaya and pineapple juice blend). Combining ginger and cardamom extracts in a 1:1 ratio raised the beverage's sensory appeal (Sarkar & Bulu 2017) [48].

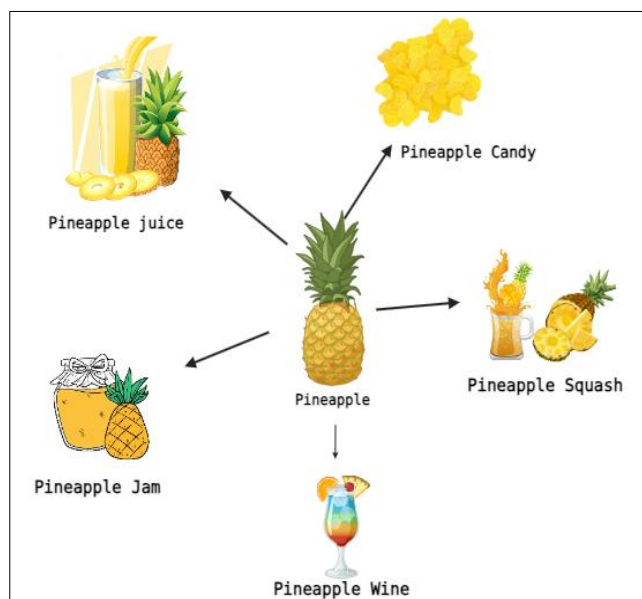


Fig 1: Pineapple by products

Pineapple mix seaweed jam

The inception of innovative seaweed-based seafood products represents a significant stride in advancing the commercialization of local seaweed offerings, and this momentum is perhaps most strikingly embodied by the creation of the intriguing pineapple-infused seaweed jam. Beyond being a mere culinary creation, this novel product serves as a beacon of both gastronomic creativity and environmental consciousness, particularly in addressing the challenge of surplus seaweed waste in Sabah. At its heart, the development of this exceptional product is driven by a dual purpose: the augmentation of seaweed-infused dishes in the market and the mitigation of the pervasive problem of seaweed waste. With an unwavering commitment to sustainability, this initiative seeks to tap into the latent potential of seaweed, propelling it into a thriving realm of locally produced seaweed commodities. The meticulous crafting of the pineapple-infused seaweed jam involves a delicate and artful process. It commences with the careful selection of pristine, freshly harvested seaweed—a marine treasure of immense value. Through precise cooking at 80 degrees Celsius under controlled conditions, the seaweed gently dissolves, laying the foundation for the culinary masterpiece. The transformation truly reaches its zenith when the delightful blend of succulent pineapple is introduced. This harmonious fusion undergoes a controlled heating phase, a pivotal step determining the optimal texture that defines premium jam. The result transcends mere flavors, converging into a symphony of tastes that resonate with every discerning palate it encounters. Yet, the allure of the pineapple mix seaweed jam transcends its delectable taste. This creation serves as a treasure trove of essential nutrients, catering to our bodies' nutritional needs. Categorized as marine macroalgae, seaweeds boast a rich tapestry of macro- and micronutrients. With over 600 edible seaweed varieties in our natural ecosystem, these aquatic marvels provide low-calorie content while harbouring a plethora of vitamins, minerals, antioxidants, carbohydrates,

and dietary fiber. Beyond its contribution to carrageenan production, this species has earned a place in diverse culinary practices, whether as dried seaweed or fresh produce (Nor *et al.*, 2020) [37]. Its global demand has surged, particularly in regions where seaweed was once a peripheral dietary element (Msuya *et al.*, 2022) [33]. The chemical and nutritional attributes of the *Kappaphycus alvarezii* species have led to its exploration as a potential dietary supplement. Its consistent metal concentrations underscore its nutritional value, affirming its role as a nourishing entity (Ariano *et al.*, 2021) [70]. But the potential of seaweeds extends beyond the kitchen. They inspire a range of delights such as pickles, jellies, wafers, and porridge (Kalia Perumal *et al.*, 2003) [28].

Table 2: Nutritional Information

Nutritional Information	Unit	Per 100 g
Energy	Kcal	145.00
Carbohydrate	Gram	35.6
Protein	Gram	0.6
Fat	Gram	0.0

Source: (Ariano *et al.*, 2021) [70]

Yoghurt drink fortified with pineapple pulp

Pineapple-infused yogurt introduces a delightful and vibrant twist to the classic dairy treat. Combining the tangy richness of yogurt with the sweet, tropical essence of pineapple, this innovative blend offers a refreshing and unique flavor profile. Yoghurt is a semi-solid, custard-like acidified fermented milk product (Munzur *et al.*, 2004) [71]. In comparison to other fermented milk products, it is a well-known and widely accepted product worldwide (Caisson *et al.*, 2005) [13]. Due to its nutritional and therapeutic benefits, which include preventing the formation of harmful bacteria, treating intestinal conditions including diarrhoea, constipation, and dysentery, acting as an anti-carcinogen, guarding against osteoporosis, hypertension, and decreasing blood cholesterol (Kamruzzaman *et al.*, 2002) [29], the product is packaged and refrigerated, it is classified as stirred yoghurt with low viscosity that has been produced through vigorous agitation that broke the coagulum. It is typically sweetened with fruit flavour or sugar. Fruit juice addition to yoghurt to fortify it is becoming increasingly popular around the world (Shukla *et al.*, 1987) [52]. Since pineapple is constantly available in India, there is no need to be concerned about its production. Despite the fact that the fortification of yoghurt with various seasonal fruits is rapidly expanding in India.

Pineapple Wine

Wine is referred a completely or partially fermented juice of the fruit's other like pineapple, plum, peach, pear, berries, strawberries, cherries, currants, apricots, Apple etc., have also been utilized for the production of wines (Jagtap *et al.*, 2015) [72]. Wine is made by fermenting grape juice with a naturally occurring organism called wild yeast. *Saccharomyces cerevisiae* strains currently make up the bulk of commercial wine yeasts due to their superior aldehyde generation and pace of sugar utilisation during fermentation (Joshi *et al.*, 2014) [73]. Making wine from these ripe fruits or their juices is thought to be an alternative to using extra and overripe fruits to help fruit growers make more money (Jagtap *et al.*, 2015) [72]. Fresh and processed fruits both enhance the nutritional value of our diet and supply vital nutrients like vitamins, minerals, carbohydrates.

Since these waste products from pineapple canneries are potential sources of sugars, vitamins, and growth factors, they have been employed as the substrate for bromelain, organic acids, ethanol, etc. Technology is advancing in the creation of wine from fruits. All across the world, fruit wines are made and drunk. Fruits and their distillation, brandy, are used to make a variety of alcoholic beverages. Making wine from pineapple and its waste materials is regarded as a developing technology. Fruit wine has numerous positive effects on human health. It has received much praise for its medical or therapeutic qualities and has been utilised as a therapeutic agent. A type of low-alcohol beverage made from pineapple is called pineapple wine. In addition to maintaining the fruit's nutritional value and positive health impacts, it also has the distinctive flavour of pineapple fruits (German *et al.*, 2000) ^[74]. Pineapple juice can be used to make high-quality wine. The amount of phenolics in an extract determines how much antioxidant activity it has, and because pineapples are high in phenolics, they may be a useful source of antioxidants. When compared to the must, the antioxidant qualities of the wine were more favourable. Production of fruit wines in those nations where fruits other than grapes are grown would undoubtedly be advantageous. In the future, it is necessary to conduct research on fruit wine on more varieties of pineapple in the world. Wine making from surplus fruits gives farmers additional revenue and economic uplift of the farmers. It also creates employment opportunities in wine.

Conclusion

The world of pineapple and its by-products represents a remarkable intersection of culinary delight, sustainable innovation, and economic viability. The evolution of the pineapple from a tropical fruit to a versatile ingredient has not only delighted taste buds but also showcased the power of diversification in agriculture and food production. Pineapple-derived products, ranging from juices and preserves to textiles and bromelain extracts, demonstrate the far-reaching potential of a single fruit. This diversification not only caters to consumer demands for variety but also addresses the imperative of reducing food waste. The extraction of valuable compounds like bromelain from pineapple by-products exemplifies the innovative spirit of sustainability. This enzyme, with applications in medicine, cosmetics, and more, exemplifies how waste can be transformed into a resource. Moreover, the trend towards utilizing pineapple by-products aligns with broader sustainability goals. However, the journey towards fully realizing the potential of pineapple and its by-products is not without challenges. Sustainable practices must be accompanied by thorough research, responsible sourcing, and an awareness of potential ecological consequences. Balancing innovation with environmental stewardship remains crucial as we explore new avenues for pineapple utilization.

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