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Pineapple waste utilization: Wealth from waste

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Abstract
Waste utilization in the fruit and vegetable processing industries is a crucial and challenging job across the world. Because waste from the fruit and vegetable industries is produced in enormous amounts, it contains high lignocellulose, fibre, sugar, and bioactive and useful compounds. The food industry can use these fruit wastes in a variety of ways, including fermentation, drying, and extraction of bioactive and useful chemicals. Using food waste is not limited to one or two products; if used properly, one can obtain a variety of products such as essential oils, ointments, herbal drinks, energy bars, and so on, which will not only promote good health and nutrition to a human body but will also help in generating zero waste. Researchers have concentrated on using pineapple waste for two purposes: first, to extract bromelain, and second, to produce ethanol, phenolic antioxidants, heavy metal, organic acids, biogas, fibre production, and organic acid at a low cost with the help of methods such as fermentation, drying etc. With the help of scientific and technological advancements, a better and more profitable market for pineapple waste may be created.

Keywords: Bromelain, organic acids, ethanol, fibre, animal feed, fermentation, heavy metals

1. Introduction
The pineapple (*Ananas comosus*) is the most valuable fruit on the planet and the most important edible member of the Bromeliaceae family. The plant can reach a height of 75-150 cm and a width of 90-120 cm. It's a short plant with a stout stump and narrow, fibrous, spiny leaves.
The plant produces a juicy, fleshy cone-shaped fruit with a crown at the end. (Tran *et al.*, 2006) [30]. In 2007, the region under pineapple cultivation was nearly 9, 20,349 ha, with a projected output of more than 18 million tonnes, according to the FAO online database. It is primarily grown commercially as canned fruits and is consumed all over the world. It is also used to make juices, concentrates, and jams. Pineapple slices have also been frozen and stored. Bromelain, a proteolytic enzyme found in pineapple stems, is also finding widespread use in pharmaceutical and food applications (Hebbar *et al.*, 2008) [11].
Pineapple is one of the world's most popular commercial fruits, because of its appealing flavour and refreshing sugar-acid balance. It also is a good choice of fruit both for fresh consumption and processing. It is also a good source of dietary fibre, vitamin A & B, carotene, water, sugar, and carbohydrates and is fairly rich in vitamin C and minerals like calcium, magnesium and iron. Pineapple itself is a nature's healing fruit that has many health benefits. (Joy and Abraham *et al.*, 2013) [20]. The most important and promising commercial varieties of pineapple in India are:

- Kew
- Queen

Fig 1: Pineapple fruit

2. Pineapple Waste

Nowadays, a major issue is fruit waste which is getting used extensively in the manufacturing of value-added products because of its dietary fibre and phenolic content which is economically beneficial to food processors. Waste from the fruits and vegetable processing industry is produced in large quantities worldwide and the utilization of this waste challenges the food industry and scientists to generate zero waste technology for the agricultural sector. Fruit waste is high in lignocellulose, fibre, sugar, and bioactive and functional compounds. These bioactive compounds are being used in a variety of industries, including food to create edible films, food to create probiotics, and other industries to create useful products. The use of low-cost waste to create a value-added commodity is a novel move toward its long-term sustainability. The key components of pineapple by-products are residual pulp, peels, stems, and leaves. The growing popularity of pineapple-processed foods has resulted in significant waste generation. This is mostly due to the selection and removal of components that are unfit for human consumption. Furthermore, during transportation and storage, rough handling of fruits and exposure to harsh environmental conditions can result in up to 55 per cent of product waste (Nunes *et al*., 2009) [21]. These wastes are normally susceptible to microbial spoilage, restricting their use. Furthermore, the cost of drying, storing, and shipping these wastes is low, so their reliable, low-cost, and environmentally friendly use is becoming increasingly important.

Pineapple waste is the inedible part of the fruit which is obtained during the processing of fruits and is discarded. Several attempts have been made in this regard to use pineapple wastes collected from various sources. Since pineapple cannery wastes are a potential source of sugars, vitamins, and growth factors, they have been used as a substrate for bromelain, organic acids, ethanol, and other compounds. Waste utilisation has become one of the main important aspects due to the generation of waste in large quantities of by-products including peels, seeds, leaves and unused flesh in different steps of the processing chain. Scientific and technical research focusing on the pineapple fruit have also highlighted the potential for better and more profitable opportunities for pineapple wastes, as well as the potential for using the waste to produce a new product. Pineapple waste is high in phytochemicals which possess a wide range of activities such as antimicrobial, anti-inflammatory, antioxidant, anticancer and nutritional aspects. The waste from pineapple fruit can be used to increase the shelf life as well as the functional properties of food due to the presence of phytochemicals, antioxidant properties which can be used as bio-preservatives in various foods and nutraceuticals. Pineapple waste extract can even also prevent the development of abnormal growth on the skin and decrease the chances of the occurrence of squamous cell skin melanoma.

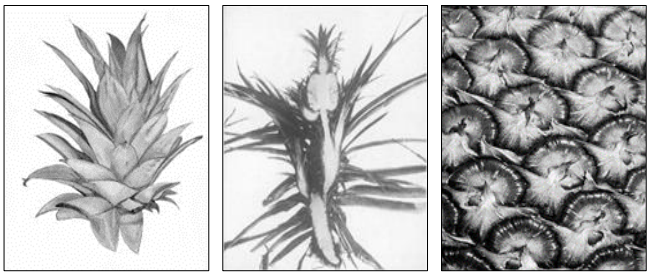

Fig 2: Pineapple waste: crown, stem, peel

3. Waste Disposal

Fruit waste is a threat to the environment. Because it gathers in an abandoned industrial yard with no or little economic value. Disposing of this fruit waste is expensive due to the high cost of transportation and the unavailability of landfills. The presence of high quantities of BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) in pineapple waste adds to the difficulty of disposal. By co-digesting pineapple waste with a variety of other fruits and vegetables, as well as slaughterhouse waste, researchers were able to reduce volatile substances by 50-60%.

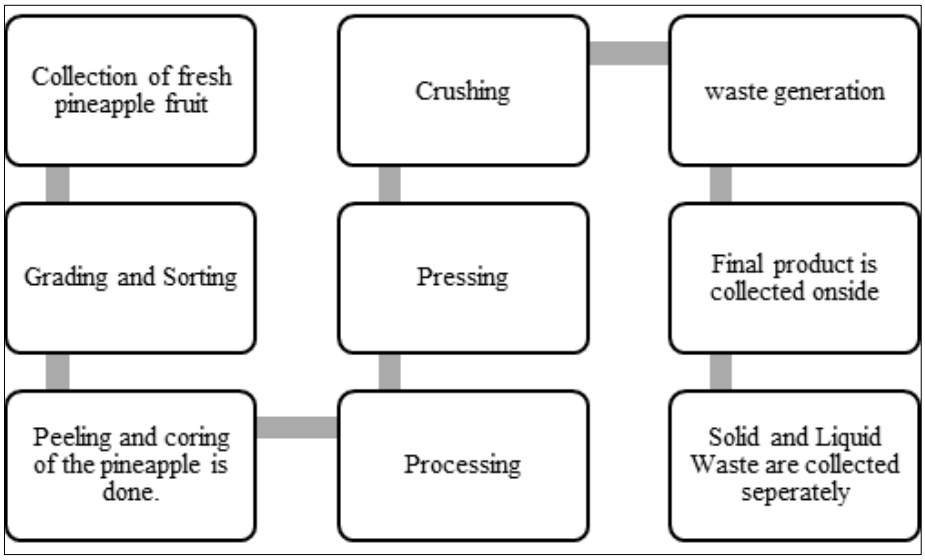

Fig 3: Flow chart diagram of waste collection in pineapple processing industries

4. Nutritional Value

The pineapple fruit is one of those fruits that is enjoyed all across the world. Pineapple is a delicious tropical fruit with high juiciness, a vivid tropical flavor, and numerous health advantages. Pineapple is high in calcium, potassium, vitamin C, carbs, crude fibre, water, and various minerals, all of which are beneficial to the digestive system and aid in maintaining a healthy weight and balanced diet. Bromelain, found in fresh

pineapples and pineapple steam and leaves, is an anti-inflammatory that helps to reduce swelling in inflammatory disorders such as acute sinusitis, sore throat, arthritis, and gout. Pineapple is a popular fruit in Bangladesh, with low fat and sodium content. It has 10 to 25 mg of vitamin A. The edible section of the pineapple has been widely studied. Pineapple has a moisture content of 81.2 to 86.2 per cent and a total solids content of 13-19 per cent, with sucrose, glucose, and fructose as the main sugars. Carbohydrates make up to 85% of total solids, while fibre makes up only 2% to 3% of total solids. The most naturally occurring organic acid in it is citric acid. There is relatively little ash, nitrogenous compounds, or lipids in the pulp (0.1 per cent). True proteins make up roughly 25-30% of nitrogenous compounds. Bromelain, a protease, is responsible for around 80% of the proteolytic activity in this fraction. Fresh pineapple contains calcium, chlorine, potassium, phosphorus, and sodium, among other minerals. Pineapple juice contains ascorbic acid and is high in vitamin C. Vitamin C, commonly known as ascorbic acid, is an antioxidant that aids in the absorption of iron as well as the prevention of bacterial and viral infections. Half a cup of pineapple juice provides 50% of an adult's daily vitamin C needs. Waste of pineapples contains a variety of essential minerals, including manganese, a trace mineral required for bone formation and the activation of certain enzymes. Pineapple waste also contains copper, which is a trace mineral. It promotes iron absorption while also regulating blood pressure and heart rate. (Debnath *et al*., 2012) [7].

Pineapple waste contains a lot of phytochemicals, which have antimicrobial, anti-inflammatory, antioxidant, anticancer, and nutritional properties. Because of the presence of phytochemicals and antioxidant properties that can be used as bio-preservatives in different foods and nutraceuticals, pineapple waste can also be used to extend the shelf life and functional properties of food. Pineapple waste extract can also help to avoid the production of premature skin growths and reduce the risk of squamous cell skin melanoma.

Carbohydrates are the main source of energy in the human diet for performing various body functions as it controls blood glucose and also promote proper functioning of the brain and gastrointestinal processes. (Muir *et al*., 2009) [27].

The dietary fibre content found in the pineapple waste is resistant to digestion and absorption. Consumption of dietary fibre was found to be inversely linked to obesity, cancer, and cardiovascular disease.

Minerals like calcium, phosphorus and iron zinc, magnesium, manganese and copper are in major quantities. Minerals are inorganic substances present in all body tissues and fluids, and their presence is needed for certain physiochemical processes to work properly

Pineapple peels mainly contain Vitamin C, Vitamin B, and Vitamin A. Pineapple peel has a very low vitamin A content. Vitamin A is much needed for maintaining healthy membranes and skin, as well as for good vision. Pineapple waste is rich in the B-complex group of vitamins such as Vitamin B1, Vitamin B2, Vitamin B3, and Vitamin B6. Vitamin C is one of the essential nutrients for a human being. A human being must obtain vitamin C from foods as well as from supplements. Vitamin C is the strong and safest antioxidant. Vitamin C-rich foods help to protect the body from scurvy, improve resistance to infectious agents, and increase immunity, toxic, and pro-inflammatory free radicals. A small portion of pineapple waste meets a significant portion of the daily requirement for this nutrient.

For the further physical and chemical composition of pineapple waste, we can refer to the below-mentioned Table 1.

Table 1: Physical and Chemical Constituents of Pineapple Pulp and Waste **(**Shukla *et al*., 2005; Pathak, 2003)

S. No.	Parameters	Pineapple waste
1.	Moisture (%)	91.35
2.	Ash content (mg/100gm)	0.04
3.	Titratable acidity (%)	1.86
4.	Ascorbic Acid (mg/100gm)	26.5
5.	Reducing sugars (%)	8.2
6.	Non-reducing sugars (%)	8.8
7.	Total soluble solids (%)	10.2
8.	Total sugars (%)	9.75
9.	Protein (%)	10
10.	Crude fibre (gm/100gm)	0.60

5. Therapeutic Properties of Pineapple

Traditionally the whole pineapple is consumed for the treatment of intestinal parasites, blood clotting, anti-inflammatory obesity, cancer etc. and it also possesses a protective effect against various diseases. For good personal health. Pineapple fruits are an excellent source of vitamins and minerals. Healthy ripe pineapple fruit can supply about 16.2% of the daily requirement for vitamin C. (Sabahelkhier, K. M.; Hussain, A.S. and Ishag, K. E. A. *et al*., 2010) [28]. For detailed therapeutic properties of pineapple fruit are mentioned below in Table 2.

Table 2: Therapeutic Properties of Pineapple

Properties possessed by Pineapple	Example of disorder/disease prevented	References
Anti-inflammatory	Asthma, hepatitis, Arthritis	(Joy, P.P *et al*., 2010) (Bhui *et al*., 2009) [15]
Anti-oxidant	Immune energy to the lungs and kidneys and also prevent cardiovascular diseases.	(Debnath, P; Dey, P; Chanda, *et al*., 2012) [7]
Anti-cancer	Tumour and cancers	(Debnath, P; Dey *et al*., 2012) [7]
Anti-microbial	Cold flew, tuberculosis	(Debnath, P; Dey, P; Chanda, *et al*., 2012) [7]
Anti-diabetic	diabetes	(Faisal, M.M.; Hossa, F.M.M.; Rahman, S.; Bashar, A.B.M.A; Hossan, S. and Rahmatullah, M. *et al*., 2014).
Anti-hyperglycaemic	Coronary heart failure, blood pressure	(Faisal, M.M.; Hossa, Bashar, Rahmatullah, M. *et al*., 2014).

5.1 Anti- Inflammatory Activity

Asthma and Arthritis are chronic inflammatory disorders. Bromelain has been shown to help with inflammatory conditions including acute sinusitis, sore throat, acne, and gout, as well as speeding up recovery from injuries and surgery. (Joy, P.P *et al*., 2010) [15]. The root and fruit are either eaten or applied topically as an anti-inflammatory and a proteolytic agent (Debnath, P; Dey, P; Chanda, A and Bhakta,

T *et al*., 2012) [7].

5.2 Anti-Cancer Activity
Vitamin C also retards the development of urinary tract infections during pregnancy and reduces the risk of certain cancers, including colon, oesophagus and stomach. The ability of the pineapple to enhance the therapeutic index of anticancer drugs has been reported (Debnath, P; Dey, P; Chanda, A and Bhakta, T *et al*., 2012) [7].

5.3 Anti-Diabetic Effect
Diabetes mellitus is one of the leading causes of mortality all over the globe and, if uncontrolled, can target multi-organ systems. Hyperglycemic and analgesic properties. That can be used as a cheaper and alternative source of medicine for reducing the high blood sugar level of diabetic patients (Faisal, M.M.; Hossa, F.M.M.; Rahman, S.; Bashar, A.B.M.A; Hossan, S. and Rahmatullah, M. *et al*., 2014). Pineapple waste is reported to have beneficial effects on fasting blood sugar, total cholesterol and LDL. Percentage reduction in postprandial blood sugar was also reported. Therefore, the traditional use of this pineapple against diabetes is really effective.

5.4 Anti-microbial Activity
Antimicrobial activity is well known as a good source for the prevention of various diseases. Citrus Fruit is considered an important medicinal plant and is cultivated mainly for its alkaloids, which contains anticancer activities as well as the antibacterial potential (Kawaii *et al*., 2000) A large spectrum of biological activity has been shown by Citrus Flavonoids including antibacterial, antifungal, antidiabetic, anticancer and antiviral activities.

6. Therapeutic Properties of Pineapple waste
Pineapple waste has many health benefits and can help in fighting many diseases like cancer, blood clot etc. the therapeutic properties of pineapple waste are mentioned below in Table 3.

Table 3: Therapeutic Properties of Pineapple Waste

Properties possessed by Pineapple waste	Example of Disorder/Diseases prevented
Anti-oxidant	Immune injury to lung and kidney, and prevent cardiovascular disease
Anti-inflammatory	Inflammation, Asthma, Hepatitis and Arthritis
Anti-Cancer	Cancer, Tumor
Anti-diabetic	Diabetes/ Regulates Blood Sugar Level
Anti-Hyperglycemic	Blood pressure, Arrhythmia, coronary heart failure.
Analgesic	All kinds of pain
Immune Booster	Boost immune system, wound healer, bacteria fighter
Digestive Aids	intestinal parasites, constipation, and possibly IBS symptoms
Dental and Bone Strengthened	grow, strengthen and repair bones and teeth
Vision Protector	Aids in battling degenerative eye diseases like glaucoma.
Blood Clot Reduction	Reduce excessive coagulation of the blood and helps with preventing blood clots from forming.

6.1 Anti-oxidant Activity
Pineapple waste is high in antioxidants, which can help to prevent chronic diseases including heart disease, diabetes, and some cancers. Since many of the antioxidants in pineapple waste are attached, their effects - last longer.

6.2 Anti-inflammatory Activity
Bromelain, a potent enzyme found in high amounts in the skin and stems of pineapples, aids in the reduction of inflammation in the body. It's been touted for reducing swelling after surgery or injury and works as an anti-inflammatory in the sinuses and throughout the body. The root and fruit are either eaten or applied topically as an anti-inflammatory and a proteolytic agent (Debnath, P; Dey, P; Chanda, A and Bhakta, T *et al.*, 2012) [7].

6.3 Analgesic
Here again, bromelain works its anti-inflammatory magic in those who have arthritis or joint pain or any kind of pain in the body. Making a potion with pineapple peels targets the root of the discomfort.

6.4 Anti-diabetic
Ananas comosus i.e. pineapple fruit leaves have anti-hyperglycaemic and analgesic properties. That can be used as a cheaper and alternative source of medicine for reducing the high blood sugar levels of diabetic patients (Faisal, M.M.; Hossa, F.M.M.; Rahman, S.; Bashar, A.B.M.A; Hossan, S. and Rahmatullah, M. *et al*., 2014).

6.5 Anti-Hyperglycaemic
Ananas comosus leaves have anti-hyperglycaemic and analgesic properties.

6.6 Immune Booster
The pineapple and its skin contain a lot of vitamin C, which helps to avoid and combat infections. Bromelain and vitamin C work together in the body as a bacteria killer, mucus breaker, cough suppressant, wound healer, and overall system booster.

6.7 Digestive Aids
Not only do the peels aid digestion, but they've also been linked to the reduction of intestinal parasites, constipation, and IBS symptoms. They also help to maintain balanced gut flora.

6.8 Dental and Bone Strengthened
Pineapple skins are rich in manganese, which helps to fight inflammation in the gums and tissues. Manganese helps in the growth, strengthening, and repair of bones and teeth. Its vitamin C and astringent properties keep gums clean and stable, which is good for oral health.

6.9 Vision Protector
The plant's beta carotene and vitamin C help to prevent degenerative eye diseases including glaucoma.

6.10 Blood Clot Reduction
Pineapples, according to Flores, can help minimize excessive blood coagulation because of their bromelain content. Pineapple is a healthy snack for frequent flyers and those who are at risk of blood clots because of this. Bromelain helps to avoid blood clots, and pineapple juice's copper content promotes the production of healthy red blood cells.

6.11 Anti-cancer Activity
Early research suggests that the quantities of manganese, vitamin C, bromelain, and antioxidants found in the skin can help combat tumours and prevent cancer.

7. Pineapple Waste as a Source of Value-Added Product
It is predicted that discarded fruit and waste material will be used in industrial processes such as fermentation, bioactive component extraction, and so on. Numerous studies have been conducted on the usage of waste from the fruit and vegetable, dairy, and meat industries. Several attempts have been undertaken in this regard to utilise pineapple wastes obtained from various sources. Because pineapple cannery wastes are a potential source of sugars, vitamins, and growth factors, they have been employed as a substrate for bromelain, organic acids, ethanol, and other compounds. Several research has been conducted throughout the years to look into the feasibility of using these wastes to produce value-added products such as wine and vinegar, Organic acid, Ferulic acid, Bromelain, Citric acid, Ethanol, Fiber, Starch etc.

7.1 Wines and Vinegar Production
As pineapple peels and waste are rich sources of sugars, they could be an ideal fermentation substrate, with the ability to produce alcohol as well as acetic acid from pineapple fruit to make vinegar and fermented beverages (Tropea *et al.*, 2014) [41]. The pulp left over after extracting juice from fruits and vegetables, as well as their peels, is used to make wine via the fermentation process. To enhance the flavour and health benefits of a fermented beverage, herbs may be added. These leftover pulp and peels are high in nutrients including sucrose, glucose, and fructose, which are basic sugars (Shilpa *et al.*, 2013) [38]. Fermentation is a straightforward process that involves the conversion of sugar to alcohol and carbon dioxide in the presence of yeast.

7.2 Starch
Starch is another possible element that may be extracted from pineapple waste, particularly the stem, using a milling technique. By avoiding chemical and technological approaches, it can be possible to obtain high purity starch with distinct properties when compared to rice, corn, and cassava starches. The significant amylose content of pineapple stem starch (34.4%), which is about twice that of corn, more than double that of cassava starch (15.4%), and five times that of rice, was responsible for some technical properties such as high gelatinisation temperature and enthalpy. As a result, pineapple starch has the highest percentage of solubility. (Nakthong *et al.*, 2017) [20].

7.3 Phenolic Antioxidant
The search for new natural antioxidants has increased rapidly in recent years, and agro-industrial by-products have been widely analyzed. One of the reasons could be the inexpensive cost of these residues, which would otherwise be dumped as waste in the environment. Phytochemicals, particularly phenolic compounds found in fruits and vegetables, is considered to be the major bioactive compounds responsible for the health benefits. Various studies have looked into the phenolic content of pineapple. Antioxidants derived from phenolic wastes are also present in higher concentrations. The antioxidant and antibacterial effects of the water extract may be due to phenolic acids such as ferulic acids and more, which were discovered in waste from the bromelain manufacturing process. (Upadhyay *et al.*, 2011) [32]. In addition, the lab also focuses on the underutilized sections of many plants and also discovered that the pineapple stem has properties like anti-inflammatory and anti-diabetic. Subsequent research on phytochemicals derived from pineapple peel and leaves has revealed a significant antioxidant activity as well as a high concentration of phenolic components. The leaf of the pineapple fruit also contains a lot of phytosterols, especially beta-sitosterol, stigmasterol, and campesterol.

Table 4: Phenolic Antioxidant from Pineapple Wastes

S no.	Source	Amount	References
1.	Residue	1.3mg/day	(Oliveira *et al.*, 2009) [22]
2.	Peel	2.01mmol/100gm	(Guo *et al.*, 2003) [10]

7.4 Organic Acid
Organic acid generation from fruit waste has been a subject of attention in the search for a low-cost substrate. Using fermentation technology, pineapple wastes have been used to generate a variety of organic acids, including citric, lactic, and ferulic acid.

7.4.1 Ferulic Acid
The most abundant hydroxycinnamic acid identified in plat cell walls is ferulic acid. The food and cosmetic industries both use this phenolic antioxidant. The alkali extraction of ferulic acid has been achieved using pineapple peel. (Tilay *et al.*, 2008) [39].

7.4.2 Citric Acid
This commercially significant product is frequently utilized as a substrate to acidify and enhance flavor in the food, pharmaceutical, and beverage sectors. (Kumar *et al.*, 2003). Using pineapple waste as substrates, some researchers analyzed the synthesis of citric acid by A. Niger under solid-state fermentation conditions. They also looked at the effect of methanol on the fermentation process, which boosted the yield from 37.8% to 54.2 per cent. (Imandi *et al.*, 2008) [14]. The citric acid output was 202.35 g/kg of dry pineapple waste after they optimized the growing conditions. The other study used wet pineapple waste as a substrate for citric acid synthesis.

7.5 Enzymes
7.5.1 Bromelain
Bromelain is the most valuable and one of the well-studied components of pineapple waste. It has been studied since 1894, and Marcano was the first to identify it in 1891. (Devakate *et. al.*, 2009) [9]. It's a pineapple crude extract that contains, among other elements, numerous closely related proteinases that have anti-inflammatory, and antithrombotic properties. It's also utilised as a meat tenderizer and a dietary supplement in the sector of the food sector. (Maurer, 2001) [18]. Bromelain is found mostly in the stem (stem bromelain) and in the fruit (fruit bromelain); but, a minor quantity of bromelain can also be detected in pineapple waste. Bromelain

is extracted and purified from a crude aqueous extract of pineapple wastes using reverse micellar systems. (Hebbar *et al*, 2008) [11]. Ion-exchange chromatography, gel filtration, and ammonium sulphate fractionation were used to purify crude commercial bromelain from the pineapple stem. Bromelain's proteolytic activity is reduced when it is processed under harsh circumstances such as sterilisation, precipitation, and auto-digestion, lowering its therapeutic effects. As a result, bromelain stability has always been a topic of discussion. When stored at -4℃ for 180 days, the natural stability of fruit bromelain was maintained to about 80% without the addition of preservatives. (Bhattacharya and Bhattacharya, 2009) [3].

7.6 Ethanol

Since the last decade, interest in the cost-effective conversion of renewable resources into alcohol by utilising low-cost substrates such as pineapple waste has grown. The potential for ethanol production from waste from a pineapple cannery has been investigated. For ethanol production, organisms such as Saccharomyces cerevisiae and Zymomonas mobilis were utilised (Ban-Kofi and Han, *et al.*, 1990). They say, however, that fermentable sugars such as sucrose, glucose, and fructose are relatively low, and that pre-treatment of the substrate with enzymes such as cellulase and hemicellulase is required for alcohol formation. After pre-treatment with the enzymes cellulase and hemicellulase, both organisms were able to produce roughly 8% ethanol from pineapple waste in 48 hours**.**

7.7 Fibre

Several studies have been done on the fibres found in pineapple fruit. However, some study has focussed on the usage of pineapple waste fibres. According to researchers, dietary fibre powder made from pineapple shells contains about 70.6 per cent total dietary fibre and has better sensory qualities than commercial dietary fibres derived from apples or any other citrus fruits. It has been reported that 2.1g fibre/100 g pineapple pulp waste yields. Pineapple leaf fibres are also being explored for usage in fibre-reinforced polymeric composites due to their high cellulose content, abundance, and low cost. They looked examined how pineapple leaf fibre-reinforced polyester behaved in tensile, flexural, and impact tests.

8. Application of Pineapple Waste

Pineapple waste can also be utilized in industries. Pineapple waste which is generated in tons can be used as an anti-dyeing agent, the animal feed can also be used as a source of energy and carbon, and it can also be used by industries for the removal of heavy metals.

8.1 Energy and Carbon Source

Pineapple wastes are mostly made up of organic materials, hence anaerobic digestion and composting could help to solve the disposal problem. Some of these wastes could be used in the gas-producing industry (Mbuligwe and Kassenga *et al*, 2004) [19]. Fruit waste bio methanation is one of the greatest waste treatments since it contributes energy in the form of methane while also producing a highly stabilized effluent with a nearly neutral pH and odourless feature. They used pineapple fruit waste to manufacture methane using semi-continuous anaerobic digestion, which produced up to 1682 ml of biogas per day with a maximum methane content of 51 per cent. (Rani and Nand *et al*., 2004) [25]. According to the study, different conditions of pineapple peels yielded biogas outputs ranging from 0.41-0.67 m3/kg volatile solids with a methane percentage of 41-65 per cent, Volatile fatty acids as well as methane both have been produced from solid waste of pineapple. They found that one kg of pineapple waste produced up to 53 g of volatile fatty acids with greater alkalinity. Acetic, propionic, butyric, and i-butyric acids were produced in addition to methane. There are reports on using pineapple waste as a carbon substrate to create hydrogen gas from sewage sludge. (Wang *et al*., 2006) [36]. Carbon and nitrogen sources for cell growth and hydrogen synthesis were found in the garbage.

8.2 Removal of Heavy Metals

Pineapple fruit remains have been utilised as a bio sorbent to remove hazardous metals such as mercury, lead, cadmium, copper, zinc, and nickel from the environment. (Senthilkumaar *et al*., 2000) [29]. They discovered that adding phosphate groups to fruit residues enhanced adsorbent capacity at lower pH levels. Citric acid produced from fermented pineapple wastes with A. Niger was used to remove heavy metals such as chromium, copper, lead, nickel, and zinc from contaminated sewage sludge. (Dacera and Babel *et al*., 2008) [7] The potential for using contaminated sewage sludge as a landfill following heavy metal removal has been demonstrated. (Dacera *et al*., 2009) [6]. Pineapple wastewater has also been used as a low-cost -source of nutrients for the bacteria Acinetobacter haemolytic us, which was employed to minimise chromium VI pollution. (Zakaria *et al*., 2007) [37].

8.3 Anti-Dyeing Agent

Textile dyes have been an environmental issue as they are noticeable in little quantities due to their brilliance when mixed and thrown with enormous volumes of wastewater from various dyeing and finishing processes. (Babu *et al*., 2008; Robinson *et al*., 2001) [2, 27]. Some research has detailed the usage of pineapple waste to remove colours. Using pineapple stem as a low-cost adsorbent, adsorption is used to remove a basic dye (methylene blue) from an aqueous solution. The pineapple leaf powder was used as an uncommon bio-adsorbent to remove methylene blue from an aqueous solution in a separate investigation. (Weng and colleagues, 2009) [47].

8.4 Animal Feed

Feed manufacturing is a relatively new industry. Animal feed made from agro-industrial waste appears to address the challenges associated with forage scarcity during important seasons. The use of pineapple waste as ruminant feed has been investigated in several research. Ruminants are given the outer peel, skin, and core of pineapples used in canning operations, as well as the leaves. (Tran *et al*., 2006) [30]. Furthermore, when used as feed, pineapple by-product has been studied for its performance and apparent digestibility. For 80 days, twenty-four cross-bred local goats were fed dehydrated pineapple by-products, and digestibility increased as the animals' weight increased. (Costa *et al*., 2007) [6]. According to a survey, pineapple waste is also used to feed small ruminants in Nigeria, and it could be used if properly processed. Several studies, however, have found that a by-product of the pineapple processing sector is not suitable for animal feed due to its high fibre and carbohydrate content

with low protein content.

9. Conclusions

The goal of this study was to figure out how to make the most of pineapple peel waste which outlines the processing of waste into foods as a method to promote innovative and sustainable development. Pineapple fruit waste comprises a number of high-value reusable materials. This tropical fruit's leaves, peels, and core could be a source of functional food ingredients with therapeutic characteristics, as well as natural anti-microbial and antioxidant substances. In this case, the use of innovative and technological procedures allowed for the creation of value-added products from pineapple waste that had a larger social and economic value than the originals, while also emphasising the reduction in pollution that this conversion allows for. Cannery waste has a high exploitation potential and a promising future. In the case of bromelain extraction, industrial applicability is very popular; new and emerging technologies, such as green technology for biogas or bioethanol production, are very likely to be used with pineapple residues. The growing market for functional foods has opened up a huge window for natural resource usage. Pineapple wastes could provide useful items if new scientific and technological procedures are used. In this aspect, low-cost substrates like pineapple wastes have a bright future. As a result, polluting by-products could be transformed into items having a higher economic value than the primary product.

10. References

1. Babel S, Fukushi K, Sitanrassamee B. Effect of acid speciation on solid waste liquefaction in an anaerobic acid digester. Water Research. 2004;38:2417-2423.
2. Babu BR, Rastogi NK, Raghavarao KSMS. Liquid-liquid extraction of bromelain and polyphenol oxidase using aqueous two-phase system. Chem. Eng. and Proce. 2008;47:83-89.
3. Ban-Koffi L, Han YW. Alcohol production from pineapple waste. World Journal of Microbiology and Biotechnology. 1990;6:281-284.
4. Bhattacharya R, Bhattacharyya D. Preservation of natural stability of fruit bromelain from *Ananas comosus* (pineapple). Journal of Food Biochemistry. 2009;33:1-19.
5. Cabrera HAP, Menezes HC, Oliveria JV, Batista RFS. Evaluation of Residual level of benomyl, methyl parathion, diuron, and vamidothion in pineapple pulp and bagasse (Smooth cayenne). J Agric. Food Chem. 2000;48:5750-5753.
6. Costa RG, Correia MXC, Da Silva JHV, De Medeiros AN, De Carvalho FFR. Effect of different levels of dehydrated pineapple by-products on intake, digestibility and performance of growing goats. Small Ruminant Research. 2007;71:138-143.
7. Dacera DDM, Babel S. Removal of heavy metals from contaminated sewage sludge using *Apergillus niger* fermented raw liquid from pineapple wastes. Bio-resource Technology. 2008;99:1682-1689.
8. Dacera DDM, Babel S, Parkpian P. Potential for land application of contaminated sewage sludge treated with fermented liquid from pineapple waste. J of Hazardous Materials. 2009;167:866-872.
9. Debnath P, Dey P, Chanda A, Bhakta T. A Survey on Pineapple and its medicinal value. Scholars Academic J Pharm. 2012, 1(1).
10. Dull GG. The pineapple: general. In: A. C. Hulme (Ed.). The biochemistry of fruits and their products, Academic Press, New York. 1971;2:303-324.
11. Devakate RV, Patil VV, Waje SS, Throat BN. Purification and drying of bromelain. Separation and Purification Technology. 2009;64:259-264.
12. Faisal MM, Hossa FMM, Rahman S, Bashar ABMA, Hossan S, Rahmatullah M. Effect of methanolic extract of Ananas comosus Leaves on glucose tolerance and acetic acid induced pain in Swiss albino mice. World J. Pharm. Res. 2014;3(8):24-34.
13. Faisal MM, Hossa, Bashar, Rahmatullah M. Effect of methanolic extract of Ananas comosus Leaves on glucose tolerance and acetic acid induced pain in Swiss albino mice. World J. Pharm. Res. 2014;3(8):24-34.
14. Fisal MM, Hossa, Bashar, Rahmatullah, M. *et al.*, 2014.
15. Guo C, Yang J, Wei J, Li Y, Xu J, Jiang Y. Antioxidant activities of peel, pulp, and seed fractions of common fruits as determined by FRAP assay. Nutrition Research. 2003;23:1719-1726.
16. Hebbar HU, Sumana B, Raghavaeao KSMS. Use of reverse micellar system for the extraction and purification of bromelain from pineapple waste Bioresource Tech. 2008;99:4896-4902.
17. Hemalatha R, Anbuselvi S. Physicochemical constituents of pineapple pulp and waste. J Chem. Pharm. Res. 2013;5(2):240-242.
18. Hossain MF, Akhtar S, Anwar M. Nutritional Value and Medicinal Benefits of Pineapple. International Journal of Nutrition and Food Sciences. 2015;4(1):84-88. DOI: 10.11648/j.ijnfs.20150401.22
19. Imandi SB, Bandaru VVR, Somalanka SR, Bandaru SR, Garapati HR. Application of statistical experimental designs of medium constituents for the production of citric acid from pineapple waste. Bioresource Technology. 2008;99:4445-4450.
20. Joy PP, Abraham Minu. Fruits, benefits, processing, preservation and pineapple recipes. Pineapple Research Station, Kerala Agricultural University, 2013.
21. Joy PP. Benefits and uses of pineapple. Pineapple Research Station, Kerala Agricultural University, Kerala, India, 2010.
22. Kawai S, Yasuhiko T, Eriko K, Kazunori OY, Masamichi K, Meisaku, ChihiroIto *et al*. Quantitative study of flavonoids in leaves of Citrus plants J Agric. Food Chem. 2000;48:3865-3871
23. Kumar D, Jain VK, Shanker G, Srivastava A. Utilisation of fruits waste for citric acid production by solid state fermentation. Process Biochemesitry. 2003;38:1725-1729.
24. Kurosumi A, Sasaki C, Yamashita Y, Nakamura Y. Utilization of various fruit juice as carbon source for production of bacterial cellulose by *Acetobacter xylinum* NBRC 13693. Carbohydrate Polymers. 2009;76:333-335.
25. Maurer HR. Bromelain: biochemistry, pharmacology and medical use. Cell Molecular Life Science. 2001;58:1234-1245.
26. Mbuligwe SE, Kassenga GR. Feasibility and strategies for anaerobic digestion of solid wastes for energy production in Dares Salaam city, Tanzania. Resources, Conservation and Recycling. 2004;42:183-203.
27. Muir JG, Rose R, Rosella O. Measurement of short-chain carbohydrates in Common Australian vegetables and fruits by high-performance liquid chromatography (HPLC), J Agric. Food Chem. 2009;57:554-565.

28. Nakthong N, Wongsagonsup R, Amornsakchai T. Characteristics and potential utilizations of starch from pineapple stem waste. Industrial Crops & Products. 2017;105:74-82.
29. Nunes MCN, Emond JP, Rauth M, Dea S, Chau KV. Environmental conditions encountered during typical consumer retail display affect fruit and vegetable quality and waste. Postharvest Biology and Technology. 2009;51:232-241.
30. Oliveira AC, Valentim IB, Silva CA, Bechara EJH, Barros MP, Mano CM, *et al*. Total phenolic content and free radical scavenging activities of methanolic extract powders of tropical fruit residues. Food Chemistry. 2009;115:469-475.
31. Pineapple India. C-26/3, Half Nagarjan, Dimapur, Nagaland, 2012, 797112.
32. Randhir R, Lin YT, Shetty K. Phenolics, their antioxidant and antimicrobial activity in dark germinated fenugreek sprouts in response to peptide and photochemical elicitors. Asia Pacific Journal of Clinical Nutrition. 2004;13:295-307.
33. Rani DS, Nand K. Ensilage of pineapple processing waste for methane generation. Waste Management. 2004;24:523-528.
34. Rasid Kader, Hosain. Fruits of Bangladesh, 1st ed. Rashid Publishing House, Joydevpur, Gazipur, Bangladesh, 1987, 232.
35. Robinson T, McMullan G, Marchant R, Nigam P. Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative. Bioresource Technology. 2001;77:247-255.
36. Sabahelkhier KM, Hussain AS, Ishag KEA. Effect of maturity stage on protein fractionation, *in vitro* protein digestibility and anti-nutrition factors in pineapple (*Ananas comosus*) fruit grown in Southern Sudan. Afr. J Food Sci. 2010;4(8):550-552.
37. Senthilkumaar S, Bharathi S, Nithyanandhi D, Subburam V. Biosorption of toxic heavy metals from aqueous solutions. Bioresource Technology. 2000;75:163-165.
38. Shilpa GM C. Alcohol Production from Fruit and Vegetable Waste. International Journal of Applied Engineering Research. 2013;8:1749-1756.
39. Tilay A, Bule M, Kishenkumar J, Annapure U. Preparation of ferulic acid from agricultural wastes: its improved extraction and purification. Journal of Agricultural and Food Chemistry. 2008;56:7664-7648.
40. Tran AV. Chemical analysis and pulping study of pineapple crown leaves. Industrial Crops and Products. 2006;24:66-74.
41. Tropea A, Wilson D, Torre LG, Curto RB, Saugman P, Davies PT, *et al*. Bioethanol production from pineapple wastes Journal of Food Research, 2014, 3(4), ISSN 1927-0887 E-ISSN 1927-0895
42. Upadhyay A, Chompoo J, Araki N, Tawata S. Antioxidant, antimicrobial, 15-lipoxygenase and advanced glycation endproducts inhibition by pineapple stem waste extract. Journal of Food Science (In communication), 2011a.
43. Upadhyay A, Chompoo J, Kishimoto W, Makise T, Tawata S. HIV-1 integrase and neuraminidase inhibitors from *Alpinia zerumbet.* Journal of Agricultural and Food Chemistry. 2011b;59:2857-2862.
44. Upadhyay A, Uezato Y, Tawata S, Ohkawa H. CYP2C9 catalyzed bioconversion of secondary metabolites of three Okinawan plants. In Proceedings of 16th International Conference on Cytochrome P450; Shoun, H.; Ohkawa, H., Ed.; Nago, Okinawa, Japan, 2009, 31-34.
45. Vijayaraghavan K, Ahmad D, Soning C. Bio-hydrogen generation from mixed fruit peel waste using anaerobic contact filter. International Journal of Hydrogen Energy. 2007;32:4754-4760.
46. Wang CH, Lin PJ, Chang JS. Fermentative conversion of sucrose and pineapple waste into hydrogen gas in phosphate-buffered culture seeded with municipal sewage sludge. Process Biochemistry. 2006;41:1353-1358.
47. Weng CH, Lin YT, Tzeng TW. Removal of methylene blue from aqueous solution by adsorption onto pineapple leaf powder. J of Hazardous Materials. 2009;170:417-424.
48. Zakaria ZA, Zakaria Z, Surif S, Ahmad WA. Biological detoxification of Cr (VI) using wood-husk immobilized *Acinetobacter haemolyticus*. Journal of Hazardous Materials. 2007;148:164-171.