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Valuable Products from Ananas Comosus Waste

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Abstract- In recent times waste from fruits and vegetable processing industry is produced in large quantities around the world and it contains high levels of lignocellulose, fibre, sugar, bioactive and functional compounds and their utilization has become one of the important and challengeable aspects. Many researches have validated that the utilization of waste by discarded fruits as well as its waste materials could be utilized for further as novel, low-cost, economical and natural sources of enzymes, antioxidants, pectin, organic acids, food additives, essential oils, etc. through different methods of extractions, purifications and fermentations etc. Focusing on the Ananas comosus (Pineapple) fruit, scientific and technological studies have already highlighted and confirmed the potential of better and more profitable markets for Ananas comosus Waste. Researchers have focused on the utilization of Ananas Comosus waste primarily for extraction of bromelain enzyme and secondarily as low- cost raw material for the production of ethanol, phenolic anti-oxidants, organic acids, biogas and fibre production. This work is intended to present a comprehensive review of on-going research on utilization of Ananas Comosus Waste.

Keywords:- Ananas comosus waste, Food processing, Waste management.

I. INTRODUCTION

The Ananas comosus (pineapple) is one of the most important tropical and subtropical plant widely cultivated in many places in the world with leading edible member of the family Bromeliaceae and it is a mature fruit contains sugar, a protein digesting enzyme bromelin, citric acid, malic acid, vitamin A and B [1].

It can be used as supplementary nutritional fruit for good health with an excellent source of vitamins and minerals and contains considerable calcium, potassium, fiber, and vitamin C. Pineapple is the third most important tropical fruit in the world after banana and citrus [2, 3]. The plant of Pineapple can grow up to a height of 80-155 cm with a spread of 95-130 cm. It is short, having a stout stump with narrow, fibrous and spiny leaves. The plant develops like a cone-shaped juicy and fleshy fruit with crown at the top [4].

According to FAO online data base, the area under pineapple plantation in 2007 was almost 920,349 ha with an estimated production of more than 18 million tons [5].

Commercially, it is mainly produced as canned fruits and consumed worldwide [6]. Besides, it is also processed as juices, concentrates, and jams. Pineapple slices have also been preserved after freezing [7]. Furthermore, bromelain, the proteolytic enzyme present in the stem of pineapple, is finding wide applications in pharmaceutical and food uses [8].

II. ANANAS COMOSUS WASTES

Tropical and subtropical fruits like mango, banana, papaya, pineapple etc. their processing have considerably higher ratios of by-products than the temperate fruits [9]. Pineapple by-products consist basically of the residual skin, peels, pulp, stem and leaves. It is mostly generated from poor handling of fresh fruit, storage, or lack of good and reliable transportation system [10]. As increasing production of pineapple, results in massive waste generations.

This is mainly due to selection and elimination of components unsuitable for human consumption. Improper management of these wastes would result in the deterioration of environmental quality which can be attributed mainly to the degradation of the sugar-rich contents. Further, the drying, storage and shipment of these wastes is cost effective and hence efficient, inexpensive and eco-friendly utilization is becoming more and more necessary.

During pineapple processing, large amount of unusable waste material is generated [11]. There is up to 40- 80% of pineapple fruit is discarded as waste which having high biological oxygen demand (BOD) and chemical oxygen demand (COD) values [12]. The chemical compositional analysis of pine apple wastes has been carried out (Table 1).

Table 1. Chemical Composition of Ananas Comosus Waste.

	Ensiled[13]	Fresh[13]	Dry[13]	Peel[14]	Whole[12]	Skin[12]	Crown[12]	Pulp[12]
Moisture %	72.49	71.07	27.43	92.2	-	-	-	-
Total solid %	27.51	29.03	72.57	7.8	-	-	-	-
Volatile solids %	87.12	96.12	95.9	89.4	-	-	-	-
pH	4	4.7	4.7	-	-	-	-	-
Ash %	12.88	3.88	4.1	10.6	0.7	0.6	0.4	0.2
As % dry basis								
Cellulose	9	11.2	12	19.8	19.4	14.0	29.6	14.3
Hemicellulose	4.7	7	6.5	11.7	22.4	20.2	23.2	22.1
Pectin	5.1	6.7	7.1	-	-	-	-	-
Ether soluble solids	4	6.1	6.7	-	-	-	-	-
Protein	0.91	3.13	3.3	-	4.4	4.1	4.2	4.6
Reducing sugar	5	25.8	27.8	-	6.5	-	-	-
Non-reducing sugar	1.7	5.7	4.9	-	5.2	-	-	-
Total sugar					11.7	-	-	-
Lignin	9	11.52	11	-	4.7	1.5	4.5	2.3

III. DISPOSAL

Fruit residues may cause serious environmental problems, since it accumulates in agro-industrial yards without having any significant and commercial value. Since disposal of these wastes is expensive due to high costs of transportation and a limited availability of landfills they are unscrupulously disposed causing concern as environmental problems. Waste management or waste disposal includes all measures involved in managing unwanted or discarded materials from inception to final stage of disposal. Management of solid waste is the second most disturbing issue affecting developing countries after water quality.

Pineapple waste is an agricultural waste which is generally described as waste produced from farming activities; it can be from natural sources (organic) or un-natural sources (inorganic).

Major industrial activities such as food and agricultural-based account for about 30% of total industrial waste generated including liquid, residues, and refuse [16].

IV. UTILIZATION OF ANANAS COMOSUS

It is predicted that discarded fruit as well as the waste material from the fruit can be utilized for further industrial processes like fermentation, bioactive component extraction, etc. There has been numerous works on the utilization of waste obtained from fruit and vegetable Industries. In this regard, several efforts have been made in order to utilize Ananas comosus wastes obtained from different sources.

The wastes from pineapple canneries have been used as the substrate for bromelain, organic acids, ethanol, etc. since these are potential source of sugars, vitamins and growth factors [7,17].

Several studies have been carried out since decades on trying to explore the possibility of using these wastes. In past, sugar has been obtained from pineapple effluent by ion exchange and further uses it in syrup for canning pineapple slices [18]. This paper would try to collect and gather information regarding the utilization of pineapple wastes.

1. Bromelain:

Bromelain is a chief protease enzymes found in Ananas comosus(pineapple) [19]. It has been known chemically since 1876 [20] and was identified for the first time by Marcano in 1891 [21]. The investigation and isolation of bromelain has been started since 1894 [22]. Sulfhydryl proteolytic enzymes are the chief constituents of bromelain [23]. Bromelain is abundant in stem and fruit of pineapple plant and it can also be isolated in small amount from pineapple waste such as core, leaves, peel etc. [24]. Bromelain present in fruit of pineapple has assigned the EC number EC 3.4.22.33 and is regarded as fruit bromelain (FBM). Likewise, bromelain present in the stem of pineapple is called stem bromelain (SBM) and its EC number is EC 3.4.22.32.

Stem bromelain possess different biochemical properties and composition as compared to fruit bromelain [25] and contains a variegated blend of different thiol- endopeptidases. Efforts are being made by researchers to achieve highly purified bromelain in less steps and low cost. Modern strategies, such as membrane filtration [26], reverse micellar systems [27], aqueous two phase extraction [28] and chromatographic techniques [29].

Researchers have described the effectiveness of commercial extraction of proteolytic enzyme from pineapple over papain from papaya [30]. Bromelain, unlike papain, does not disappear as the fruit ripens. Crude commercial bromelain from pineapple stem has been purified by successive use of ion-exchange chromatography, gel filtration, and ammonium sulfate fractionation [31].

Recently, purifications of bromelain from crude extract are reported using aqueous two-phase system [32] and metal affinity membranes [33]. Processing under harsh conditions of sterilization, precipitation and auto-digestion reduces the proteolytic activity of bromelain, thereby reducing medicinal properties. Thus, stability of bromelain has always been a subject of interest [34].

2. Ethanol:

Because of current interest in the economic conversion of renewable resources into alcohol, residues of a number of crops were evaluated as substrates for alcohol production. Pineapple waste was one.

About 100,000 tons of pineapple are produced annually in the Ivory Coast and about 40 to 80% is discarded as waste, being composed of peel, cores and pomace [35]. These materials, having high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values, cause a serious pollution problem if not disposed of properly [36]. Pineapple waste, consisting mainly of cellulose and starch, was suggested as a substrate for production of valuable fermentation and no fermentation products [37].

In the past, pineapple waste from canneries has been utilized as the substrate for bromelin, vinegar, wine, food/feed yeast and organic acids [38]. Hence pineapple waste is potential as a substrate for ethanol fermentation.

Organisms like Saccharomyces cerevisiae and Zymomonas mobilis were used for ethanol fermentation [12]. However, they have fermentable sugars which included sucrose, glucose and fructose were relatively low and pretreatment of the substrate with enzymes like cellulose and hemi-cellulose were necessary for alcohol production.

Both organisms were capable of producing about 8% ethanol from pineapple waste in 48h after pretreating with enzymes cellulose and hemi-cellulose. [17] has used respiration deficient strain Saccharomyces cerevisiae ATCC 24553 for continuous ethanol production from pressed juice of pineapple cannery waste. No pretreatment of juice was done and the liquid effluents collected from various stages of processing were added.

At a dilution rate of 0.05 h-1, the ethanol production was 92.5% of the theoretical value. Immobilization of the yeast in k-carrageenan increased the volumetric ethanol productivity by 11.5 times higher than yeast cells at a dilution rate of 1.5 h-1 [39].

The other study used Zymomonas mobilis ATCC 10988 as fermenting organisms for ethanol production [11]. The raw material used here was pineapple cannery waste as well as the juice of rotten or discarded fruit. Ethanol production was 59.0g/l without supplementation and regulation in pH. Alcohol production from pineapple waste is carried out (Table 2).

Table 2. Alcohol production from Ananas waste.

Organism	Yield (% of theoretical values)	Productivity (g/l/h)	Reference
Z. mobilis	92.4	2.81	[11]
S. cerevisiae	92.5	3.75	[17]
S. cerevisiae	86.3	42.8	[39]

3. Phenolic Antioxidant:

Search for new natural antioxidants has been increased over the past years and in this regard agro-industrial by-products are extensively being explored. The low cost of these residues, which otherwise would be discarded as waste in the environment, may be one of the reasons.

Phytochemicals, especially phenolic, in fruits and vegetable are suggested to be the major bioactive compounds for the health benefits.

These compounds are derivatives of the pentose phosphate, shikimate and phenyl porpanoid pathways in plats [40]. The chemistry of phenolic compounds in relation to their antioxidant activity and their occurrence in various food, their bioavailability and metabolism has been described [41].

The phenolic content of pineapple has been reported by several researchers (Table 3). Fruit phenolic content was found as 40.4 mg/100g as gallic acid equivalent with the highest ethyl acetate bound phenolic [42], 2.58 as chlorogenic acid equivalent [43], while juice had 358 mg/L as gallic acid equivalent [44].

Phenolic antioxidants from the wastes are also found to be in higher amounts. The methanol extraction yield and total phenolic contents of pineapple residue (pulp, seeds and peel) were 30.2% and 10 mg/g GAE [45]. They co-related the antioxidant activities of the phenolic compounds using DPPH free radical scavenging activity and superoxide anion scavenging activity. Phenolic such as myricetin, salicyclic acid, tannic acid, trans-cinnamic acid and p-coumaric acid has been identified in the high dietary fiber powder form pineapple shell [7]. The FRAP value for pineapple peel has been reported as 2.01 mmol/100 g wet weight [46].

Our previous work with the waste obtained from the bromelain manufacturing process has shown that phenolic acids, such as syringic and ferulic, might be responsible for the antioxidant and antimicrobial activities of the water extract [21].

We have synthesized potent fungicides from cinnamic, p- coumaric and ferulic acids that were isolated from pineapple stems [47]. We have also proposed that phenolic antioxidant from pineapple waste may be converted to more potent compounds by cytochrome P4502C9 isozyme in vitro [21]. Besides, our laboratory focus on the underutilized parts of various plants [47],[21] and in this regard we have also identified anti-inflammatory and anti-diabetic potential of pineapple stem waste. Our ongoing work on phytochemicals from pineapple peel and leaf showed a high antioxidant activity with high phenolic compounds.

The leaf also has significant amount of phytosterol content, particularly beta- sitosterol, stigmasterola and campestrol. Furthermore, the highest amount of phenolic from pineapple peel was extracted in 30 minutes using 75% ethanol at 75oC.

Phenolic compounds from pineapple wastes (residual pulp, peels and skin) have been enhanced using certain bioprocesses [48]. Total phenolic were increased by two times when the fungus Rhizopus oligosporus was incubated for 12 days in 1:1 pineapple: soybean flour mixture. Another bioprocess where mixture of pineapple residue and soy flour (9:1 and 5:5) using R. oligosporus has revealed that extracts obtained after 2 days with 9:1 treatment showed potent α-amylase inhibition while the extract obtained after 10 days with 5:5 treatment exhibited Helicobacter pylori inhibition [49]. They have linked these activities with the phenolic compounds present in the system.

Table 3. Phenolic antioxidants from the Ananas wastes.

Source	Amount	Reference
Fruit	40.4 mg/ 100 g as GAE	[42]
Fruit	2.58 mg/100g as CAE	[43]
Juice	358 mg/L as GAE	[44]
Residue	1.3 mg/g GAE	[45]
Shell	22.7 mg/g dry matter	[7]
Peel	2.01 mmol FRAP/100g wet weight	[46]
PSW	269.8 mg/100g GAE	In communication
Peel	111.1 mg/g dry matter GAE	(Unpublished)

4. Butanol:

An increasing concern to discovery of alternative energy has been an issue due to fuel crisis and inadequate resource of petroleum. The advantage of bioenergy was renewable substrate resulting in enhanced opportunity to produce sustainable and cost-effective fermentation fuel.

Since its resemblance properties to gasoline, butanol has potential to be an alternative fuel. These similarities include energy level, low vapour pressure, and non- corrosivity. Butanol was a precursor for many chemicals using in numerous industries [50]. Clostridium sp. could generate butanol using acetone-butanol-ethanol (ABE) fermentation [51].

This metabolism using sugar- and starch-based carbon sources is broadly recognized, and has been patented and utilized in industrial process [52]. Two of the most identified solvent genic species for butanol production are C. beijerinckii and C. acetobutylicum.

Although these microorganisms are able to ferment a broad range of sugary substrates [53], few reports on the utilization of fruit industry waste to produce biogas and bio alcohol were available [54].

Pineapple, Ananas comosus, is one of the important fruits being commercially produced and consumed fruit. Pineapple production in this country reached 1.8 million tons per year in 2016 and increased to 2.5 million tons per year in 2017 [53].

However, the procedure of the industrial canned pineapple creates approximately 40% (w/w) waste in form of core and peel [53]. Nonetheless, the liquid portion of this waste contained high reducing sugar concentration of 40.40 g/L with 16.75 g/L sucrose, 19.72 g/L glucose and 20.62 g/L fructose [56]. Raganti et al [53] Utilized commercial high-sugar-content beverages and, under optimized conditions, the butanol concentration and yield from pineapple juice were 13.3 g/L and 0.16 g/g, respectively, using C. acetobutylicum DSM 792 [52].

Bio butanol production (ABE concentration of 5.23 g/L and ABE yield of 0.15 g/g) from pineapple peel waste using C. acetobutylicum B527 were also achieved with acid hydrolysis and detoxification by activated carbon [53].

Pineapple waste juice was utilized as a carbon source for Clostridium beijerinckii TISTR (Thailand Institute of Scientific and Technological Research) 1461. The juice was collected from 'Pattavia' pineapple waste and utilized to prepare culture medium.

The maximum viable C. beijerinckii concentration (2.40 ± 0.12 x 108 CFU/mL) was obtained at 168 h of cultivation with pineapple waste juice under anaerobic condition at 37°C. The butanol concentration of 3.14 ± 0.16 g/L was subsequently produced. A yield of 0.08 g butanol·g-1 reducing sugars was achieved suggesting the necessity to improve fermentation process for higher level of butanol concentration [57].

5. Organic acids:

The organic acids present in Ananas waste juice originate from biochemical processes, from their addition as acidulants, stabilizers, or preservatives, or from the activity of some microorganisms (particularly yeasts and bacteria). They contribute to taste and flavor of juice. For instance, malic and acetic acids bear a negative though significant correlation to sweet taste and scented flavors [58].

[59] found citric (336 mg/100 g), malic (536 mg/100 g), succinic (5.9 mg/100 g), and volatile acids such as acetic acid (6 mg/100 g) as the main organic acids in pineapple juice. The variation in content was not presented, which makes the results difficult to interpret.

Citric and malic acids have been reported as the main non-volatile acids, whereas acetic acid has been reported as the main volatile acid of canned Malayan pineapple juice. [60] identified more volatile acids in canned pineapple juice. Acetic acid (3 mg/100 g), caproic acid (0.2 mg/100 g), and caprylic acid (0.1 mg/100 g) were found in canned pineapple juice produced in the Philippines with nine other acids, including propionic acid, isobutyric acid, n-butyric acid, 2- methylbutyric acid, isovaleric acid, capronic acid, caprylic acid, capric acid, and cinnamic acid. [61] identified isocitric acid as another organic acid of fresh pineapple juice (Table 4). Citric and malic acids provide the basic acid taste that characterizes pineapple juice, [62] but numerous other acids contribute to the overall sour sensation.

Cold sterilization is known to minimize the effect of heat treatment on the factors determining the sensorial quality of fruit juice. [63] reported, for instance, that cold sterilization and clarification of pineapple juice by microfiltration did not affect the acidity of pineapple juice with an average value of 800 mg/100 g citric acid, which is the same as the one reported by [64] (Table 4). A practical problem of cold sterilization and clarification is that such processing methods are far more expensive than traditional processing technologies. Hendrix et al [65] reported that the use of commercial pectinase (0.03%, v/v) as clarifying agent before ultrafiltration did not affect the acidity of the pineapple juice as compared with the fresh juice. Therefore, the use of commercial pectinase seems to be interesting for the juice processing industry as far as acidity is concerned.

Table 4. organic acid content of pineapple Waste juice.

	Amount (mg/100g)				
Organic acid	Minimum	Average	Maximum	Detection method	References
Malic acid	300.0	400.0	536.3	HPLC, GLC	[61],[64]
Citric acid	400.0	800.0	1100.0	HPLC	[61],[64]
Ascorbic acid	9.2	50.8	93.8	Titration, fluorometry	[61]
Isocitric acid	8.0	17.2	26.5	HPLC	[64]

V. DYE ADSORBENT

Dye has become an indispensable tool for a variety of industries. More than 100000 types of dyes were produced exceeding 150 metric tons per year. They are used extensively in many industries which make the research on the colour production more important. Despite that, dye can cause major environmental problems due to its toxicity and carcinogenic properties.

So, it is important for the dyes to be treated before being disposed into the environment [66]. So, activated carbon derived from different pineapple wastes namely pineapple crown, core and peel which prepared by chemical activation by using phosphoric acid (H3PO4) and sodium hydroxide (NaOH) were utilized to adsorb methylene blue and malachite green dyes [67]. Pineapple waste is easily available and has the potential to be used for small industries that releases dye as effluent.

VI. DECOMPOSABLE POTS

Sustainable development has been defined in many ways to develop industrial sustainability to move toward a low-carbon society [68]. So we reported on the suitability of pineapple waste for production of decomposable nursery pots [69].

The experiment was completely randomized, with three replicates and eighteen formula treatments. Treatments consisted of varying ratios of pineapple waste to binder, including 2:1, 1:0 (fresh pineapple waste), 1:1, 1:1.5, and 1:2; the textures tested were coarse, medium, and fine, and the pot thicknesses were 0.5, 1.0 and 1.5 cm. The results revealed that the physical and chemical properties of pineapple waste were suitable for use in nursery pots on an experimental scale.

The optimal physical and chemical properties for a decomposable pot included a 1:0 ratio of pineapple waste to binder, a coarse structure, and a pot thickness of 1 cm. With these properties, the pot degraded in more than 45 days, N and P release rates were 0.49% and 7.97 mg-P/kg, respectively, and the average absorption rate was 258.43%. Saturation occurred in 45 min, and the water evaporated in 444 h [69].

VII. ENERGY AND CARBON SOURCE

Pineapple wastes generally comprise of organic substances and hence the disposal problem could be attenuated by anaerobic digestion and composting. Some of these wastes could have industrial applications for gas generations [70].

Biomethanation of fruit wastes is the best suited waste treatment as it both adds energy in the form of methane and also results in a highly stabilized effluent with almost neutral pH and odorless property [71].

They utilized pineapple waste for the production of methane using semi-continuous anaerobic digestion which could produce up to 1682 ml/day of biogas with methane content of 51% in maximum. [72] reported that different conditions of pineapple peels gave biogas yields ranging from 0.41-0.67 m3/kg volatile solids with methane content of 41-65%.

Solid pineapple waste has been used to produce volatile fatty acids and methane [73]. They reported that at higher alkalinity, up to 53 g volatile fatty acids were produced from one kg of pineapple waste. Acetic, propionic, butyric, i-butyric and valeric acids were produced along with methane. Reports on utilizing pineapple waste as the carbon substrate to produce hydrogen gas from municipal sewage sludge is found [74].

The waste contained carbon and nitrogen source for cell growth and hydrogen production. In other report, pineapple fruit wastes have been suggested as a source of carbon for bacterial production of cellulose by Acetobacter xylinum [75].

Pineapple waste, as one of the substrates in mixed fruit wastes, has been utilized for biogas generation [76]. When using 15% pineapple peel in the mixed fruit peel waste, bio-hydrogen gas was generated at 0.73m3/kg of volatile solid destroyed [77].

The sugars contained in pineapple cannery effluent have been utilized for the production of single cell protein using continuous cultivation [17]. The dilution rate had significant effect on biomass as well as protein content. There was an increase in biomass and protein content of Candida utilis with increasing dilution rate.

VIII. ANIMAL FEED

Pineapple waste is a by-product from pineapple planting and processing. Pineapple leaf is just thrown away at farm site and left for open burning before replanting [78]. Meanwhile, the pineapple waste after processing such as, skin, pulp, and rotten flesh are also thrown to the dumping site to decompose naturally or burnt on site. Such pineapple waste is being wasted because it still rich in sugars, organic acids, and fiber [79].

One of the possible ways to utilize the pineapple waste is by converting it into valuable products such as animal feeds. The pineapple waste which rich in fiber can be used as an energy source as well as a good digestive feed for animals such as poultry [80], broiler [80] and cow [81].
Feeding dairy cows with pineapple waste can also increase the milk production due to increase in digestion rate [82]. However, feeding the dairy cows with fresh pineapple waste are difficult since the waste are easily rotten and cannot be stored for the long-term usage. Thus, converting pineapple waste into pellets are the suitable method in handling such waste where the pellet form can increase the bulk density, improve the storability as well as reduce the cost of transportation. Furthermore, feed pellets are easier to control over the desired feed ration with the nutritional needs for animals [83].

Pineapple leaf powder was compacted into pellets in the twin-screw extruder (Thermo Scientific EuroLab 16 mm XL) with two different process parameters (screw speed of the extruder and moisture content of the powder). The screw speed was varied at 50 and 150 rpm during the extrusion of pineapple leaf powder. The moisture content of the pineapple leaf powder was studied between 35% to 55% in order to determine the suitable moisture content for feed pellets. The barrel temperature was kept constant at 100oC. The die diameter of the extruder was fixed at 7 mm for pellet dimension. The physical properties of the pellets such as, friability, true density, bulk density, porosity and hardness were determined.

The pineapple leaf waste was analyzed for its nutritional content (crude protein, crude fiber, ash, fat and sugar) before converting the waste into animal feed pellets. (Table 5) shows the nutritional value of pineapple leaf waste. It shows that the waste contained high fiber (48.7 g/100 g) which has high digestibility potential in animal. Feeding dairy cows with pineapple waste silage improved the milk production by 20% which due to the high fiber content that increase the digestion rate in cows [82]. It was also found that pineapple residue is a good feedstock for dairy cows [84].

Table 5. nutritional value of pineapple waste samples per 100 grams.

Nutritional content	Pineapple leaf waste (g)
Dry mater	12.91
Crude Protein	7.3
Fat	1.8
Ash	5.7
Moisture	8.5
Crude Fibre	48.7
Total Sugar	9.6

Pellets from pineapple leaf waste were prepared at different moisture content and screw speed. The physical properties of the pellets were determined such as, friability, bulk density, true density, porosity and hardness. It can be concluded that the pineapple leaf waste has high fiber content which suitable for dairy cows. The ranges of pellet's friability, bulk density, true density, hardness and porosity were between 0.71 - 1.51 %, 300.56 - 343.33 kg/m3, 1474.33 - 1513.67 kg/m3, 1.05 - 3.9 kg/cm2 and 76.71 - 80.14 %, respectively

IX. CONCLUSION

Pineapple waste contains many reusable substances of high value. The wastes from canneries have high exploitation potential with encouraging future. Industrial applicability in case of bromelain extraction is very popular; new and emerging technologies, such as green technology for biogas or bioethanol production is highly likely with pineapple residues.

Furthermore, dietary fibers and phenolic antioxidants could be used as impending nutraceutic resource, capable of offering significant low-cost nutritional dietary supplement for low-income communities. If novel scientific and technological methods are applied, valuable products from pineapple wastes could be obtained. In this regard, cheap substrates, such as pineapple wastes have promising prospect. Thus, environmentally polluting by-products could be converted into products with a higher economic value than the main product. However, verification of this hypothesis is indispensable in order to apply pineapple cannery waste as industrial raw materials.

Therefore, there is need for sustainable utilization of pineapple waste into a value-added product, to reduce the wastage, and also produce a viable product, that can be commercialized as an environment-friendly alternative for carbon source utilization this can aid in reducing pollution of the environment.

FUTURE ASPECTS

The pineapple waste approach not only addresses the environmental issues but also creates an opportunity to build multi-million industries to manufacture different types of products. The plant could be set up in the vicinity of pineapple processing facilities and offer opportunities for development of processing encouraging circular economy and generating wealth from waste. Challenges such as year-round operation of such plants may pose an operational risk which could be addressed setting up a facility where multiple feed stocks can be processed throughout the year. Process intensification and green processes should also be kept in the focus to reduce the cost, water and energy footprint which will contribute to the economy and lead to a diversification of by-products for the sustainable value addition of pineapple waste.

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