

Article citation info:

Wollur C., Satish S., Manahala A.K.H., Mudlappa C.B., Jayarama M., Hemakumar K.H. 2026. A Comprehensive Review of Pineapple Peel Extract as a Sustainable Engineering Material. *Drewno. Prace naukowe. Doniesienia. Komunikaty* 69 (217): 00083. <https://doi.org/10.53502/wood-216578>



Łukasiewicz
Puzos
Institute of
Technology

Drewno. Prace naukowe. Doniesienia. Komunikaty Wood. Research papers. Reports. Announcements

Journal website: <https://drewno-wood.pl>



A Comprehensive Review of Pineapple Peel Extract as a Sustainable Engineering Material

Channabasavaraj Wollur^{a*} 

Sanya Satish^b

Anil Kumar Haridgeri Manahala^c

Chethan Byragondlu Mudlappa^d

Manjunath Jayarama^e

Hemakumar K H^f

^a Civil Engineering, Cambridge Institute of Technology, KR Puram Bangalore

^b Data Science, Cambridge Institute of Technology, KR Puram Bangalore

^c Civil Engineering, Ballari Institute of Technology & Management (BITM), Ballary, Karnataka, India

^d Civil Engineering, Neethu Contractors

^e Civil Engineering, Cambridge Institute of Technology, KR Puram Bangalore

^f Department of Chemistry, Cambridge Institute of Technology, KR Puram Bangalore

Article info

Received: 26 August 2025

Accepted: 9 January 2026

Published: 18 March 2026

Keywords

pineapple peel
extraction method
soxhlet extraction
sustainable material
SDG11

Pineapple (*Ananas comosus* L.), a prominent perennial herb of the Bromeliaceae family, stands as a globally cultivated tropical and subtropical fruit of significant economic importance. Ranking third in global tropical fruit production, it accounts for approximately 20 % of the total, following banana and citrus. Beyond fresh consumption, pineapple finds extensive use in various food products, including canned fruit, jellies, pickles, jams, squashes, juice concentrates, and essences. It is also recognized for its rich nutrient profile, encompassing minerals, vitamins, dietary fiber, and notable antioxidant activities.

Despite its widespread utilization, the processing residues of pineapple, particularly the peel, have largely remained underexplored. Historically, researchers have concentrated on two primary applications for general pineapple waste: the extraction of bromelain and the production of substances like ethanol, phenolic antioxidants, heavy metal adsorbents, organic acids, biogas, and fibers. These endeavors often leverage cost-effective methods such as fermentation and drying.

This paper focuses specifically on pineapple peel (PP), treating it not only as an agricultural residue but as a potential engineering material. It aims to give a clear, comprehensive overview of where PP is generated, its detailed physicochemical composition, and the different extraction techniques used to obtain valuable compounds from it. The discussion includes how various pre-treatment strategies influence and improve the efficiency of extracting these high-value constituents. The work also emphasizes the potential applications of PP extracts in both biomedical and engineering sectors, demonstrating that PP can serve purposes far beyond conventional waste disposal or low-value by-product use. In addition, the paper outlines the emerging role of PP extract as a novel engineering feedstock, envisioning its contribution to the design and development of sustainable materials. Overall, the study seeks to reposition PP from a discarded residue to a versatile, high-potential resource with wide-ranging and impactful applications.

DOI: 10.53502/wood-216578

This is an open access article under the CC BY 4.0 license:

<https://creativecommons.org/licenses/by/4.0/deed.en>.

* Corresponding author: builerraju@yahoo.com

Introduction

Pineapple (*Ananas comosus L.*), a prominent perennial herb belonging to the Bromeliaceae family [17, 100, 152, 180, 202] holds significant economic importance as a globally cultivated tropical and subtropical fruit. With Malaysia, Thailand, and other Asian nations being key growing regions [49, 164, 210] ranks third in global tropical fruit production, accounting for approximately 20 % of the total, following banana and citrus [182, 145, 155, 176, 130]. This fruit juice is the third most preferred worldwide after orange and apple juices [32]. According to a 2018 survey [122], the annual global pineapple production ranged from 16 to 19 million tons. By 2019, global production had risen considerably to 28.17 million tons, marking a substantial 48 % increase within one year, and in 2021, it is reported that 28.65 million tons of pineapple production across the globe [66, 210]. In the Indian context, the 2019 pineapple production reached 1.71 million tons, which constituted approximately 6.07 % of the total global production [64].

Its widespread popularity stems from its appealing flavor profile, characterized by a refreshing sugar-acid balance, making it a favored choice for both fresh consumption and diverse processing applications. Pineapple is utilized in the production of various food products, including canned fruit, jellies, pickles, jams, squashes, juice concentrates, essence [5, 52, 84, 141, 207], and dried products [96, 110, 202]. The pineapple plant itself is a relatively short-statured herb, typically reaching heights of 75–150 cm and widths of 90–120 cm. It features a stout stem and narrow, fibrous leaves often bearing spines. The plant culminates in the production of a distinctive, juicy, and fleshy cone-shaped multiple fruit, crowned by a characteristic leafy top [138, 150, 215]. Generally, the optimum storage temperature for pineapple is in the range of 7–13 °C [184, 227]. In India, key commercial varieties include 'Kew' and 'Queen' [138, 215]. The unique multiple fruit structure of pineapple, resulting from the fusion of numerous berries, contributes to its characteristic form and edible nature as a prominent tropical fruit [150].

Pineapple is rich in nutrients and minerals, vitamins, and dietary fiber, as well as effective in antioxidant activities. [27, 72, 132, 112, 230]. Pineapple fruit is composed of 30 % pulp, where 70 % of it is discarded in the form of peel, crown, core, trimmings, and residue [140, 147, 180]. Pineapple production (tons/ha) in India accounts for 16.45, whereas world production reaches 25.04. To calculate the average pineapple waste per hectare that would have produced in 2019, peel (30 %) 4.93 tons/ha, core (7 %) 1.15 tons/ha, crown (13 %) 2.14 tons/ha and Pulp (50 %) 8.22 tons/ha (pomace 2.47 tons/ha and juice 5.76 tons/ha) [23, 82, 85, 130, 188]. Pineapple processing residues have not been explored much [122]. So far researchers have concentrated on using pineapple waste

for two purposes: first, to extract bromelain, and second, to produce ethanol, phenolic antioxidants, heavy metals, organic acids, biogas, fiber production, and organic acids at a low cost with the help of methods such as fermentation, drying [141, 209]. The present study mainly focuses on the various possible applications of PP, especially as an engineering material.

This review specifically concentrates on pineapple peel (PP), seeking to deliver an in-depth overview of its generation, physicochemical profile, and diverse extraction methodologies. It emphasizes the pivotal influence of pre-processing and conditioning strategies on maximizing the recovery of high-value constituents from PP. In particular, the article underscores the prospective uses of PP-derived extracts in biomedical and engineering domains, arguing for their relevance far beyond conventional waste disposal or by-product handling. It also examines the emerging prospects of PP extract as an innovative engineering feedstock, anticipating a scenario in which this abundant residue plays a prominent role in sustainable material design and development. By illuminating these under-explored avenues, the study aspires to reposition PP from a low-value discard to a strategic bioresource with wide-ranging and impactful technological applications.

Methods

An exhaustive literature search was conducted using leading scientific research databases, including Web of Science, Science Direct, and Scopus. The survey focused on combinations of keywords such as “chemical composition,” “extraction,” “biological application,” and “engineering application.” As depicted in Figure 1. Additionally, the “References” sections of each article were reviewed to identify further relevant publications.

The initial search, conducted for articles published during the years 2009–2024, yielded 112 scientific papers. From this initial pool, only articles directly relevant to the aforementioned keywords were selected for further analysis. A focused search on the topic of “chemical composition” for articles published between 2009 and 2024 resulted in the identification of 12 additional relevant studies. Similarly, the review of literature on the “extraction process,” based on publications from 2010 to 2024, led to the discovery of 41 further articles. In the case of “engineering and biological applications,” examining works published between 2011 and 2024 yielded 69 additional publications. As in the earlier stages, the reference lists of these articles were also examined to identify further relevant sources.

In addition to peer-reviewed publications, relevant source documents and book chapters across all available years were examined. Particular attention was given to the original publications where the key concepts and



Fig. 1. The keywords used for reviewing the paper are weighted by relevance, with larger font sizes indicating higher relevance

keywords were first introduced or defined. All collected materials were analyzed in terms of their relevance to the extraction processes, engineering and biological applications, and chemical composition, in order to highlight the most valuable contributions within the field.

Pineapple Cultivars: A Global Overview

The number of pineapple types is about 37. This is classified as cultivars. The four major commercial cultivars include the red Spanish, the princess, abacaxi, and the smooth cayenne. [121,180]. Table 1 indicates the variety of pineapple reported by the various authors in different countries.

Pineapples are one of the leading commercial fruits of the tropics around the world, and the major producing areas are Southeast Asia and Latin America. Table 2 gives the statistics of the pineapple producers around the world.

Chemical Profile of Pineapple Peel

Over 400 compounds have been identified among different cultivar of fresh and processed pineapple products [31, 60, 108, 136, 170, 208, 214] Pineapple fruit is primarily

composed of 80–85 % water and 12–15 % sugar, along with smaller amounts of acid (0.6 %), protein (0.4 %), ash (0.5 %), fat (0.1 %), fiber, and vitamins, particularly A and C [12, 121, 172, 177, 183, 184, 191, 202].

In contrast, PP, like most plant fibers, possesses a complex structure of crystalline cellulose microfibrils encased within an amorphous region. This region largely consists of lignin, hemicellulose [187], pectin, extractives, waxes [93], antioxidants, starch, and phenolics [54, 177]. Notably, PP is a rich source of gallic acid, catechins, epicatechins, and ferulic acids. These bioactive compounds, including saponins, flavonoids, tannins, and anthocyanins, have significant potential as active antioxidant ingredients [120, 142, 193, 211, 213].

Among all the valuable components in pineapple waste, bromelain stands out as the most extensively studied and commercially valuable. This proteolytic enzyme, found in the Bromeliaceae plant family, was first identified in 1891 by Marcano and has been investigated since 1894 [21, 52]. While stems and fruits contain higher concentrations, bromelain is also present in pineapple waste such as cores, peels, and leaves, albeit in smaller quantities [104, 128, 203, 217]. Recent studies indicate that PP contains approximately 13.158 $\mu\text{m}/\text{ml}$

Table 1. Common Varieties of pineapple reported by the authors around the world

Sl No	Variety of pineapple	Country	Latitude and longitude	Reference
1	Josapine	Malaysia	4.2105°N, 101.9758° E	[140]
2	Queen and Kew	India	21.0000°N, 78.0000° E	[96,138, 173, 215]
3	Golden MD2	Missouri, USA	38.5739°N, -92.6038° W	[44, 161]
4	Pérola and Jupi	Itapororoca, Brazil	-6.8115°S, -35.2448°W	[34, 137]
5	Morris	Malaysia	4.2105°N, 101.9758° E	[58]
6	Amritha	India	21.0000°N, 78.0000° E	[119, 174]
7	Tripura	India	21.0000°N, 78.0000° E	[96, 173, 215]
8	Pattavia	Thailand	15.8700°N, 100.9925°E	[226]
9	Bali	China	35.0000°N, 105.0000°E	[211]

Table 2. Quantity of Pineapple available around the world

Sl no.	Country	Quantity grown / year	Reference
1.	Thailand	1.979 million metric tons	[33, 37, 144,104]
2.	Philippines	1.618 million metric tons	[204]
3.	Malaysia	300,000 metric tonnes	[38, 58, 151, 116, 139, 197, 200]
4.	Brazil	2,650.48 metric tons	[144, 204]
5.	Costa Rica	3,056.45 metric tons	[197, 204, 222]
6.	India	1.71 million metric tons	[64, 94, 121, 131, 180]
7.	Portugal	948 metric tons	[202]
8.	West Africa	2.3 million metric tons	[121]
9.	China	2.25 million metric tons	[211, 212, 233]
10.	Nigeria	1.91 million metric tons	[2, 10, 67, 58, 221]
11.	Mexico	1.27 million metric tons	[71, 161]
12.	Colombia	850,000 metric tons	[192]
13.	Indonesia	3.15 million metric tons	[117, 140, 179, 219, 218,]

of bromelain, while crowns contain about 113.79 $\mu\text{m}/\text{ml}$ [150]. PP also contains a significant amount of citric acid (45-46 % yield), ash (10.6 %), moisture (92.2 %), cellulose (19.8 %), and hemicellulose (11.7 %) [150].

The identification of bromelain in pineapple waste represents a significant opportunity for valorization [58, 192]. This enzyme is in high demand across the food, medical, and cosmetic industries due to its diverse applications [41, 58]. It is worth noting that pineapple extract also contains other compounds like peroxidase, acid phosphatase, various protease inhibitors, and organically bound calcium, which might influence bromelain activity or protein cleavage [29, 104, 217].

Previous research has extensively documented the nutrient profile of pineapples, covering aspects like fiber, protein, carotenoids, mineral composition, and total polyphenol content [9, 75, 216]. However, the antioxidant capacity of pineapples has received considerably less attention. One notable study by [50] examined the total phenolic content and antioxidant activities in methanolic extracts of pineapple residues (pulp, seeds, and peels from a local juice factory) through DPPH and superoxide anion scavenging activity assays [211].

Sample Preparation and Pre-processing

To extract the different chemical constituents from the PP, a rigorous preparation is needed for various applications, consistently beginning with thorough cleaning to remove impurities, typically using tap water [45, 167, 165] or distilled water [30, 150], sometimes followed by sanitization with chlorine solution [36]. After washing,

drying methods vary widely, including cabinet drying at 40°C for 6 hours [180, air oven drying at 40 °C for 48 hours [88, 229], hot air oven drying at 55–60 °C for 48 hours [151, 193], drying at 70 °C for 12 hours [165], or at 105 °C until crisp [144]. Alternative approaches include shade drying [131], freeze-drying [33, 161], refractance window drying at 80 °C for 4 hours [44], and sun drying for 5 days [124, 201].

Before drying, peels are often cut into smaller pieces or cubes ranging from 1 mm to 5 cm to expedite drying [77, 121, 167, 150]. Once dried, the peels are ground into powder using various equipment such as kitchen blenders [165], high-speed grinders [77], disc mill crushers, saw-milling apparatus, primary knife grinders [167], or hammer mills [67]. The powders are then sieved to achieve uniform particle sizes, with mesh sizes reported from 0.5 mm to 100 mesh [88,131], 35 mesh [167], 40 mesh [165], 170 mesh for particles smaller than 88 microns [30], and ranges like 150–300 micrometers [144] or 500 micrometers [67]. The varied mesh sizes are used depending on their applications.

The prepared PP powder or dried material is stored under conditions that preserve its quality, including refrigeration at 4°C [180], desiccators [88, 165, 229], airtight containers [100, 219], vacuum-sealed bags [121], or freezing at –20 °C [33] or at –80 °C [161].

Further processing depends on the intended use. Extraction methods include soaking powder samples in methanol or cold water, shaking for one hour, filtering, and repeating the extraction. Combined extracts are rotary evaporated at 40 °C, freeze-dried, and stored at –80 °C [25, 87, 92]. Other techniques involve maceration in distilled water followed by

heating [150], or advanced extraction methods such as Soxhlet, supercritical fluid, and solvent extraction for polyphenols [121].

Chemical pre-treatments include sulfuric acid hydrolysis to break down lignin and expose cellulose [34, 67], carbonization at 250°C, and calcination between 300°C and 800°C to produce bio-catalysts, with 600°C identified as optimal [30].

Overall, these diverse preparation methods highlight the versatility of PP as a raw material for various industrial and scientific applications.

Extraction of pineapple peel

The use of PP to make valuable products involves different methods to extract useful chemicals. Researchers use a variety of techniques, from traditional methods to newer, more eco-friendly ones. Table 3 shows the different extraction methods used by researchers, which are mainly chosen based on the type of compound they want to obtain.

Microwave-Assisted Extraction (MAE) is a highly effective method where increased temperature and

Table 3. Extraction method and component extracted by various researchers

Sl no	Extraction Method	Component Extracted	National /International Standard	Reference
1	Soxhlet Extraction	Crude lipid, rutin, simple method for extracting polyphenolic compounds, Quercetin	ISO 13944, 2 nd edition 2012-08-01	[88, 121, 131]
2	Nanofiltration Membrane	Bromelain	No standardised method	[58]
3	Ultrasound Assisted Extraction	Polyphenols	No standardised method	[229]
4	Microwave Assisted Extraction	Preparation of crude bromelain extract, Phenolics	No standardised method	[61, 152]
7	Mass Culturing	For extraction of bacteria cells from pineapple peel extract	No standardised method	[166]
8	Enzyme Digestion	Extraction of dietary fibre	No standardised method	[88]
9	Two-Phase Partitioning System	Bromelain	No standardised method	[129]
10	Reverse Micellar Extraction	Bromelain	No standardised method	[17, 129, 225]
11	Solid-Liquid Extraction	Optimisation of natural antioxidants	ASTM D6953-18	[202]
12	Response Surface Methodology (RSM)	Extraction of hydro soluble bioactive compounds	No standardised method	[202]
13	Supercritical Fluid Extraction	Method used to extract bioactive compounds (polyphenolic compounds), Essential oils	No standardised method	[121, 223]
14	Solvent Extraction	Widely used method for bioactive compound extraction (polyphenolic compounds)	ASTM E3008	[121]
15	Phosphomolybdenum Method	Evaluation of Total Antioxidant Capacity (TAC)	No standardised method	[211]
16	Hydrothermal Treatment	Preparation of carbon dots from pineapple peel	No standardised method	[14, 133]
17	Acid Hydrolysis Method	Isolation of pineapple peel cellulose nanocrystals	No standardised method	[122]
18	Colorimetric method	Flavonoid content	ASTM E275	[100]
19.	Thermogravimetric method	Cellulose content of pretreated pineapple peel	ISO 11358-1	[167]

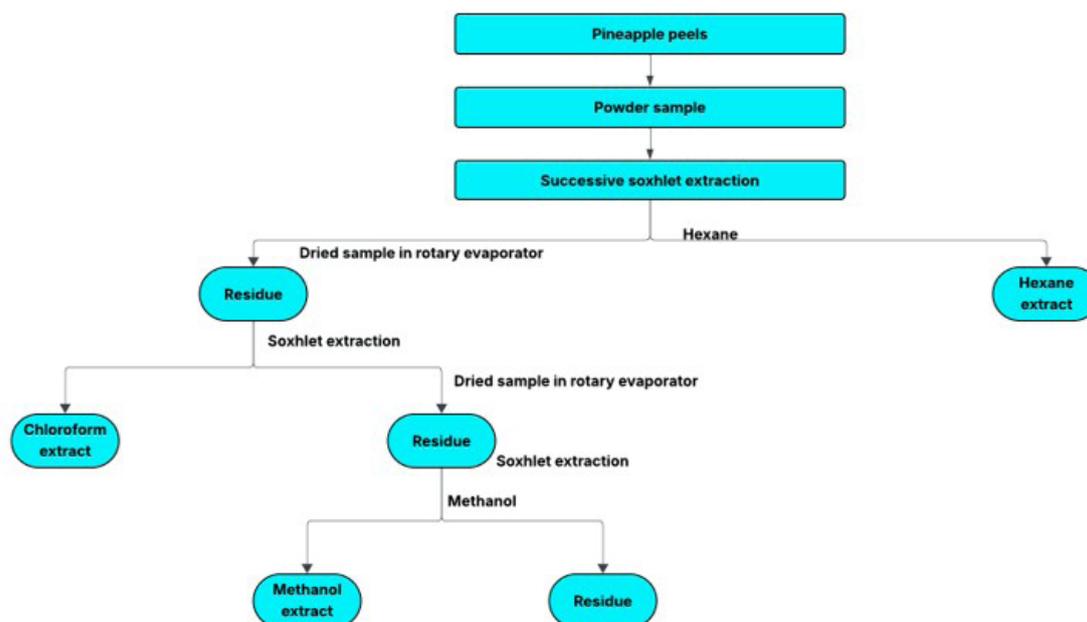


Fig. 2. Soxhlet extraction process

pressure alter the cell structure, enhancing solvent penetration [180]. For instance, crude bromelain extract has been successfully prepared from pineapple rind powder using MAE at 2450 MHz with distilled water. This process involves mixing 5 g of powder with 50 mL of distilled water, followed by microwave treatment, centrifugation (5000 g, 10 min), filtration, and storage of the supernatant at 20 °C. Bromelain purification is often achieved via gel filtration chromatography with Sephadex G-75 resin, and enzyme activity is determined using casein as the substrate. MAE has consistently yielded bromelain with high proteolytic activity and protein content, with purified bromelain showing the highest specific activity and a semi-crystalline nature by XRD analysis [180]. Beyond bromelain, MAE has also been used to extract pectin from PP, which exhibits plasticizing and antioxidant properties for food packaging films [94, 143, 181]. For pectin, MAE parameters can include sulfuric acid at pH 1.83, a 1:30 (w/v) solid-to-solvent ratio, extraction times of 1–20 minutes, temperatures of 70–80°C, pH 1.0–2.5, and microwave power of 400–600 W [101, 151, 169, 195,]. Extracts obtained via MAE are typically cooled, filtered, centrifuged, and pectin can be coagulated with ethanol, washed, oven-dried, and stored [151]. Additionally, microwave ovens operating at 2.55 MHz frequency and 60% power (420W) for 1 minute are used with various solvents, including water-ethanol, methanol, and deep eutectic solvents (DESs) like choline chloride-glycerol [44, 220]. Autohydrolysis and MAE using traditional solvents (water, ethanol, methanol) are also employed for phenolic compound extraction [11, 196].

Soxhlet extraction is a traditional and common method for isolating various bioactive compounds from PP. The flow of the extraction process is as depicted in Figure 2, suggested by [131, 235]. The efficiency of extraction is influenced by solvent type (e.g., methanol, gasoline, ethyl acetate, or aqueous methanol), duration, and temperature [121, 126]. For lipid determination, petroleum ether is commonly used [88]. In one study, 5g of sample was refluxed with 250 mL of solvent (e.g., 50 mL ethanol in 200 mL deionized water) at 78 °C for several hours. The extract was concentrated, and total phenolic content was measured using the Folin-Ciocalteu method, while antioxidant activity was assessed by DPPH radical scavenging assays [11]. Other studies have compared Soxhlet extraction with magnetic stirring and orbital shaking for phenolic compound isolation [11]. A typical Soxhlet protocol for phenolics involves continuously extracting 4 g of dried PP powder with 80 % methanol for 90 minutes. Subsequent solvent-solvent extraction with hexane (1:1 ratio with distillate) yields extract and raffinate phases, with the extract phase collected for specific compound determination, like quercetin, via colorimetric analysis at 510 nm. For hot continuous extraction, finely chopped, air-dried PP (250 g) can be successively extracted with petroleum ether, ethyl acetate, ethanol, and water for eight hours each. The extracts are then filtered, concentrated via rotary evaporation at 50 °C, and yields are calculated [113]. Similarly, 70 g of dried PP powder has been extracted with n-hexane for 7 hours to obtain yellow oil, followed by methanolic hot extraction for other crude extracts [6, 162].

Supercritical Fluid Extraction (SFE), particularly using non-toxic and low-cost carbon dioxide (CO₂), is considered a greener and highly efficient alternative. SFE operates with fluids above their critical temperature and pressure, allowing them to dissolve compounds with properties of both liquids and gases. This method offers high extraction efficiency in shorter times and selectively extracts compounds without harmful residues [59, 121, 135]. SFE has demonstrated higher yields of essential oil (0.17 %) compared to hydro-distillation (HD) and enzyme-assisted hydro-distillation (HDEA), with the essential oil primarily composed of propanoic acid ethyl ester, lactic acid ethyl ester, and 2-heptanol [56, 135, 160].

Traditional solvent extraction (Maceration) involves soaking dried plant powder in solvent, such as 80 % methanol for 48 hours [2] or ethanol for 72 hours [100, 119], followed by filtration and rotary evaporation to dryness. Extracts are typically stored at 4 °C to 8 ± 2 °C [2, 100, 119, 158]. Another general method involves extracting 2 g of ground sample with 20 mL of 70 % aqueous methanol by magnetic stirring for 3 hours, followed by centrifugation and filtration [168, 210].

Green extraction techniques like Ultrasound-Assisted Extraction (UAE) are gaining traction due to their simplicity and lower processing costs [13, 67]. UAE can be performed in an ultrasonic water bath at an ambient temperature with a specific working amplitude [202].

Optimized conditions for hydro-soluble compound extraction from PP often involve using Response Surface Methodology (RSM) with a Central Composite Rotatable Design (CCRD). Parameters like solvent-to-peel ratio (e.g., 1:1 to 1:6) and extraction time (e.g., 5–45 min) are varied, with Total Phenolic Content (TPC) as a key response. The effects of temperature (ambient up to 100°C), UAE at ambient temperature, and consecutive extraction steps are explored. The influence of solvent type, including water and ethanol-water mixtures, is investigated at various temperatures. Hydroalcoholic extracts, after centrifugation, may undergo ethanol evaporation under low pressure to yield an aqueous extract [202].

Characterization of derived products

After extraction, various analytical techniques are employed to characterize the PP extracts and derived products.

Antioxidant activity of PP extracts is commonly quantified using DPPH (2,2-diphenyl-1-picrylhydrazyl) and FRAP (Ferric Reducing Antioxidant Power) assays. One study reported values of 91.79 ± 1.98 μmol Trolox/g dry extract by DPPH and 174.50 ± 9.98 μmol Trolox/g dry extract by FRAP [202]. Total

Phenolic Content (TPC) is often evaluated using the Folin-Ciocalteu method [98], while Total Flavonoid Content (TFC) is assessed via the aluminum chloride method [115, 228]. HPLC (High-Performance Liquid Chromatography analysis) is used to quantify specific phenolic compounds like ferulic acid, which has been identified as a highly abundant phenolic in PP extracts [121]. Phytochemical tests confirm the presence of various compounds, Wagner's reagent for alkaloids, Molisch's test for carbohydrates, Keller Kelliani's test for cardiac glycosides, alkaline reagent test for flavonoids, ferric chloride test for phenols, precipitate test for phlobatannins, ninhydrin test for proteins, foaming test for saponins, Liebermann-Burchard test for steroids, Braymer's test for tannins, Salkowki's test for terpenoids, and HCl test for quinones [78, 162]. Proximate analysis of PP provides crucial nutritional information. This includes determining moisture content (drying at 105°C to constant weight), lipid content (gravimetrically after Soxhlet extraction with petroleum ether), ash content (burning in a muffle furnace at 550 °C), nitrogen content (Kjeldahl method for protein calculation with a 5.7 conversion factor), and crude fiber content (organic residue after acid/alkali digestion using a Fibertec analyzer). Carbohydrate content is then calculated by difference [7, 210].

Other characterizations include pH and color measurements (pH meter at 25 °C for 1:10 w/v sample: water mixture, and colorimeter, respectively) [109]. Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) are also determined using modified methods [4, 210]. Cellulose content can be determined using a thermogravimetric method [67, 167]. PP is a versatile substrate for producing various value-added products. This includes bromelain, ethanol, phenolic antioxidants, heavy metal adsorbents, organic acids, biogas, and fibers, often through methods like fermentation and drying [141]. Alkaline pre-treatment (e.g., with NaOH or KOH) under moderate conditions has been shown to enhance bioethanol production [46, 102, 134, 206]. Carbon Dots (CDs) can be prepared from PP via a hydrothermal method involving juice extraction and reaction with ethanol in an autoclave at 150°C, followed by extraction, dialysis, and centrifugation to yield highly fluorescent CDs [14, 111]. PP activated carbons (PPAC) are prepared via chemical activation (e.g., with 1N HCl solution) at various temperatures (300–500 °C). These carbons are characterized for properties like pH, conductivity, moisture/ash/volatile content, iodine/methylene blue values, and fixed carbon by standard procedures, with surface morphology analyzed using Scanning Electron Microscopy (SEM) [97, 144, 148, 163].

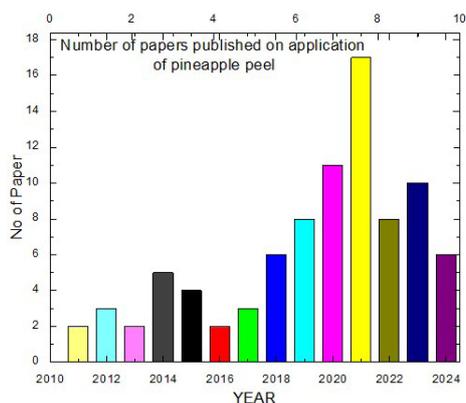


Fig. 3. Scientific papers on applications of pineapple peel

Diverse applications of pineapple peel extracts and derivatives

PP, a significant by-product of the pineapple processing industry, is increasingly recognized as a valuable resource with a wide array of applications across engineering and biological fields. Its rich composition allows for the transformation of waste into high-value products, addressing both environmental concerns and industrial demands [11, 141, 154]. Figure 3 illustrates the number of papers published annually on PP applications in various industries such as biomedical, pharmaceutical, and engineering domains.

Engineering applications

Biofuel production: PP is a viable low-cost substrate for producing bioethanol through microbial degradation, serving as an alternative to gasoline and offering economic benefits, especially for small-scale community production [35, 53, 102, 153, 162, 223]. It can also be utilized for biogas production [141, 223] and bio-butanol [162].

Bio-composites and reinforcement materials: The high cellulose content in pineapple leaf fiber makes it an excellent reinforcement material in composite materials [70]. For example, incorporating pineapple fibers into epoxy composites enhances thermal stability and creep resistance, especially with the addition of lignin [73]. Pineapple leaf fibers also improve the thermal stability and mechanical properties of polylactic acid bio-composites, significantly increasing thermal conductivity with up to 50% fiber loading [70, 76]. These bio-composites hold potential for diverse applications such as automotive bumper guards [1], offering both cost reduction and enhanced safety. They are also suitable for outer decorative purposes in housing, building infrastructure, interior parts in automotive and aerospace fields, structural building in boats and naval ships, and the sports sector, owing to their

load-carrying capability, corrosion resistance, and biocompatibility [70].

Adsorbents for wastewater treatment: Pineapple waste, including the core and peel, serves as an economically feasible biosorbent for removing pollutants from aqueous solutions. Pineapple core and peel show promise for effectively treating wastewater, with the peel specifically demonstrating potential for removing Pb (II) ions [219]. PP powder can also adsorb cationic dyes like methylene blue, which is commonly used in various industries [144].

Polymer materials and packaging: PP is a potential source of cellulose for producing hydrogels [48], plasticizers [167, 181], and nanocellulose [48, 81, 167], which can be used in food packaging films, exhibiting plasticizing and antioxidant properties [94, 181]. Alginate films encapsulating PP bioactive compounds have also shown effective microbial inhibition and retarded lipid oxidation in meat [94, 186].

Thermal behavior

Understanding the thermal properties of PP is crucial for its industrial applications, particularly in catalyst preparation and composite material development.

Thermal decomposition: PP components exhibit sequential decomposition with increasing temperatures. Organic substances typically decompose first (120–190°C), followed by hemicellulose (190–320°C), cellulose (320–400°C), and finally lignin (above 400°C). Differences in decomposition temperatures can occur due to variations in atmospheric conditions (e.g., nitrogen vs. air) during analysis. This understanding guides the selection of calcination temperatures (e.g., 300–800°C) for preparing catalysts, as these temperatures induce compositional changes relevant to their efficiency in processes like glycerol carbonate synthesis via transesterification [30, 71, 89].

Flammability: Pineapple fiber-reinforced composites tend to show increased flammability due to the

presence of cellulose, a complex carbohydrate composed of carbon and hydrogen atoms, which promotes burning [105]. Flammability assessments are conducted according to standards like ASTM D-635 and UL-94 V/HB, evaluating both horizontal and vertical modes using a Bunsen burner [70].

Thermal conductivity: The thermal conductivity of pineapple fiber and cellulose-reinforced polyester composites is assessed using methods like the Lee disc method [63, 70].

Biological and health applications

Antioxidant and anti-inflammatory properties: Pineapple contains healthy nutrients and phytochemicals with significant antioxidant and anti-inflammatory capacities [3, 11, 15, 18, 19, 121, 131, 141, 171, 180, 221]. Flavonoids like quercetin act as antioxidants, neutralizing free radicals that cause cellular damage, aging, and contribute to diseases like heart disease and cancer [95, 131, 171, 178].

Cancer prevention and treatment: Studies suggest pineapple components, including bromelain and antioxidants like manganese and vitamin C, help in fighting tumors and prevent various cancers, with bromelains from pineapple fruit stalk being particularly effective against breast cancer (BC) tumor cells [55, 83, 180]. Bromelain has also shown potential as an anticancer agent and for modulating tumor growth [17, 43, 128]. Pineapple waste extract may even prevent abnormal skin growth and reduce squamous cell skin melanoma [141].

Digestive health: PP aids digestion and has been linked to reducing intestinal parasites, constipation, and Irritable Bowel Syndrome (IBS) symptoms [162]. Their high content of insoluble dietary fibers (IDFs) promotes good bowel health and insulin sensitivity, lowering the risk of diabetes [130]. PP powder can also fortify the properties of probiotic yogurt [190].

Anti-microbial and anti-bacterial activities: PP extracts exhibit anti-bacterial and anti-microbial activities [113]. Bioactive compounds from PP, encapsulated in alginate films, have shown effective microbial inhibition on meat [94, 118, 186].

Wound healing and anti-edematous effects: Bromelain, a proteolytic enzyme from pineapple, demonstrates anti-edematous, anti-inflammatory, and fibrinolytic activities, and is used in various stages of wound healing and the treatment of soft tissue injuries [17, 26, 28].

Arthritis and inflammation relief: Bromelain acts as an anti-inflammatory agent for arthritis [162], can treat osteoarthritis, and reduce swelling and inflammation after surgery [26, 79, 80, 103]. Flavonoids, including quercetin, function as antihistamines, lessening

allergies and alleviating inflammation and pain associated with arthritis [131].

Dermatological and cosmetic uses: Glucosylceramide from pineapple shows effects such as skin moisturizing, improvement of atopic dermatitis, and protection of the skin barrier [107, 146]. Bromelain is widely used in the cosmetic industry [41, 58, 128]. Pineapple waste extract can also prevent the development of abnormal skin growth [141].

Pharmaceutical and medical applications: Pineapple extracts are used in traditional medicine for various ailments, including coughing, intestinal bleeding, diarrhea, malaria, typhoid infections, and gastrointestinal complaints [16, 62, 91, 99, 119, 156, 157, 199, 231]. Bromelain is well-known for clinical and therapeutic applications, including improving antibiotic action, and as a drug for systemic treatment of inflammatory, blood coagulation-related, and malignant diseases [17, 128, 189]. A mixture of PP extract and calcium hydroxide paste is even being considered as an alternative intra-canal medicament in root canal treatment [86, 90].

Food industry applications: Bromelain is used for meat tenderization, grain protein solubilization, beer clarification, baking, and protein hydrolysate production [17, 128, 224]. PP can also be used as a functional ingredient in food, particularly for developing calorie-reduced and dietary fiber-enriched products [33, 88, 151]. In animal feed, it is applied as protein hydrolysis and palatability enhancement [33]. PP mixed with forage sorghum produces good silage for ruminants [68, 185].

Other biological applications: Pineapple waste is applicable for producing an eco-enzyme through fermentation [179]. Ferulic acid from PP residues can be a precursor to vanillin through microbial biological transformation [114, 175]. The aromatic compounds in pineapple skin can even repel mosquitoes [232].

Environmental impact of pineapple peel

The pineapple processing industry generates substantial amounts of waste, primarily consisting of peels, cores, crowns, pomace, and stems, which often go untreated [130, 180, 11]. This waste constitutes a significant portion of the fruit, with estimates ranging from approximately 35 % to as high as 80 % of the total pineapple weight [3, 15, 47, 106, 127, 161, 221]. Specifically, PP alone accounts for roughly 29–42 % (w/w) of the total by-products [42, 94, 151]. The sheer volume of this discarded organic material, estimated at 8.31–11.46 million tons globally in 2021 [210] and projected to increase with rising pineapple production [65], poses severe environmental challenges. When inadequately disposed of, this waste can lead to serious hazards and a burden to the municipal solid waste dump.

Environmental hazards

Greenhouse gas emissions: Decomposition of organic pineapple waste in landfills generates methane, a potent greenhouse gas, contributing to climate change [149, 180, 210].

Air pollution: Burning pineapple waste, a common disposal method, releases smoke and haze into the atmosphere [74, 167]. Additionally, rapid decomposition of high-water-content waste causes a putrid odor, contributing to air contamination [193].

Land and water pollution: Dumping waste directly into the environment leads to soil pollution, characterized by microbial growth and foul odors [125, 193]. Furthermore, pineapple waste can cause water pollution due to its high concentration of nutrients and low pH [44]. The high Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values associated with pineapple waste also indicate its significant polluting potential in water bodies [17, 24].

Economic and resource waste: Beyond environmental damage, the inadequate disposal of pineapple waste represents significant economic and nutritional waste [234]. This is particularly impactful given the rich nutritional composition of pineapple by-products, including carbohydrates (50–80 %), vitamin C, and beta-carotene, which are suitable for developing value-added products [20, 34, 39]. Industries are losing an estimated €360 million in potential economic value annually by treating 60 % of their by-products as waste [33].

Solutions and opportunities

Recognizing these issues, concerted efforts are being made to repurpose pineapple processing waste (PPW), transforming it from a liability into a valuable resource [150, 219]. This waste can be utilized in various industries for purposes such as extracting bioactive compounds for pharmaceuticals, food, and cosmetics [121, 152, 229], producing bioethanol [153], or serving as an anti-dyeing agent, animal feed, energy source, or for heavy metal removal [69, 141, 183]. While a small portion is traditionally used as livestock feed or fertilizer [167], modern approaches focus on converting this bio-waste into highly beneficial products for scientific and technological advancements [219]. Researchers are exploring strategies like co-digestion with other organic wastes to reduce volatile solids [8, 17] and even vermicomposting, which rapidly decomposes pulp and peel, changing waste pH from acidic to neutral/alkaline [17, 123]. The significant amount of PP available, particularly after fresh-cut processing (40–50 % in regions like Chiang Rai, Thailand) [57], underscores its potential as a readily

available source for valuable extractions like bromelain [104]. By embracing these recovery and utilization strategies, industries can mitigate environmental pollution while creating new economic opportunities from what was once considered waste.

Conclusions

Pineapple (*Ananas comosus L.*), representing the third most cultivated tropical fruit globally, generates substantial agro-industrial waste in the form of peels and leaves. These by-products, particularly PP, have emerged as versatile substrates rich in valuable phytochemicals and nutrients. Advanced extraction techniques such as Microwave-Assisted Extraction (MAE), Soxhlet extraction, and Supercritical Fluid Extraction (SFE) have demonstrated efficiency and selectivity in isolating bioactive compounds, including bromelain, phenolic antioxidants, quercetin, and rutin, from pineapple waste. Phytochemical analyses further confirm the presence of alkaloids, flavonoids, cardiac glycosides, and a wide variety of other functional compounds.

PP and leaf-derived materials exhibit significant potential for value-added applications, including the production of organic acids, bioethanol, biogas, heavy metal adsorbents, and fiber-reinforced composites. Notably, pineapple leaf fibers enhance the thermal and mechanical performance of bio-composites, although cellulose-rich composites may increase flammability. The sequential thermal decomposition profile of PP components is influenced by atmospheric conditions, underpinning the importance of process optimization for industrial applications.

Health-wise, pineapple-derived constituents such as bromelain and antioxidants show promise for anti-cancer, anti-inflammatory, and antioxidant therapies, with emerging evidence supporting their roles in tumor suppression and prevention. Despite these benefits, the high BOD and COD values associated with pineapple waste highlight its significant environmental impact if not managed properly.

Overall, the multifaceted application potential of PP underscores its value as a sustainable resource for food, pharmaceutical, environmental, and material science sectors. Further research focused on optimized extraction, valorization strategies, and environmental management is warranted to fully harness the benefits of pineapple agro-waste, while mitigating its ecological risks.

Future recommendation

Based on an extensive analysis of PP valorization techniques, this paper proposes several key recommendations to guide future studies in sustainable materials science.

1. Develop and optimize integrated extraction processes (e.g., MAE–SFE hybrid systems) to improve yield, selectivity, and energy efficiency of bioactive compound recovery. Conduct techno-economic assessments and life cycle analyses (LCA) to evaluate the scalability and sustainability of pineapple waste valorization processes.
2. Bio-based flame retardants: Developing non-toxic, halogen-free flame retardants (e.g., using lignin, phytic acid, or mineral-based fillers like magnesium hydroxide) to coat PP before composite fabrication.
3. Green synthesis of nanoparticles: Utilizing pineapple peel extracts as reducing and capping agents for the “green synthesis” of silver (Ag) or zinc oxide (ZnO) nanoparticles, which have potent antimicrobial properties.
4. Sequential extraction: Developing a multi-stage process where bromelain is extracted first, followed by antioxidants, and the remaining fibrous residue is used for bioethanol or biogas production.

Conflict of interest

The author(s) declare(s) that there is no conflict of interest concerning the publication of this article.

References

- A. Mani, G. R. Jinu, M. Shunmuga Priyan (2024)** “Enhancing Vinyl Ester Composites With Biocarbon From Pineapple Leaf Fiber And Dragon Fruit Peel Waste: A Characterization Study”, *Biomass Conversion And Biorefinery* Vol: 14, PP: 30771–30787.
- Abayomi M. Ajayi A, Adekunle I. Coker, Oyetola T. Oyebanjo, Iyanuoluwa Mary Adebajo, Olusegun G. Ademowo, (2021)** “Ananas Comosus (L) Merrill (Pineapple) Fruit Peel Extract Demonstrates Antimalarial, Anti-Nociceptive And Anti-Inflammatory Activities In Experimental Models”, *Journal of Ethnopharmacology*, Vol: 282, <https://doi.org/10.1016/J.jep.2021.114576>.
- Acosta-Estrada B.A, Gutiérrez-Uribe, J.A, Serna-Saldívar S.O (2014)** “Bound Phenolics In Foods, A Review”. *Food Chem.* Vol: 152, PP: 46–55. DOI: 10.1016/j.foodchem.2013.11.093
- Adebiyi J.A , Obadina A.O, Mulaba-Bafubandi A.F, Adebo O.A , Kayitesi.E, (2016)** “Effect Of Fermentation And Malting On The Microstructure And Selected Physicochemical Properties Of Pearl Millet (*Pennisetum Glaucum*) Flour And Biscuit”. *Journal of Cereal Science.* Vol:70, PP:132–139. <https://doi.org/10.1016/j.jcs.2016.05.026>
- Aili Hamzah A.F, Hamzah M.H, Che Man H, Jamali N.S, Siajam S.I, Ismail M.H. (2021)** “Recent Updates On The Conversion Of Pineapple Waste (Ananas Comosus) To Value-Added Products, Future Perspectives And Challenges”. *Agronomy*, Vol:11. <https://doi.org/10.3390/agronomy11112221>
- Ajani O.O, Owwoye F.T, Owolabi F.E, Akinlabu D.K and Audu O.Y (2019).** “Phytochemical Screening and Nutra-ceutical Potential of Sandbox Tree (*Huracrepitans L.*) Seed Oil”. *Foods and Raw Materials*, Vol:7, PP: 143–150. DOI: 10.21603/2308-4057-2019-1-143-150
- Akrapunam M.A, Darbe J.W, (1994).** “Chemical Composition And Functional Properties Of Blends Of Maize And Bambara Groundnut Flours For Cookie Production”. *Plant Foods for Human Nutrition.* Vol:46, PP:147–155. DOI: <https://doi.org/10.1007/BF01088767>
- Alavrez R and Liden G. (2007)** “Semi-Continuous Codigestion of Solid Slaughterhouse Waste, Manure and Fruit and Vegetable Waste”. *Renewable Energy.* Vol:33, PP: 726-734. <https://doi.org/10.1016/j.renene.2007.05.001>.
- Alejandra R and Emperatriz P.D.D (2011)** “Chemical Composition and Bioactive Compounds in Pineapple, Guava, And Soursop Pulp”. *Interciencia.* Vol:36, PP:71–75.
- Ali M, Hashim N, Abd Aziz S, Lasekan O. (2020)** “Pineapple (Ananas Comosus): A comprehensive review of nutritional values, volatile compounds, health benefits, and potential food products”. *Food Research International.* Vol:137. DOI: <https://doi.org/10.1016/j.foodres.2020.109675>
- Alias N.H (2017)** “Preliminary Investigation On the Total Phenolic Content and Antioxidant Activity of Pineapple Wastes Via Microwave-Assisted Extraction at Fixed Microwave Power”. *Chemical Engineering Transactions.* Vol:56, PP:1675–1680. DOI:10.3303/CET1756280
- Alotham M, Bhat R, & Karim A.A. (2009).** Anti-Oxidant Capacity and Phenolic Content of Selected Tropical Fruits from Malaysia, Extracted with Different Solvents. *Food Chemistry.* Vol:115, PP:785-788. DOI: <https://doi.org/10.1016/j.foodchem.2008.12.005>
- Ameer K, Shahbaz H.M, Kwon J-H. (2017)** “Green Extraction Methods for Polyphenols from Plant Matrices and Their Byproducts”. *Comprehensive Reviews in Food Science and Food Safety*, Vol:16, PP:295–315. DOI: <https://doi.org/10.1111/1541-4337.12253>.
- Anjugam Vandarkuzhal S, Natarajan S, Jeyabalan S, Sivaraman G, Singaravadivel S, Muthusubramanian**

- S, & Viswanathan B (2018)**. “Pineapple Peel-Derived Carbon Dots: Applications as Sensor, Molecular Keypad Lock, And Memory Device”. ACS Omega. Vol:3, PP:12584–12592. DOI: 10.1021/acsomega.8b01146
- Aruna T.E (2019)** Production of Value-Added Product from Pineapple Peels Using Solid State Fermentation. Innovative Food Science & Emerging Technologies. Vol: 57. DOI: <https://doi.org/10.1016/j.ifset.2019.102193>.
- Asase A, Akwetey G.A, Achel D.G (2010)**. “Ethnopharmacological Use of Herbal Remedies for The Treatment of Malaria in The Dangme West District of Ghana”. J. Ethnopharmacol. Vol:129, PP:367–376. DOI: 10.1016/j.jep.2010.04.001.
- Atul Upadhyay, Jeewan Prava Lama And Shinkichi Tawata (2010)**, “Utilization of Pineapple Waste: A Review”, Journal of Food Science and Technology Nepal, Vol: 6. DOI:10.3126/jfstn.v6i0.8255.
- B Moreira, Eliana Pereira, Tiane C. Finimundy, José Pinela, Ricardo C. Calhelha, Márcio Caroch, Dejan Stojkoviš, Marina Sokovic, Isabel C.F.R. Ferreira, Cristina Caleja, Lillian Barros (2021)** “Pineapple Peel As A Source Of Bioactive Compounds With Health Benefits And Potential Application In The Food Industry,” 5th International Symposium on Phytochemicals in Medicine and Food, DOI: <http://hdl.handle.net/10198/25014>
- B. A. Ashwar, A. Gani, A. Shah, I. A. Wani, And F. A. Masoodi (2016)** “Preparation, Health Benefits and Applications of Resistant Starch—A Review” Starch - Stärke, Vol. 68, PP:287–301. DOI: <https://doi.org/10.1002/star.201500064>.
- Baidhe E, Kigozi J, Mukisa I, Muyania C, Namubiru L, Kitarikawe B (2021)** “Unearthing The Potential of Solid Waste Generated Along the Pineapple Drying Process Line in Uganda: A Review”. Environmental Challenges. Vol:2. DOI: <https://doi.org/10.1016/j.envc.2020.100012>
- Balls A. K., Thompson R. R. And Kies M. W. (1941)**. Bromelain. Properties and Commercial Production. Industrial & Engineering Chemistry. Vol:33. DOI: <https://doi.org/10.1021/ie50379a028>
- Balogun, O.L., Adewuyi, S.A., Disu, O.R., Afodu, J.O., Ayo-Bello, T.A., (2018)** Profitability and technical efficiency of pineapple production in Ogun state, Nigeria, International Journal of Fruit Science, Vo: 18, PP: 436–444. 10.1080/15538362.2018.1470594
- Banerjee S, Ranganathan V, Patti A, Arora A (2018)** Valorisation Of Pineapple Wastes For Food And Therapeutic Applications. Trends in Food Science & Technology, Vol:82, PP:60–70. DOI: <https://doi.org/10.1016/j.tifs.2018.09.024>
- Ban-Koffi L and Han Y. W. (1990)**. Alcohol Production from Pineapple Waste. World Journal of Microbiology and Biotechnology. Vol:6, PP:281–284. DOI: <https://doi.org/10.1007/BF01201297>
- Barretto, L.C.; Moreira, J.D.; Santos, J.A.; Narendra, N.; Santos, R.A. (2013)** Characterization and extraction of volatile compounds from pineapple (Ananas comosus L. Merrill) processing residues. Food Science Technology International, , Vol: 33(4), PP: 638–645. <https://doi.org/10.1590/S0101-20612013000400007>
- Bartholomew D.P, Paull R.E and Rohrbach K.G (2003)**. The Pineapple: Botany, Production and Uses. CABI, Wallingford. <https://doi.org/10.1079/9780851995038.0000>
- Benítez S, Soro L, Achaerandio I, Sepulcre F, Pujolá M. (2014)** “Combined Effect Of A Low Permeable Film And Edible Coatings Or Calcium Dips On The Quality Of Fresh-Cut Pineapple”. Journal of Food Process Engineering. Vol:37, PP:91–99. DOI: 10.1111/jfpe.12063
- Bhui K, Prasad S, George J. And Shukla Y (2009)**. “Bromelain Inhibits COX-2 Expression By Blocking The Activation Of MAPK Regulated NF-Kappa B Against Skin Tumor Initiating Triggering Mitochondrial Death Pathway”. Cancer Lett, Vol:28, PP:167–176. DOI: [10.1016/j.canlet.2009.03.003](https://doi.org/10.1016/j.canlet.2009.03.003)
- Bitange N T, Zhang W, Shi Y X and Wenbin Z (2008)**. “Therapeutic Application of Pineapple Protease (Bromelain)”. Pakistan Journal of Nutrition, Vol:7, PP: 513–520. DOI: 10.3923/pjn.2008.513.520
- Boossayamas Topool, Manop Charoenchaitrakool, Kandis Sudsakorn (2023)**, “Facile Synthesis Of Glycerol Carbonate Using Green Catalysts Derived From Pineapple Peels”, Topics In Catalysis, Vol: 66, PP:1619–1630, DOI: <https://doi.org/10.1007/S11244-023-01800-Z>
- Brat P, Thi-Hoang L.N, Soler A, Reynes M & Brillouet J. M (2004)**. “Physicochemical Characterization Of A New Pineapple Hybrid (FLHORAN41 Cv.)” J Journal of Agricultural and Food Chemistry. Vol:52, PP:6170–6177. DOI: [10.1021/jf0492621](https://doi.org/10.1021/jf0492621).
- Cabrera H. A. P, Menezes H. C, Oliveira J. V and Batista R. F. S (2000)**. “Evaluation of Residual Levels of Benomyl, Methyl Parathion, Diuron, And Vamidotion in Pineapple Pulp and Bagasse (Smooth Cayenne)”. Journal of Agricultural and Food Chemistry. Vol:48, PP:5750–5753. DOI: [10.1021/jf9911444](https://doi.org/10.1021/jf9911444)
- Campos D.A, Ribeiro T.B, Teixeira J.A, Pastrana L, Pintado M.M (2020)** “Integral Valorization of Pineapple (Ananas Comosus L) By-Products Through a Green Chemistry Approach Towards Added Value Ingredients”. Foods. Vol:9, PP:1–21. DOI: <https://doi.org/10.3390/Foods9010060>
- Caroline Gomes Dos Reis, Rossana Maria Feitosa De Figueirêdo, Alexandre José De Melo Queiroz, Yaroslávia Ferreira Paiva, Lumara Tatiely Santos Amadeu, Francislaine Suelia Dos Santos, João Paulo De Lima Ferreira, Thalís Leandro Bezerra De Lima, Fabrícia Santos Andrade, Josivanda Palmeira Gomes, Wilton Pereira Da Silva And Dyego Da Costa Santos (2023)** “Pineapple Peel Flours: Drying Kinetics, Thermodynamic Properties, And Physicochemical Characterization”. Transport Processes in Porous Material and Porous Media: Latest Developments and New Approaches, Vol:11. DOI: <https://doi.org/10.3390/Pr11113161>

- Casabar J T, Ramaraj R, Tipnee S, Unpaprom Y (2020)** “Enhancement Of Hydrolysis With Trichoderma Harzianum For Bioethanol Production Of Sonicated Pineapple Fruit Peel”. *Fuel*, Vol:279. DOI: <https://doi.org/10.1016/j.fuel.2020.118437>
- CEAGESP.** Programa Brasileiro Para Modernização Da Horticultura: Normas De Classificação Do Abacaxi; CQH. Documentos 24; Central De Qualidade Em Horticultura: São Paulo, Brazil, 2003.
- Chaitip P, Chaiboonsri C, Dewitt A (2015)** “Canned Pineapple in Syrup from Thailand Export by Using Panel ARDL Method”. *Procedia Economics and Finance*. Vol:24, PP:101–107. DOI: 10.1016/S2212-5671(15)00624-3
- Chan Y.K (2000)** “Status of The Pineapple Industry and Research and Development in Malaysia”. *Acta Horticult*. Vol:529, PP:77–83. DOI:10.17660/ActaHortic.2000.529.7
- Charoenphun N (2019)** “Utilization Of Pineapple Residue For Pineapple Paste And Gluten-Freepie”. *Journal of Food Health and Bioenvironmental Science*. Vol:12, PP:20–28.
- R S, Sakhare P Z, Bhaskar N, H U (2015)** Efficacy of reverse micellar extracted fruit bromelain in meat tenderization. *Journal of Food Science and Technology*. Vol:52, PP:3870–3880. doi: 10.1007/s13197-014-1454-z
- Chaurasiya, R. S., & Umesh Hebbar, H. (2013)** Extraction of bromelain from pineapple core and purification by RME and precipitation methods, *Separation and Purification Technology*, Vol:111, PP: 90–97. [10.1016/j.seppur.2013.03.029](https://doi.org/10.1016/j.seppur.2013.03.029)
- Chen Y, Zhang H, Feng X, Liang M, Yuhao Z, Hongjie Dai (2021)** “Lignocellulose nanocrystals from pineapple peel: Preparation, characterization and application as efficient Pickering emulsion stabilizers”. *Food Research International*. Vol:150. DOI: <https://doi.org/10.1016/j.foodres.2021.110738>
- Chobotava K, Vernallis A. B, Majid F. A. A (2009)** “Bromelains Activity and Potential as an Anti-Cancer Agent: Current Evidence And Perspectives”. *Cancer Lett*. Vol:290, PP:148-156. DOI: [10.1016/j.canlet.2009.08.001](https://doi.org/10.1016/j.canlet.2009.08.001)
- Claudia L Vargas-Serna, Claudia I Ochoa-Martínez and Carlos Vélez-Pasos (2022)** “Microwave-Assisted Extraction of Phenolic Compounds from Pineapple Peel Using Deep Eutectic Solvents”. *Horticulturae*. Vol: 8, DOI: 10.3390/horticulturae8090791.
- Dacera D. D. M., Babel S. and Parkpian P. (2009)** Potential for land application of contaminated sewage sludge treated with fermentaed liquid from pineapple wastes. *Journal of Hazardous Materials*, Vol:167(1-3), PP: 866-872. [10.1016/j.jhazmat.2009.01.064](https://doi.org/10.1016/j.jhazmat.2009.01.064)
- Dahunsi So (2019)** Liquefaction of pineapple peel Pretreatment and process optimization, *Energy*, Vol: 185(2), PP: 1017-1031. [10.1016/j.energy.2019.07.123](https://doi.org/10.1016/j.energy.2019.07.123)
- Dai H, Huang H (2017)** “Synthesis, Characterization and Properties of Pineapple Peel Cellulose-G-Acrylic Acid Hydrogel Loaded with Kaolin and Sepia Ink”. *Cellulose*. Vol:24, PP:69–84. DOI: 10.1007/s10570-016-1101-0.
- Dai H, Zhang H, Ma L, Zhou H, Yong Y, Guo T, Zhang Y, Huihua H (2019)** “Green Ph/Magnetic Sensitive Hydrogels Based On Pineapple Peel Cellulose And Polyvinyl Alcohol: Synthesis, Characterization And Naringin Prolonged Release”. *Carbohydr Polym*. Vol:209, PP:51–61. DOI: 10.1016/j.carbpol.2019.01.014.
- Dale O. Evans, Wallace G. Sanford, Duane P. Bartholomew (2002)** Pineapple Cultivation in Hawaii, Cooperative Extension Service. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/f_n-7.pdf
- De Oliveira A.C, Valentim I.B, Silva C.A, Bechara E.J.H, Barros M.P, Mano C.M, Goulart M.O.F (2009)** “Total Phenolic Content and Free Radical Scavenging Activities of Methanolic Extract Powders of Tropical Fruit Peels”. *Food Chemistry*. Vol:115, PP:469–475. DOI: <https://doi.org/10.1016/j.foodchem.2008.12.045>
- Debnath P, Dey P, Chanda A, Bhakta T (2012)**, A Survey On Pineapple and Its Medicinal Value. *Scholars Academic Journal of Pharmacy*. Vol:1.
- Devakate RV, Patil V V, Waje S, Throat B (2009)** “Purification and Drying of Bromelain. Separation and Purification Technology”. *Separation and Purification Technology*. Vol:64, PP:259-264. DOI: 10.1016/j.seppur.2008.09.012
- Devi A, Bajar S, Kour H, Kothari R, Pant D, Singh A. (2022)** Lignocellulosic biomass valorization for bioethanol production: a circular bioeconomy approach, *Bioenergy Research*, Vol: 15(4), PP: 1820-1841. <https://doi.org/10.1007/s12155-022-10401-9>
- Diaz-Vela J, Totosa A, Cruz A, Lourdes P C (2013)** “In Vitro Evaluation Of The Fermentation Of Added-Value Agroindustrial By-Products: Cactus Pear (Opuntia Ficus-Indica L.) Peel And Pineapple (Ananas Comosus) Peel As Functional Ingredients”. *International Journal of Food Science & Technology*. Vol:48, PP: 1460 1467. DOI: 10.1111/ijfs.12113.
- Dinyarian, K. (2020)**. How Vitamin “C” Can Help Gum And Teeth Health? Available Online At: <https://www.smileperfectors.com/blog/how-vitamin-c-can-help-gum-and-teethhealth/>
- Djilani, A., Dicko, A. (2012)** The therapeutic benefits of essential oils, Nutrition, well-being and health, Dr. Jaouad Bouayed, ISBN: 978-953-51-0125-3, PP: 155–167. <http://www.intechopen.com/books/nutrition-well-being-and-health/the-therapeutic-benefits-of-essential-oils>
- DOAE (2009)**. Plant Production in Chaing Rai, National Agricultural Statistics Database of Department of Agricultural Extension (DOAE), Chaing Rai, Thailand. Available at: www.chiangrai.doe.go.th.
- Efaliza Misran, Ani Idris and Harisun Ya’akob. (2022)**, “Bromelain Extraction Using Single Stage Nanofiltration Membrane Process”, *Journal of food science and technology*, Vol: 60 , PP:315–327, <https://doi.org/10.1007/S13197-022-05618-7>

- Elean S, Suhanan S, & Ariyanto T (2022)** “Porous Carbon from Pineapple Peel as Electrode Material of Supercapacitor”. *ASEAN Journal of Systems Engineering*. Vol:6. DOI:<https://doi.org/10.22146/ajse.v6i1.73662>
- Els S, Preston C, Hertzog C, Heckel F, Richling E, & Schreiber P (2005)** “Aroma Profiles of Pineapple Fruit (*Ananas Comosus* [L.] Merr.) And Pineapple Products”. *Lebensm Wiss U Technol*. Vol:38, PP:263-74. DOI: 10.1016/j.lwt.2004.07.014
- Eskilsson, C. S., and Björklund, E. (2000)** Analytical-scale microwave-assisted extraction, *Journal of Chromatography A*, Vol: 902, PP: 227–250. [10.1016/s0021-9673\(00\)00921-3](https://doi.org/10.1016/s0021-9673(00)00921-3)
- Fadimu, O.Y, Iliya M, Sani R.Z, (2014)** “Ethnomedicinal Survey Of Anti-Typhoid Plants In Ijebu Ode Local Government Area Of Ogun State, Nigeria”. *International Journal of Science and Nature*. Vol:5, PP:332–336.
- Fadzullah, S. S. M., and Z. Mustafa (2016)** Fabrication and processing of pineapple leaf fiber reinforced composites, *Engineering Science Reference* (an imprint of IGI Global), ISSN: 2327-5448 PP:125–147. [10.4018/978-1-5225-0424-5.ch006](https://doi.org/10.4018/978-1-5225-0424-5.ch006)
- FAO, The Food and Agriculture Organization corporate statistical database (2019)**. Available [http:// faost at3. fao. org/ download/T/ TP/E](http://faostat3.fao.org/download/T/TP/E). Accessed 17 Apr 2021
- FAO: Food And Agriculture Organization Of The United Nations (2020)** Medium-Term Outlook: Prospects For Global Production And Trade In Bananas And Tropical Fruits 2019 To 2028. Rome
- FAOSTAT., 2023**. Pineapple Production Worldwide From 2002 To 2021. Retrieved From:<https://www.statista.com/statistics/298505/global-pineapple-production/> Accessed 7 June 2023 2023.
- Favour Okechi Ifeanyi-Nze, Usman Ismail, Daniel Ebubechi Obasi, Kelechi Kaycee Amamba, Esther Abigail Udoh, Arinze Joseph Akubude, Jacqueline Awhobiwom Aboh, Ebikemiyen Marcus, Stephen Ubanioshave Aiso, Davidson Chukwudi Onwumelu, Olaoluwa Joseph Edun, Priscilla Achaab, Prince-Timothy Bethany Wokoma, Oluwafemi Samson Afolabi, Obinna Kenneth Didigwu, Innocent Ugochukwu Okonkwo, Zoum Fon Alain, Abdullahi Kasim Ismail. (2024)**, “Valorisation Of Pineapple Peel Feedstock As A Source Of Glucose For Bioethanol And Biochemical Production: Kinetic And Thermodynamic Insights Into Cellulose Hydrolysis”, *Progress In Chemical And Biochemical Research*, Vol:7, PP: 256-270. DOI: <https://doi.org/10.48309/pcbr.2024.435556.1333>
- Food and Agriculture Organization (2013)** The State of Food Insecurity in the World, The multiple dimensions of food security, ISBN: 978-92-5-107916-4, PP: 1–56. <https://www.fao.org/4/i3434e/i3434e.pdf>
- Fouda-Mbanga BG, Tywabi-Ngeva Z. (2022)** Application of pineapple waste to the removal of toxic contaminants, *Toxics*, Vol: 10(10), PP: 561. [0.3390/toxics10100561](https://doi.org/10.3390/toxics10100561)
- G. Kirubakaran, C. SenthamaraiKannan (2024)**. “Development Of Fruit Peel Biomass Cellulose And Pineapple Leaf Fibre Polyester Composite: Fatigue, Creep, Fammability, And Thermal Conductivity Behaviour”, *Biomass Conversion And Biorefnery*. Vol:15, PP: 8609-8619. DOI:[10.1007/s13399-024-06013-2](https://doi.org/10.1007/s13399-024-06013-2)
- García-Rosales G, Longoria-Gándara L C, Martínez-Gallegos S, González-Juárez J (2013)** “Synthesis and Characterization of Carbon Conditioned With Iron Nanoparticles Using Pineapple-Peel”. *Advances in Nanoparticles*. Vol: 2, PP: 384 390. DOI: 10.4236/anp.2013.24053
- Gardner P. T, White T.A, Mcphail D.B, Duthie G. G (2000)** “The Relative Contributions Of Vitamin C, Carotenoids And Phenolics To The Antioxidant Potential Of Fruit Juices”. *Food Chemistry*. Vol:68, PP: 471–474. DOI: 10.1016/S0308-8146(99)00225-3.
- Giridharan K, Sasirekha S, Padmanabhan S, Chakravarthi G, Stalin B (2023)** “Effect of green pea pod lignin addition on thermal degradation, flame resistance, DMA, and creep resistance of pineapple fibre epoxy composite”. *Biomass Conversion and Biorefinery*. Vol:14, PP:29843–29852. DOI: <https://doi.org/10.1007/s13399-023-04841-2>
- Gnanasekaran S, Nordin N I A A, Jamari S, Sharifuddin J (2022)** Effect of Steam-Alkaline coupled treatment on N36 cultivar pineapple leave fibre for isolation of cellulose. *Materials Today Proceedings*. Vol: 48, PP: 753–760. DOI: 10.1016/j.matpr.2021.02.216
- Gorinstein S, Zemser M, Haruenkit R, Chuthakorn R, Grauer F, Martin-Belloso O, Trakhtenberg S (1999)** “Comparative Content of Total Polyphenols and Dietary Fiber in Tropical Fruits and Persimmon”. *Journal of Nutritional Biochemistry*. Vol:10, PP: 367–371. DOI: 10.1016/s0955-2863(99)00017-0
- Gorrepotu S R, Debnath K, Mahapatra R N (2023)** “Mechanical, thermal, and morphological behavior of pineapple leaf fibre and polylactic acid green composites fabricated by varying fiber loading, fiber length, and injection parameters”. *Polymer Engineering & Science*. Vol: 63, PP: 2498–2510. DOI: <https://doi.org/10.1002/pen.26391>
- Gu Yanbo and Jiang Bing (2020)** “Kinetic Analysis and Optimum Design of Extracting Pectin from Pineapple Peel by Ion Exchange”, *IOP Conference Series: Earth and Environmental Science*. Vol: 546, doi:10.1088/1755-1315/546/5/052048
- Gunwantrao, B. Balasaheb, S. K. Bhausaheb, B. Sagar Ramrao, and K. S. Subhash, (2016)** Antimicrobial activity and phytochemical analysis of orange (*Citrus aurantium* L.) and pineapple (*Ananas comosus* (L.) Merr.) peel extract, *Annals of Phytomedicine: International Journal*, Vol: 5, PP: 156–160. [10.21276/ap.2016.5.2.22](https://doi.org/10.21276/ap.2016.5.2.22)
- Guo R, Canter P. H, Ernst E (2006)** “Herbal Medicines For The Treatment Of Rhinosinusitis: A Systematic Review”. *Otolaryngology-Head and Neck Surgery*. Vol: 135, PP: 496–506. DOI: 10.1016/J.Otohns.2006.06.1254.

- Gutfreund A.E, Taussig S. J, Morris A. K (1978)** “Effect Of Oral Bromelain On Blood Pressure And Heart Rate Of Hypertensive Patients”. *Hawaii medical journal*. Vol: 37, PP: 143–146.
- H. Suryanto, T. A. Sutrisno, M. Muhajir, N. Zakia, and U. Yanuhar (2019)**, Crystallinity and morphology of the bacterial nanocellulose membrane extracted from pineapple peel waste using high-pressure homogenizer, *AIP Conference Proceedings*, Vol: 2120(1), PP: 080015. [10.1063/1.5115753](https://doi.org/10.1063/1.5115753)
- Hadidi M, Amoli PI, Jelyani AZ Et Al (2020)** Polysaccharides From Pineapple Core As A Canning By-Product: Extraction Optimization, Chemical Structure, Antioxidant And Functional Properties. *International Journal of Biological Macromolecules*. Vol: 163, PP: 2357–2364. <https://doi.org/10.1016/j.ijbiomac.2020.09.092>
- Haiyan S, Funing M, Keming L, Wei S, Guiying X, Rulin Z, & Shenghe C (2020)**. Growth of Breast Cancer Cells Inhibited by Bromelains Extracted from The Different Tissues of Pineapple. *Folia Biologica (Kraków)*, vol: 68, PP:81–88. DOI: https://doi.org/10.3409/fb_68-3.10
- Hebbar H.U, Sumana B and Raghavarao K. S. M. S. (2008)**. Use of Reverse Micellar Systems for The Extraction and Purification of Bromelain from Pineapple Wastes. *Bioresource Tech*, Vol:99, PP:4896-902, DOI: 10.1016/j.biortech.2007.09.038
- Hikal, W.M., Mahmoud, A.A.; Said-Al Ahl H.A.H., Bratovic, A., Tkachenko, K.G. (2021)** Pineapple (*Ananas comosus* L. Merr.), waste streams, characterization and valorisation: An Overview, *Open Journal of Ecology*, Vol: 11, PP: 610-634, <https://doi.org/10.4236/oje.2021.119039>.
- Hossain MF, Akhtar S, Anwar M. (2015)** Nutritional Value and Medicinal Benefits of Pineapple, *International Journal of Nutrition and Food Sciences*. Vol:4(1), PP: 84-88. 10.11648/j.ijnfs.20150401.22 <https://doi.org/10.1016/J.FBP.2019.09.010>
- Huang C. W, Lin I J, Liu Y M, & Mau, J L (2021)** Composition, Enzyme and Antioxidant Activities of Pineapple. *International Journal of Food Properties*, Vol:24(1), PP: 1244–1251. DOI: <https://doi.org/10.1080/10942912.2021.1958840>
- Huang Y L, Chow C J and Fang Y J (2011)** “Preparation And Physicochemical Properties Of Fiber-Rich Fraction From Pineapple Peels As A Potential Ingredient”. *Journal Of Food And Drug Analysis*. Vol:19, PP:318-323 DOI:10.38212/2224-6614.2179
- Idris A, Zain NM, Noordin MY (2007)** Synthesis, characterization and performance of asymmetric polyether-sulfone (PES) ultrafiltration membranes with polyethylene glycol of different molecular weights as additives, *Desalination* Vol: 207(1–3), PP:324–339. <https://doi.org/10.1016/j.desal.2006.08.008>
- Intan Fajrin Arsyada, Devi Rianti, And Elly Munadzihroh (2018)** “Antibacterial activity of mixed pineapple peel (*Ananas comosus*) extract and calcium hydroxide paste against *Enterococcus faecalis*”. *Dental Journal*. Vol:51, PP:20-24. DOI: <https://doi.org/10.20473/j.djmk.v51.i1.p20-24>
- Iyamah P C, Idu M (2015)** “Ethnomedicinal Survey of Plants Used in The Treatment of Malaria in Southern Nigeria. *J Ethnopharmacol*. Vol: 173, PP: 287–302. DOI: 10.1016/j.jep.2015.07.008.
- J. Gull, B. Sultana, F. Anwar, R. Naseer, M. Ashraf, and M. Ashrafuzzaman, (2012)** Variation in antioxidant attributes at three ripening stages of guava (*Psidium guajava* L.) fruit from different geographical regions of Pakistan, *Molecules*, Vol: 17, PP. 3165–3180. 10.3390/molecules17033165.
- Jabbar A, Militký J, Wiener J, Bandu M K, Usman A, Samson R (2017)** Nanocellulose Coated Woven Jute/Green Epoxy Composites: Characterization Of Mechanical And Dynamic Mechanical Behavior. *Composite Structures*. Vol: 161, PP: 340–349. DOI: <https://doi.org/10.1016/J.Compstruct.2016.11.062>
- Jatav J, Tarafdar A, Saravanan C, & Bhattacharya B (2022)** “Assessment Of Antioxidant And Antimicrobial Property Of Polyphenol-Rich Chitosan-Pineapple Peel Film”. *Journal of Food Quality*, Vol:7, PP: 1–10. DOI: 10.1155/2022/8064114.
- Jovanović, M., Milutinović, M., Kostić, M., Miladinović, B., Kitić, N., Branković, S., Kitić, D., (2018)** Antioxidant capacity of pineapple (*Ananas comosus* (L.) Merr.) extracts and juice, *Lekovite sirovine*, Vol: 38, PP: 27–30. <http://dx.doi.org/10.5937/lekir18380271>
- Joy P P and Abraham Minu (2013)** “Fruits, Benefits, Processing, Preservation and Pineapple Recipes”. *Pineapple Research Station, Kerala Agricultural University*.
- Jusoh, N. Othman, N. Idris, A. Nasruddin, A. (2014)** Characterization of liquid pineapple waste as carbon source for production of succinic acid *J. Teknol.*, Vol: 69, PP: 11–13. [0.11113/jt.v69.3165](https://doi.org/10.11113/jt.v69.3165)
- K Rathnakumar, A K Anal and K Lakshmi (2017)** “Optimization Of Ultrasonic Assisted Extraction Of Bioactive Components From Different Parts Of Pineapple Waste,” *International Journal Of Agriculture Environment & Biotechnology*, Vol: 10, PP: 553–563. DOI: 10.5958/2230-732X.2017.00068.7
- Kadir M F, Sayeed M S B, Mia M M K (2012)** “Ethnopharmacological Survey Of Medicinal Plants Used By Indigenous And Tribal People In Rangamati, Bangladesh”. *J. Ethnopharmacol*. Vol:144, PP:627–637. DOI: 10.1016/j.jep.2012.10.003
- Kalaiselvi M, Gomathi D, & Uma C (2012)** “Occurrence Of Bioactive Compounds In *Ananas Comosus* (L.): A Quality Standardization By HPTLC”, *Asian Pacific Journal Of Tropical Biomedicine*, Vol: 2, PP: 1341-1346. DOI: [https://doi.org/10.1016/S2221-1691\(12\)60413-4](https://doi.org/10.1016/S2221-1691(12)60413-4)
- Kalopathy U, And Proctor A (2001)** “Effect Of Acid Extraction And Alcohol Precipitation Conditions On The Yield And Purity Of Soy Hull Pectin”. *Food*

- Chemistry, Vol: 73, PP:393-396. DOI:[https://doi.org/10.1016/S0308-8146\(00\)00307-1](https://doi.org/10.1016/S0308-8146(00)00307-1)
- Kanthavelkumaran N, Jayaram R S, Brabin Nivas M L & Prasanth P V (2023)**. “Bioethanol (Environment Support Fuel) Production And Optimization From Pineapple Peel And Banana Peel”. *Global NEST Journal*. Vol: 25, PP: 61-67. DOI: <https://doi.org/10.30955/Gnj.005251>
- Kasemsuk T, Saengpetch N, Sibmooh N, Unchern, S (2016)** “Improved WOMAC Score Following 16-Week Treatment with Bromelain for Knee Osteoarthritis”. *Clinical Rheumatol*. Vol:35, PP: 2531–2540. DOI: 10.1007/S10067-016-3363-1.
- Ketnawa S, Chaiwut P, & Rawdkuen S (2011)**, “Extraction Of Bromelain From Pineapple Peels”, *Food Science And Technology International*, Vol: 17, PP: 395–402. DOI: <https://doi.org/10.1177/1082013210387817>
- Khan M K, Alshahrani H, Arun Prakash V R (2023)** “Effect of Grid Pattern And Infill Ratio On Mechanical, Wear, Fatigue And Hydro- Phobic Behaviour Of Abaca Bracts Biocarbon-ABS Biocomposites Tailored Using 3D Printing”. *Biomass Conversion and Biorefinery*. Vol: 15, PP: 3915-3924. DOI: <https://doi.org/10.1007/S13399-023-05196-4>
- Kumar K, Srivastav S, Sharanagat V S (2021)** “Ultrasound Assisted Extraction (UAE) Of Bioactive Compounds from Fruit and Vegetable Processing By-Products: A Review”. *Ultrason Sonochem*, Vol: 70. DOI: <https://doi.org/10.1016/J.Ulsonch.2020.105325>
- Kuwata T, Hashimoto T, Ohto N, Kuwahara H, Lee J W, Bamba, Mizuno M T (2017)** “A Metabolite Of Dietary Glucosylceramide From Pineapples Improves The Skin Barrier Function In Hairless Mice”. *Journal of Functional Foods*. Vol: 30, PP: 228–236. DOI: 10.1016/J.Jff.2017.01.017.
- Lamikanra O and Richard O (2004)** “Storage And Ultraviolet-Induced Tissue Stress Effects On Fresh- Cut Pineapple”. *The Journal of the Science of Food and Agriculture*. Vol:84, PP: 1812–1816. DOI: <https://doi.org/10.1002/jsfa.1891>
- Lario Y, Sendra E, Garcí X, A P 'Erez J, Fuentes C, Sayas Barber' A E, Fern Andez Lopez J, P'Erez-Alvarez J A (2004)**. “Preparation Of High Dietary Fiber Powder From Lemon Juice By-Products”. *Innovative Food Science & Emerging Technologies*. Vol:5, PP: 113–117. DOI: <https://doi.org/10.1016/J.Ifset.2003.08.001>.
- Larrauri, J.A., Rupérez, P. and Calixto, F.S. (1997)** “Pineapple Shell as a Source of Dietary Fiber with Associated Polyphenols”. *Journal of Agricultural and Food Chemistry*. Vol: 45, PP: 4028-4031. DOI: <http://dx.doi.org/10.1021/jf970450j>.
- Longoria-Gándara, L. C. (2013)** Synthesis and Characterization of Carbon Conditioned with Iron Nanoparticles Using Pineapple-Peel, *Advances in Nanoparticles*, Vol: 02(4), PP: 384–390. <https://doi.org/10.4236/ANP.2013.24053>
- Lu X. H, Sun D. Q, Wu Q.S, Liu S.H, Sun G. M. (2014)** “Physico-Chemical Properties, Antioxidant Activity and Mineral Contents of Pineapple Genotypes Grown in China”. *Molecules*. Vol:19, PP:8518–8532. DOI: 10.3390/Molecules19068518.
- Lubaina A.S, Renjith P.R, & Kumar P (2019)** “Antibacterial Potential of Different Extracts of Pineapple Peel Against Gram-Positive and Gram-Negative Bacterial Strains. *Asian Journal of Pharmacy and Pharmacology*. Vol: 5, PP: 66–70. DOI: <https://doi.org/10.31024/AJPP.2019.5.S1.5>
- Lun O.K, Wai T.B, Ling L.S. (2014)** “Pineapple Cannery Waste as A Potential Substrate for Microbial Biotransformation to Produce Vanillic Acid and Vanillin”. *International Food Research Journal*. Vol: 21, PP: 953–958.
- M. A. Hossain and S. M. M. Rahman (2011)** “Total Phenolics, Flavonoids and Antioxidant Activity of Tropical Fruit Pineapple”. *Food Research International*. Vol: 44, PP: 672–676, DOI: 10.1016/j.foodres.2010.11.036
- M. Asim, M. Jawaid, M. Nasir And N. Saba (2017)** “Effect Of Fiber Loadings And Treatment On Dynamic Mechanical, Thermal And Flammability Properties Of Pineapple Leaf Fiber And Kenaf Phenolic Composites”, *JOURNAL OF RENEWABLE MATERIALS*, Vol: 6. DOI: 10.7569/JRM.2017.634162
- M. Asim, M.T. Paridah, N. Saba, M. Jawaida, Othman Y Alothman, M. Nasir, Z. Almutairid (2018)** “Thermal, Physical Properties and Flammability of Silane Treated Kenaf/ Pineapple Leaf Fibres Phenolic Hybrid Composites”. *Composite Structures*. Vol:202. DOI: <https://doi.org/10.1016/J.Compstruct.2018.06.068>
- M. Jakovljevic, S. Jokic, M. Molnar et al., (2019)** Bioactive profile of various *Salvia officinalis* L. preparations, *Plants*, Vol: 8, PP: 55–85. [10.3390/plants8030055](https://doi.org/10.3390/plants8030055)
- M. Kalaiselvi, D. Gomathi, G. Ravikumar, K. Devaki & C. Uma (2014)** “Therapeutic Effect of Ananus Comosus Peel On Breast Cancer Induced by 7, 12- Dimethylbenz(A)Anthracene”, *Plant Science Today*. Vol: 1, PP: 13-21, DOI: <http://dx.doi.org/10.14719/Pst.2014.1.1.8>
- M. Sari, Y. Rati, T. M. Linda, Y. Hamzah, And A. S. Rini (2021)** “Biosynthesis of ZnO Micro-Nanoflower with Ananas Comosus Peel Extract,” *Journal of Aceh Physics Society*. Vol: 10, PP: 84–87, Doi: 10.24815/Jacps.V10i4.18951.
- Madhumeena S, Preetha R, & Prasad S (2021)** “Effective Utilization Of Pineapple Waste”, *Journal of Physics Conference Series*, Vol:1979, DOI: <https://doi.org/10.1088/1742-6596/1979/1/012001>
- Madureira A. R, Atoprak T, Çabuk D, Sousa F, Pullar R.C, & Pintado M (2018)** “Extraction and Characterisation of Cellulose Nanocrystals from Pineapple Peel”. *International Journal of Food Studies*, Vol: 7. DOI: <https://doi.org/10.7455/IJFS/7.1.2018.A3>
- Mainoo N. O. K, Barrington S, Whalen J. K And Sampedro L (2009)** “Pilot-Scale Vermin-Composting Of

- Pineapple Wastes With Earthworms Native To Accra, Ghana". *Bioresource Technology*, Vol: 100, PP: 5872-5875. DOI: 10.1016/j.biortech.2009.06.058.
- Manaf S, Jahim J, Harun S & Luthfi A (2018)** "Fractionation of Oil Palm Fronds (OPF) Hemicellulose Using Dilute Nitric Acid For Fermentative Production Of Xylitol". *Industrial Crops and Products*. Vol: 115, PP: 6–15. DOI: 10.1016/j.indcrop.2018.01.067
- Mandalari G, Bennett R N, Bisignano G, Saija A, Dugo G, Faulds C B, Waldron KW (2006)** "Characterization of Flavonoids and Pectin from Bergamot (Citrus Bergamia Risso) Peel, A Major by Product of Essential Oil Extraction". *Journal of Agricultural and Food Chemistry*, Vol: 54, PP: 197-203. DOI: 10.1021/jf051847n.
- Marialice Pinto Coelho Silvestre & Raquel Linhares Carreira & Mauro Ramalho Silva & Flávia Campos Corgosinho (2012)** Effect of pH and Temperature on the Activity of Enzymatic Extracts from Pineapple Peel, *Food Bioprocess Technol*, Vol: 5: PP: 1824–1831. 10.1007/s11947-011-0616-5
- Martins J.G.P, Matta Júnior M.D, Almeida M.A, Santos T, Spoto M.H.F. (2012)** "Avaliação Sensorial De Bolo Com Resíduo De Casca De Abacaxi Para Suplementação Do Teor De Fibras". *Revista Brasileira de Produtos Agroindustriais*. Vol: 14, PP: 281–287. DOI: 10.15871/1517-8595/rbpa.v14n3p281-287
- Maurer HR (2001)** "Bromelain: Biochemistry, Pharmacology and Medical Use". *Cell Molecular Life Science*. Vol: 58, PP: 1234–1245. DOI: 10.1007/PL00000936
- Meena L, Sengar A.S, Neog R & Sunil C K (2021)** "Pineapple Processing Waste (PPW): Bioactive Compounds, Their Extraction, And Utilisation: A Review", *Journal of Food Science and Technology-Mysore*, Vol: 59, PP:1–13. <https://doi.org/10.1007/S13197-021-05271-6>
- Meena L, Sengar A.S, Neog R & Sunil C.K (2022)** "Pineapple Processing Waste (PPW): Bioactive Compounds, Their Extraction, and Utilization: A Review". *Journal of Food Science and Technology*, Vol: 59, PP: 4152–4164. DOI: 10.1007/s13197-021-05271-6
- Meena Vangalapati, Srijana V, Venkata Siva A, Hima Bindu V N V, Nareesh V U B. (2005)** Experimental studies and Development of Modelling equation of Quercetin from Pine apple peel using Soxhlet Extractor, *International Journal of Innovative Research in Science, Engineering and Technology*, Vol: 5(4), PP: 2866-2892.
- Mhatre M, Tilak-Jain J, De S, Devasagayam T.P.A (2009)** "Evaluation of The Antioxidant Activity of Non-Transformed and Transformed Pineapple: A Comparative Study". *Food and chemical toxicology*. Vol: 47, PP: 2696–2702. DOI: 10.1016/J.Fct.2009.06.031
- Miao, P.; Han, K.; Tang, Y.; Wang, B.; Lin, T.; Cheng, W. (2015)** Recent advances in carbon nanodots: synthesis, properties and biomedical applications, *Nanoscale*, Vol: 7, PP: 1586–1595. <https://pubs.rsc.org/en/content/articlelanding/2015/nr/c4nr05712k>
- Mirahmadi K, Kabir M.M, Jeihanipour A, Karimi K. And Taherzadeh M.J (2010)** "Alkaline Pretreatment of Spruce and Birch to Improve Bioethanol and Biogas Production". *Bioresources*. Vol: 5, PP: 928-938. DOI: 10.15376/biores.5.2.928-938.
- Mohamad N, Ramli N, Abd-Aziz S, Ibrahim M.F (2019)** "Comparison Of Hydro-Distillation, Hydro-Distillation With Enzyme-Assisted And Supercritical Fluid For The Extraction Of Essential Oil From Pineapple Peels". *3 Biotech*. Vol: 9. DOI: 10.1007/s13205-019-1767-8
- Montero-Calderón M, Rojas-Graü M. A & Martín-Belloso O (2010)** "Aroma Profile And Volatiles Odor Activity Along Gold Cultivar Pineapple Flesh". *Journal of Food Science*. Vol: 75, PP: 506-512. DOI: 10.1111/j.1750-3841.2010.01831.x
- Morais, D. R., Rotta, E. M., Sargi, S. C., Bonafe, E. G., Suzuki, R. M., Souza, N. E., Matsushita, M., and Visentainer, J. V. (2017)** Proximate composition, mineral contents and fatty acid composition of the different parts and dried peels of tropical fruits cultivated in Brazil, *Journal of The Brazilian Chemical Society*, Vol: 28(2), PP: 308-318. <https://doi.org/10.5935/0103-5053.20160178>
- Morton J. (1987)**. Pineapple. In, *Fruits Of warm Climates*, Miami, FL, ISBN 0-9653360-5-0; PP: 1-1135.
- MPIB. Malaysian Pineapple Industry Board (2021)** Pineapple Cultivar. <https://www.mpib.gov.my/en/cultivar/?Lang=En>. Accessed 25 Oct 2021
- Muhammad Yazid Abd Halim, Siti Aimi Sarah Zainal Abidin and Siti Roha Ab Mutalib (2024)** "Effect Of Storage Conditions On The Bromelain Activity Of Pineapple Peel Variety Josapine", *Science Letters*, Vol: 18, PP: 21 – 27, DOI: 10.24191/Sl.V18i1.24113
- Muskan Gupta (2022)**. "Pineapple Waste Utilization: Wealth From Waste", *The Pharma Innovation Journal*, Vol: 11, PP: 1971-1978.
- N. M. Adzahan, N. Hussain, R. Sulaiman, And G. H. Chong (2016)** "Current Trends Of Tropical Fruit Waste Utilization," *Critical Reviews In Food Science And Nutrition*, Vol. 58, DOI: 10.1080/10408398.2016.1176009.
- N. Mirabella, V. Castellani, S. Sala (2014)** Current options for the valorization of food manufacturing waste: a review, *J. Clean.Prod*, Vol: 65, PP: 28–41. [10.1016/j.jclepro.2013.10.051](https://doi.org/10.1016/j.jclepro.2013.10.051)
- Nabilah Aminah Lutpi, Wong Yee Shian, Ain Nihla Kamarudzaman And Teong Hui Yin (2021)**, "Removal Of Methylene Blue Using Pineapple Peel Powder As Adsorbent", *CUTSE International Conference*
- Nadzirah K Z, Zainal S, Noriham A, Normah I, Siti Roha A M, Nadya H (2013)** Physio-chemical properties of Pineapple variety N36 harvested and stored at different maturity stages. *International Food Research Journal*. Vol:20, PP: 225-231.
- Nakano, F.; Iwasaki, D.; Nojima, J.; Ohto, N.; Kuwamura, H.; Miyakoshi, M.; Murakami, T.** Glucosylceramides

- From The Fruits Of Pineapple. *Shoyakugaku Zasshi*. 2015, 69, 66–67.
- Nakthong N, Wongsagonsup R, Amornsakchai T (2017)** “Characteristics and Potential Utilizations of Starch from Pineapple Stem Waste”. *Industrial Crops and Products*. Vol: 105, PP: 74–82. DOI: <https://doi.org/10.1016/j.indcrop.2017.04.048>
- Nandiyanto A, Girsang G. C. S, Maryanti R, Ragadhita R, Anggraeni S, Fauzi F. M, Sakinah P, Astuti A. P, Usdiyana D, Fiandini M, Dewi M. W & Al-Obaidi A.Sh.M. (2020)** “Isotherm Adsorption Characteristics Of Carbon Microparticles Prepared From Pineapple Peel Waste”. *Communications in Science and Technology*. Vol: 5, PP: 31–39. DOI: <https://doi.org/10.21924/CST.5.1.2020.176>
- Nasoha N. Z, Luthfi A. A. I, Roslan M. F, Hariz H. B, Bukhari N. A, & Manaf S. F. A (2023)** “Exploring Pineapple Peel Hydrolysate as A Sustainable Carbon Source for Xylitol Production”. *Scientific reports*. DOI: <https://doi.org/10.21203/rs.3.rs-3285350/v1>
- Nivedita N & Kaur G (2024)** “Green And Sustainable Synthesis Of Cobalt Oxide Nanoparticles From Pineapple Peel Wastes”, *E3S Web Of Conferences*, Vol: 552, PP: 10780–1078, DOI: <https://doi.org/10.1051/E3sconf/202455201078>.
- Noorzetty Akhtar Zakaria, Roshanida A. Rahman, Dayang Norulfairuz Abang Zaidel, Daniel Joe Dailin, Mazura Jusoh (2021)** “Microwave-assisted extraction of pectin from pineapple peel”. *Malaysian Journal of Fundamental and Applied Sciences*. Vol:17, PP:33–38. DOI: 10.11113/mjfas.v17n1.2164
- Nor Halaliza Alias and Zulkifly Abbas (2017)** “Microwave-Assisted Extraction Of Phenolic Compound From Pineapple Skins: The Optimum Operating Condition And Comparison With Soxhlet Extraction”, *Malaysian Journal Of Analytical Sciences*, Vol: 21, PP: 690 – 699, DOI: <https://doi.org/10.17576/Mjas-2017-2103-18>
- Nu'man A H, L Nurwand, I Bahtiar and S Omar (2020),** “Pineapple Peel Industry Determination with Weighted Location Method”, *IOP Conf. Series: Materials Science And Engineering*. Vol: 830 032099. PP: 1–7 Doi:10.1088/1757-899X/830/3/032099
- Nunes M. C. N., Emond J. P., Rauth M., Dea S. and Chau K. V. (2009)** Environmental conditions encountered during typical consumer retail display affect fruit and vegetable quality and waste, *Postharvest Biology and Technology*, Vol:51, PP: 232–241. [10.1016/j.postharvbio.2008.07.016](https://doi.org/10.1016/j.postharvbio.2008.07.016)
- Oculi J, Bua B, Ocwa A (2020)** Reactions of Pineapple Cultivars to Pineapple Heart Rot Disease in Central Uganda. *Crop Protection*. Vol: 135. DOI: <https://doi.org/10.1016/j.cropro.2020.105213>
- Odugbemi T.O, Akinsulire O.R, Aibinu I.E, Fabeku P.O (2007)** Medicinal Plants Useful for Malaria Therapy in Okeigbo, Ondo State, Southwest Nigeria. *African journal of traditional, complementary, and alternative medicines*. Vol: 4, PP: 191–198. <https://doi.org/10.4314/ajtcam.v4i2.31207>
- Olatunji, B.P., Ajibola, D.O., Adebayo, E.O., Nyong, E.E., Moody, J.O (2014)** Ethnomedicinal Survey Of Botanicals Used By Herbal Practitioners In Yagba East Local Government Of Kogi State, Nigeria. *Eur. J. Med. Plants*. Vol :4, PP: 1479–1488. <https://doi.org/10.9734/EJMP/2014/10393>
- Omorotionmwan, F.S., -O., Ogwu, H.I., Ogwu, M.C. (2019)**. Antibacterial Characteristics And Bacteria Composition Of Pineapple (*Ananas Comosus* [Linn.] Merr.) Peel And Pulp. *Food And Health*, Vol: 5, PP:1–11. <https://doi.org/10.3153/FH19001>
- Ordesi, P.; Pisoni, L.; Nannei, P.; Macchi, M.; Borloni, R.; Siervo, S (2014)** Therapeutic Efficacy of Bromelain in Impacted Third Molar Surgery: A Randomized Controlled Clinical Study. *Quintessence Int*. Vol: 45, PP: 679–684. [10.3290/j.qi.a32237](https://doi.org/10.3290/j.qi.a32237)
- Orodu, V.E.; Ivan, A. (2021)** Extraction And Gc-Ms Analysis Of Oil Extracted From Pineapple (*Ananas Comosus*) Peels, *Modern Physical Chemistry Research*, Vol:1 , PP: 1–8. [10.23977/mpcr.2021.010101](https://doi.org/10.23977/mpcr.2021.010101)
- Ortega-Hernández, E.; Martinez-Alvarado, L.; Acosta-Estrada, B.A.; Antunes-Ricardo, M (2023)** Solid-State Fermented Pineapple Peel: A Novel Food Ingredient With Antioxidant And Anti-Inflammatory Properties. *Foods*, Vol: 12, PP: 4162. <https://doi.org/10.3390/Foods12224162>
- Owoeye, T. F., Akinlabu, D. K., Ajayi, O. O., Afolalu, S. A., Popoola, J. O., & Ajani, O. O. (2022)**. Phytochemical Constituents And Proximate Analysis Of Dry Pineapple Peels. *IOP Conference Series: Earth And Environmental Science*, Vol: 993, PP: 012027. <https://doi.org/10.1088/1755-1315/993/1/012027>
- P. D. Ashtaputrey And S. D. Ashtaputrey., (2016)**. REMOVAL OF DYE FROM AQUEOUS SOLUTION BY PINEAPPLE PEEL ACTIVATED CARBON AS AN ADSORBENT., *International Journal Of Advanced Research (IJAR)*, Vol :4, PP: 1513–1518. DOI: <http://dx.doi.org/10.21474/IJAR01/1957>
- Pantastico, E.B. (1975)** *Postharvest Physiology, Handling, and Utilization of Tropical and Subtropical Fruits and Vegetables*, Avi Publishing Company, ISBN: 9780870551567, 0870551566, PP: 560. https://www.google.co.in/books/edition/Postharvest_Physiology_Handling_and_Util/LTMjAQAAMAAJ?hl=en
- Pathanibul, P., & Hongkulsup, C. (2021)**. Production Of Succinic Acid From Pineapple Peel Waste, *Research Square Platform LLC*. <https://doi.org/10.21203/rs.3.rs-474844/v1>
- Pawar P, Modi M And Shrivastav A. (2022)** Production And Characterization Of Polyhydroxyalkanoate Obtained From Pineapple Peel Waste, *International Journal Of Biology, Pharmacy And Applied Sciences (IJBPAS)*, Vol: 11, PP: 6084–6090. <https://doi.org/10.31032/IJBPAS/2022/11.12.6694>

- Pereira, P. H., Ornaghi, H. L., Oliveira, D. M. De, Pereira, B., Arantes, V., & Cioffi, M. O. H. (2022)**, Effect Of Chemical Treatment Sequence On Pineapple Peel Fiber: Chemical Composition, Thermal Stability And Thermal Degradation Kinetics, Vol: 29, PP: 8587–8598. <https://Doi.Org/10.21203/Rs.3.Rs-1121648/V1>
- Piayura, S., Itthivadhanapong, P., (2023)**. The Effects Of Feed Moisture And Dried Coconut Meal Content On The Physicochemical, Functional, And Sensory Properties Of Gluten-Free Riceberry Rice Flour-Based Extruded Snacks. *Front. Sustain. Food Syst.* Vol :7 , <https://Doi.Org/10.3389/Fsufs.2023.1194594>.
- Pinheiro, E. R., Silva, I. M. D. A., Gonzaga, L. V., Amante, E. R., Teófilo, R. F., Ferreira, M. M. C., And Amboni, R. D. M. C. (2008)**. Optimization Of Extraction Of High-Ester Pectin From Passion Fruit Peel (*Passiflora Edulis Flavicarpa*) With Citric Acid By Using Response Surface Methodology. *Bioresource Technology*, Vol:99, PP: 5561–5566. <https://doi.org/10.1016/j.biortech.2007.10.058>
- Pino, J. A. (2013)**. Odour-Active Compounds In Pineapple (*Ananas Comosus* [L.] Merrilcv. Red Spanish). *Int. J. Food Sci. Technol.* Vol: 48, PP: 564–570. <http://dx.doi.org/10.1111/j.1365-2621.2012.03222.x>
- Piskounova, E., Agathocleous, M. And Murphy, M.M., Et Al. (2015)**. Oxidative Stress Inhibits Distant Metastasis By Human Melanoma Cells. *Nature*, Vol: 527, PP: 186–191. [10.1038/nature15726](https://doi.org/10.1038/nature15726)
- Prakash, D.V.S., Sree Satya, N. and Meena, V. (2012)** Determination of Partition Coefficient for Chebulinic Acid Extraction from Various Extracts of Terminalia Chebula Species, *International Journal of Chemical Sciences*, Vol: 10(4), PP: 2111–2116. <https://www.tsijournals.com/abstract/determination-of-partition-coefficient-for-chebulinic-acid-extraction-from-various-extracts-of-terminalia-chebula-specie-12011.html>
- Prasenjit Debnath, Prasanta Dey, Abhijit Chanda, Tejendra Bhakta .(2012)** Dept. Of Pharmaceutical Chemistry, C. L. Baid Metha College Of Pharmacy, Chennai-97, India. Regional Institute Of Pharmaceutical Science & Technology, Abhoynagar, Tripura (W), 799005, India. Vol: 1,
- Praveena B A , Balachandra P Shetty, Vinayaka N, Srikanth H V , Shiv Pratap Singh Yadav & Avinash L, (2020)** Mechanical Properties And Water Absorption Behaviour Of Pineapple Leaf Fibre Reinforced Polymer Composites , Vol : 8, PP: 1–16. <https://doi.org/10.1080/2374068X.2020.1860354>
- Priefert, H.; Rabenhorst, J.; Steinbuchel, (2001)** A. Biotechnology Production Of Vanillin. *Appl. Microbiol. Biotechnol.*, Vol: 56, PP: 296–314, <https://doi.org/10.1007/S002530100687>
- Pyar H, Liong MT, Peh KK (2014)** Potentials Of Pineapple Waste As Growth Medium For Lactobacillus Species. *Int J Pharm Pharm Sci.* Vol : 6 PP: 142–145. https://www.researchgate.net/publication/287636238_Potentials_of_pineapple_waste_as_growth_medium_for_Lactobacillus_species
- R. Maurischa, A. Putri, T. Yuanita, And M. Roelianto. (2016)** Daya Anti Bakteri Ekstrak Kulit Nanas (*Ananas Comosus*) Terhadap Pertumbuhan Bakteri *Enterococcus Faecalis* Antibacterial Potency Of Pineapple Peel Extract (*Ananas Comosus*) On *Enterococcus Faecalis* Growth, Vol: 6, PP: 61–65. <https://doi.org/10.20473/cdj.v6i2.2016.61-65>
- R. Ramli, N. S. Ahmad Zaghlul, and N. A. H. Ahmad Nasir (2020)** The potential of antioxidants and phytochemicals components in fruit waste (peel) of citrus *hystrix* and *anas comosus*, in *Charting the Sustainable Future of ASEAN in Science and Technology*, PP: 123–135, Springer, Singapore. [10.1007/978-981-15-3434-8_11](https://doi.org/10.1007/978-981-15-3434-8_11)
- Riska S. Ningrum, Rizky Karima, Elga Renjana, Aisyah H. Ramadani, Umarudin Umarudin, Nurul Istiqomah, Tri Aminingsih (2024)** Investigation Of Eco-Enzyme From Pineapple (*Ananas Comosus* (L.) Merr.) Waste: Chemical Composition, Antibacterial Activity, And Molecular Docking Approach, *Waste And Biomass Valorization*, Vol:15, PP:4793–4805. [10.1007/s12649-024-02492-6](https://doi.org/10.1007/s12649-024-02492-6)
- Ritika Kaushal, Brahmeet Kaur, Parmjit S. Panesar, Anil K. Anal, Son Chu-Ky (2024)**, Valorization Of Pineapple Rind For Bromelain Extraction Using Microwave Assisted Technique: Optimization, Purification, And Structural Characterization, *J Food Sci Technol*, Vol: 61, PP:551–562. <https://doi.org/10.1007/s13197-023-05863-4>
- Rodsamran P, Sothornvit R (2019)** Preparation And Characterization Of Pectin Fraction From Pineapple Peel As A Natural Plasticizer And Material For Biopolymer Flm. *Food Bio Prod Process.* Vol: 118, PP :198–206. <https://doi.org/10.1016/j.fbp.2019.09.010>
- Rohrbach, K. G. Leal, F. d'Eeckenbrugge, (2003)** G. C. History, Distribution And World Production. In *The Pineapple: Botany, Production And Uses*, 1st Ed.; Bartholomew, D. P., Paull, R. E., Rohrbach, K. G., Eds.; CABI Publishing: New York, NY, USA. PP :1–12. https://www.academia.edu/10300271/History_distribution_and_world_production_in_the_pineapple_botany_production_and_uses
- Rosalia Santika Puspa Dewi, Lydia Rohmawati (2022)**, Analysis Of Crystalline Phase And Functional Groups Of ZnO From Pineapple Peel Extract, *Indonesian Physical Review*, Vol: 5, PP: 148–156. DOI: <https://doi.org/10.29303/Ipr.V5i3.160>
- Rosnah shamsudin, wan ramli wan daud, mohd sobri takriff and osman hassan. (2009)**, chemical compositions and thermal properties of the josapine variety of pineapple fruit (*anas comosus* l.) In different storage systems, *journal of food process engineering*, Vol: 34, PP: 1558–1572. <http://dx.doi.org/10.1111/j.1745-4530.2009.00510.x>
- S. A. R. G. Chacón1, T. L. A. C. Araújo, L. A. Pinedo, D. M. Lima Junior, L. C. S. L. C. Assis, M. W. F. Pereira & P. O. Lima (2024)**, Vol: 53, <https://doi.org/10.4314/sajas.v53i4.02>
- S. C. Lourenço, M. J. Fraqueza, M. H. Fernandes, M. Moldão Martins, And V. D. Alves, (2020)** Application

- Of Edible Alginate Films With Pineapple Peel Active Compounds On Beef Meat Preservation, Antioxidants, Vol: 9, PP: 667. DOI: 10.3390/antiox9080667
- S. Poadang, N. Yongvanich, And S. Phongtongpasuk (2017)** Synthesis, Characterization, And Antibacterial Properties Of Silver Nanoparticles Prepared From Aqueous Peel Extract Of Pineapple, *Ananas Comosus*, C. J. Nat. Sci, Vol: 16, PP: 123, Doi:10.12982/Cmujns.2017.0010.
- S. Saloni, K. Chauhan Assistant Professor, S. Tiwari Assistant Professor, K. Chauhan, and S. Tiwari, (2017)** Pineapple production and processing in north eastern India. E-ISSN: 2278-4136, P-ISSN: 2349-8234, PP: 665-672. <https://www.phytojournal.com/archives/2017/vol6issue6S/PartP/SP-6-6-149.pdf>
- S' Anchez-Burgos, J.A., De Lourdes García-Magãna, M., (2017).** Pineapples (*Ananas Comosus*). In: Fruit and Vegetable Phytochemicals: Chem And Human Health, Second Ed. Vol: 2, PP: 1173–1178. <http://dx.doi.org/10.1002/9781119158042.ch60>
- Sah BNP, Vasiljevic T, Mckechnie S, Donkor ON (2016)** Physicochemical, Textural And Rheological Properties Of Probiotic Yogurt Fortified With Fibre-Rich Pineapple Peel Powder During Refrigerated Storage. *LWT - Food Sci Technol* Vol: 65, PP: 978–986. <https://doi.org/10.1016/j.lwt.2015.09.027>
- Salunkhe, D.K. And Desai, B.B. 1984.** Postharvest Biotechnology Of Fruits. CRC Press Inc., Boca Raton, FL.
- Sarah L. Paz-Arteaga a, Juan A. Ascacio-Vald' es b, Crist' obal N. Aguilar b, Edith Cadena-Chamorro a, Lili- ana Serna-Cock c, Miguel A. Aguilar- Gonz' alez d, Nathiely Ram' ırez-Guzm' an e, Cristian Torres-Le' on (1991).** Identification of additional pineapple volatile, Vol: 39, PP :1848-1851 <https://doi.org/10.1016/j.ifset.2023.103313> . 22 February 2023
- Saraswaty V, Risdian C, Primadona I, Andriyani R, Andayani D G S And Mozef T (2017)** IOP Conference Series: Earth And Environmental Science Vol :60 ,(Institute Of Physics Publishing)
- Sardjono, S. A., Suryanto, H., & Muhajir, M. (2019)** Crystallinity and morphology of the bacterial nanocellulose membrane extracted from pineapple peel waste using high-pressure homogenizer, *AIP Conference Proceedings*, Vol: 2120, PP: 0800151-0800155. <https://doi.org/10.1063/1.5115753>
- Sayah, M. Y., Chabir, R., Benyahia, H., Kandri, Y. R., Chahdi, F. O., Touzani, H., And Errachidi, F. (2016).** Yield, Esterification Degree And Molecular Weight Evaluation Of Pectins Isolated From Orange And Grapefruit Peels Under Different Conditions, *Plos One*, Vol: 11, PP: 1-16. <https://doi.org/10.1371/journal.pone.0161751>
- Sep' ulveda, L.; Roman' ı, A.; Aguilar, C.N.; Teixeira, J. (2018)** Valorization Of Pineapple Waste For The Extraction Of Bioactive Compounds And Glycosides Using Autohydrolysis. *Innov. Food Sci. Emerg. Technol.* Vol: 47, PP:38–45. <http://dx.doi.org/10.1016/j.ifset.2018.01.012>
- Shakya A, Agarwal T (2019)** Removal Of Cr(VI) From Water Using Pineapple Peel Derived Biochars: Adsorption Potential And Re-Usability Assessment. *J Mol Liq* Vol: 293, PP:111497. <https://doi.org/10.1016/j.molliq.2019.111497>
- Shareena Fairuz Abdul Manaf, Jamaliah Md Jahim, Shuhaida Harun, Abdullah Amru Indera Luthfi, A. (2018).** Fractionation Of Oil Palm Fronds (OPF) Hemicellulose Using Dilute Nitric Acid For Fermentative Production Of Xylitol. *Ind. Crops Prod.* Vol :115, PP: 6–15. <https://doi.org/10.1016/j.indcrop.2018.01.067>
- Siddiq, M. (Ed.) (2012).** Tropical And Subtropical Fruits: Postharvest Physiology, Processing And Packaging, Wiley-Blackwell, Oxford, UK. ISBN: 978-0-8138-1142-0
- Sindhu Mathew, Zainul Akmar Zakaria, (2015)** Antioxidant property and chemical profile of pyroligneous acid from pineapple plant waste biomass ,Nur Fashya Musainstitute Of Bioproduct Development, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia , Vol: 50, PP: 1985-1992, [Http://Dx.Doi.Org/10.1016/J.Procbio.2015.07.007](http://Dx.Doi.Org/10.1016/J.Procbio.2015.07.007)
- Sluiter, A. Et Al. (2008)** Determination Of Structural Carbohydrates And Lignin In Biomass: Laboratory Analytical Procedure (LAP) Tech. Rep. NREL/TP-510-42618 PP:1–15 <https://docs.nrel.gov/docs/gen/fy13/42618.pdf>
- Sofia C. Lourenço, Campos, D. A., G' omez-Garc' ıa, R., Pintado, M., Oliveira, M. C., Santos, D. I., Corr' ea-Filho, L. C., Mold' ao-Martins, M., & Alves, V. D. (2021)** Optimization Of Natural Antioxidants Extraction From Pineapple Peel And Their Stabilization By Spray Drying, *Foods*, Vol:10, PP:1255. <https://doi.org/10.3390/FOODS10061255>
- Sriwatanapongse A, Balaban M And Teixeira A (2000).** Thermal Inactivation Kinetics of Bromelain In Pineapple Juice. *Journal Of American Society Agriculture Engineering* Vol: 43, PP: 1703–1708. <http://dx.doi.org/10.13031/2013.3071>
- Statista (2023)** Leading countries in pineapple production worldwide in 2023. <https://www.statista.com/statistics/298517/global-pineapple-production-by-leading-countries/>.
- Steingass, C.B., Grauwet, T., Carle, R. (2014)** Influence of Harvest Maturity and Fruit Logistics on Pineapple (*Ananas Comosus* [L.] Merr.) Volatiles Assessed by Headspace Solid Phase Microextraction and Gas Chromatography-Mass Spectrometry (HS-SPME-GC/MS), *Food Chem.*, Vol: 150, PP: 382–391. [10.1016/j.foodchem.2013.10.092](https://doi.org/10.1016/j.foodchem.2013.10.092)
- Sukkaew, A., Boonsong, P., Thongpradistha, S. & Intan, M. (2017)** Physical and chemical pretreatment of lignocellulosics in pineapple (*Ananus comosus*) peels dried for investment, *AIP Conference Proceedings*, Vol: 1868, PP: 090001. [10.1063/1.4995193](https://doi.org/10.1063/1.4995193)
- Sukruansuwan V, Napathorn SC (2018)** Use of agro-industrial residue from the canned pineapple industry for

- polyhydroxybutyrate production by *Cupriavidus necator* strain A-04, *Biotechnology for Biofuels*, Vol: 11, PP: 1-15. <https://doi.org/10.1186/s13068-018-1207-8>
- Takeoka, G. R., BATTERY, R. G., Teranishi, R., Flath, R. A., & G Untert, M. (1991)**. Identification Of Additional Pineapple Volatiles. *J. Agric. Food Chem.* Vol: 39, PP:1848-51. <https://doi.org/10.1021/JF00010A032>
- Tanaka K., Hilary Z. D. and Ishizaki A. (1999)** Investigation of the utility of pineapple juice and pineapple waste material as low cost substrate for ethanol fermentation by *Zymomonas mobilis*, *Journal of Bioscience and Bioengineering*, Vol: 87, PP: 642-646. [10.1016/S1389-1723\(99\)80128-5](https://doi.org/10.1016/S1389-1723(99)80128-5)
- Thatchajaree Mala, Sumeth Piayura And Pimchada Itthivadhanapong. (2024)**, Characterization Of Dried Pineapple (*Ananas Comosus L.*) Peel Powder And Its Application As A Novel Functional Food Ingredient In Cracker Product, *Future Foods*, Vol: 9, PP: 100322-100322. <https://doi.org/10.1016/j.fufo.2024.100322>
- Ti Li, P. Shen, W. Liu Et Al. (2014)** Major Polyphenolics In Pineapple Peels And Their Antioxidant Interactions, *International Journal Of Food Properties*, Vol. 17, PP. 1805–1817. <https://dx.doi.org/10.1080/10942912.2012.732168>
- Tianyi Lv, Yuan Chen, Yuyuan Luo, Difei Dai, Xin Feng, Hai Chen, Yong Yu, Liang Ma, Yuhao Zhang And Hongjie Dai Tuning. (2022)** The Properties Of Pineapple Peel Cellulose Nanofibrils By TEMPO-Mediated Oxidation And Ball Milling <https://doi.org/10.21203/Rs.3.Rs-1530006/V1>
- Tilay A, Bule M, Kishenkumar J, Annapure U. (2008)** Preparation of ferulic acid from agricultural wastes: its improved extraction and purification, *Journal of Agricultural and Food Chemistry*, Vol: 56, PP: 7664-7648. [10.1021/jf801536t](https://doi.org/10.1021/jf801536t)
- Tokitomo, Y., Steinhaus, M., Büttner, A., & Schieberle, P. (2005)**. Odor-Active Constituents In Fresh Pineapple (*Ananas Comosus [L.] Merr.*) By Quantitative And Sensory Evaluation. *Biosci. Biotechnol. Biochem.* Vol: 69, PP: 1323-3130. <https://doi.org/10.1271/bbb.69.1323>
- Tran A. V. (2006)**. Chemical Analysis And Pulping Study Of Pineapple Crown Leaves. *Industrial Crops And Products*, Vol: 24, PP: 66-74. <https://doi.org/10.1016/j.indcrop.2006.03.003>
- Ukanwoko AI, Nwachukwu J (2017)** Nutrient and anti-nutritional composition of crop residues and kitchen wastes fed to small ruminants in Choba, Port Harcourt Greener Journal Agriculture Science, Vol:7(2), PP: 054–059. <https://doi.org/10.15580/gjas.2017.2.032317044>
- Umesh HH, Sumana B And Raghavarao KSMS (2008)**. Use Of Reverse Micellar Systems For The Extraction And Purification Of Bromelain From Pineapple Wastes. *Bioresource Technology* Vol: 99, PP: 4896–4902. <https://doi.org/10.1016/j.biortech.2007.09.038>
- V Nida, V Saraswaty, R C Nissa, E S Endah, D Ratnaningrum, C Risdian And H Setiyanto. (2023)** Antibacterial Potential Of Zinc Oxide Nanoparticles Derived From Pineapple Peel Aqueous Extract, *IOP Conf. Series: Earth And Environmental Science*, Vol: 1201, PP: 012086, Doi:10.1088/1755-1315/1201/1/012086
- V Saraswaty, R C Nissa, E S Endah, D Ratnaningrum, C Risdian1 And H Setiyanto3, V Nida1, (2023)** Antibacterial Potential Of Zinc Oxide Nanoparticles Derived From Pineapple Peel Aqueous Extract, *Earth Environ. Sci*, Vol:1201, PP: 012086. <https://doi.org/10.1088/1755-1315/1201/1/012086>
- Venkatesh, V., Sathgatta Zaheeruddin, M. S., & Raghavendra, P. S. (2019)** A facile synthesis of glycerol carbonate by transesterification of glycerol with dimethyl carbonate: Ceria based catalysts, *Journal of the Mexican Chemical Society*, Vol:62(4), PP: 148–159. <https://doi.org/10.29356/JMCS.V62I4.859>
- Vieira, I.M.M.; Santos, B.L.P.; Santos, C.V.M.; Ruzene, D.S.; Silva, D.P. (2022)** Valorization Of Pineapple Waste: A Review On How The Fruit's Potential Can Reduce Residue Generation. *Bioenergy Res*, Vol:15, PP: 924–934. <https://link.springer.com/article/10.1007/s12155-021-10318-9>
- W. W. Ingwersen, Life Cycle Assessment Of Fresh Pineapple From Costa Rica. (2012)** *J. Clean. Prod.* Vol: 35, PP: 152-163. <https://dx.doi.org/10.1016/j.jclepro.2012.05.035>
- Wafaa M. Hikal , Hussein A. H. Said-Al Ahl , Kirill G. Tkachenko , Amra Bratovic ,Małgorzata Szczepanek, Ronald Maldonado Rodriguez (2022)**, Sustainable and Environmentally Friendly Essential Oils Extracted from Pineapple Waste , *Biointerface Research in Applied Chemistry*, Vol :12, PP: 6833 – 6844 , <https://doi.org/10.33263/BRIAC125.68336844>
- Walsh G (2002)**. *Protein Biochemistry and Biotechnology*, 1st edn. London, England: John Wiley and Sons, Vol: 37–38, PP: 419–435. <https://download.e-bookshelf.de/download/0002/2812/64/L-G-0002281264-0003064020.pdf>
- Wan J, Guo J, Miao Z, Guo X (2016)** Reverse Micellar Extraction Of Bromelain From Pineapple Peel - Effect Of Surfactant Structure. *Food Chem* , Vol : 197 PP : 450–456. <https://doi.org/10.1016/J.Foodchem.2015.10.145>
- Watcharin Kaewapichai, Pakorn Kaewtrakulpong , Asa Prateepasen , Kittiya Khongkraphan (2007)**, Fitting A Pineapple Model For Automatic Maturity Gradingm, Vol: 321-323, PP: 1186-1191. <http://dx.doi.org/10.4028/www.scientific.net/KEM.321-323.1186>
- Wills, R.H.H., Lee, T.H., Graham, D., Mcglasson, W.B. And Hall, E.G. (2004)**. *Postharvest: An Introduction to The Physiology And Handling Of Fruit And Vegetables*, New South Wales University Press Limited, New South Wales, Australia. ISBN: 9781742247854, https://www.researchgate.net/publication/315737074_Postharvest_An_Introduction_to_the_Physiology_and_Handling_of_Fruit_and_Vegetables_6th_Edition
- Y. S. Namrata, T. Sharma, And Helix (2017)** Biogenesis Pvt Ltd Anti-Microbial, Antioxidant Activity And

- Phytochemical Screening Of Polyphenolic Flavonoids Isolated From Peels Of Ananas Comosus, *International Journal Of Engineering Research*, Vol: 6, PP: 285–298. <http://dx.doi.org/10.17577/IJERTV6IS090176>
- Yahya, N. A., Wahab, R. A., Lim, T. S. X., & Hamid, M. A. (2019)** Ultrasound-Assisted Extraction Of Polyphenols From Pineapple Skin, *AIP Conference Proceedings*, Vol: 2155, PP: 020002. <https://doi.org/10.1063/1.5125506>
- Yeoh, W. K.; Ali, A. (2017)** Ultrasound Treatment On Phenolic Metabolism And Antioxidant Capacity Of Fresh-Cut Pineapple During Cold Storage. *Food Chem.*, Vol: 216, PP: 25–247. DOI: 10.1016/J.Foodchem.2016.07.074.
- Yetein, M.H., Houessou, L.G., Lough 'Egnon, T.O., Teko, O., Tente, B., (2013)**. Ethnobotanical Study Of Medicinal Plants Used For The Treatment Of Malaria In Plateau Of Allada, Benin (West Africa). *J. Ethnopharmacol. B*, Vol:146, PP: 154–163. <https://doi.org/10.1016/j.jep.2012.12.022>
- Yossie Kharisma Dewi, Vonny Setiaries Johan, Nur Hasnah, Yanti Nopiani, Rizka Utami, And Nourma Yunita (2024)**. *BIO Web Of Conferences* Vol: 99, PP: 02019. <https://doi.org/10.1051/Bioconf/20249902019>
- Zhang, X., Shen, Y., Prinyawiwatkul, W., & Xu, Z. (2012)**. Volatile Compounds In Fresh-Cut Pineapple Heated At Different Temperatures. *J. Food Process. Pres.* Vol:36, PP: 567-573. <http://dx.doi.org/10.1111/jfpp.12009>
- Zziwa, A.; Jjagwe, J.; Kizito, S.; Kabenge, I.; Komakech, A.J.; Kayondo, H.(2021)** Nutrient Recovery From Pineapple Waste Through Controlled Batch And Continuous Vermicomposting Systems. *J. Environ. Manag.* Vol: 279, PP: 111784. <https://doi.org/10.1016/j.jenvman.2020.111784>
- Terzopoulou, P., & Kamperidou, V. (2022)**. Chemical characterization of Wood and Bark biomass of the invasive species of Tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle), focusing on its chemical composition horizontal variability assessment. *Wood Material Science & Engineering*, 17(6), 469–477. <https://doi.org/10.1080/17480272.2021.1888315>.

List of Abbreviations

Golden MD2	Golden Millie Dillard
DPPH	2,2-Diphenyl-1-Picrylhydrazyl
PP	Pineapple Peel
RSM	Response Surface Methodology
TAC	Total Antioxidant Capacity
MAE	Microwave-Assisted Extraction
XRD	X-ray Diffraction
DESS	Deep Eutectic Solvents
SFE	Supercritical Fluid Extraction
CO ₂	Carbon dioxide
HD	Hydro-distillation
HDEA	Enzyme-assisted hydro-distillation
UAE	Ultrasound-Assisted Extraction
RSM	Response Surface Methodology
CCRD	Central Composite Rotatable Design
TPC	Total Phenolic Content
FRAP	Fluorescence recovery after photobleaching
TFC	Total Flavonoid Content
HPLC	High-Performance Liquid Chromatography
HCl	Hydrochloric Acid
pH	Potential of Hydrogen
WAC	Water Absorption Capacity
OAC	Oil Absorption Capacity
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide

CDs	Carbon Dots
PPAC	Pineapple peel activated carbons
SEM	Scanning Electron Microscopy
Pb (II)	Lead (II)
UL-94 V/HB	Underwriters Laboratories (UL) 94 horizontal burn (HB) and vertical burn (V) ratings
ASTM D-635	Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
BC tumor cells	Breast Cancer tumor cells
IBS	Irritable Bowel Syndrome
IDFs	Insoluble dietary fibers
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
PPW	Pineapple Processing Waste