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Antibacterial and Phytochemical Analysis of Ethanolic Extract of *Ananas comosus* (Pineapple) Peel

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ABSTRACT

The rapidly increasing global population and the impending food shortages in near future necessitate sustainable strategies to meet the prospective nutritional requirements in addition to basic food needs. Concerning this, one promising approach is the use of fruit peels as nutraceutical which may provide health benefits. *Ananas comosus* (pineapple) peel are abundant in bioactive compounds, particularly polyphenols, which offer potential therapeutic effects and boosts overall health. The present study was carried out to assess the total polyphenol content, phytochemical profile, and antibacterial potential of the ethanolic extract of pineapple peel (PPEE). The phytochemical composition of PPEE was identified using HRLCMS-QTOF in both positive and negative ionization modes, it showed the presence of variety of phenolic and polyphenolic compounds, the total polyphenol content was 359.14 ± 2.12 mg GAE/g. The antibacterial activity of PPEE was evaluated against six organisms including *Escherichia coli* NCIM 2065, *Proteus vulgaris* NCIM 2027, *Shigella flexneri* NCIM 5265, *Staphylococcus aureus* NCIM 2079, *Pseudomonas aeruginosa* NCIM 2036 and *Lactobacillus casei* var *shirota*. using agar well diffusion method. PPEE inhibited all the test pathogens at 50 mg/mL concentration while had no inhibitory effect on *L. casei* var *shirota*.

Keywords HRLCMS-QTOF, Antibacterial, Probiotic, Polyphenols, Pineapple peel.

INTRODUCTION

Pineapple (*Ananas comosus* L. Merr.) is a widely consumed tropical fruit produced majorly in Southeast Asia (Indonesia, Thailand and Phillipines), Central America (Costa Rica) and South America (Brazil, Columbia). It is also popular in countries like Nigeria, India and China (Hikal *et al.* 2021). It is one of the fruit which is in high demand globally, and can be processed into various products like juice, canned goods, and dried fruit (Abraham *et al*. 2023). About 75% of the original fruit, however, is generated as waste, which constitutes 29–40% peels (Lourenço *et al.* 2021, Ketnawa *et al.* 2012). In 2021, an estimated 8.31–11.46 million tons of pineapple peel waste was produced globally (Mala *et al.* 2024). Overlooking the non-nutrient components like water and cellulose

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(fiber content), the above statistics transcribe to wastage of substantial quantities of bioactive compounds that could be extracted from pineapple peels. These include sugars (sucrose, glucose, fructose), organic acids (malic, citric, quinic), essential minerals (potassium, magnesium, calcium), hemicellulose, pectin, lignin, enzymes, vitamins A and C and polyphenols (Campos *et al.* 2019, Mehraj *et al.* 2024). Bromelain, a proteolytic enzyme found primarily in pineapple pulp, exhibited broad range of medicinal and industrial applications including anti-inflammatory properties, digestive support, wound-healing capabilities, antimicrobial effects, and potential use in cancer therapy (Zhou *et al.* 2021).

Among the diverse bioactive compounds, pineapple peels are particularly rich in polyphenols, including phenolic acids, flavonoids and tannins, which exhibit wide range of biological activities (Li *et al.* 2014). The antioxidant potential of compounds such as catechins, gallic acid, ferulic acid and flavonoids is well documented (Suleria *et al.* 2020). Additionally, saponins, flavonoids, quinones and tannins act as natural antimicrobials, which aid in reducing food spoilage (Hochma *et al.* 2021). These compounds are abundant in pineapple peel, making it good candidate for use as natural preservative in food packaging industries.

Pineapple peel have long been recognized in traditional medicine for its therapeutic potential (Hikal *et al.* 2021, Mehraj *et al.* 2024). Efficacy of it is reported in treatment of pain, inflammation and ailments such as malaria, arthritis, diabetes, typhoid, and gastrointestinal disorders (Ajayi *et al.* 2022, Pandey and Rizvi 2009). These effects are suggested to stem from the action of either polyphenols alone or their synergy with other components in the peel (Hikal *et al.* 2021). In general, flavonoids are linked with low risk of developing diabetes, cardiovascular diseases and other chronic diseases (Knekt *et al.* 2002). Additionally, catechins and many other polyphenols are known to prevent inflammatory bowel disease and other related gastrointestinal disorders (Dryden *et al.* 2006). Polyphenols like alkaloids, saponins, flavonoids, terpenes, coumarins and glycosides have shown promising effect against cancer (Tomar *et al.* 2024). Given that these compounds are plentiful in pineapple peel, this highlights their potential in pharmaceutical and nutraceutical applications.

The present study was carried out with an objective to evaluate the total polyphenol content, phytochemical profile and antibacterial activity of pineapple peel ethanol extract (PPEE) and determine its suitability as a nutraceutical ingredient.

MATERIALS AND METHODS

Materials

The raw materials (pineapples and their peels) were sourced from a local market in Kalyan, Thane District, Maharashtra, India. All chemicals, including Folin-Ciocalteu reagent, sodium carbonate, gallic acid, and methanol, were of analytical grade and obtained from Sigma Aldrich, Mumbai, India. Food-grade ethanol was supplied by Manosol, Mumbai. Mueller and Hinton agar, De Man–Rogosa–Sharpe agar (MRS) agar, nutrient agar, potato dextrose agar were purchased from Hi Media, India.

Test organisms

The cultures from Culture Collection of Department of Microbiology, Faculty of Science, Smt CHM College, Ulhasnagar, Maharashtra were used in the study. The organisms used comprised of *Escherichia coli* NCIM 2065, *Proteus vulgaris* NCIM 2027, *Shigella flexneri* NCIM 5265, *Staphylococcus aureus* NCIM 2079, *Pseudomonas aeruginosa* NCIM 2036 and *Lactobacillus casei* var *shirota.*

Standardization of inoculum

Bacterial strains were maintained on sterile nutrient agar slants. These strains were initially cultivated on Mueller-Hinton medium at 37°C for 18–24 hrs. The bacterial inoculum was subsequently transferred to a physiological suspension medium and adjusted to a turbidity equivalent to the 0.5 McFarland standard (10^8 cfu/ml).

The *Lactobacillus casei* var *shirota* strain was isolated from a commercially available probiotic drink, Yakult, using sterile MRS agar and incubated

anaerobically at 30°C. The purified culture was preserved on sterile MRS agar slants. The inoculum of *L. casei* var *shirota* was prepared following the same procedure as described for the bacterial strains.

Preparation of pineapple peel extract

The pineapple peels were thoroughly washed with tap water, followed by sterile distilled water, and sun-dried for three days. After drying, the peels were finely ground using a pre-sterilized mixer grinder and stored in airtight containers. To extract the bioactive compounds, 10 g of the powdered peel was soaked in 90 mL ethanol (96%) for 48 h and then filtered using Whatman filter paper No. 1. Pineapple peel ethanol extract (PPEE) was concentrated under vacuum at approximately 40°C using a Trident Labortek Rotary Evaporator. The dried extracts were exposed to UV radiation for 2 h and tested for sterility on sterile nutrient agar and potato dextrose agar plates. The sterile extracts were then stored in labelled sterile containers at 4°C until further use (Shinde 2012).

Antibacterial assay

The antibacterial activity of PPEE was evaluated using the agar well diffusion method (CLSI 2006). Sterile molten Mueller-Hinton agar for bacteria and sterile MRS agar for *L. casei*, cooled to approximately 40°C, was inoculated with various microbial cultures, and plates were prepared. Once the agar solidified, wells of 6 mm diameter were punched into the medium. Peel extracts dissolved in 10% DMSO at different concentrations (100 mg/mL, 50 mg/mL, 25 mg/mL) were added to the wells. The plates were then incubated overnight at 37°C for bacterial cultures and anaerobically for *L. casei* at 30°C. After incubation, the zones of inhibition were measured and documented. Control were maintained, all tests were performed in triplicates.

Total polyphenol content (TPC)

The Folin-Ciocalteu method was used to estimate the total polyphenol content of PPEE. A 1:10 diluted Folin Ciocalteau reagent (2.5 mL) along with equal volume of 7.5% sodium carbonate was mixed with 0.5mL PPEE. After incubating at room temperature for 30 minutes, the blue color intensity produced in the reaction was measured using a spectrophotometer at 760 nm (Waterhouse 2002). The total phenolic content was expressed in Gallic Acid Equivalents (GAE mg/g), calculated from a standard gallic acid curve (0.01 to 0.05 mg/mL). All analyses were performed in triplicate.

$$T = C \times \frac{V}{M}$$

Where T is the total phenolic content in 'mg/g' of the extract, C is the concentration of gallic acid established from the calibration curve in 'mg/mL', V is the volume of the extract solution in 'mL', and M is the weight of the extract in 'g'.

HR-LCMS analysis of pineapple peel ethanol extract

High-Resolution Liquid Chromatography Mass Spectrometry with Quadrupole Time-of-Flight (HRLCMS-QTOF) was carried out to identify phytochemical components in PPEE. The analysis was conducted on MS Q-TOF G6550A (Agilent Technologies, Santa Clara, CA) present at SAIF, IIT Bombay. Mass spectrometry was performed in both positive and negative ESI modes and recorded over a range of m/z 50 to 1500. The chromatographic separation was carried out on Kinetex XB-C18 column, mobile phase of 0.1% formic acid in water and acetonitrile, drying gas temperature 250°C and sheath gas temperature 350°C. Tandem MS/MS were obtained by auto MS/MS acquisition mode and collision energy (CE) was set at 20–40V. Identification was accompanied by comparison of MS with reported libraries (Galeano Gracia *et al.* 2018).

RESULTS AND DISCUSSION

Antibacterial activity

Pineapple peel ethanol extract had inhibitory activity on all the pathogens used in the study (Table 1). Among the five pathogens tested, *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* were inhibited at a concentration of 25 mg/mL. However, even at the highest concentration (100 mg/

Table 1. Antibacterial activity of pineapple peel ethanol extract. – = No inhibition.

Sl. No.	Concentration (mg/mL)→ Organisms ↓	100	50	25
1	*Staphylococcus aureus* NCIM 2079	23.67± 0.58	19.33± 1.15	18.67± 1.15
2	*Proteus vulgaris* NCIM 2027	24 ±1	19± 1	17.33± 0.58
3	*Escherichia coli* NCIM 2065	27.33 ±0.58	23.67± 1.15	-
4	*Shigella flexneri* NCIM 5265	24.33±0.58	22.67± 1.15	-
5	*Pseudomonas aeruginosa* NCIM 2036	24.67± 1.53	22.33± 1.53	20.67±0.58
6	*Lactobacillus casei* var *shirota*	–	–	-

mL), *L. casei* was not inhibited. Typically, the bitter tasting polyphenolic compounds (like glycosides and flavonoids) and alkaloids demonstrate antimicrobial potential (Hikal *et al.* 2021). This property in fruit peels can be extremely useful in drug development, plant health management, preventing post-harvest diseases and food packaging industries (Budiati *et al.* 2022, Saleem and Saeed 2019). Several research studies have linked the antibacterial effectiveness of fruit wastes to the abundance of phenolic acids and polyphenols. Phenolic acids penetrate cell membranes, resulting in cytoplasmic acidification, and polyphenols precipitate microbial membrane proteins and inhibit essential enzymes like glycosyl transferases, leading to cell disintegration (Lobiuc *et al.* 2022). One of the reasons why polyphenols do not inhibit lactic acid bacteria, such as *L. casei* in this study, is their ability to utilize diverse metabolic pathways. These pathways allow them to process higher concentrations of polyphenols and other natural compounds, with the help of enzymes such as reductases, decarboxylases, and glycosidases, as long as they remain within safe dietary levels (Makarewicz *et al.* 2021).

Total polyphenol content

The ionic nature of polyphenols allows them to form covalent bonds with inorganic derivatives found in peels. This can potentially decrease their water solubility. Hence, less polar solvents like methanol or ethanol are preferred over highly polar solvents like water for extracting a broad range of compounds from plant materials. Methanol is toxic whereas ethanol is classified as Generally Recognized As Safe (GRAS) for human consumption by the FDA (USFDA 2024). For this reason, ethanol was selected for the extraction process. The TPC in PPEE was measured to be 359.14 ± 2.12 mg GAE/g of extract. This value was significantly higher than the TPC reported for pineapple peel from Hainan, China (7.98 mg GAE/g) (Li *et al.* 2014) and Torres Vedras, Portugal (11.10 ± 0.01 mg GAE/g) (Lourenço *et al.* 2021). Remarkable amount of TPC (5803.21 mg GAE/g) was reported in pineapple peel from Nongkhai Province, Thailand (Lasunon *et al.* 2022). The polyphenol content and composition of plant materials vary greatly depending on intrinsic factors such as plant genetics and cultivar (Mignard *et al.* 2021) as well as extrinsic factors like soil composition, growing conditions, maturity, and post-harvest processing (Faller and Fialho 2010). For this reason, variations in TPC of plant materials can occur between different regions.

HR-LCMS analysis of pineapple peel ethanol extract

In total, the HRLCMS-QTOF analysis of PPEE identified many phytochemicals like amino acid derivatives, lipid derivatives, organic acid derivatives and organoheterocyclic compounds, the emphasis is given more to polyphenols and phenolic acids in the current study. Nearly, 13 phenolic and 16 polyphenolic compounds were identified in PPEE (Table 2). The literature indicates wide variations in the composition of pineapple peels. Flavonoids such as catechin and epicatechin, along with phenolic acids such as ferulic acid and gallic acid (Li *et al.* 2014, Lubaina *et al.* 2020). The HPLC analysis of PPEE revealed a polyphenolic profile that included various compounds such as gallic acid, catechol, caffeic acid, syringic acid, p-coumaric acid, cinnamic acid, ferulic acid, myricetin, ellagic acid quercetin, kaempferol, and apigenin (Lubaina *et al.* 2020). This study revealed a notable diversity of polyphenolic

Table 2. Phytochemical profile of pineapple peel ethanol extract analyzed by HRLCMS-QTOF.

Sl. No.	Name of compound	Class	Formula	Mass (DB)	m/z	RT	Diff (DB, ppm)	Diff (DB, mDa)
Phenolic compounds identified in the negative ion mode								
1	4-((2,4-Dihydroxy-phenyl) azo) benze-nesulfonic acid	Benzenoids (phenolic acids)	$C_{12}H_{10}N_2O_5S$	294.03	353.0448	6.496	-0.39	-0.12
2	Eszopiclone	Cyclopyrrolones	$C_{17}H_{17}C_lN_6O_3$	388.10	433.1058	8.132	-1.1	-0.43
3	Flumioxazin	N-phenylphtha-limides	$C_{19}H_{15}FN_2O_4$	354.10	399.1012	10.707	-4.02	-1.42
4	Chlorprothixene	Thioxanthenes	$C_{18}H_{18}ClNS$	315.08	360.0869	5.083	-12.66	-3.99
Phenolic compounds identified in the positive ion mode								
5	Alpha-naphthyla-cetamide	Aromatic amides	$C_{12}H_{11}NO$	185.08	186.0903	4.883	6.03	1.12
6	L-Arogenate	Aromatic amino acids	$C_{10}H_{13}NO_5$	227.07	250.0694	5.598	-3.64	-0.83
7	Methyl 2-benza-midoacetate	Benzenoids (Benzamides)	$C_{10}H_{11}NO_3$	193.07	194.0801	3.524	5.5	1.06
8	Methyl n-formyl-anthranilate	Benzenoids (benzoic acid derivatives)	$C_9H_9NO_3$	179.05	180.0644	3.761	6.11	1.09
9	4-(3,5-Diphenyl-cyclohexyl) phenol	Benzenoids (phenols)	$C_{24}H_{24}O$	328.18	351.174	4.458	-3.12	-1.02
10	3-tert-Butyl-5-me-thylcatechol	Catechols	$C_{11}H_{16}O_2$	180.11	181.1212	13.78	6.39	1.15
11	BQ 123	Cyclic peptides	$C_{31}H_{42}N_6O_7$	610.31	306.1666	6.763	-11.27	-6.88
12	4,4'-Diaminodi-phenyl ether	Diphenyl ethers	$C_{12}H_{12}N_2O$	200.09	201.1011	5.917	5.51	1.1
13	Alpha-ethyl-alpha, beta-diphenyl-2-pyridineethanol	Phenethyl alcohols	$C_{21}H_{21}NO$	303.16	304.1737	6.692	3.85	1.17
Polyphenolic compounds identified in the negative ion mode								
14	1-OH-Nogalamy-cinone	Anthracyclines	$C_{21}H_{18}O_9$	414.09	413.0828	8.13	12.04	4.99
15	6-(2-Carboxyethyl)-7-hydroxy-2,2-dim-ethyl-4-chroma-none glucoside	Flavonoids	$C_{20}H_{26}O_{10}$	426.15	485.1654	6.056	3.6	1.53
16	Hyperin 6''-(gluco-syl-(1->3)-rham-noside)	Flavonoids	$C_{33}H_{40}O_{21}$	772.20	817.2087	12.047	-13.02	-10.05
17	Isoorientin 2''-(feruloyl-(->6)-glucoside)	Flavonoids	$C_{37}H_{38}O_{19}$	786.20	831.203	9.914	-4.65	-3.65
18	Isorhamnetin 3-O-(b-D-glucopyranosyl-(1->2)-(a-L-rhamno-pyranosyl-(1->6))-b-D-glucopyranoside)	Flavonoids	$C_{34}H_{42}O_{21}$	786.22	831.2243	12.857	-5.2	-4.09
19	Kuwanon L	Flavonoids	$C_{35}H_{30}O_{11}$	626.17	671.1718	9.027	8.28	5.19
20	Spinacetin 3-(2''-api-osylgentiobioside)	Flavonoids	$C_{34}H_{42}O_{22}$	802.21	847.2192	12.411	-4.72	-3.79

Table 2. Continued.

Sl. No.	Name of compound	Class	Formula	Mass (DB)	m/z	RT	Diff (DB, ppm)	Diff (DB, mDa)
Polyphenolic compounds identified in the negative ion mode								
21	Tricin 7-[sinapoyl-(->2)-glucuronyl-(1->2)-glucuronide)	Flavonoids	$C_{40}H_{40}O_{23}$	888.19	947.1976	7.404	14	12.44
22	6-Cinnamoyl-1,2-digalloyl-glucose	Hydrolyzable tannins	$C_{29}H_{26}O_{15}$	614.12	659.1277	8.089	-0.99	-0.61
23	Patientoside A	Iridoid glycosides	$C_{19}H_{21}C_lO_8$	412.09	411.0858	7.049	-1.37	-0.57
24	3,9-Dinitrofluoranthene	Nitrofluoranthenes	$C_{16}H_8N_2O_4$	292.04	337.0501	7.32	-11.98	-3.5
Polyphenolic compounds identified in the positive ion mode								
25	Auramycinone	Anthracyclines	$C_{21}H_{18}O_8$	398.10	399.1053	10.828	5.44	2.16
26	N-D-Glucosylarylamine	Arylamine glycosides	$C_{12}H_{17}NO_5$	255.11	256.1164	3.718	7.15	1.82
27	3-Hydroxycoumarin	Coumarins	$C_9H_6O_3$	162.03	163.0381	7.496	5.7	0.92
28	Quercuslactone A	Lactones	$C_9H_{16}O_2$	156.11	179.1053	9.409	-5.64	-0.88
29	Niazirinin	Glycosides (Glucosinolates)	$C_{16}H_{19}NO_6$	321.12	322.1291	5.784	-4.39	-1.41

compounds, with a substantial number of peaks corresponding to presence of uncommon flavonoids and glycosides not identified previously in pineapple. For example, tricin had been documented only once in pineapple leaves (Huang *et al.* 2015), to the best of our knowledge, flavonoid such as the kuwanon L and the glycosides D-Glucosyl arylamines, niazirinin, patientoside A and N-D-Glucosylarylamine were not identified and probably not reported in pineapple or their by-products in the past.

Flavonoids are mainly recognized for their antioxidant, antimicrobial or anti-inflammatory activities (Sahana *et al.* 2021, Cho *et al.* 2020, Górniak *et al.* 2019). However, they display a wide range of bioactivities, including anticancer, antiparasitic, cardioprotective, hepatoprotective, neuroprotective, antispasmodic and many other properties (Hu *et al.* 2023, Rahaman *et al.* 2022, Tanaka *et al.* 2019, Ji *et al.* 2018, Esposito *et al.* 2015, Verma *et al*. 2013). For example, hyperin had been reported to exhibit antihyperglycemic potential at doses of 25 and 50 mg/kg over 30 days in streptozotocin-induced diabetic rats (Verma *et al.* 2013). It was also reported for its anti-apoptotic and antidepressant activities (Rahaman *et al.* 2022). Kuwanon had shown efficiency in melanoma therapy by inducing cytotoxic endoplasmic reticulum stress and impairing autophagy flux in mouse models (Hu *et al.* 2023). Biochemical studies further indicate that it can inhibit the catalytic activity of HIV-1 integrase, demonstrating potential in antiviral applications (Esposito *et al.* 2015).

CONCLUSION

From the study undertaken, it can be concluded that ethanolic extract of pineapple peel has antibacterial properties and good polyphenol content. This was further confirmed by HRLCMS-QTOF analysis which revealed the different types of polyphenols present. The selective inhibition of pathogenic microbes while supporting growth of lactic acid bacteria, further demonstrate the prebiotic potential of PPEE. These properties can be used to formulate new products to be used in food industry as natural antioxidant and also as natural food pre-

servatives. Considering all the parameters studied in the current study, pineapple peel may become potential nutraceutical ingredient in the near future.

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