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Original Research Paper

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EXTRACTION, NUTRITIONAL PROFILING, ANTIMICROBIAL EVALUATION AND FOOD SUPPLEMENT APPLICATION OF PECTIN FROM CARICA PAPAYA PEEL WASTE

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ABSTRACT The increasing amount of fruit processing waste has become a major environmental concern worldwide, leading researcher to construct sustainable manoeuvres for the conversion of these wastes into valuable products. Fruit peels, which are primarily discarded during processing, are considerable sources of dietary fibre, bioactive synthetic substances, and polysaccharides such as pectin. Utilizing these by-products nonetheless solely diminishes ecological destruction but simultaneously favours the conservation of biodiversity implementation. In recent years, agricultural waste valorization has attracted substantial interest as an eco-friendly strategy for crafting value-added functional ingredients for food, pharmaceutical, and nutraceutical commercial enterprises. Present study focuses on the extraction of pectin from Carica papaya peel waste and the evaluation of its nutritional composition, antibacterial activity, and hypothetical application as a food supplement ingredient. This study shows the relevance of exploiting fruit processing waste as a renewable source of functional chemicals and encourages the development of sustainable and value-added products for food and health-related uses.

KEYWORDS : Carica Papaya Peel, Antibacterial Activity, Functional Chemicals, Value Added Products

INTRODUCTION

Fruits serve a pivotal part in human nutrition by restoring indispensable vitamins, minerals, and natural antioxidants. Globally, fruit production continues to expand, with countries like India being among the foremost producers. Fruits contain a wide range of bioactive components such as vitamin C, phenolics, tocopherols, and carotenoids that help protect the body against oxidative stress and tonnes of health-related illnesses. These substances are known for their antioxidant capabilities and contribute greatly to preserving overall health and well-being. (Altaf,et al.,2015).

Among tropical fruits, papaya (Carica papaya L.), which pertains to the Caricaceae family, is widely cultivated and consumed due to its rich nutrient composition and medicinal ability to heal. Papaya is widely acknowledged as a substantial source of vitamins, minerals, dietary fibre, and natural enzymes. The fruit features plenty of useful chemical compounds, including polyphenols, proteins, enzymes, and antioxidants that contribute to its therapeutic and dietary appropriateness. Because of its nutritional richness and therapeutic characteristics, papaya is extensively deployed in both traditional and modern food supplement applications. (Rocha,et al.,2024). Objective of the study is to extract pectin and bioactive compounds from Carica papaya peel waste and evaluate their physicochemical, antioxidant, and antimicrobial properties for potential food industry applications.

MATERIALS AND METHODS

Collection of Raw Material

Fresh papaya fruits (Carica papaya) were collected from the local market. The fruits were washed thoroughly with tap water, followed by distilled water to remove dust and surface contaminants. The peels were manually separated using a clean stainless-steel knife and used as the raw material for the study. The collected peels were immediately processed to prevent microbial contamination and degradation of bioactive compounds. (Dotto and Abihudi, 2019)

Sample Processing

The collected papaya peels were washed thoroughly with tap water followed by distilled water to remove impurities and cut into small pieces. The peel pieces were shade dried at room temperature (25–30°C) for 5–7 days until constant weight was obtained. The dried peels were ground into fine powder using a mechanical grinder and sieved to obtain uniform particle size. The processed powder was stored in airtight containers in a dedicator to prevent moisture absorption and used for further extract (Trease and Evans, 2002)

Extraction of Pectin Using Citric Acid (Acid Hydrolysis Method)

Pectin was extracted from the papaya peel powder using the acid hydrolysis method with citric acid. Briefly, a known weight of papaya peel powder was mixed with distilled water in a 1:20 (w/v) ratio, and the pH of the solution was adjusted to 1.5–2.0 using citric acid. The mixture was heated at 80–90°C for about 1 hour with continuous stirring to facilitate extraction. The hot extract was filtered through muslin cloth, followed by Whatman No.1 filter paper to remove solid residues. The filtrate was cooled to room temperature, and pectin was precipitated by adding double the volume of ethanol. The precipitated pectin was allowed to settle, then filtered, washed with ethanol to remove impurities, and dried in a hot air oven at 40–50°C. The dried pectin was powdered, weighed, and stored in airtight containers for further characterization and analysis. (Voragen et al., 1995).

Quantitative Phytochemical Analysis

Quantitative phytochemical analysis was carried out to estimate total phenolic content using the Folin–Ciocalteu method, total flavonoid content using the aluminium chloride method, total tannin content using the Folin–Denis's method, total carbohydrate content using the Anthrone method, and protein content using the Lowry method. The results were expressed in mg/g of extract. (Singleton et al., 1999).

Pharmacological Activities

The antioxidant activity of the papaya peel extract was determined using the DPPH radical scavenging assay. Different concentrations of the extract were mixed with DPPH solution and incubated in the dark for 30 minutes at room temperature. The absorbance was measured at 517 nm using a UV–Visible spectrophotometer, with ascorbic acid used as the standard. The percentage of radical scavenging activity was calculated, and the antioxidant activity was expressed as percentage inhibition and IC_{50} value. (Blois,1958).

Antimicrobial Activity of the Aqueous Extract

The antibacterial activity was tested using E.coli. The organism was inoculated in tryptic soy broth and incubated at 37°C overnight. After incubation, 100 μL of the culture was spread onto Mueller–Hinton agar plates using a sterile cotton swab. The antibacterial activity was evaluated using the agar well diffusion assay. In each Petri dish, four wells of 6 mm

diameter were punched using a sterile cork borer. Different concentrations of the extract (50 μL, 75 μL, and 100 μL) were added to the wells. Ethanol was used as the control, and a vancomycin antibiotic disc was placed to compare the zone of inhibition. The plates were then incubated at 37°C for 24 hrs. (Bauer et al., 1966).

STRUCTURAL CHARACTERIZATION

UV–Visible Spectroscopy

UV–Visible spectroscopy was used to analyze the absorbance characteristics of extracted pectin. About 1 mg/mL pectin solution was prepared in distilled water and filtered. The absorbance was recorded in the wavelength range of 200–400 nm using a UV–Visible spectrophotometer with distilled water as blank. The absorption peaks were recorded and used to confirm the presence of pectin. (Thakur,et al.,1997).

FTIR Analysis

Fourier Transform Infrared (FTIR) spectroscopy was used to identify functional groups present in the extracted pectin. The dried pectin sample was mixed with potassium bromide (KBr) and compressed into a pellet. The FTIR spectrum was recorded in the range of 4000– 400 cm^{-1}. The characteristic peaks corresponding to ester groups, carboxyl groups, and polysaccharide structure were analyzed to confirm pectin structure. (Fishman et al., 2006).

Particle Size Analysis (DLS) and Zeta Potential Analysis

The zeta potential of the pectin solution was measured to determine the surface charge and stability of pectin particles. The pectin solution was prepared in distilled water and placed in a zeta potential analyser cell. The zeta potential values were recorded, which indicate the stability and dispersion behaviour of pectin particles (Coates, 2000).

RESULT

Extraction of Pectin Using Acid Hydrolysis Method

Pectin was successfully extracted from fruit waste using the acid hydrolysis method with citric acid. During extraction, protopectin present in the plant cell wall was converted into soluble pectin under acidic conditions and heat treatment. The extracted pectin was precipitated using ethanol, filtered, and dried to obtain powdered pectin.

Preliminary Phytochemical Analysis

Preliminary phytochemical screening of the fruit waste extract revealed the presence of various bioactive compounds such as carbohydrates, phenols, flavonoids, quinones, alkaloids, saponins, coumarins, and glycosides. These phytochemicals are known for their antioxidant, antimicrobial, and therapeutic properties.

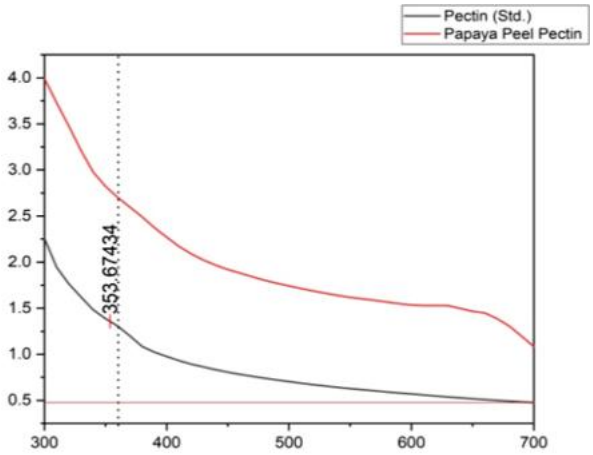
Table 1. Preliminary Phytochemical Tests from the Extracts of Papaya Peel

S. No.	Test	Aqueous extract	Ethanol
1.	Carbohydrate	+	-
2.	Tannins	-	+
3.	Saponins	+	+
4.	Flavonoids	+	+
5.	Alkaloids	-	-
6.	Quinones	+	-
7.	Glycosides	-	-
8.	Cardiac glycosides	+	+
9.	Terpenoids	+	+
10.	Phenols	+	-
11.	Coumains	+	+
12.	Steroids	+	+
13.	Phlorotannins	-	-
14.	Anthroquinones	-	-

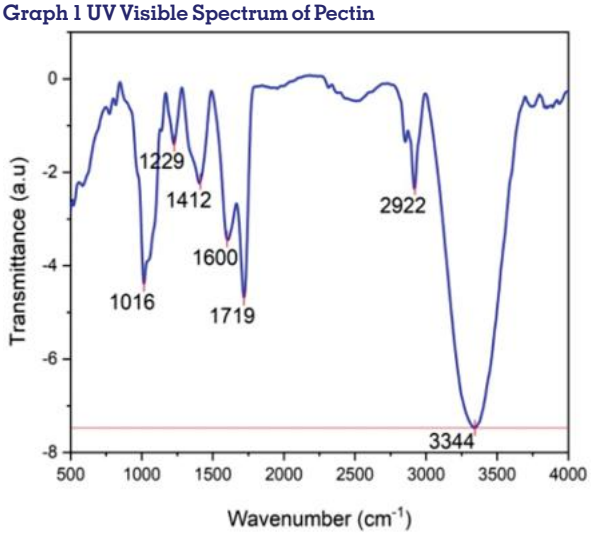
Antimicrobial Activity

The antimicrobial activity of the fruit waste extract was tested against bacterial species such as Escherichia coli and fungal species such as Candida albicans using the agar well diffusion method. The extract showed inhibitory activity against both bacterial and fungal organisms, indicating its antimicrobial potential.

Structural Characterization Of Papaya Peel Pectin



Graph 1 UV Visible Spectrum of Pectin



Graph 2 FTIR Spectrum of Pectin

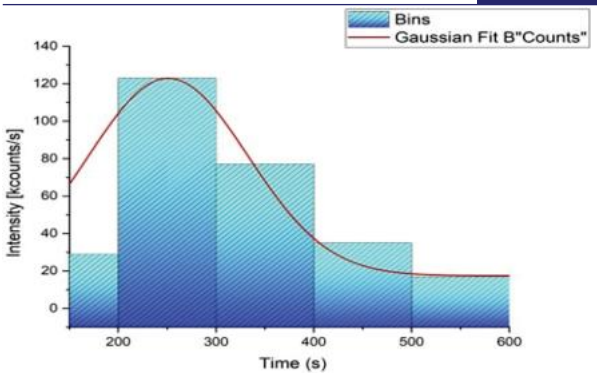
UV–Visible Spectroscopy

The UV–Visible spectrum of extracted pectin showed absorption in the range of 280– 300 nm, which corresponds to the presence of polysaccharide and possible phenolic compounds associated with fruit peel extract. The absorbance pattern confirms the presence of pectin and associated phytochemical components. The similarity in absorption profile between standard and extracted pectin confirms structural similarity and successful extraction.

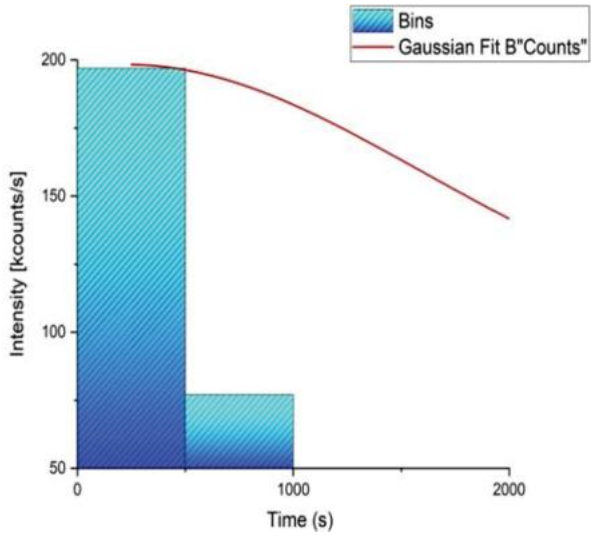
Table 2: IR Spectrum Table Shows the Functional Groups Analyzed From Pectin.

Wave number (cm^{-1})	Functional Group	Assignment
3344	O–H stretching	Polysaccharide hydroxyl groups
2922	C–H stretching	Alkyl groups
1719	C=O ester	Esterified carboxyl group
1600	COO^- stretching	Carboxylate ion
1412	C–H bending	Polysaccharide structure
1229	C–O stretching	Ester linkage
1016	C–O–C	Glycosidic bond

Particle Size Analysis Using – Dynamic Light Scattering (DLS) and Zeta Potential Analysis



Graph 3 Standard Pectin



Graph 4 Papaya Peel Extract

The Papaya peel pectin showed a broader particle size distribution compared to standard pectin, indicating higher polydispersity and heterogeneous particle size distribution. The broader distribution may be attributed to differences in molecular weight distribution, degree of esterification, and partial aggregation during extraction.

DISCUSSION

Fruit waste, such as peels and rinds, was collected from local markets and households and used as raw material for the extraction of pectin and phytochemicals. The samples were washed, cut into small pieces, shade dried, and powdered. Drying reduced moisture content and prevented microbial degradation. The powdered samples were stored in airtight containers for further analysis. Samples showed uniform particle size and were suitable for extraction, demonstrating that fruit waste can be utilized as an eco-friendly and cost-effective source for value-added products such as pectin and bioactive compounds.

The yield of pectin obtained indicated that fruit waste is a good source of pectin. The extracted pectin appeared as a light brown to off-white powder and showed good solubility in hot water, confirming the presence of pectin substances. The acid hydrolysis method was found to be effective for pectin extraction because it produced a good yield and preserved the functional properties of pectin. The obtained pectin can be used in food, pharmaceutical, and biomedical applications as a gelling, stabilizing, and thickening agent

The presence of phenolic and flavonoid compounds suggests that the fruit waste extracts possess significant antioxidant potential. These compounds play an important role in neutralizing free radicals and preventing oxidative stress. These results indicate that fruit waste can be utilized as a potential natural source of bioactive compounds for pharmaceutical and nutraceutical applications (Boughari, 2012).

The FTIR spectrum of extracted pectin showed characteristic absorption bands corresponding to polysaccharide structure. A broad peak at 3344 cm^{-1} represents O–H stretching vibrations of hydroxyl groups present in polysaccharides. The peak at 2922 cm^{-1} corresponds to C–H stretching of aliphatic groups. The strong absorption band at 1719 cm^{-1} indicates esterified carboxyl groups, while the band at 1600 cm^{-1} corresponds to asymmetric stretching of carboxylate ions. Peaks observed at 1229 cm^{-1} and 1016 cm^{-1} represent C–O stretching and glycosidic linkage vibrations, confirming the presence of pectin polysaccharide structure. These results confirm successful extraction of pectin from fruit peel.

The presence of a Gaussian distribution trend confirms Nano scale particle formation and successful extraction of pectin as compared with standard pectin, which showed a narrow particle size distribution with a Gaussian distribution profile, indicating uniform particle size distribution and good dispersion stability. The intensity distribution peak was observed in the mid-size range, confirming homogeneous particle distribution without significant aggregation.

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