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Original Research

Utilization of Pomegranate Peel Pectin as a Functional Ingredient for Nutritive Jelly Formulation: A Step Toward Healthier Processed Food

Trishna Roy[1], Nilufa Yeasmin[1,*], Ayesha Begum[1,*], Md. Altaf Hossain[1,2], Mohammad Mozibul Haque[1], Kanij Fatema Nishan[1], Md. Zia Uddin Al Mamun[3], Anjum Mahfuza[4] and Sultana Jannat Pomy[1]

[1]Department of Applied Food Science and Nutrition, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University (CVASU), Khulshi, Chattogram-4225, Bangladesh
[2]Department of Food Science, University of Otago, Dunedin 9054, New Zealand
[3]Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh
[4]Department of Environmental Science, Kunming University of Science and Technology, Kunming, Yunnan, China

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***Correspondence:**
Ayesha Begum; Nilufa Yeasmin
Address: Department of Applied Food Science and Nutrition, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University, Khulshi, Chattogram-4225, Bangladesh.
Email: asha03du@gmail.com (AB); lily.fst2010@gmail.com (NY)

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ABSTRACT

Background: The growing prevalence of chronic diseases has increased interest in natural functional foods over synthetic alternative. Pomegranate peel pectin, a natural gelling agent with dietary fiber, bioactive substances that helps with better digestion, glycemic control and antioxidant defense. As a healthy substitute for commercial pectin, the current study aimed to extract pectin from pomegranate peel and assess its stability and functionality in jelly preparation. **Methods:** Pectin was extracted from pomegranate peel powder using citric acid. Fourier Transform Infrared (FT-IR) spectroscopy was used to investigate structural characteristics. Galacturonic acid, amidation, ash content, degree of methyl esterification, and water holding capacity of the extracted pectin were all measured. Pomegranate juice's proximate composition was ascertained. Both commercial and extracted pectin were used to make the jellies, sweetened with sugar or honey and tested for proximate composition, fiber content, antioxidant activity, sensory quality, and microbiological safety while being stored. **Results:** The extracted pectin yield was 8.2%, with a high methoxyl content, 1.15% ash, and 235.25% water-holding capacity. Pomegranate juice contained 85.3% moisture, 10.5%, total sugars, 0.15g citric acid, 0.9g ascorbic acid, and 0.03g ash. Jellies made with extracted pectin showed similar sensory and proximate property to those made with commercial pectin. Fiber content increased in jellies with extracted pectin, particularly with honey. Microbial investigation found sugar-added jelly safe for two months and honey-added for three months when refrigerated. **Conclusion:** This study shows pomegranate peel pectin, a health promoting organic substitute for commercial pectin, can be effectively used in jelly formulation.

Keywords: Pomegranate peel pectin; functional food; jelly formulation; antioxidant activity; dietary fiber; food preservation

1. INTRODUCTION

In recent years, the food market has witnessed a consistent emergence of new trend due to consumers' evolving tastes for healthier food options. The growing interest in natural alternative that ensures both products quality and functional health benefits rather than processed food has led to a focus on the use of functional ingredients that are safe and offer potential medicinal and nutritional benefits.[1,2]

Punica granatum L., which is part of the Punicaceae family, has been regarded as a type of functional fruit due to evidence of its health-promoting qualities from several studies, primarily ascribed to punicalagin and, to a lesser extent, other metabolites, like flavonols and anthocyanin.[3,4] Bioactive phytochemicals found in pomegranate fruit, flowers, bark and leaves have antimicrobial properties, lower blood pressure, and prevent major diseases like diabetes and cancer. These results validate the traditional use of the pomegranates as a medicine.[5] Despite it's phytochemical richness, approximately 30-40% of the fruit's weight is wasted as peel during juice preparation. This by-product contains an abundance of polyphenols, flavonoids, dietary fiber, and pectin, all associated with antioxidant, anti-inflammatory, and metabolic health benefits.[6]

According to Abid et al. (2017), the pomegranate peel is a major non-edible part that contains about 10% pectin, making it a promising and novel pectin source.[7] Pectin, a natural heteropolysaccharide utilized as a gelling agent, has drawn interest for both its technological applications and its therapeutic potential. Recent studies evidences its capacity to reduce cholesterol, regulate blood glucose, enhance gut health, and prevent cancer cell aggregation, establishing it as a highly valuable biofunctional food component.[8-10]

There have been multiple reports of functional food products containing compounds from pomegranate peel. Incorporating peel extracts into nutraceutical gummies and jellies have been found to increase antioxidant activity and polyphenol bioaccessibility,[11,12] while using pectin derived from the peel as a fat substitute in confectionaries has improved oxidative stability.[13] Pectin produced from citrus fruits has also demonstrated promising as a natural emulsifier in dairy systems and in bioactive films that can prolong the shelflife of food.[14,15]

There being an increasing interest in the use of fruit-by products for functional food production, there is limited study that specifically investigates pectin derived from pomegranate peel as the principle gelling ingredient in jelly formulation. This gap limits the implementation of pomegranate peel pectin in practical uses that could increase product texture and provide health advantages including antioxidant activity, dietary fiber enrichment, and metabolic regulation. Bridging this knowledge gap would enhance the development of healthier confectionary products and facilitate the sustainable utilization of fruit by-products while processing. Therefore, this study aims to investigate the potential of pomegranate peel pectin as a functional food ingredient by its extraction, characterization, and application in jelly formulation.

2. METHODS

2.1 Materials and Reagents

Fresh pomegranates (*Punica Granatum* L) were obtained from local markets in Chattogram, Bangladesh. All analytical grade reagents and chemical such as hydrochloric acid (HCl), sodium hydroxide (NaOH), ethanol, acetone, citric acid and phenol-sulfuric acid, 2,2-Diphenyl-1-picryl hydrazyl (DPPH), were acquired from Sigma-Aldrich Co. (St. Louis, Missouri, USA) for the extraction and characterization of pectin.

For jelly preparation, ingredients such as sugar, honey, and Commercial grade fruit pectin were procured from local grocery stores. All materials were handled with proper hygienic practices to ensure quality and safety throughout the study.

2.2 Sample Collection and Preparation of Pomegranate Peel Powder

Mature and good-quality pomegranate fruits were purchased from Chattogram City Corporation's community market. Collected fruits were washed and peeled manually. To deactivate the pectinase enzyme, pomegranate peels were immersed in a hot water bath (90°C) for two minutes. After being dried in an air cabinet drier (Bosch MKM 600, Germany) for 48 hours at 60℃ until achieving a consistent weight, the peels were ground into a powder and stored at 4℃ for the next step. Figure 1 depicts the entire experimental procedure employed in this study.

2.3 Extraction of Pectin from Pomegranate Peel Powder by Citric Acid Based Aqueous Extraction

A modified version of Sathish et al. (2018) method, pectin was extracted combining 10gm of sample with 150 mL of distilled water.[16] After that, the pH was reduced to approximately 3 using citric acid. After 25 minutes of boiling, the sample was filtered to remove peel. An equal amount of ethanol was added to the filtered extract, and it was then let to stand for an hour. The extracted pectin was separated by filtering, then precipitated with 96% ethanol and treated with 1ml of acetone. Following separation, the pectin was dried for 24 hours at 50°C before being kept at 4°C.

2.4 Physiochemical Analysis of Pectin Derived from Pomegranate Peel

To determine the effectiveness of the dried pectin extracted from pomegranate peel, a range of qualitative (Color, solubility in different solvent) and quantitative (Moisture, ash, water holding capacity, degree of esterification, amidation, galacturonic acid content, pH, and FT-IR analysis) tests were carried out.

2.4.1 Qualitative test of pomegranate peel pectin

The color was assessed visually. The solubility of dry pectin in different solvents was identified using the method provided by Aina et al. (2012).[17]

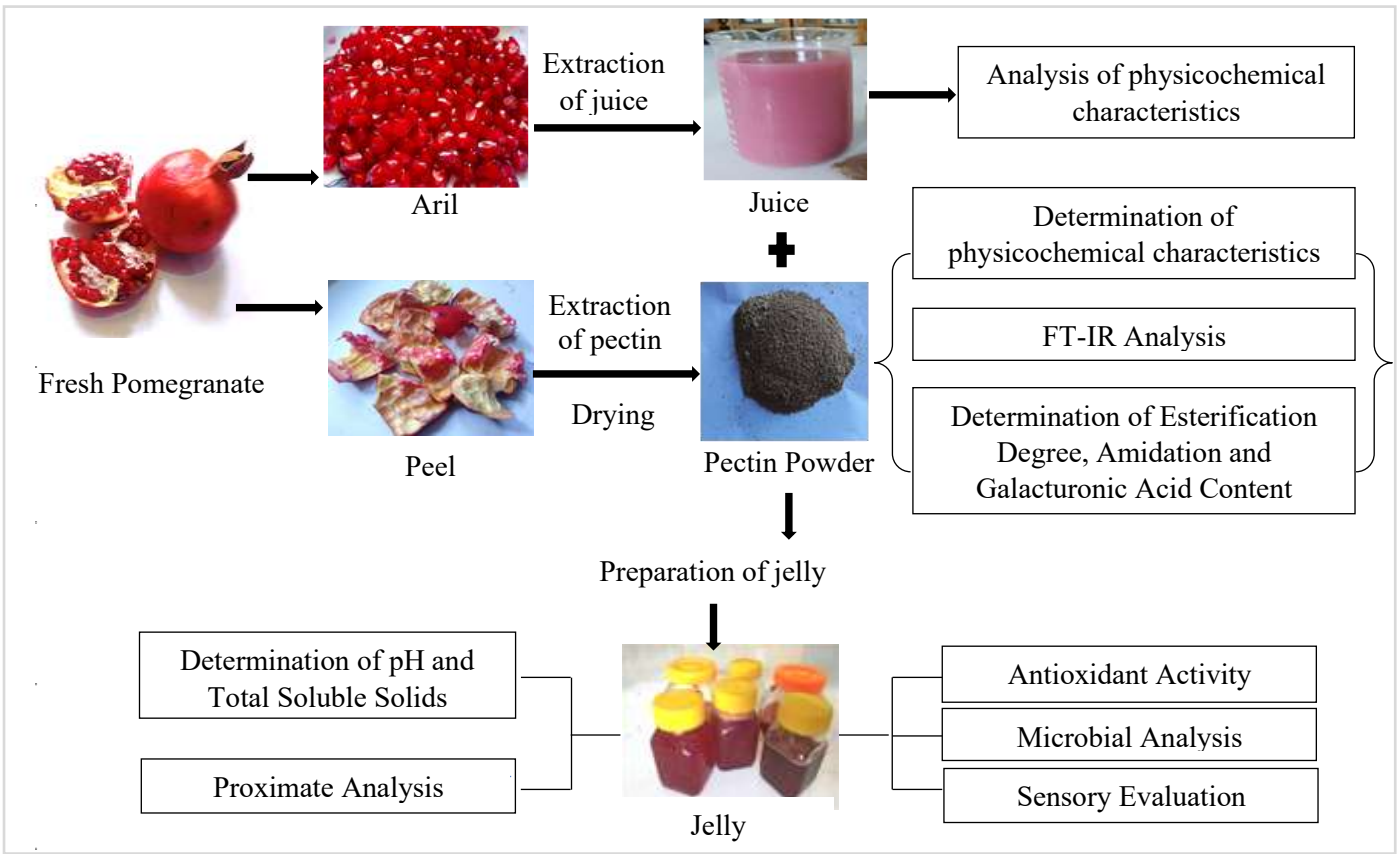

Figure 1. Schematic flow of overall experimental procedure

2.4.2 Quantitative analysis of pomegranate peel pectin

For the quantitative test, pH was measured with a pH meter (model: HI-98107, Hanna Instrument, Italy). Moisture percentage and ash content of dry pectin were determined following AOAC (2000) procedures.[18] Using the Joint Expert Committee on Food Additives of the FAO and WHO (2009) procedure, the amidation, esterification degree, and glucuronic acid level of pectin was determined.[19] The method provided by Zhang et al. (2017) was used to determine the liquid holding capacity (LHC) of pectin.[20]

2.4.3 Fourier-Transform Infrared (FT-IR) spectroscopic analysis

FT-IR analysis of pectin by potassium bromide (KBr) pellet method was conducted using a Jasco FT/IR430 spectrophotometer (Japan) to ascertain the presence of functional group. 2mg of pectin samples were mixed with 300mg of dry KBr crystal and crushed into pellets with a rotary vacuum pump. The KBr pellet was subsequently analyzed using FT-IR spectrophotometer within 400-4000cm-1 spectral range.[21]

2.5 Preparation of Jelly Using Pomegranate Fruit Juice and Extracted Peel Pectin

Uniformly ripe pomegranate fruits were picked, cut into two to four pieces, crushed in a grinder, and the resulting bulk was filtered through muslin cloth to collect and measure the juice for further analysis and jelly preparation. The juice's pH was measured using an HI-98107 pH meter (Hanna Instrument, Italy), and its moisture, ash, vitamin C, and titratable acidity were determined following the standard procedures of the Association of Official Analytical Chemists (2000).[18]

Jelly was prepared in four varieties using pomegranate juice, pectin extracted from pomegranate peel, sugar, and honey in different percentages and was designated as Jelly T1, T2, T3, and T4. Table 1displays the different treatment compositions of jelly. Pomegranate juice along with sugar or honey was simmered for 5 minutes over medium heat while being constantly stirred. Pectin and citric acid were then added to alter the pH level. While stirring, the heating was kept up. A refractometer reading of 65–67 °Brix TSS in the combination after 15 minutes indicated the endpoint. Subsequently, the jelly was transferred into a sterilized glass, appropriately labeled, and stored under freezing conditions for further experimental analysis.

Table 1. List of treatments

Treatment	Sample	Treatment combination
T_0	PJ_a (Control)	Pomegranate jelly made with 1g commercial Pectin
T_1	PJ_b	Sugar 40% + Pomegranate fruit juice 60% + 1g Extracted peel pectin
T_2	PJ_c	Honey 40% + Pomegranate fruit juice 60% + 1g Extracted peel pectin
T_3	PJ_d	Honey 50% + Pomegranate fruit juice 50% + 1g Extracted peel pectin
T_4	PJ_e	Sugar 50% + Pomegranate fruit juice 50% + 1g Extracted peel pectin

T= Treatment; PJ= Pomegranate peel pectin jelly

2.6 Physiochemical Analysis of Jelly

The prepared jelly's physical characteristics, including pH and total soluble solids, were measured. Total soluble solids were investigated with an Atego RX 1000 digital refractometer and pH was determined with a pH meter (model: HI-98107, Hanna Instrument, Italy). The Association of Official Analytical Chemists (2000) recommended technique was used to do moisture, crude fibre, ash, fat, protein, carbohydrate analysis on the jelly.[18]

2.7 Antioxidant Activity of Jelly by DPPH Scavenging Assay

With slight modifications, Azlim et al.'s (2010) DPPH test was implemented to measure antioxidant capability.[22] 1gm of sample was placed in the Felcon tube for extract preparation. Following this, 10 mL of 100% methanol was added and the resultant mixture was let to sit for 72 hours. Continuous straining was done out every 4 hours. Filtration was followed by the collection of the methanolic extract. The DPPH solution was made by dissolving 6 mg of DPPH in 100 mL of methanol. For the assay, 1 mL of each extract was combined with 2 mL of the methanolic DPPH solution, and the mixture was left to incubate for 30 minutes in the dark. At 517 nm, absorbance was taken three times with a UV-VIS spectrophotometer (UV-2600, Shimadzu Corporation, USA). Methanol by itself was utilized as the blank, while a combination of 1 mL methanol and 2 mL DPPH solution was utilized as the control. Trolox served as the standard of reference. Milligrams of Trolox equivalent per gram of extract (mg TE/g) was used to express the antioxidant capacity, which reflected the sample's power to scavenge DPPH free radicals.

The following formula was used to determine the free radical scavenging capacity of DPPH activity:

$$\% \text{ inhibition} = \frac{(\text{Abs.1} - \text{Abs.2})}{\text{Abs.1}} \times 100$$

Where, Abs.1 = Absorbance of control and Abs.2 = Absorbance of sample.

2.8 Microbiological Analysis of Jelly

Microbial quality was determined via monitoring fungal growth, fecal coliform (Escherichia coli). Fungal contamination was investigated using the standard plate count method on Sabouraud Dextrose Agar (SDA) and cultured at 25-30 C for upto six weeks, where yeasts appeared creamy and mold as multicolored filaments.[23,24] Fecal coliforms were detected using mFC agar supplemented with rosolic acid. Blue colonies after 24 hours incubation at 44.5 °C indicated presumptive E. coli. For confirmation, presumptive colonies were

subcultured on MacConkey agar, incubated at 37 ± 0.5 °C, and then inspected under long-wave UV light, where fluorescence indicated the presence of E. coli, with UV lamp accuracy verified beforehand to ensure reliable detection.[25]

2.9 Sensory Evaluation

The developed pomegranate peel-pectin jelly's acceptance among consumers was evaluated by a group of ten panelists. The panelists were chosen at random from among students, faculty, and staff from the Applied Food Science and Nutrition department of Chattogram Veterinary and Animal Sciences University (CVASU). On a 1-to-9-point hedonic scale, panelists were asked to score the distinctiveness of the five formulations of jelly's appearance, color, smell, taste, sweetness, texture, and overall acceptability. The scale is set up as follows: 9 = Like Extremely, 8 = Like very much, 7 = Moderately liked, 6 = Like highly, 5 = Neither like nor dislike, 4 = Slightly dislike, 3 = Dislike moderately, 2 = Very much dislike, and 1 = Dislike extremely. The panelists were provided with water to rinse their mouths between tastings.

2.10 Statistical Analysis

Data were compiled using Microsoft Excel 2013 and analyzed using IBM SPSS Statistics version 25. Descriptive statistics were calculated for the sensory attributes and proximate composition. One-way analysis of variance (ANOVA) was performed to assess significant differences in proximate composition, phytochemical content, antioxidant capacity, and sensory evaluation among the samples. Statistical significance was determined at the 95% confidence level ($p < 0.05$). Results are expressed as mean ± standard deviation based on three independent replicates.

2.11 Ethical Practices

This study utilized panelists from the Department of Applied Food Science and Nutrition of CVASU. Before sensory evaluation, expert assessment confirmed the jelly's safety and non-hazardous production. The sensory evaluation was performed with all participants informed about the nature of the study. Every participant was made aware of the purpose of the study before the sensory evaluation was conducted. The panel was not compensated for their voluntary participation. Participants gave their verbal consent, and their anonymity and confidentiality were strictly maintained.

3. RESULTS AND DISCUSSION

3.1 Pectin Yield of Pomegranate Peel

As a control, we utilized apple pectin powder from Triveni Interchem Pvt. Ltd. Pomegranate peel (PP) pectin yields were found to be 8.2%. The pectin yields of the peels analyzed in this study were higher than those reported in the literature, which ranged from 3.62 to 4.48%; from 11.46 to 22.09% for citrus peels (lemon, mandarin, orange and grapefruit); from 2.8% and 8.8% for banana and mango peels; from 1.99 and 2.86% for quince.[26-28] It highlights the potential of pomegranate peel as an excellent natural source of pectin possess extra health advantages beyond its functional purpose.

3.2 Physiochemical Analysis of Pectin Extracted from Pomegranate Peel

3.2.1 Qualitative parameters of pomegranate peel pectin

The pectin extracted from pomegranate peel was grayish to light brown. Table 2 displays its solubility in different solvents. Pectin dissolved in NaOH (1M) more readily than it did in acetone and methanol. A study on lemon, grapefruit and orange peel pectin solubility resulted in the formation of yellow-colored solutions under cold alkaline conditions (20°C, 0.1 N NaOH), whereas milky solutions were formed in hot alkaline conditions (85–95 °C, 0.1 N NaOH).[17]

Table 2. Solubility of pomegranate peel pectin in different solvents

Solvent	Solubility
NaOH	Soluble
Methanol	Not soluble
Acetone	Not soluble
Hot water	Soluble
Cold water	Not soluble

3.2.2 Quantitative parameters of pomegranate peel pectin

The quantitative parameters of physiochemical analysis of pectin derived from pomegranate peel identified numerous significant factors that reflects its purity and functional characteristics. The pH of the extracted pectin was recorded at 4.2, indicating a somewhat acidic characteristic. Figure 2a delineates the moisture content, ash content, esterification degree (DE), amidation, and galacturonic acid (GA) content. The ash content measured 1.15%, signifying a minimal presence of inorganic contaminants, which is advantageous for

high quality pectin. Because, the purity of the pectin increases as the ash content decreases.[29]

The degree of esterification (DE) was measured to be 57.74, classifying the isolated pectin as a high methoxyl pectin which is consistent with findings in previous studies.[26,30] Pomegranate pectin's amidation level was 3.75%, and galacturonic acid (GA) content was 78.48%. The results showed that extracted pectin had larger quantities of GA than gold kiwifruit pectin (28.96% to 58.57%) when they were compared to those of prior studies, but pomegranate peel derived pectin had higher amidation degrees than orange and lemon peel pectin (2.20% and 1.44%, respectively).[26,30] Pectin with high GA offers several health benefits. Galacturonic acid is a constituent of dietary fiber, linked to improve digestive health, including increased gut motility and reduced risk of constipation.[29] Pomegranate peel's galacturonic acid exhibit immunomodulatory properties that may assist in infection prevention and bolster the immune system.[31] Liquid holding capacity was evaluated and illustrated in Figure 2b. It was found that the extracted pectin was better at retaining water and dimethyl sulfoxide (DMSO) than acetic acid and acetone. A polymer with a higher ability to retain fluid can facilitate the production of low-calorie foods by enhancing volume without substantially increasing calorie content. Additionally, it directly impacts the food's texture and viscosity. As a result, the pomegranate peel pectin's capability to hold liquid is essential for food production from a technological and medicinal standpoint.[29,32]

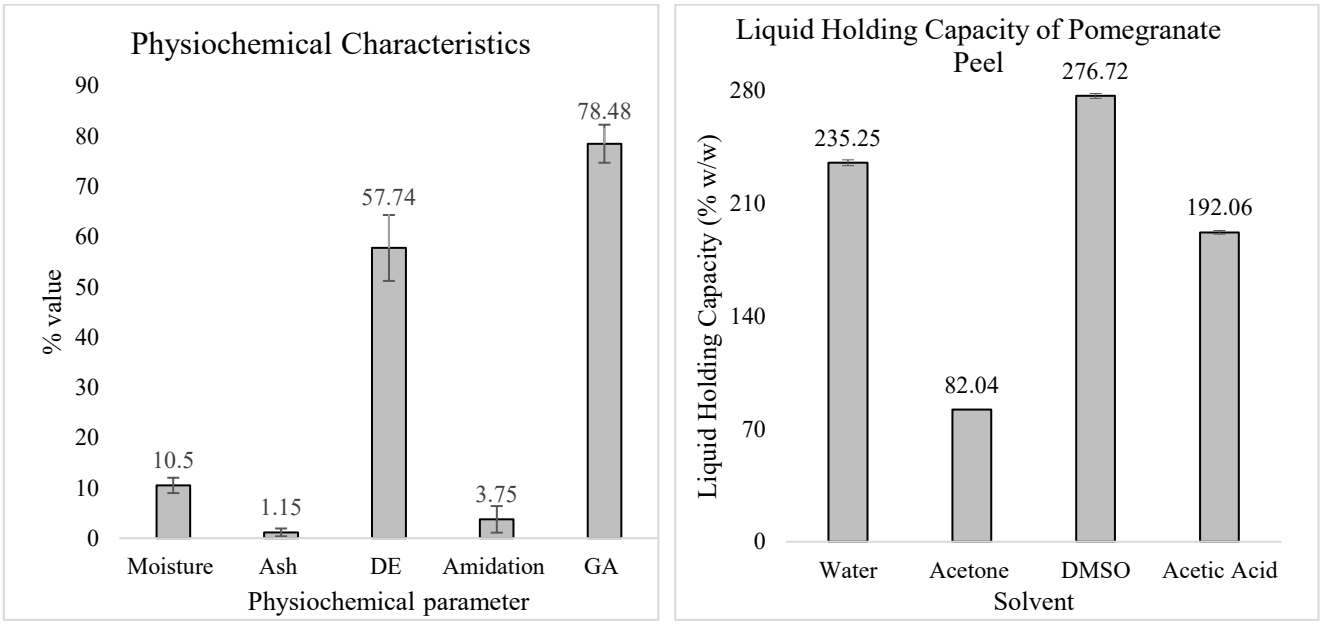

Figure 2. Physiochemical characteristics (a) and **l**iquid holding capacity (b) of pectin derived from pomegranate (*Punica granatum* L.) peel

The FT-IR spectral analysis of the extracted pectin, as shown in **Figure 3**, revealed several characteristic absorption bands. A broad band between 3500-3300 cm-1 corresponds to non-associated hydroxyl (-OH) group. The absorbance near 2926 cm-1 is attributed to -CH, -CH2, and -CH3 stretching vibrations from galacturonic acid methyl esters. A distinct peak at 1740 cm-1 indicates C=O stretch, likely originating from esterified acetyl (COCH3) groups. The peak observed at 1630 cm-1 is linked to the -OH tensile vibration band, while those at 1320 cm-1 and 1445 cm-1 suggest the presence of -CH3 groups. Finally, the peak near 1026 cm-1 is associated with C-O stretching or bending vibrations. The structural characteristics observed in the FTIR spectrum, specifically methyl/acetyl esterification and a resilient polysaccharide structure demonstrate the possible physiological and nutritional advantages of this pectin.

3.3 Physiochemical Properties of Pomegranate Juice

Pomegranate juice's pH was 3.2. The pH range of 3.1-3.3 is ideal for gel sets. Typically, gel formation is poor when the pH is above 3.5, while the gel is hard when the pH is below 3. According to the findings, fresh juice contains 85.3% moisture, 10.5% sugars (mostly fructose and glucose), 0.15g of total acidity (citric acid), 0.7mg of ascorbic acid, and 0.03g of ash per 100 mL. The chemical composition of pomegranate juice showed in Table 3 exhibit similarities to those reported in previous research by Sreekumar et al. (2014).[33]

Table 3. Chemical composition of pomegranate juice

Parameters	Value*
pH	3.2±0.05
Moisture (%)	85.3±0.16
Total sugar (%)	10.5±0.02
Total acidity(g/100ml)	0.15±0.35
Ascorbic acid (mg/100ml)	0.9±0.03
Ash(g/100ml)	0.03±0.01

*Data expressed as mean ± standard deviation.

3.4 Physiochemical Analysis of Pomegranate Jelly

The pH, Acidity, and TSS of the five jelly samples found in this study are shown in Table 4. The table indicates a statistically significant difference in pH values among the samples, with readings from 2.81±0.01 to 3.02±0.01, which fall within the typical range for jellies. TSS values for pomegranate jelly in this study ranged from 0.62±0.01 to 0.67±0.02, which is roughly comparable to the values for dragon fruit jelly discovered by Islam et al. (2012).[34]

The proximate makeup of the jelly samples is shown in Table 5. The table shows that, in contrast to the jellies created using extracted pectin, the control sample has a higher moisture content. The relatively low moisture content observed in samples b and e might be due to sugar, as sugar reduces the moisture content, which inhibits the growth of food-spoiling microbes. Samples PJ_c and PJ_d exhibit higher moisture content compared Samples PJ_b and PJ_e due to the presence of honey, which acts as a hydrophilic agent in low humid condition. The sample will therefore have a longer shelf life than the sample containing honey when stored under the same conditions due to its lower moisture content.[35] Fiber, ash, protein, and fat content do not have any significant differences from control PJ_a, indicating that extracted pectin possess a quality comparable to commercial pectin, as pectin does not alter this composition. Samples PJ_b and PJ_e have higher carbohydrate content than samples PJ_c and PJ_d, as these have been prepared with sugar

Table 4. Physical parameters of jelly

Sample	pH	Acidity	TSS
PJ_a	$2.93±0.02^b$	$0.64±0.01^b$	$0.62±0.01^c$
PJ_b	$3.02±0.01^a$	$1.03±0.01^a$	$0.67±0.02^a$
PJ_c	$3.00±0.02^a$	$1.00±0.02^a$	$0.66±0.06^a$
PJ_d	$2.81±0.01^c$	$0.60±0.01^{bc}$	$0.65±0.04^b$
PJ_e	$2.9±0.05^b$	$0.63±0.03^b$	$0.61±0.01^c$
p-value	0.01	0.02	0.01

Values are presented as mean ± SD. Within the same column, means sharing identical superscripts do not differ significantly ($P < 0.05$). Where, PJ_a: Pomegranate jelly made with commercial pectin (control), PJ_b: 40% Sugar + 60% Pomegranate fruit juice + Extracted pectin, PJ_c: 40% Honey + 60% Pomegranate fruit juice + Extracted pectin, PJ_d: 50% Honey + 50% Pomegranate fruit juice + Extracted pectin, PJ_e: 50% Sugar + 50% Pomegranate fruit juice + Extracted pectin

3.5 Antioxidant Activity of Pomegranate Jelly

Antioxidant capacity of the prepared jelly is demonstrated in Figure 4, indicates that there were no significant differences between the control and other samples in terms of antioxidant capacity, which means that extracted pectin has increased antioxidant activity. The substantial antioxidant capacity of pomegranate jelly is due to its high concentration of polyphenols and flavonoids which provide protection against disorders associated to oxidative stress, including cardiovascular diseases, diabetes, and cancer.[36,37] These findings highlight the functional dietary potential of pomegranate jellies; nevertheless, further real-time studies are required to confirm their bioavailability and long term health impacts.

Table 5. Chemical composition of pomegranate jelly (expressed as percentage, %)

Parameters	PJ_a	PJ_b	PJ_c	PJ_d	PJ_e
Moisture	$36.76 ±0.01^a$	$30.70±0.01^c$	$33.82± 0.01^b$	$34.75±0.01^b$	$31.07±0.01^c$
Crude Fibre	$1.30±0.04^b$	$1.59±0.03^a$	$1.80±0.06^a$	$1.92±0.02^a$	$1.93± 0.01^a$
Ash	$0.81±0.03^a$	$1.61±0.02^a$	$1.30±0.01^a$	$1.37±0.03^a$	$0.71±0.06^a$
Fat	$0.92±0.02^a$	$1.20±0.09^a$	$1.58±0.06^a$	$1.79±0.02^a$	$1.35±0.03^a$
Protein	$1.58±0.03^a$	$1.50±0.05^a$	$1.98±0.02^a$	$1.87±0.01^a$	$1.40±0.06^a$
Carbohydrate	$58.63±0.06^b$	$64.32±0.04^a$	$59.52±0.03^b$	$58.3±0.01^b$	$63.54±0.02^a$

Values are presented as mean ± SD. Within the same column, means sharing identical superscripts do not differ significantly ($p < 0.05$). Where, PJ_a: Pomegranate jelly made with commercial pectin (control), PJ_b: 40% Sugar + 60% Pomegranate fruit juice + Extracted pectin, PJ_c: 40% Honey + 60% Pomegranate fruit juice + Extracted pectin, PJ_d: 50% Honey + 50% Pomegranate fruit juice + Extracted pectin, PJ_e: 50% Sugar + 50% Pomegranate fruit juice + Extracted pectin

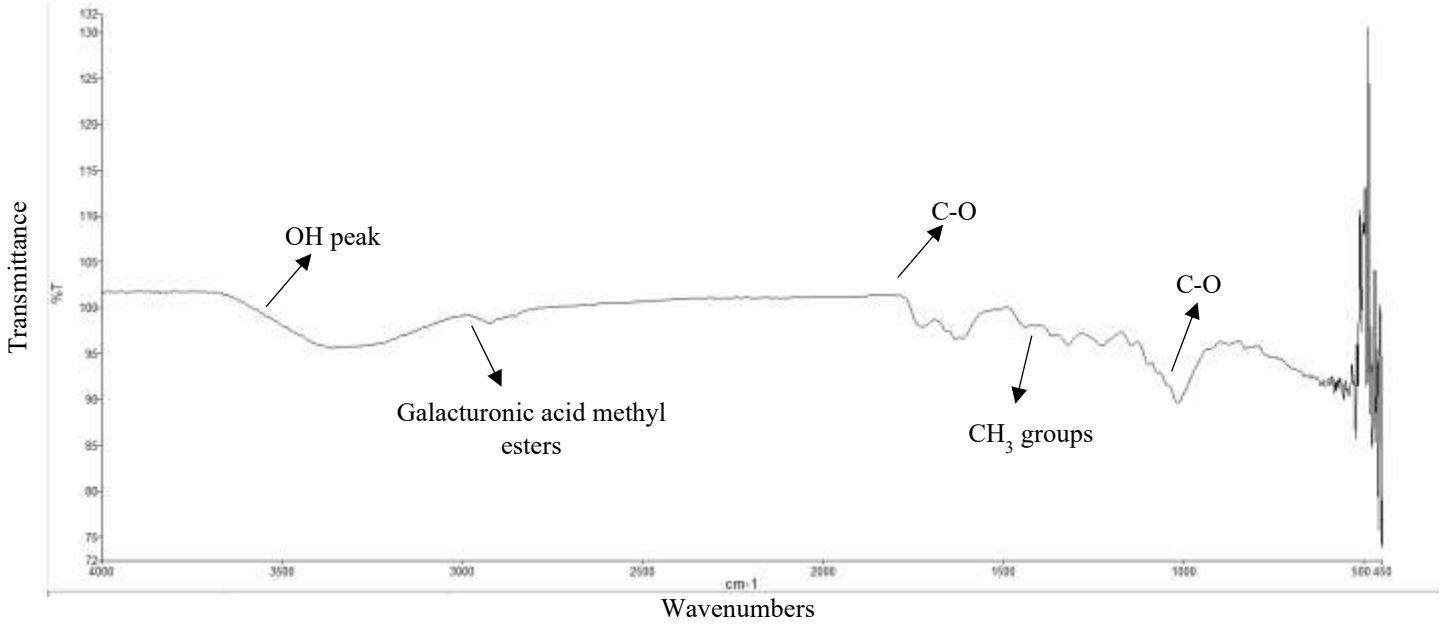

Figure 3. FT-IR spectrum of pectin obtained from dried pomegranate peel; Wavenumber (cm^{-1}) is ranged from 450 to 4000 cm^{-1} (x axis); %T is the percentage of transmittance (y axis)

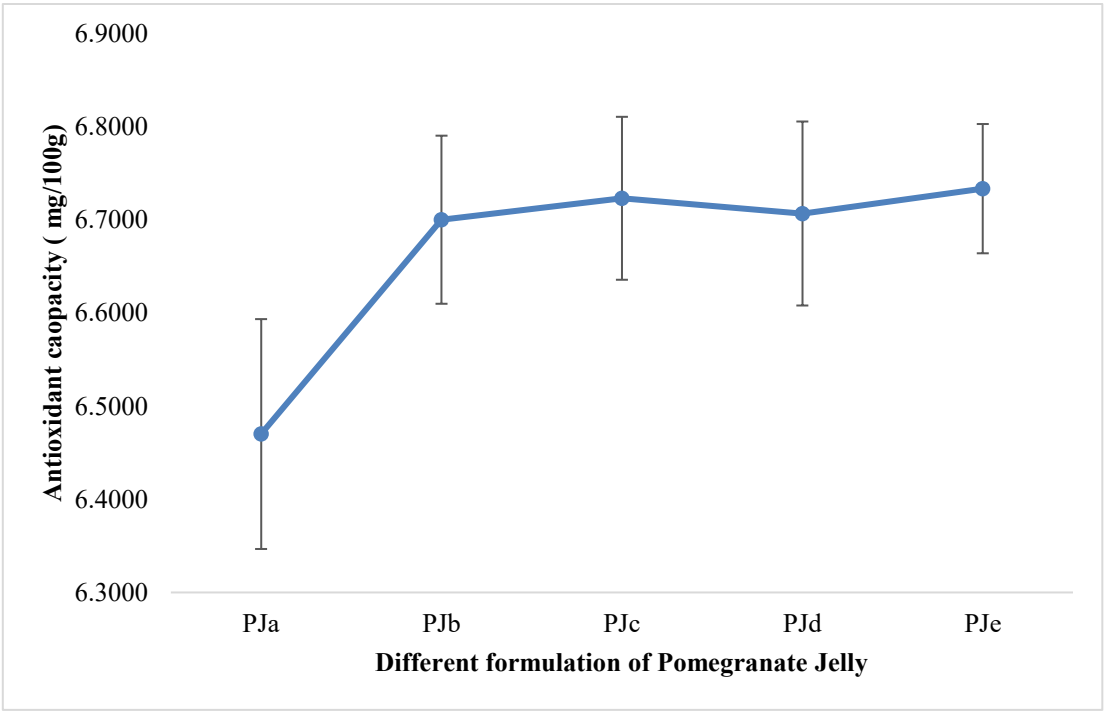

Figure 4. Antioxidant activity of pomegranate jelly

3.6 Microbial Analysis of Pomegranate Jelly

Up to 90 days of storage at 5°C, there was no growth of *E. coli* in the jelly sample. According to Pramanick et al. (2021), the complete absence of total coliform count, total fungal count, *E. coli*, *Streptococcus* spp., *Vibrio* spp. in jelly was an indication of better and safer quality jelly production.[38] Yeast and mold were not found in the jelly up to 30 days of storage time. After that period, yeast and mold were grown gradually according to Table 6.

At 5°C storage conditions, the yeast and mold count of jelly was zero till 30 days. But it was increased slightly from 0.2×103 cfu/g to 2×103 cfu/g after 30 days. From previous study on wood apple jelly stored at ambient temperature conducted by Kumar and Deen (2017) showed 3×103 cfu/g microbial counts.[39] Gaikwad (2016) also found similar results for sapota and beetroot

blended jelly, where the microbial count was 2×103 cfu/g.[35] In the present findings, the microbial count of sample PJ_b and PJ_e had exceeded this limit means that after 60 days, the jelly could lose its acceptable organoleptic property. Despite having higher moisture content than the control samples, honey-added jelly (Samples PJ_c and PJ_d) had a progressive decrease in microbial growth, suggesting that honey was inhibitory to the growth of microorganisms.

Table 6. Microbial count of jelly at 5°C up to 90 90-day storage period

Storage days	Yeast and mold (cfu/gm)				
	PJ_a	PJ_b	PJ_c	PJ_d	PJ_e
0	Not found	Not found	Not found	Not found	Not found
30	Not found	Not found	Not found	Not found	Not found
60	$1±0.12×10^{3a}$	$0.9±0.11×10^{3c}$	$0.4±0.26×10^{3b}$	$0.2±0.23×10^{3b}$	$1±0.27×10^{3a}$
90	$2±0.17×10^{3a}$	$2±0.14×10^{3a}$	$1±0.54×10^{3c}$	$1±0.56×10^{3c}$	$1.9±0.43×10^{3b}$

PJ_a: Pomegranate jelly made with commercial pectin (control), PJ_b: 40% Sugar + 60% Pomegranate fruit juice + Extracted pectin, PJ_c: 40% Honey + 60% Pomegranate fruit juice + Extracted pectin, PJ_d: 50% Honey + 50% Pomegranate fruit juice + Extracted pectin, PJ_e: 50% Sugar + 50% Pomegranate fruit juice + Extracted pectin

3.7 Sensory Evaluation

According to sensory analysis, it was interpreted that with an overall acceptance score of 5.5±0.02, the jelly made with additional sugar (sample PJ_e) had the highest score of any formulation (Figure 5). This positive rating is probably the result of its pleasing flavor, taste, color, texture, and appearance. Interestingly, sample PJ_e performed similarly to the control (PJ_a). As illustrated in Figure 5, the honey-based samples PJ_c and PJ_d, on the other hand, obtained the lowest sensory scores, with ratings of 4.8±0.01 and 4.5±0.03, respectively.

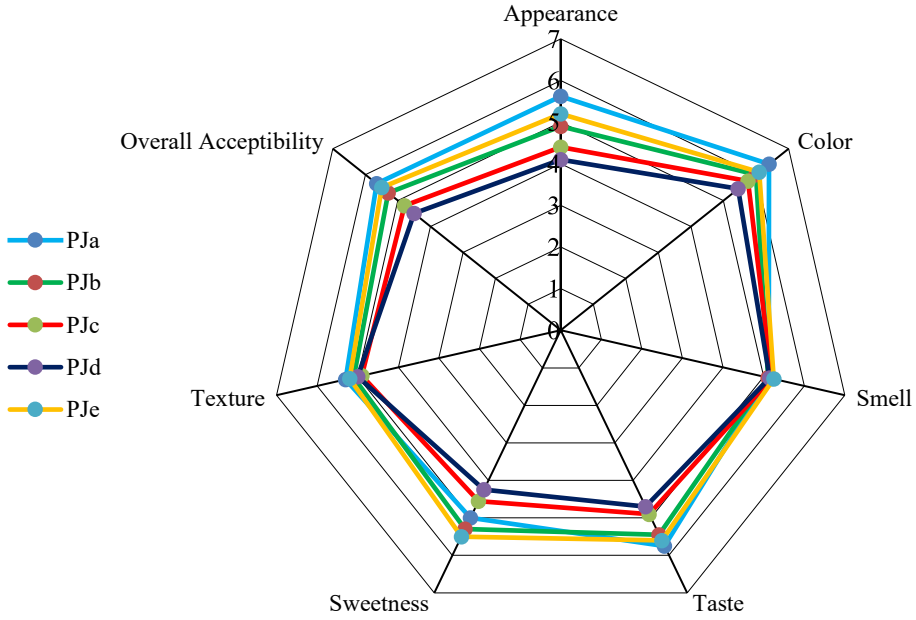

Figure 5. Radar chart of sensory properties. Values are means of 10 panelists. Where, PJ_a: Pomegranate jelly made with commercial pectin (control), PJ_b: 40% Sugar + 60% Pomegranate fruit juice + Extracted pectin, PJ_c: 40% Honey + 60% Pomegranate fruit juice + Extracted pectin, PJ_d: 50% Honey + 50% Pomegranate fruit juice + Extracted pectin, PJ_e: 50% Sugar + 50% Pomegranate fruit juice + Extracted pectin

One possible explanation for the jelly's deeper hue and slightly acidic flavor is the honey content, which was different from that of the control sample (PJ_a). Furthermore, the jelly's flavor and taste were significantly shaped by the combination of pectin and citric acid. Increasing the volumes of gelatin and citric acid improve the texture and consistency of the jelly, as reported by Basu and Shivhare (2010).[40]

The study provides valuable insights into the physiochemical characteristics of pomegranate peel pectin to be used as a gelling agent in jelly formation. In comparison to the commercial pectin (control), the

extracted pectin formulated jelly showed enhanced nutritional composition, increased antioxidant activity, and favorable textural qualities. The findings suggest that pomegranate peel pectin can successfully substitute synthetic gelling agents while providing additional functional health benefits. However, certain limitations in this study must be acknowledged. The study was conducted at a laboratory setting, but specific clinical evidence is scarced, requiring further research to confirm the bioavailability, efficacy and potential health benefits of pomegranate peel pectin jelly in dietary applications. The sensory evaluation conducted in this study relied on a limited panel, which might not properly represent consumer diversity. Furthermore, for generating more robust proof for the incorporation of pomegranate peel pectin in functional foods and expand its utilization in food sector, future study should focus on investigating the bioavailability of functional compounds in human model.

4. CONCLUSION

Pomegranate peel pectin is a natural ingredient that has the potential to be a promising alternative to synthetic pectin in the production of jellies that provide additional nutritional benefits. From this study, it is evident that the pectin extracted from pomegranate peel exhibited jelly-forming properties similar to that of commercial pectin. It boosts the jelly's health promoting value by adding fiber and bioactive substances in addition to its gelling properties. The property of sugar-added pomegranate peel pectin jelly to remain consumable for up to three months at 5C confirmed its viability for both industrial and consumer use. Future studies should concentrate on sugar-reduces or sugar-free formulations, assessment of the bioavailability of bioactive compounds, and optimization for large-scale extraction. Determining its antioxidant, probiotic, and diseases preventing properties might enhance the role of pomegranate peel pectin as a sustainable by-product and a functional food component that promotes human health.

Ethical Approval

The sensory evaluation procedures of this study were conducted in accordance with the ethical guidelines of the Department of Applied Food Science and Nutrition, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University (CVASU). Ethical approval was granted under Ref. No. CVASU/Head/AFSN-01/2012/1276(1). All participants provided informed consent prior to participation and were informed of their right to withdraw at any time without consequence.

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Competing Interests

All the authors declare that there are no conflicts of interest.

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Underlying Data

Derived data supporting the findings of this study are available from the corresponding author on request.

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