Valorization of dragon fruit (*Hylocereus polyrhizus*) peel: comparative extraction ofbetacyanin and high-methoxyl pectin using conventional and emerging technologies

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Abstract

Dragon fruit peel represents a valuable functional biomass rich in natural pigments and gelling agents, yet it remains largely discarded despite its significant phytochemical potential. Addressing this gap is essential for promoting sustainable resource utilization and reducing agro-waste. In this study, betacyanin and pectin were extracted using multiple techniques to compare their efficiency and the quality of recovered compounds. Methanol extraction yielded a higher betacyanin content and superior retention of bioactive compounds compared to ethanol, with notable levels of DPPH activity (88.37 ± 0.001 %), ABTS activity (0.29 ± 0.02 TEAC), total phenolics (0.253 ± 0.02 mg GAE/g extract), flavonoids (0.38 ± 0.01 mg QE/g extract), alkaloids (5.33 ± 0.03 mg/g extract), and terpenoids (2.451 ± 0.02 mg/g extract). Betacyanin stability was strongly influenced by temperature and storage conditions. For pectin extraction, ultrasonic treatment produced the highest yield (7.50 %) and a methoxy content of 11.8% (w/w) at 70°C for 30 minutes, outperforming solvent and microwave methods. Key extraction parameters including time, temperature, solvent concentration, pH, and microwave power substantially affected pectin yield and quality. The findings underscore the potential of fully matured dragon fruit peel as a sustainable source of natural colorants and pectin, a bio-polymer for functional food applications, highlighting the broader importance of valorizing fruit-processing waste for eco-friendly product development and circular bioeconomy initiatives.

Keywords: Dragon fruit, extraction, betacyanin, pectin, microwave, ultrasound

1. Introduction

Dragon fruit (*Hylocereus polyrhizus)* has gained substantial commercial importance in recent years owing to its attractive sensory qualities, nutritional value, and adaptability to diverse climatic conditions. As a member of the Cactaceae family, the crop thrives in tropical and subtropical regions and is available primarily in two cultivated varieties: red dragon fruit (*H. polyrhizus*) and white dragon fruit (*H. undatus*) [1] Globally, dragon fruit production is expanding rapidly, with Vietnam contributing over 1.3 million tons annually from approximately 50,000-60,000 hectares, followed by Thailand, Malaysia, and Indonesia. In India, the fruit has received significant attention as a high-value horticultural crop, and in Mizoram the cultivation area has increased notably in the last decade. According to the Department of Horticulture, Mizoram [2], the state produces roughly 1,320 metric tons from 3,569 hectares, indicating its growing potential as a sustainable livelihood crop in the region.

Despite these developments, research focusing specifically on the characteristics and valorization potential of dragon fruit cultivated in Mizoram is still limited. This knowledge gap is significant considering that nearly 35-38% of the fruit mainly its peel is discarded during processing and consumption, contributing to agricultural waste and resource underutilization [3]. The peel, however, is a rich repository of high-value biomolecules such as betacyanins and pectin, which have been identified as promising candidates for food, nutraceutical, and pharmaceutical applications. Betacyanins, responsible for the intense red coloration of H. *polyrhizus*, are water-soluble pigments with demonstrated antioxidant, anti-inflammatory, and potential anticancer properties. Their natural origin and high coloring capacity make them appealing alternatives to synthetic dyes, particularly as consumer demand for clean-label and chemical-free products continues to grow.

In addition to pigments, dragon fruit peel contains considerable amounts of pectin, a structurally complex plant polysaccharide widely used in food manufacturing due to its gelling, stabilizing, thickening, and emulsifying properties [4]. The functionality and industrial suitability of pectin are largely dictated by its degree of esterification (DE) and methoxyl content, which determine whether it is classified as high-methoxyl or low-methoxyl pectin [5]. Variations in DE influence gelation mechanisms, sugar and acid requirements, and thermal stability, thereby affecting its application potential in products such as jams, jellies, dairy formulations, confectioneries, and low-calorie food systems. Understanding these structural and functional attributes is therefore essential to determining the broader utility of pectin extracted from locally available dragon fruit peel.

Beyond its biochemical value, valorizing dragon fruit peel aligns with current global movements toward sustainable food processing, circular bioeconomy, and waste minimization. Converting fruit peel from a waste material into a source of natural colorants and functional hydrocolloids can enhance economic returns for farmers and processors, support environmentally responsible production, and provide industries with affordable natural alternatives to synthetic additives. However, the efficiency of extracting these compounds and their stability under different processing and storage conditions vary significantly depending on extraction methods, solvent systems, temperature, and pH. Comparative studies are therefore essential to optimize recovery, maximize quality, and ensure applicability in real food systems.

Considering the rapid rise of dragon fruit cultivation in Mizoram and the lack of comprehensive research on the valorization of its peel, there is a pressing need to investigate the extraction, characterization, and stability of its key bioactive constituents. The present study addresses this gap by examining the extraction of betacyanin and pectin from red dragon fruit peel, comparing extraction techniques, and evaluating how processing and storage parameters influence pigment stability and pectin quality. Through this investigation, the study aims to strengthen scientific understanding of dragon fruit peel as a functional bioresource and promote sustainable utilization of locally available agrowaste for value-added food applications.

2. Materials and methods

2.1 Sample Collection and preparation for betacyanin extraction

Dragon fruit (*Hylocereus polyrhizus*) specimens were procured from local markets in Aizawl, Mizoram, where the crop is predominantly cultivated. The fruits were manually peeled, and the collected peels were washed, air-dried, and subsequently ground into a fine powder. The powdered peel was stored in airtight containers at ambient temperature until further analysis.

2.2 Extraction of betacyanin

Betacyanin was extracted from dragon fruit peel powder following the solvent extraction method described by [6]. Methanol and ethanol were separately used as extraction solvents to compare extraction efficiency. The absorbance of each extract was measured at 538 nm using a UV-VIS spectrophotometer, and total betacyanin content was calculated using the following equation:

$$\text{Betacyanin (mg/100g)} = \frac{\text{A x MW x V x df x 1000}}{E\ x\ L\ x\ W}\ X100$$

Where A=absorbance, MW = molecular weight (550 g/mol), V = volume extract, df = dilution factor, E (mean molar absorptivity) = 6.5×10^4 L/mol.cm in water, L (path length) =

1 cm and W = fresh weight of extracting material.

2.3 Stability and degradation kinetics of betacyanin

Aliquots (5 mL) of each extract were stored at room temperature, and absorbance at 538 nm was measured hourly for 5 h to evaluate pigment stability [7]. Thermal degradation kinetics was estimated using the Arrhenius model [8].

$$k = Ae^{(-E/RT)}$$

Where, R = gas constant (1.987 cal/ K mol), A= Frequency factor, e= base of the natural logarithm, k= Degradation rate constant, T= Absolute temperature (K), E= Activation energy

2.4 Proximate analysis of dragon fruit peel

Moisture, ash, fat, and protein contents were determined according to standard procedures described by [9]. Carbohydrate content was calculated by difference using the method of [10].

Carbohydrate (%) = 100 − (moisture + ash + protein + fat).

2.5 Determination of antioxidant properties

Total phenolic content (TPC) was determined by the Folin–Ciocalteu method [12]. Total flavonoid content (TFC) was measured using the aluminium chloride colorimetric assay. Antioxidant activity was assessed by DPPH radical scavenging assay and ABTS assay according to established procedures [13]. Alkaloid and terpenoid contents were quantified using standard phytochemical methods.

2.6 Extraction of pectin

2.6.1 Ultrasound-assisted extraction (UAE)

One gram of peel powder was mixed with 30 mL of 0.5 M hydrochloric acid adjusted to pH 2 and subjected to ultrasonic treatment at 60-75 °C for 15-45 min. After extraction, samples were centrifuged at 1500 rpm for 20 min, and the supernatant was dried at 60 °C to constant weight [14].

2.6.2 Microwave-assisted extraction (MAE)

One gram of peel powder was mixed with 30 mL of 0.5 M hydrochloric acid (pH 2) and exposed to microwave irradiation at 300 or 600 W for 1–3 min. The extracted mixtures were centrifuged at 1500 rpm for 20 min to recover the pectin-containing supernatant [15].

2.6.3 Conventional acid extraction

One gram of peel powder was mixed with 30 mL of 0.5 M hydrochloric acid (pH 2) at a solid-to-liquid ratio of 1:30 (g/mL) and heated at 80 °C for 45 min under continuous acid hydrolysis conditions.

2.7 Determination of pectin yield

The pectin yield of the dragon fruit peel was determined by using the following equation.

Pectin yield (%) = (A/B) X 100

Where,

A = amount of pectin recovered and B = initial weight of peel powder

2.8 Physicochemical characterization of extracted pectin

Equivalent weight

Equivalent weight was determined according to [16] by titration with 0.1 N NaOH and calculated using:

$$\text{Equivalent weight} = \frac{\text{weight of sample (g)x 1000}}{\text{ml of alkali x Normality of alkali}}$$

2.9 Methoxyl content

Methoxyl content was determined by adding 25 mL of 0.25 N NaOH to the previously neutralized solution, followed by thorough mixing and a 30 min resting period at room temperature in a sealed flask. Subsequently, 25 mL of 0.25 N HCl was added, and the mixture was titrated again to the original pink endpoint. The methoxyl content was then calculated using the appropriate formula.

$$\text{Methoxyl content (\%)} = \frac{\text{meq of NaOH x 31 x 100}}{\text{weight of the sample (mg)}}$$

where, 31 is the molecular weight of the methoxyl group.

2.10 Anhydrouronic acid (AUA)

The Anhydrouronic acid (AUA) content was calculated using the corresponding values of equivalent weight and methoxyl content, based on the established formula.

$$\text{\% AUA} = \frac{\text{176 x 100}}{\text{z}}$$

Where, 176 is the molecular weight of AUA and $z = \frac{weight\ of\ the\ sample\ (mg)}{meq\ of\ alkali\ of\ free\ acid + meq\ of\ alkali\ for\ methoxyl}$

2.11 Degree of esterification

The degree of esterification (DE) of pectin was determined by using the formula given below.

$$\text{DE (\%)} = \frac{\text{176 x Methoxyl contentx 100}}{\text{31 x AUA}}$$

2.12 Gel strength and slump strength analysis

Gel strength was evaluated using a modified IFT Committee (1959) method [17]. Briefly, 0.4 g pectin was mixed with 13 g sucrose and diluted to 20 mL with distilled water. The mixture was heated to dissolve, cooled, and allowed to set at room temperature. Slump strength was

assessed by inverting the gel onto a glass plate and measuring gel deformation after 2 min. Instrumental gel firmness was determined using a Texture Analyzer (Stable Microsystems TA-XT2), and slump strength was calculated as [18]Slump strength (%) = $\frac{(A-B)}{A}\ X\ 100$

Statistical analysis:

All analyses were performed in triplicate. Data were processed using SPSS (Version 30.0.0.0), and mean comparisons were conducted using one-way ANOVA. Statistical significance was accepted at $p \leq 0.05$.

3. Results and Discussion

3.1 Betacyanin Extraction Efficiency

Methanol extraction resulted in a higher yield percentage compared to ethanol. The betacyanin yields obtained using methanol and ethanol, respectively, were 53.33 mg/L and 46.88 mg/L, based on triplicate analyses. This may be attributed to the slightly higher polarity, lower viscosity, and smaller molecular size of methanol, which enhance solvent penetration and mass transfer, thereby improving betacyanin solubility from the peel matrix. Therefore, methanol was identified as the more efficient solvent and was selected as the optimal solvent for subsequent analyses.

3.2 Retention and stability of betacyanin

Based on the results presented in Fig. 3, extraction from fresh dragon fruit peel yielded higher efficiency compared to dried peel. However, the extract obtained from dried peel exhibited greater stability, consistent with findings reported in previous studies [6].

3.3 Degradation rate analysis

The rate of degradation was found to be generally comparable between the two extracts, as shown in Table 1. The observed degradation is attributed to thermal treatment, which accelerates the breakdown of betalain pigments the primary contributors to the red coloration of the extract [8]. Using the Arrhenius model, with a reference rate constant ($k_{(}$reference$_{)}$) of 1.01 × 10^{-4} and activation energy (E_a) of 56.12 kJ/mol, the calculated k values at temperatures ranging from 70-90 °C were between 2.01 × 10^{-5} and 1.70 × 10^{-5}. These values align closely with those reported in existing literature. Despite similar degradation patterns, the fresh peel extract exhibited comparatively higher betacyanin content than the dried peel extract.

Table 1: Kinetics of degradation (Arrhenius equation)

Degradation rate constant	**Ethanol extract ($^{-}$ ^{s})**	**Methanol extract ($^{-s}$)**
k_{ref}	1.05 x 10^{-4}	1.05 x 10^{-4}

k_1	2.01×10^{-5}	2.51×10^{-5}
k_2	1.89×10^{-5}	2.09×10^{-5}
k_2	1.70×10^{-5}	1.85×10^{-5}

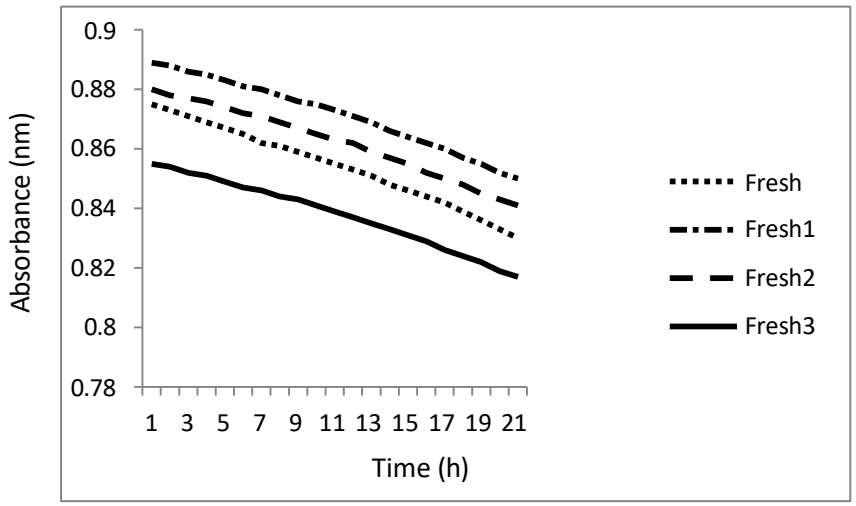

Figure 1: Graph showing the stability of betacyanin extracted from fresh peel

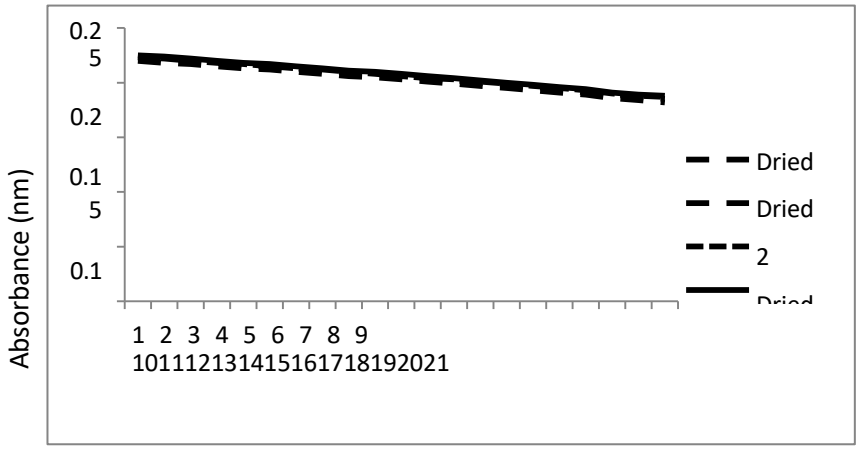

Figure 2: Graph showing the stability of betacyanin extracted from dried peel

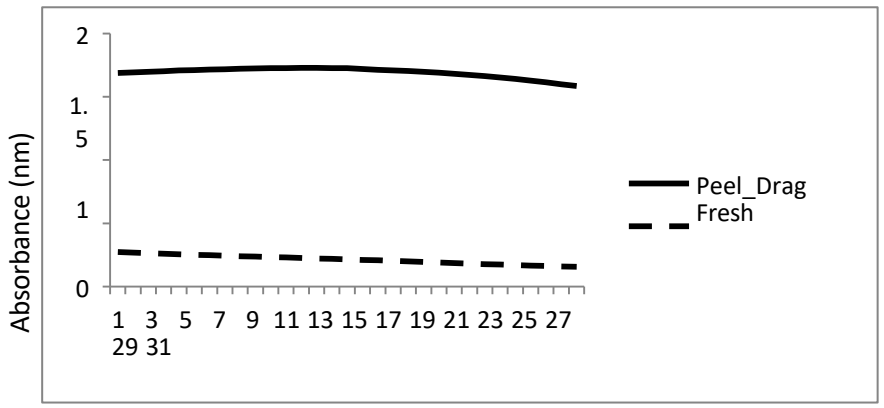

Figure 3: Graph showing the degradation rate of the betacyanin extracted

3.4 Proximate analysis of physico-chemical properties

The physicochemical properties of dragon fruit peel were evaluated on both wet and dry bases. The peel showed high moisture content, consistent with the succulent nature of Hylocereus fruit, and in agreement with reported values of 88-90% depending on cultivar and maturity. Protein and fat contents were low, typical of fruit by-products, with minimal lipid levels favoring pectin extraction by avoiding interference during alcohol precipitation. Ash content was low in fresh peel but increased on a dry basis, reflecting mineral concentration, and fell within previously reported ranges of 8-14% [19]. Carbohydrates constituted the majority of dry matter, highlighting the polysaccharide-rich composition of the peel, predominantly cellulose, hemicellulose, and pectic substances, and its potential for pectin recovery [20]. The results are shown in Table 3.

Table 2: Stability of extract within 5 hours

Duration (Hours)	Methanol extract (mg/L)	Ethanol extract (mg/L)
1	0.575	0.186
2	0.473	0.185
3	0.456	0.184
4	0.435	0.181
5	0.418	0.178

Table 3: Proximate analysis table of extracted pectin

Parameters	Wet Basis (%)	Dry Basis (%)
Moisture content	88.88 ± 0.56	---
Protein	0.408 ± 0.33	3.70 ± 0.48
Fat	0.066 ± 0.05	0.60 ± 0.45
Ash	1.12 ± 0.14	10.08 ± 0.50
Carbohydrates	9.53 ± 0.35	85.62 ± 0.51

3.5 Antioxidant Activities and Phytochemical Constituents of Dragon Fruit Peel Extracts

Methanol extraction resulted in a higher yield percentage and more efficient extraction of antioxidant-related parameters such as DPPH activity, ABTS activity, total phenolic content (TPC), total flavonoid content (TFC), alkaloids, and terpenoids compared to ethanol extraction. This is consistent with previous findings demonstrating that methanol is generally more

effective than ethanol for recovering phenolics, flavonoids, and other antioxidant constituents due to its higher polarity and stronger solubilizing capacity [21]. The quantified values obtained from the methanol extract are presented in Table 4.

Table 4: Antioxidant and phytochemical parameters of dragon fruit peel extracts

Parameters	Result
DPPH (%)	88.37 ± 0.001
ABTS (TEAC)	0.29 ±0.02
TPC (mg GAE)	0.253±0.02
TFC (mg QE/g)	0.38±0.01
Alkaloid (mg/g)	5.33±0.03
Terpenoid (mg/g)	2.451±0.02

3.6 Ultrasound-Assisted Extraction (UAE)

Ultrasound-assisted extraction (UAE) was used to recover high-methoxy pectin from the peel under varying extraction times (15, 30, 45 min) and temperatures (60 °C, 70 °C). The highest yield occurred at 30 mins and 70 °C, indicating that moderate sonication combined with elevated temperature enhances cavitational disruption of cell walls and improves pectin solubilization. Longer extraction (45 min) did not increase yield, likely due to partial degradation of pectic polymers under extended ultrasonic and thermal exposure, a trend consistent with previous UAE studies [22]. These findings support earlier reports that optimal UAE conditions must balance efficient tissue disruption with minimal polymer breakdown. The findings are shown in table 5.

Table 5: Extraction of pectin using ultrasonic-assisted extraction

Runs	Extraction time (min)	Extraction temperature (°C)	Solid – liquid ratio (g/mL)	Yield percentage (%)
1	15 min	60°C	1:30 g/mL	6.61%
2	15 min	60°C	1:30 g/mL	6.44%
3	15 min	70°C	1:30 g/mL	6.93%
4	15 min	70°C	1:30 g/mL	6.50%
5	30 min	60°C	1:30 g/mL	6.50%
6	30 min	60°C	1:30 g/mL	6.30%
7	30 min	70°C	1:30 g/mL	7.70%
8	30 min	70°C	1:30 g/mL	7.31%

9	45 min	60°C	1:30 g/mL	5.74%
10	45 min	60°C	1:30 g/mL	5.31%
11	45 min	70°C	1:30 g/mL	6.53%
12	45 min	70°C	1:30 g/mL	6.40%

3.7 Microwave-Assisted Extraction (MAE)

Microwave-assisted extraction of pectin from dragon fruit peel varied with changes in extraction time and microwave power. The highest yield (6.81%) was obtained at 2 minutes and 300 W, as shown in table 6, indicating that moderate power with an optimal extraction duration favors efficient pectin release. Shorter extraction (1 min) likely resulted in insufficient disruption of plant cell walls, consistent with reports that limited microwave exposure restricts solvent penetration and pectin solubilization [23]. Conversely, prolonged exposure (3 min) may have caused thermal degradation or depolymerization of pectin, a phenomenon widely observed when extraction times exceed the optimal window [22]. Extraction at higher power (600 W) also produced lower yields, in line with studies noting that excessive microwave intensity leads to rapid overheating, structural breakdown of protopectin, and reduced pectin recovery [17; 24]. Overall, controlled heating at 300 W for 2 minutes proved most effective, aligning with previous findings that moderate microwave power combined with short extraction times maximizes pectin yield while preserving its structural integrity.

Table 6: Extraction of pectin using Microwave-Assisted extraction

Runs	Extraction time (min)	Microwave power (W)	Solid – liquid ratio (g/mL)	Yield percentage (%)
1	1 min	300 W	1:30 g/mL	4.41
2	1 min	300 W	1:30 g/mL	3.80
3	1 min	600 W	1:30 g/mL	5.90
4	1 min	600 W	1:30 g/mL	5.24
5	2 min	300 W	1:30 g/mL	6.81
6	2 min	300 W	1:30 g/mL	3.17
7	2 min	600 W	1:30 g/mL	5.14
8	2 min	600 W	1:30 g/mL	4.70
9	3 min	300 W	1:30 g/mL	5.23
10	3 min	300 W	1:30 g/mL	6.22
11	3 min	600 W	1:30 g/mL	5.00

12	3 min	600 W	1:30 g/mL	4.20	

3.8 Solvent based extraction

Solvent-based extraction using methanol and ethanol under constant temperature and time revealed that methanol produced a higher pectin yield from dragon fruit peel. This is likely due to its higher polarity, which enhances protopectin solubilization and cell wall disruption. Similar findings have been reported for pectin extraction from various fruit peels, where methanol-based systems consistently yield more pectin than ethanol [25]. The results are shown in table 7.

Table 7: Extraction of pectin using solvent extraction

Sl. No	Runs	Factor1 Extraction time (min)	Factor2 Extraction temperature (°C)	Solid - liquid ratio (g/mL)	Precipitating agent	Response 1 Yield percentage (%)
1	1	60min	80	1: 30	Ethanol	6.45%
2	2	60min	80	1: 30	Ethanol	3.95%
3	3	60min	80	1: 30	Ethanol	4.14%
4	4	60min	80	1: 30	Methanol	5.57%
5	5	60min	80	1: 30	Methanol	7.12%
6	6	60min	80	1: 30	Methanol	4.76%

Fig 4: Ultrasound Extracted Pectin

Fig 5: Microwave Extracted Pectin

Fig 6: Solvent Extracted Pectin

3.9 Equivalent weight, methoxyl content, anhydrouronic acid (AUA) and degree of esterification

The physicochemical properties of pectin extracted from dragon fruit peel were compared with commercial pectin (Bake King). The extracted pectin showed an equivalent weight of 1250.63 ± 0.18 g/mol, slightly higher than the commercial sample (1236.00 ± 19.80 g/mol), indicating a

stable pectic structure with fewer free acid groups, consistent with previous observations on fruit-derived pectins [26]. The methoxyl content of the extracted pectin (2.52 ± 0.18 %) was lower than that of commercial pectin (3.55 ± 0.08 %), yet similar to values reported for red dragon fruit peel pectin [27]. The anhydrouronic acid (AUA) content was notably higher in the extracted pectin (5.15 ± 1.00 %) compared to the commercial sample (1.19 ± 0.73 %), reflecting greater polysaccharide purity and aligning with findings from recent studies on dragon fruit and other fruit by-products [28]. Both samples exhibited high degrees of esterification (DE), with 83.45 ± 0.21 % for the extracted pectin and 84.36 ± 0.14 % for the commercial sample, classifying them as high-methoxy pectins. This suggests similar gelling behavior under acidic and high-sugar conditions, as typically observed in HM pectins used in jams, jellies, and confectionery applications [29].

3.10 Gel strength of extracted pectin

The gelation capacity of dragon fruit peel pectin was evaluated using a slump test and compared with commercial pectin (Bake King) purchased from local market. The extracted pectin exhibited significantly higher slump strength (84.34%) than the commercial sample (52.65%), indicating superior gel-forming ability. This enhanced performance is closely associated with its high degree of esterification (83.45 %), since high-methoxy (HM) pectin with DE > 70% typically develop stronger gels due to hydrophobic interactions and hydrogen bonding within the polymer network [30]. Classical pectin studies further report that HM pectin requires low pH (2.8–3.5) and high sugar concentrations (55-65 %) to form stable gels [31]. Comparable findings have been reported for high-DE pectins extracted from citrus, passion fruit, and other fruit by-products, which demonstrate gel strengths equal to or greater than commercial pectin sources [32]. The strong gelling response of the extracted pectin therefore suggests its suitability for applications requiring firm gel structures, such as jams, jellies, and confectionery products [33].

4. Conclusion

The present study demonstrates that red dragon fruit (*Hylocereus polyrhizus*) peel grown in Mizoram possesses strong potential as a valuable source of bioactive compounds, particularly betacyanin and high-methoxy pectin. Although extensive research exists globally, studies focusing on dragon fruit cultivated in Mizoram remain limited despite its high production within the state. The findings confirm that the quality and characteristics of both betacyanin and pectin extracted from local peel samples align with previously reported values from other tropical regions.

Methanol extraction yielded higher concentrations of volatile and phenolic constituents

compared to ethanol, indicating its superior efficiency for recovering bioactive compounds. Betacyanin exhibited good stability under refrigerated storage but degraded significantly upon heat exposure, highlighting the need for temperature-controlled processing. The pectin extracted from the peel showed superior functional properties relative to commercial pectin particularly in methoxyl content, gel strength, and associated bioactive components attributes that support its classification as high-quality high-methoxy bio polymer based pectin. Overall, the study confirms that dragon fruit peel is an underutilized agro-waste with substantial potential for valorization in the food sector.

Declaration

The authors declare that this manuscript contains all original work that has not been published anywhere before.

Conflicts of Interest

The authors declare no conflicts of interest.

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List of equations:

Equation No	Equation
1.	% Betacyanin = $\frac{\text{A x MW x V x df x 1000}}{E\ x\ L\ x\ W} X100$
2.	$k = Ae_{RT}^{-E}$
3.	Carbohydrate (%db) = 100% - (moisture content + ash content + protein content + fat content)
4.	Pectin yield (%) = (A/B) X 100
5.	Equivalent weight= $\frac{weight\ of\ sample(g)X\ 1000}{ml\ of\ alkali+Normality\ of\ alkali}$
6.	MeO%= $\frac{meq\ of\ Sodium\ Hydroxide\ X\ 31X\ 100}{ml\ of\ alkali+Normality\ of\ alkali(mg)}$
7.	AUA %= $\frac{176X\ 100}{Z}$
8.	Z= $\frac{weight\ of\ sample(g)X\ 1000}{ml\ of\ alkali\ of\ free\ acid+ml\ of\ alkali\ for\ Methoxyl}$
9.	%DE = $\frac{176\ X\ MeO\%\ X\ 100}{31\ X\ AUA\%}$
10.	Slump strength (%) = $\frac{A-B}{A}\ X\ 100$

Appendices:

List of abbreviations:

Sl. No	Abbreviation	Full form
1	MT	Metric Tonnes
2	DE	Degree of Esterification
3	HMP	High Methoxyl Pectin
4	LMP	Low Methoxyl Pectin
5	hrs	Hours
6	nm	nanometer
7	AOAC	Association of Official Agricultural Chemist
8	Hz	Hertz
9	µm	Micrometer
10	W	Watt
11	TPC	Total Phenolic content
12	FC	Follin-Ciocalteu
13	TFC	Total Flavanoid Content
14	mL	Milliliter
15	ABTS	2,2’ Azino-bis(3

		ethylbenzothiazoline-6 sulfonic acid
16	UAE	Ultrasound Assisted Extraction
17	M	Molarity
18	HCl	Hydrochloric acid
19	N	Normality
20	NaOH	Sodium Hydroxide
21	AUA	Anhydrounic acid
22	MeO	Methoxyl
23	ANOVA	Analysis of Variance
24	MAE	Microwave Assisted Extraction