GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(RESEARCH ARTICLE)

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Physicochemical characterization, and carbohydrate composition of pectin from sweet potato (*Ipomoea batatas*) and Irish potato (*Solanum tuberosum*) peels

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GSC Advanced Research and Reviews, 2026, 28(01), 130–143

Publication history: Received on 29 May 2026; revised on 07 July 2026; accepted on 10 July 2026

Article DOI: https://doi.org/10.30574/gscarr.2026.28.1.0162

Abstract

Introduction: Pectin is a naturally occurring polysaccharide widely used in the food and pharmaceutical industries because of its excellent gelling, stabilizing, and thickening properties. Commercial pectin is primarily obtained from citrus peels and apple pomace, however, the search for alternative, low-cost, and sustainable sources has increased due to the abundance of agricultural wastes. Therefore, this study evaluated the extraction, physicochemical characteristics, and carbohydrate composition of pectin isolated from sweet potato (*Ipomoea batatas*) and Irish potato (*Solanum tuberosum*) peels.

Methods: Pectin was extracted from dried sweet potato and Irish potato peels using hydrochloric acid under acidic condition. The extracts were evaluated for percentage yield, equivalent weight, moisture, ash, crude protein, and carbohydrate composition using standard analytical procedures and high-performance liquid chromatography (HPLC).

Results: Sweet potato peel produced a higher pectin yield (13.75%) than Irish potato peel (9.86%). The equivalent weight ranged from 3,333.33 to 5,000.00 mg/mol. Moisture, ash, and crude protein contents ranged from 12.79-13.24%, 3.47-4.13%, and 6.79-9.27%, respectively. Carbohydrate analysis showed glucose contents of 151.51–323.44 mg/g, sucrose 196.38-215.51 mg/g, fructose 118.84-137.96 mg/g, and maltose 95.99-114.08 mg/g. Raffinose (183.72 mg/g) was detected only in sweet potato pectin. Therefore, sweet potato pectin exhibited superior extraction yield, while both pectin extracts possessed acceptable physicochemical characteristics and distinct carbohydrate values that may influence their functional properties.

Conclusion: Sweet potato and Irish potato peels are promising alternative sources of pectin with acceptable physicochemical and carbohydrate composition. Their utilization for pectin production provides a sustainable approach to agricultural waste valorization, environmental protection, and the development of locally sourced pectin for food and pharmaceutical applications.

Keywords: Acid extraction; Agricultural waste; Carbohydrate composition; Irish potato peel; Pectin; Sweet potato peel

1. Introduction

Pectin functions as a structural heteropolysaccharide within the cell walls and middle lamella of dicotyledonous plants, where it is essential for maintaining both firmness and pliability (Jarvis, 1984; Han et al., 2024). This polymer typically constitutes between 2% and 35% of the dry weight of plant cell walls and is instrumental in upholding cellular stability (Han et al., 2024). From a chemical standpoint, its primary structure is a chain of D-galacturonic acid residues, although this linear backbone is periodically disrupted by the insertion of rhamnose sugars via (1,2)-glycosidic linkages (Nascimento et al., 2018).

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The properties and uses of pectins are majorly influenced by their structures depending on their sources (i.e plant species and tissues) and also on extraction methods adopted (Belkheiri *et al.,* 2021). Presently, pectins have wide application in industries such as cosmetic, pharmaceutical, and foods, used as binding and gelling agents (Williams, 2011). Successfully, pectins have been used for many years as a thickening agent, and also as a colloidal stabilizer in the food industry (Kavitha *et al.*, 2016). Pectins as Natural polymers are used in the formulation of tablets in the pharmaceutical industry and other related sector because of its affordability, accessibility, and nontoxic nature, with their potential to be biodegradable and biocompatible with the host (Belkheiri *et al.*, 2021; Owusu *et al.,* 2023). Among the statistics of the foods wasted annually, almost 50% are from fruits and vegetables. Commercial pectin is mainly produced from the byproducts of citrus peels and apple (Han *et al.*, 2024). However, the extraction of pectin from industrial waste byproducts, also represents a potential source of this compound. The efficient utilization of food waste contributes greatly to the optimal protection of environments and provides a valuable source of functional compounds, including bioactive secondary metabolites, essential oils, pigments, enzymes, and non-starch polysaccharides (Picot-Allain *et al.,* 2020). Among these food wastes, sweet and irish (*Solanum tuberosum*) potato peels are a major by-product produced during potato processing. These wastes contain abundant nutrition elements, bioactive compounds, and other high value-added substances, generally, the reutilization of potato peels hold significance in improving their added value (Rodriguez-Martinez *et al.*, 2021). Potato peels as residues are byproducts of potato processing, and it has high pectin content, which makes it a potential alternative raw material for the production of commercial pectin (Han *et al.*, 2024). Potato residue contains about 20.63–31.48 % dietary fiber, 4.1 % protein, and 0.4 % lipids on a dry weight basis, along with almost 15 % pectin (Abang Zaidel *et al.*, 2015). The potato is the fourth largest food crop in the world aside rice, wheat and maize, and is forms another important part of human diets (Gaudino *et al.,* 2020). world potato production was estimated to be about 388 million tons in 2017 (Gaudino *et al.,* 2020). Currently, the potato-processing industry generates large amounts of waste, mainly peel, fried products, screen solids, as well as wastewater (Rodriguez-Martinez *et al.,* 2021). The potato peel by-product can represent up to about 10% of the total potato waste (Rodriguez-Martinez *et al.,* 2021). Peeling during potato processing produces a substantial quantity of peel as a by-product, which is usually utilized as livestock feeds on local farms. Meanwhile, the large volume of peel generated poses considerable threat for its proper disposal which seems almost impossible (Pathak *et al.,* 2018). Potato peels are a valuable source of various bioactive compounds, including phenolic compounds, glycoalkaloids, polysaccharides, proteins, and vitamins. (Rodriguez-Martinez *et al.,* 2021). Pectin from potato waste contains an appreciable amount of rhamnogalacturonan I (RG-I), a hairy region of pectin (Rodriguez-Martinez *et al.*, 2021). Pectin extraction is greatly influenced by mass transfer into the process medium which makes the yield and quality of the recovered pectin impou factor for assessing the suitability of the extraction method. (Picot-Allain *et al.,* 2020). Pectin exists in plant cell walls as an insoluble protopectin. Its extraction involves the hydrolysis of protopectin using hot, dilute mineral acids to convert it into soluble pectin (Belkheiri et al., 2021). The extraction technique employed plays a crucial role in determining the compositional, structural, and functional characteristics of the recovered pectin (Owusu et al., 2023). Among the available methods, acid extraction is the most widely applied because it effectively solubilizes pectin by hydrolyzing the polysaccharide structure, initially targeting the side chains of the rhamnogalacturonan-I (RG-I) regions before affecting the homogalacturonan (HG) backbone (Abang *et al.,* 2020). The choice of extraction method has a significant influence on both the yield and physicochemical properties of pectin (Han *et al.,* 2024). Acidic media facilitate pectin release by breaking down the complex cross-linking structures within the plant cell wall, whereas salt-based extraction promotes pectin solubilization by chelating calcium (Ca^{2+}) and other metal ions that stabilize the pectin network (Han *et al*., 2024). Previous studies have reported considerable variations in the extraction yield of sweet potato pectin, ranging from 1.028% to 74.43%, with galacturonic acid contents between 32.3% and 77.4% (Abang *et al.*, 2015; Abang Zaidel et al., 2020). Similarly, pectin extracted from potato peels has been reported to produce yields of 7.15–14.87%, galacturonic acid contents of 14.45–36.37%, and degrees of esterification ranging from 15.35% to 41.82% across different extraction conditions (Owusu et al., 2025). Despite these findings, comprehensive information regarding the extraction and structural characteristics of sweet potato pectin remains limited (Han *et al.,* 2024). Consequently, agricultural residues such as sweet potato processing waste have attracted increasing attention as sustainable raw materials for pectin production (Han *et al.,* 2024). Therefore, this study evaluated the extraction efficiency and carbohydrate composition of pectin isolated from sweet potato (Ipomoea batatas) and Irish potato (Solanum tuberosum) peels using different extraction methods. this study focuses on extracting and characterizing pectin from sweet potato and Irish potato peels and evaluating their potential as alternative sources of commercial pectin

2. Materials and methods

2.1. Sample Collection

The sweet potatoes (*Ipomoea batatas*) and Irish potatoes (*Solanum tuberosum*) used in this work were obtained from Ikoko Market, Owo, Ondo State, Nigeria. The tubers were thoroughly washed to remove dirt and peeled about 1 mm from the tubers. The peels were removed, thoroughly washed, and cut into pieces

2.2. Sample Preparation

The peels of both samples (A and B) were air-dried for 30 days. The dried crispy potato peels were separately comminuted with the aid of a blender into powder forms and stored separately in a well labeled airtight container. The resultant dried materials were passed through a sieve For easier extraction.

2.3. Materials

Hydrochloric acid (HCl), sodium hydroxide (NaOH), ethanol (98%), phenol red indicator, boric acid (H_3BO_3), concentrated sulphuric acid (H_2SO_4), Kjeldahl catalyst tablets, mixed indicator, and other analytical-grade reagents used in this study were obtained from the Chemistry Laboratory, Rufus Giwa Polytechnic, Owo, Nigeria. Distilled water was used throughout the experimental procedures. The equipment used included an analytical weighing balance, laboratory blender, hot plate with temperature control, pH meter, drying oven, muffle furnace, desiccator, sieve shaker, conical flasks, beakers, burettes, pipettes, measuring cylinders, Kjeldahl digestion and distillation apparatus, and a High-Performance Liquid Chromatography (HPLC) system equipped with a refractive index detector for carbohydrate analysis. All glassware were thoroughly cleaned and rinsed with distilled water before use.

2.4. Acidic Extraction of Pectin

200 g of each of the pulverised sweet potato and Irish potato peels were separately poured inside 1000 ml of 1.0 M hydrochloric acid and heated at 90°C for 1 hour at pH 1.5. the wet sweet potato residue was weighed and the mixture was cooled and subsequently filtered through a seive (Owusu *et al.*, 2025; Han *et al*., 2024).

2.5. Determination of Percentage Yield

The weight of the powdered peel (W1) was determined. The weight of the dried, extracted pectin (W2) was also determined using a weighing balance. The percentage yield was calculated

$$\text{Percentage yield}(\%) = (W2 / W1) \times 100$$

Where:
-W1 = Weight of dried powdered potato peels used for extraction (g)
-W2 = Weight of dried pectin obtained after extraction and drying (g)

2.6. Determination of Equivalent Weight

1 g of each of the pectin samples (A and B) was weighed into two separate clean 250 mL conical flask that contained 5 mL of ethanol (98%). 3g of sodium hydroxude was added and few drops of red phenol and it was made up to 100ml The resulting mixture was titrated against 0.1 N NaOH till the color changed to purple. The neutralized solution was stored to determine methoxyl content (Ranganna, 1995). Equivalent weight was determined using Equation below (Owusu et al., 2025):

Equivalent weight = (Weight of pectin sample (1g) × 1000 mg) / (Volume of Alkaline (3mL) × Molarity of acid 0.1M)

2.7. Moisture content determination

Two clean and dry crucibles were weighed and their weight were recorded (W1), each sample was added into the empty crucibles and their weight were also recorded as (W2). The crucibles containing the samples were transferred into the oven at 105°C and were dried for four hours. The crusibles were transferred into desiccator and was cooled for one hour and they were reweighed again (W3). The percentage moisture content was calculated The moisture content was determined by using drying method which is based on weight loss (Remi *et al*., 2022).

2.8. Ash content determination

Two clean crucibles were weighed and the weight was recorded (W1). 2g of each sample was weighed into the crucible (W2) and was transferred into the muffle furnace and the muffle furnace was ignited at 600 C for four hours until a grayish white substance was obtained. The crucibles were transferred into a desiccator and was cooled and was reweighed again (W3) (Remi *et al*., 2022).

2.9. Determination of protein contents

2g of each sample was weighed into two different 250ml kjedahl flask, and 12.5ml of concentrated H2SO4 was added to each flask with one kjedahl catalyst tablet. The flask was heated on a heater with a low heat for about 15minutes, and

increase to medium heat for about 30minutes and finally at high heat until digested. The flask was rotated at intervals until the digest is clear, and the heating continue for few minutes after that to ascertain completed digestion. The flask was allowed to cool and the sample residue was washed and filtered, to make the digest up to 50ml (V1). After the digestion was completed, 5ml of 2% boric acid (H3BO3) was placed into 100ml conical flask (as receiving flask) and 3 drops of mixed indicator was added. The receiving flask, was placed so that the tip of the condenser tube is below the surface of the boric acid, out of the 50ml of the digest 5ml (V2) was pipetted into the distillation tube and 10ml of 40% NaOH was added. The heater was turn on and the distillation continues until approximately 50ml of distillate has been collected into the receiving flask, and then the heater was turn off. The distillate was titrated with 0.01M HCl and blank was titrated with the acid (Remi *et al*., 2022).

2.10. Determination of Carbohydrate Composition (Glucose, Sucrose, Fructose, Maltose and raffinose)

The carbohydrate composition of the pectin samples was determined using High-Performance Liquid Chromatography (HPLC) adopted from the method described by Han et al. (2024). Pectin samples were dissolved in distilled water, and the resulting solution was filtered through a 0.22 µm filter prior to injection. The analysis was performed using a liquid chromatograph equipped with a refractive index (RI) detector and a carbohydrate analysis column. The mobile phase consisted of distilled water or acetonitrile:water mixture at a flow rate of 0.6-1.0 mL/min, with the column temperature maintained at 30-40°C. Identification and quantification of glucose, sucrose, fructose, and maltose were achieved by comparison with authentic standards. Sugar concentrations were calculated using standard curves prepared from known concentrations of each sugar standard (Han *et al*., 2024; Abang Zaidel *et al*., 2020). All measurements were performed in triplicate and results were expressed as mg/g of sample.

2.11. Statistical Analysis

All analyses were carried out in triplicate and results expressed as mean ± standard deviation. Data were analyzed using ANOVA. Differences between means were considered significant at $p < 0.05$.

3. Results and discussion

Table 1 Percentage yield of pectin extracted from Sample A (Sweet Potato) and Sample B (Irish Potato)

S/N	Parameter	Sample A	Sample B
1	W1 (g)	200.00	200.00
2	W2(g)	27.50	19.72
3	Percentage Yield (%)	13.75 ± 0.15	9.86 ± 0.20

Values are expressed as mean ± standard deviation (n = 3).

Where
W1: Weight of dried potato peels
W2: Weight of Dried Pectin Obtained

Sample A (Sweet Potato)

Percentage Yield (%) = (W2 / W1) × 100

= (27.50 / 200.00) × 100

= 13.75%

Sample B (Irish Potato)

Percentage Yield (%) = (W2 / W1) × 100

(19.72 / 200.00) × 100

= 9.86%

The results in Table 1 presented the percentage yield of pectin extracted from sweet potato peels (Sample A) and Irish potato peels (Sample B) and it was determined gravimetrically. The weight of the dried powdered peels (W1) and the weight of the dried extracted pectin (W2) were recorded, and the percentage yield was calculated. The percentage yield of Sample A (Sweet Potato) was 13.75 ± 0.15%, while Sample B (Irish Potato) had a yield of 9.86 ± 0.20%. Sample A exhibited a higher percentage yield compared to Sample B, indicating that sweet potato peels yielded more pectin than Irish potato peels following the same extraction conditions. The higher yield observed in Sample A may be attributed to the higher pectin content of sweet potato peels compared to Irish potato peels. Sweet potato residue has been reported to contain approximately 15–20% pectin on a dry matter basis (Abang Zaidel *et al*., 2015; Han *et al.*, 2024), while potato peels generally contain lower amounts of pectin (Pathak *et al.*, 2018). The variation in yield between the two samples may as well be due to differences in the cell wall structure and pectin composition of the two potato varieties (Rodriguez-Martinez *et al.,* 2021).

Table 2 Comparison of the percentage yield of pectin extracted from Sample A (Sweet Potato) and Sample B (Irish Potato) with literature

S/N	Source	Yield (%)	Reference
1	Sample A	13.75	This study
2	Sample B	9.86	This study
3	Sweet Potato Residue	7.2-29.3	Abang Zaidel *et al.,* 2015
4	Sweet Potato Pectin (HCl extraction)	23.48	Abang Zaidel *et al.*, 2020
5	Potato Peel Pectin	7.15-14.87	Owusu *et al.,* 2025
6	Watermelon Rind Pectin	14.10	Owusu *et al.*, 2022
7	Plantain Peel Pectin	4.88-7.61	Owusu *et al.*, 2023

The yield obtained from sweet potato peels (13.75%) falls within the range reported for sweet potato pectin extraction (7.2 – 29.3%) (Abang *et al.,* 2015). The yield from Irish potato peels (9.86%) is within the range reported for potato peel pectin (7.15 – 14.87%) (Owusu *et al.*, 2025). The slightly lower yield compared to some literature values may be attributed to differences in extraction conditions, raw material composition, the efficiency of the extraction processb and the differences that exist betwwen the sources of the materials (Han *et al*., 2024).

The percentage yield of pectin is an important parameter for assessing the economic viability of pectin extraction from agricultural waste (Belkheiri *et al*., 2021). The yields obtained in this study (13.75% and 9.86%) indicate that both sweet potato and Irish potato peels are viable sources of pectin. The higher yield from sweet potato peels suggests that this agricultural waste may be a more promising source for commercial pectin production. The recovery of pectin from these agricultural by-products not only mitigates environmental problems but also enhances the profitability of the food industry (Rodriguez-Martinez *et al.*, 2021). The use of locally available sweet potato and Irish potato peels as pectin sources presents an opportunity for developing sustainable, low-cost pectin production, reducing dependence on imported pectin (Pathak *et al.*, 2018).

The percentage yields obtained in this study are comparable to those reported in the literature. Abang Zaidel et al. (2015) reported pectin yields ranging from 7.2% to 29.3% from sweet potato cell wall materials. Owusu et al. (2025) reported pectin yields from potato peel ranging from 7.15%-14.87%. The yield from sweet potato peels (13.75%) falls within these reported ranges, confirming that sweet potato peels are a viable source of pectin.

The yield from Irish potato peels (9.86%) is slightly lower than some reported values but is still within an acceptable range. The variation in yield may be attributed to differences in the potato variety, growing conditions, and extraction parameters such as pH, temperature, and extraction time (Rodriguez-Martinez *et al*., 2021). Acid extraction has been reported to yield pectins with high yields because the acidic conditions facilitate the release of pectin from the cell wall while preserving the galacturonic acid backbone (Abang Zaidel *et al.*, 2015).

Table 3 Equivalent weight of pectin extracts from Sample A (Sweet Potato) and Sample B (Irish Potato)

1	Parameter	Sample A	Sample B
2	Weight of Pectin (g)	1.00	1.00
3	Normality of NaOH (N)	0.10	0.10
4	Titre value (mL)	3.00	2.00
5	Equivalent Weight (mg/mol)	3,333.33±0.02	5,000.00±0.11

Calculation

Sample A (Sweet Potato)

Equivalent weight = (1.00g × 1000 mg)/(3.00 mL × 0.10 N)

= 1000 / 0.30

= 3,333.333g

Sample B (Irish Potato)

Equivalent weight = (1.00 g × 1000 mg) / (2.00 mL × 0.10 N)

= 1000 / 0.20

= 5,000.00g

Equivalent weight is a measure of the free galacturonic acid content in pectin (Owusu *et al*., 2023). It is defined as the weight of pectin that contains one mole of free galacturonic acid carboxyl groups (Ranganna, 1995). The equivalent weight is an important parameter in pectin characterization because it provides information about the purity and gelling properties of the pectin (Ismail et al., 2012). High equivalent weight indicates a higher proportion of free carboxyl groups, which can contribute to enhanced gelling properties (Twinomuhwezi et al., 2020). The equivalent weight depends on the plant source, the quality of raw material, and the extraction technique (Ismail et al., 2012). The equivalent weight was determined using the titration method described by Ranganna (1995). The volume of 0.1 N NaOH required to reach the endpoint (purple colour) was recorded for each sample. The equivalent weight was calculated.

Equivalent weight = (Weight of pectin sample (g) × 1000 mg) / (Titre value (mL) × Normality of acid)

The equivalent weight of Sample A (Sweet Potato) was 3,333.33 mg/mol. This value indicates a very high amount of free galacturonic acid in the pectin extract. The high equivalent weight suggests that the sweet potato pectin extract contains a substantial proportion of non-esterified galacturonic acid residues, which are important for the gelling properties of pectin (Belkheiri *et al*., 2021). Pectin with high equivalent weight has been reported to exhibit enhanced gelling properties due to the increased availability of free carboxyl groups for cross-linking with calcium ions (Han *et al*., 2024). The equivalent weight of sweet potato pectin reported by Owusu *et al*., 2023) 1666.67 ± 0.032 mg/mol for acid-extracted plantain pectin was lower compared to the value of equivalent weight of pectin in this study. The high equivalent weight of Sample A indicates that the sweet potato pectin extract may be suitable for applications requiring good gelling properties. It may also reflect the efficiency of the extraction method used. Acid extraction has been reported to yield pectins with high equivalent weights because the acidic conditions facilitate the release of pectin from the cell wall while preserving the galacturonic acid backbone (Abang Zaidel *et al.,* 2015). The equivalent weight of pectin is affected by the type of plant, quality of raw materials, and method of extraction (Ismail *et al.*, 2012). The equivalent weight of Sample B (Irish Potato) was 5,000.00 g. This value is higher than the equivalent weight of Sample A, indicating a higher proportion of free galacturonic acid in the Irish potato pectin extract. However, the equivalent weight of pectin from other potato sources has been studied. Pathak *et al.* (2018) reported that potato peel contains various pectic substances with different degrees of esterification. The equivalent weight of potato pectin may vary depending on the variety, growing conditions, and extraction method (Rodriguez-Martinez *et al*., 2021). The higher equivalent weight of Sample B compared to Sample A may also be attributed to differences in the raw material composition or the extraction

conditions (Han *et al.*, 2024). Irish potato peels may contain pectin with a lower degree of esterification, which would result in a higher equivalent weight (Belkheiri *et al.*, 2021). The equivalent weight of Sample B (5,000.00 mg/mol) is comparable to the equivalent weight of alkaline-extracted plantain pectin reported by Owusu *et al.* 2023) as 3125.000 ± 0.065 mg/mol. The lower equivalent weight of Sample B suggests that the Irish potato pectin extract may have different gelling properties compared to the sweet potato pectin extract (Belkheiri et al., 2021).

Table 4 Comparison of the equivalent weight of pectin extracted from Sample A (Sweet Potato) and Sample B (Irish Potato) with literature

1	Source	Equivalent Weight (mg/mol)	Reference
2	Sample A	3,333.33	This study
3	Sample B	5,000.00	This study
4	Acid-Extracted Plantain Pectin	1666.67	Owusu et al., 2023
5	Alkaline-Extracted Plantain Pectin	3125.00	Owusu et al., 2023
6	Papaya Peel Pectin	1666.60	Altaf et al., 2015

Equivalent weight is also a measure of the purity of pectin. High equivalent weight indicates that the pectin extract has a higher proportion of galacturonic acid and fewer impurities (Ismail *et al.*, 2012). The equivalent weights of both samples (3,333.33 and 5,000.00 mg/mol) are within the range reported for pure pectins (Ismail *et al*., 2012). The equivalent weight of pectin influences its suitability for specific applications. Pectin with high equivalent weight is preferred for applications requiring strong gelling properties, such as jams and jellies (Belkheiri *et al.*, 2021). Pectin with lower equivalent weight may be more suitable for applications requiring weak gels or thickening properties (Han *et al.,* 2024).

Table 5 Proximate composition of pectin extracts from Sample A (Sweet Potato) and Sample B (Irish Potato)

1	Parameter (%)	Sample A	Sample B
2	Moisture Content	12.79 ± 0.14	13.24 ± 0.24
3	Ash Content	3.47± 0.01	4.13 ± 0.04
4	Crude Protein Content	6.79 ± 0.02	9.27 ± 0.04

Values are expressed as mean ± standard deviation (n = 3)

Moisture content is an important physicochemical property used to evaluate pharmaceutical and food-grade excipients because it affects powder flow characteristics, microbial proliferation, and storage stability (Perez, *et al.,* 2022*;* Joel *et al.,* 2018*)* . In pharmaceutical applications, controlling moisture levels is essential for maintaining good powder flow and minimizing microbial growth (Perez, *et al.,* 2022*;* Joel *et al.,* 2018). Excessive moisture can result in caking, poor flowability, and a greater risk of microbial contamination during storage (Pathak *et al*., 2018). Therefore, the determination of moisture content is essential for assessing the quality and shelf-life of pectin powders (Rodriguez-Martinez *et al*., 2021). The moisture content of Sample A (Sweet Potato) was 12.79 ± 0.14%, while Sample B (Irish Potato) contained 13.24 ± 0.24%. Sample B exhibited higher moisture content than Sample A, suggesting that the Irish potato pectin extract may have a higher tendency for microbial growth and poorer flow properties compared to the sweet potato pectin extract when stored for longer periods (Owusu *et al*., 2023). Both samples, however, had moisture contents within the acceptable pharmacopoeia standards, which was stated to be either 15% w/w or below by British Pharmacopoeia prescribes (Ayensu *et al.,* 2022*;* Owusu *et al*., 2023; BPC, 2013). This indicates that both pectin extracts meet the quality requirements for pharmaceutical applications in terms of moisture content. Han *et al*., (2024) reported a moisture content of 7.82 ± 0.15% for ammonium oxalate-extracted purified sweet potato pectin (AMOP). The moisture content of Sample A (12.79%) was higher than the value reported by Han *et al*., (2024), which may be attributed to differences in drying conditions and the extent of purification. The refined pectin obtained by Han *et al.,* (2024) underwent enzymatic hydrolysis and dialysis, which may have contributed to its lower moisture content. In the present study, the absence of such refinement steps likely resulted in higher moisture content in the pectin extracts. The moisture content of sweet potato residue has been reported to be 79.7 ± 1.7% (Abang Zaidel *et al*., 2020). The significantly lower moisture content of the pectin extracts (12.79–13.24%) compared to the raw residue indicates successful drying during the extraction and purification process. This reduction in moisture content is essential for

improving the storage stability and handling characteristics of the pectin powder (Pathak *et al*., 2018). The moisture content of acid and alkaline extracted plantain pectin has been reported as 11.785% and 6.614%, respectively (Owusu *et al.*, 2023). The moisture content of Sample A (12.79%) was almost similar to the acid-extracted plantain pectin, while Sample B (13.24%) was higher than both values. The higher moisture content in Sample B may be due to differences in the raw material composition or drying conditions (Owusu *et al*., 2025). The moisture content values obtained in this study have practical implications for the storage and handling of the pectin extracts. Both samples should be stored in airtight containers to prevent moisture absorption and microbial growth (Owusu et al., 2023). Sample B, with its higher moisture content (13.24%), may require more careful storage conditions to prevent early-onset degradation (Owusu *et al.,* 2025). The moisture content of both samples was within acceptable limits for pharmaceutical excipients. However, Sample B (Irish Potato) with higher moisture content (13.24%) may require careful storage in airtight containers to prevent early-onset degradation (Owusu *et al.*, 2023).

Ash content is a measure of the inorganic mineral content of a sample and is used as an indicator of pectin purity (Ismail *et al.*, 2012; Owusu *et al*., 2023). The ash content represents the purity of pectin. The lower the ash content, the higher the purity of pectin (Ismail *et al.*, 2012). High ash content indicates the presence of mineral impurities, which may be derived from the raw material or introduced during the extraction process (Rodriguez-Martinez *et al*., 2021). For pharmaceutical and food applications, low ash content is desirable to ensure consistent performance and minimize interactions with other ingredients (Belkheiri *et al.*, 2021). The ash content of Sample A (Sweet Potato) was 3.47± 0.01%, while Sample B (Irish Potato) contained 4.13 ± 0.12%. Both samples exhibited low ash content, with Sample A having a lower ash content than Sample B. The low ash content of both samples indicates high purity of the extracted pectins (Owusu *et al*., 2023). The ash contents obtained were comparatively lower than those in other reported literature studies, indicating a higher quality of the extracted pectins (Owusu *et al*., 2023). Decreased ash values translate into higher pectin purity (Ismail *et al.*, 2012). The higher ash content in the pectin extracts (3.47–4.13%) compared to the raw residue may be due to the concentration of minerals during the extraction process. As water is removed during drying, mineral salts become concentrated in the pectin powder (Pathak et al., 2018). The ash content of acid and alkaline extracted plantain pectin has been reported as 2.56% and 4.06%, respectively (Owusu et al., 2023). The ash content of Sample A (3..47%) %) was almost similar to the acid-extracted plantain pectin, while Sample B (4.13%) was also closer to the value for alkaline-extracted plantain pectin. The low ash content of both samples suggests that the extraction methods employed in this study effectively removed mineral impurities. The ash content of sweet potato pectin extracted using ammonium oxalate was also reported as 0.78 ± 0.21% after refinement (Han *et al.*, 2024). The higher ash content observed in the present study (3.47–4.13%) may be due to the absence of a refinement step or differences in the extraction method and raw material used. The refinement process described by Han *et al.* (2024) included dialysis, which effectively removes mineral ions and other low molecular weight impurities (Han *et al.,* 2024). The low ash content of both samples has significant implications for their potential applications. Pectin with low ash content is preferred for pharmaceutical formulations, as mineral impurities can interact with active pharmaceutical ingredients and affect drug stability. In food applications, low ash content ensures that the pectin does not contribute undesirable mineral flavors or affect the sensory properties of the final product (Belkheiri *et al.*, 2021).

Crude protein content is an important attribute of pectin because it can influence its functional characteristics (Owusu *et al*., 2023). Studies have shown that protein components associated with pectin polymer chains contribute significantly to the activation and stabilization of pectin powders, particularly when used as emulsifying agents in pharmaceutical formulations (Mada *et al*., 2022; Funami *et al.*, 2007). The presence of protein in pectin extracts can influence their emulsifying, stabilizing, and interfacial properties (Belkheiri *et al*., 2021). For sugar beet pectin, which is known for its excellent emulsifying properties, the protein content has been reported to contribute significantly to its surface activity (Rodriguez-Martinez *et al.*, 2021). The crude protein content of Sample A (Sweet Potato) was 6.79 ± 0.02%, while Sample B (Irish Potato) contained 9.27 ± 0.04%. Sample B exhibited higher protein content than Sample A. The relatively higher amount of protein in Sample B (Irish Potato) may be due to increased covalent linkages between proteins and pectin, resulting in co-precipitation by ethanol (Owusu *et al*., 2023). The lower crude protein concentrations in Sample A (Sweet Potato) can be attributed to protein hydrolysis during the acidic extraction medium (Owusu *et al.*, 2023). The crude protein content of acid and alkaline extracted plantain pectin has been reported as 8.123% and 11.633%, respectively (Owusu *et al.,* 2023). The crude protein content of Sample B (9.27%) was slightly higher than the acid-extracted plantain pectin, while Sample A (6.79%) was lower than both values. The higher protein content in Sample B may be due to the natural protein content of Irish potato peels, which has been reported to contain protein (1.2–2.3%) (Calcio *et al.*, 2020). The significantly higher protein content in the pectin extracts (6.79–9.27%) compared to the raw peel may be due to the concentration of protein during the extraction and purification process. The protein content of sweet potato pectin extracted using ammonium oxalate was reported as 0.35 ± 0.10% after refinement (Han *et al*., 2024). The significantly higher protein content observed in the present study (6.79-9.27%) may be due to the absence of a refinement step or differences in the extraction method and raw material used. The refinement process described by Han *et al.,* (2024) included enzymatic hydrolysis with glucoamylase and dialysis, which

effectively removes protein and other macromolecular impurities (Han et al., 2024). The protein content of pectin extracts has implications for their functional properties. Higher protein content may enhance the emulsifying and stabilizing properties of pectin, making it suitable for applications such as oil-in-water emulsions (Belkheiri *et al.*, 2021). Conversely, high protein content may also introduce allergenic concerns or affect the gelling properties of pectin (Rodriguez-Martinez *et al.*, 2021). For pharmaceutical applications, the protein content should be considered to ensure compatibility with active pharmaceutical ingredients (Owusu *et al.,* 2023).

Table 6 Comparison of the Moisture, Ash, and Protein of Pectin Extracted From Sample A (Sweet Potato) and Sample B (Irish Potato) with References

S/N	Source	Moisture (%)	Ash(%)	Protein (%)	References
1	Sample. A	12.79	3.74	6.79	This study
2	Sample. B	13.24	4.23	9.27	This study
3	Sweet Potato Pectin	7.82	0.78	0.35	Han *et al.,* 2024
4	Acid-Extracted Plantain Pectin	11.79	2.56	8.12	Owusu *et al*., 2023
5	Alkaline-Extracted Plantain Pectin	6.61	4.06	11.63	Owusu et al., 2023
6	Sweet Potato Residue	79.70	1.08	-	Abang Zaidel et al., 2020
7	Raw Potato Peel	83.3–85.1	-	1.2–2.3	Calcio Gaudino et al., 2020

The moisture content of the pectin extracts in this study (12.79-15.24%) was within the acceptable pharmacopoeia standards (< 15% w/w) (Owusu *et al*., 2023). The ash content (2.56-3.12%) was lower than the recommended standards in literature (< 10%), pointing to high-quality pectin in the extracted materials. The crude protein content of the pectin extracts in this study (6.79-9.27%) was higher than the protein content of raw potato peel (1.2–2.3%) (Calcio Gaudino *et al.,* 2020). This suggests that the protein content was concentrated during the extraction and purification process. The higher protein content of Sample B (9.27%) compared to Sample A (6.79%) may reflect the natural protein content of the raw materials or differences in the extraction efficiency.

Table 7 Results of carbohydrates content of sample A and B

S/N	parameter	Sample A (mg/g)	Sample B (mg/g)
1	Glucose	323.44±0.07	151.51±0.15
2	Sucrose	215.51±0.011	196.38±0.01
3	Fructose	118.84±0.00	137.96±0.11
4	Maltose	95.99±0.04	114.08±0.01
5	Raffinose	183.72±0.17	-

Values are expressed as mean ± standard deviation (n = 3)

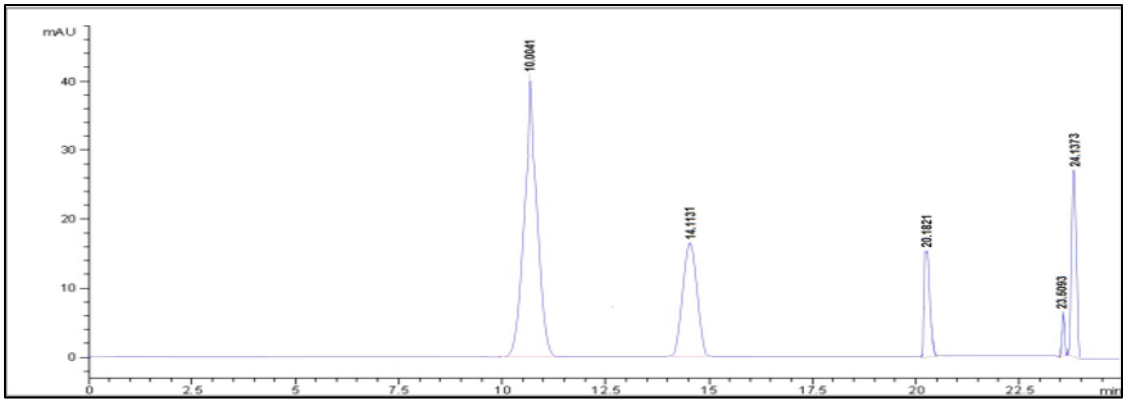

Figure 1 Carbohydrates content of sample A

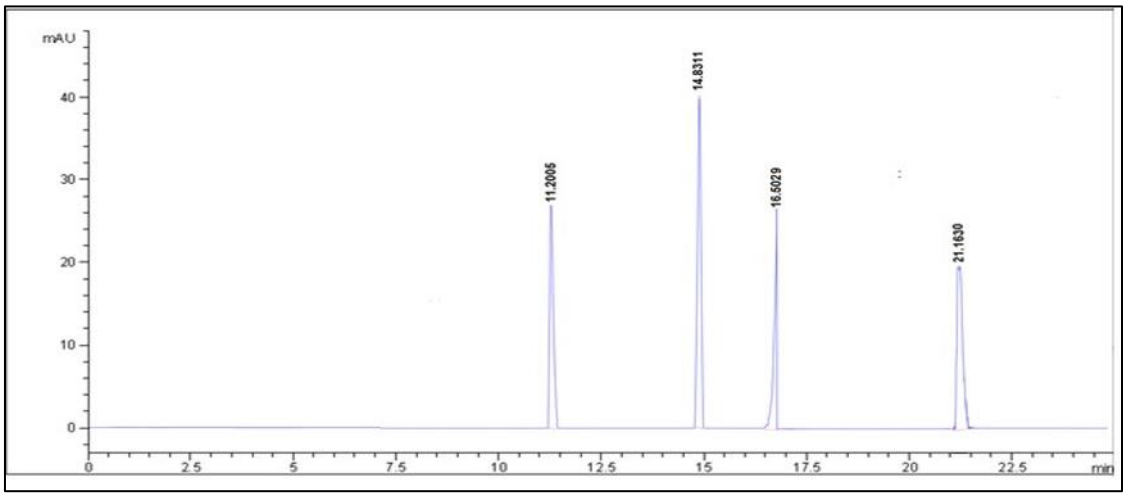

Figure 2 Carbohydrates content of sample B

Glucose is one of the neutral monosaccharides that may be detected in pectin, although pectin is composed predominantly of galacturonic acid together with smaller amounts of rhamnose, galactose and arabinose (Han et al., 2024). The presence of glucose in pectin extracts can also indicate the presence of contaminating polysaccharides such as starch, which may affect the purity and functional properties of the extracted pectin (Rodriguez-Martinez *et al*., 2021). The glucose content of Sample A (Sweet Potato) was 323.44 mg/g, while Sample B (Irish Potato) contained 151.51 mg/g. This indicates that Sample A had higher glucose content compared to Sample B, with Sample A containing more than twice the glucose content of Sample B. The high glucose content observed in Sample A suggests that the sweet potato pectin extract may contain substantial residual starch or other glucose-rich polysaccharides. The relatively lower glucose content in Sample B may reflect differences in the inherent carbohydrate composition of Irish potato peels, extraction efficiency, or the amount of glucose-containing polysaccharides remaining after extraction. Han et al. (2024) identified glucose as a minor monosaccharide constituent (1.69 mol%) of purified sweet potato pectin. Although the units are different and therefore not directly comparable, both studies confirm the presence of glucose in sweet potato-derived pectin. Abang Zaidel et al. (2020) reported that sweet potato residue contained 34.3 ± 2.7% total carbohydrate, demonstrating that sweet potato residues are naturally rich in carbohydrates. The high glucose content observed in Sample A (323.44 mg/g) may suggest the presence of residual glucose-containing polysaccharides or other carbohydrate components that remained associated with the extracted pectin following the extraction process. Rodríguez-Martínez et al. (2021) reported that potato peel polysaccharides contain approximately 76.25% glucose, indicating that glucose is the predominant monosaccharide in potato peel polysaccharides and further explained that potato peel contains both starch and non-starch polysaccharides, including pectin, which may contribute to the glucose detected after hydrolysis. The glucose content observed in this study provides useful information regarding the composition and potential purity of the extracted pectin. The higher glucose content observed in Sample A may be associated with differences in the botanical origin of the raw material, extraction conditions, or the presence of glucose-containing polysaccharides in the extract. Furthermore, the glucose content data provide a baseline for optimizing the extraction and purification processes to achieve higher pectin purity in future studies. The use of locally available sweet

potato and Irish potato peels as pectin sources also presents an opportunity for developing sustainable, low-cost pectin production in Nigeria, reducing dependence on imported pectin (Rodriguez-Martinez et al., 2021).

Sucrose is a non-reducing disaccharide composed of glucose and fructose linked by an α-(1-2)-β-glycosidic bond. Sucrose is the principal transport sugar in higher plants and an important reserve carbohydrate in storage organs such as sweet potato. Sweet potato naturally contain soluble sugars, mainly sucrose, glucose, and fructose, which contribute to their nutritional quality and sensory characteristics (Laveriano-Santos et al., 2022). The sucrose content of Sample A (sweet potato pectin) was 215.51 mg/g, whereas Sample B (Irish potato pectin) contained 196.38 mg/g. This indicates that Sample A contained slightly more sucrose than Sample B. The observed variation may be associated with differences in the botanical origin of the raw materials, cultivar characteristics, extraction conditions, or the amount of soluble sugars that remained associated with the extracted pectin after purification. Xu et al. (2023) reported sucrose concentrations ranging from 22.50 to 146.41 mg/g, with a mean value of 86.42 mg/g, in eighty-one sweet potato varieties. Although these values are lower than the sucrose content obtained for Sample A in the present study, which may be due to the fat that fresh sweet potato storage roots was used in the reference, whereas the present study determined sucrose associated with extracted pectin. Differences in cultivar, environmental conditions, extraction procedures, and analytical methods may therefore explain the observed variation. Furthermore, Xu et al., (2023) identified sucrose, glucose, and fructose as the principal soluble sugars in sweet potato storage roots, confirming that sucrose is a naturally occurring carbohydrate in sweet potato tissues. The relatively high sucrose contents observed in the present study suggest that part of these naturally occurring soluble sugars remained associated with the extracted pectin during extraction and purification. The higher sucrose content observed in Sample A may reflect differences in the carbohydrate composition of sweet potato peels or variations in extraction efficiency compared with Irish potato peels. The findings obtained in this study provide useful baseline information for optimizing extraction and purification procedures where pectin with lower residual soluble sugar content is required. Belkheiri *et al*., (2021) explained that sucrose plays an important role in the gelation of high-methoxyl pectin by reducing water activity and promoting interactions between pectin molecules under acidic conditions. Therefore, the sucrose content of the extracted pectin may be advantageous for food products requiring gel formation, whereas additional purification may be desirable for pharmaceutical applications where higher pectin purity is required.

Fructose is a naturally occurring monosaccharide commonly found in fruits and storage roots, where it contributes to sweetness and serves as an important soluble carbohydrate. In sweet potato, fructose occurs together with sucrose and glucose as one of the principal soluble sugars, while its concentration varies depending on cultivar, maturity, and environmental conditions. (Xu et al., 2023). The fructose content of Sample A (sweet potato pectin) was 118.84 mg/g, whereas Sample B (Irish potato pectin) contained a higher fructose content 137.96 mg/g. The observed difference may be attributed to variations in the botanical origin of the raw materials, varietal differences, extraction conditions, or the amount of soluble sugars that remained associated with the extracted pectin following purification. Comparable findings have been reported by Xu et al. (2023), who evaluated eighty-one sweet potato varieties and found that fructose content varied considerably among cultivars, demonstrating that soluble sugar composition is highly dependent on genetic background and growing conditions. Although the present study determined fructose associated with extracted pectin rather than fresh storage roots, the occurrence of fructose in both studies confirms that it is a naturally occurring carbohydrate in sweet potato tissues. Similarly, Laveriano-Santos *et al*., (2022) reported that sweet potato contains appreciable amounts of soluble sugars, particularly sucrose, glucose, and fructose, which contribute to its nutritional quality and functional properties. The higher fructose content observed in Irish potato pectin in the present study may therefore reflect differences in the carbohydrate composition of Irish potato peels or differences in the efficiency of the extraction and purification process. The fructose contents obtained in this study provide useful information regarding the carbohydrate composition of the extracted pectin. Since fructose is a soluble sugar rather than a structural component of pectin, its presence may indicate that part of the naturally occurring sugars remained associated with the extracted polysaccharides after extraction. These findings provide a useful basis for improving extraction and purification procedures where pectin of higher compositional purity is required. Furthermore, the presence of fructose may contribute to the sweetness and potential food applications of the extracted pectin, whereas additional purification may be desirable for pharmaceutical applications requiring highly purified pectin. Han et al. (2024) emphasized that purification procedures influence the composition and quality of sweet potato pectin extracts.

Maltose is a reducing disaccharide composed of two glucose units linked by an α-(1,4)-glycosidic bond. It is not typically a primary storage sugar in raw plant tissues but is often formed during starch degradation, especially through enzymatic or thermal hydrolysis of starch molecules during processing or extraction (Xu et al., 2023). The maltose content of Sample A (sweet potato pectin) was 95.99 mg/g, while Sample B (Irish potato pectin) contained 114.08 mg/g. This indicates that Sample B had a higher maltose content than Sample A. The difference observed between the two samples may be associated with variations in starch composition, degree of starch hydrolysis during extraction, and processing conditions such as acid treatment and heating, which can promote conversion of starch into maltose.

In sweet potato and other tuber crops, starch is the dominant carbohydrate reserve, and its breakdown can lead to the formation of maltose (Xu et al., 2023). Maltose is not a primary soluble sugar naturally present in fresh sweet potato roots but can appear as a product of starch hydrolysis during processing or thermal treatment (Xu et al., 2023). This supports the idea that maltose detected in the present study is likely derived from partial breakdown of starch present in the raw materials during pectin extraction rather than being a native free sugar in the tissue. The higher maltose content observed in Irish potato pectin may suggest a greater extent of starch degradation during extraction or a higher starch content in Irish potato peels compared to sweet potato peels. Irish potato is known to contain substantial starch reserves, which can undergo hydrolysis under acidic and heated extraction conditions commonly used in pectin isolation. From a compositional perspective, maltose in pectin extracts is considered a residual soluble sugar rather than a structural component of pectin. Its presence therefore provides information about the efficiency and severity of the extraction process. Higher maltose levels may indicate stronger hydrolysis of starch during extraction, whereas lower levels suggest milder processing conditions or lower starch content in the raw material. Maltose does not contribute to the backbone structure of pectin, its presence may influence the physicochemical properties of the extract, particularly in food systems where reducing sugars can participate in browning reactions and affect product stability during thermal processing. For applications requiring high-purity pectin, such as pharmaceutical uses, the presence of maltose may be undesirable and may require further purification.

Raffinose is a trisaccharide belonging to the raffinose family oligosaccharides (RFOs), composed of galactose, glucose, and fructose units. It is commonly found in plant tissues where it functions as a storage and transport carbohydrate, particularly in seeds, tubers, and other storage organs. In plants, raffinose and related oligosaccharides are involved in carbon transport and stress protection mechanisms, and their concentrations vary depending on species, tissue type, and physiological conditions (Liu *et al*., 2021). The raffinose content was detected only in Sample A (sweet potato pectin) at a concentration of 183.72 mg/g, while it was not detected in Sample B (Irish potato pectin). The presence of raffinose exclusively in Sample A suggests a possible difference in the carbohydrate composition of the raw materials or variations in extraction and purification processes that influenced the retention or removal of oligosaccharides. Sweet potato is known to contain a wider range of soluble carbohydrates compared to Irish potato, including oligosaccharides such as raffinose, which may accumulate depending on cultivar and physiological conditions. Studies on sweet potato carbohydrate composition have reported the presence of multiple soluble sugars and oligosaccharides, although raffinose is typically present in smaller quantities compared to sucrose, glucose, and fructose (Xu et al., 2023). The detection of raffinose in the present study may therefore reflect the retention of minor oligosaccharide fractions associated with the pectin matrix during extraction. The absence of raffinose in Sample B may be attributed to differences in the carbohydrate profile of Irish potato peels or more efficient removal of soluble oligosaccharides during extraction and purification. Irish potato is generally characterized by a starch-dominant composition with relatively lower levels of soluble oligosaccharides compared to sweet potato, which may explain the non-detection of raffinose in this sample. From a compositional view, raffinose in pectin extracts is considered a residual soluble carbohydrate rather than a structural component of pectin. Its presence therefore provides information about the purity of the extracted pectin and the extent to which low-molecular-weight carbohydrates were removed during purification. Higher levels of such oligosaccharides may indicate incomplete removal of soluble sugars during ethanol precipitation. Raffinose does not contribute to the structural integrity of pectin, its presence may influence functional properties in food systems, particularly in terms of fermentability and potential prebiotic effects, as raffinose family oligosaccharides are known to resist digestion in the upper gastrointestinal tract and are fermented by gut micr**obiota.**

4. Conclusion

This study demonstrated that both sweet potato (*Ipomoea batatas*) and Irish potato (*Solanum tuberosum*) peels are promising alternative sources of pectin with acceptable carbohydrates composition and physicochemical characteristics. Acid extraction successfully recovered pectin from both agricultural by-products, with sweet potato peels producing a higher extraction yield (13.75%) than Irish potato peels (9.86%), indicating a greater pectin recovery potential under the extraction method employed. The study confirms that potato peels, which are commonly discarded as agro-industrial wastes, can be successfully converted into value-added pectin, providing a sustainable approach to waste utilization while safeguarding the environment as well as offering a potential local source of commercial pectin for food and pharmaceutical applications.

Recommendations

Based on the findings of this study, the following are recommended:

- Mineral characterization of the extracted pectin should be carried out to determine the levels of essential minerals and possible trace elements. This will provide additional information on the purity, nutritional value, and suitability of the pectin for food and pharmaceutical application;
- Vitamin analysis should be conducted to determine whether any vitamins are retained in the extracted pectin. This would provide valuable information on its nutritional quality and potential application as a functional food ingredient;
- Further purification and structural characterization of the extracted pectin, including the determination of galacturonic acid content, degree of esterification, methoxyl content, and molecular weight, are recommended to better evaluate its quality and compare it with commercial pectin;
- Application studies should be carried out to evaluate the performance of the extracted pectin as a gelling, thickening, stabilizing, or suspending agent in food and pharmaceutical formulations.

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