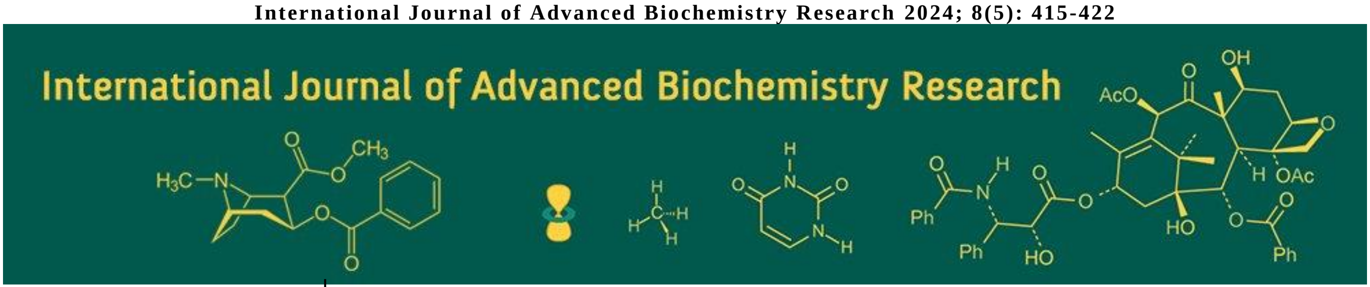

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Pectin extraction from Jackfruit waste by Acid extraction method

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Abstract
Jackfruit waste which comprises about 60% of total jackfruit was used for pectin extraction. The jackfruit rind was dried with convective hot air drying and solar drying, the dried peel was extracted with acid extraction, at varied temperatures 85 °C, 90 °C, 95 °C and pH levels 1.5, 2.0 and 2.5 respectively. The effect of all independent parameters on yield, moisture content, ash content, pH, methoxyl Content, anhydronic acid, equivalent weight, degree of esterification, galacturonic acid, intrinsic viscosity, spredability, colour (L), colour (a), colour (b) was studied. The sample dried with convective hot air drying method with acid extraction at exposure temperature 85 °C showed the best result where yield (7.569%), moisture content (7.758%), ash content (3.110%), methoxyl Content (3.433%), anhydronic acid (55.460), equivalent weight (474.362), degree of esterification (34.777), galacturonic acid (44.732), intrinsic viscosity (2.173), spredability (160.444) and 1.5 pH showed the best result where yield (9.450%), moisture content (8.025%), ash content (2.922%), pH (3.866%), methoxyl Content (3.949%), anhydronic acid (54.898), equivalent weight (473.700), degree of esterification (34.344), galacturonic acid (44.917). The experiments conducted using factorial completely randomized design at ($p \leq 0.05$).

Keywords: Pectin, acid extraction, degree of esterification, Methoxyl content, Galacturonic acid

1. Introduction

A man's diet plays a vital role in maintaining a healthy lifestyle. Obesity, hypertension, cancer, and other lifestyle disorders can all be caused by an unsuitable diet. Growing dietary consciousness among consumers leads them to seek out and go for lower-calorie items because of their benefits. Consumers find these items even more appealing when they see less sugar and fat and the addition of food additives without lowering the product's quality. Vegetable hydrocolloids are among these additions. They are prized for their health advantages in addition to their practical qualities, which make them valuable from a technology standpoint. These include their high water binding capacity and their ability to thicken and gel. They serve as dietary fibre, for example, and can therefore help to induce feelings of fullness. Some of the hydrocolloids found in low-calorie foods are heteropolysaccharides called pectins. Pectin preparations have two roles in food products: they are bioactive components in a soluble portion of dietary fibre and thickening, stabilising, and gelling agents.

Pectins (E440) are water-soluble polysaccharides, or heteropolysaccharides. They are found in both the central sections of the plant's intercellular gaps and its cell walls, they are distinguished by their natural origin. They regulate water balance and serve as the skin-forming substance within. According to Zykwinska *et al*. (2009) [17], pectins made from citrus peel and apple pomace are the most widely used on the market. Esters of polygalacturonic acid and methyl alcohol make up pectins. Pectins are mostly composed of galactosalic acid residues connected in lengthy chains by α → 1,4-glycoside linkages (Harholt *et al*., 2010) [10].

The fruit crop known as jackfruit (*Artocarpus heterophyllus*) is extensively grown and well-liked in India. Ripe jackfruit bulbs are edible and can be eaten raw or processed to make a variety of goods, such as chips, jam, and cans. The inner perigones (nonedible perianth), center core, and outside prickly rind make up around 60% of the inedible portion of the entire fruit and are considered wasted material. The processing industries and pollution monitoring agencies are having trouble dealing with these fruit wastes. Value-added goods can be produced from these wastes through appropriate processes. By-product recovery from fruit wastes can significantly lessen environmental pollution while also enhancing the overall financial performance of processing facilities.

These fruit waste materials can yield a useful by-product called pectin. The project aims to design a procedure for extracting pectin from waste jackfruit material, including variables like pH and extraction temperature.

2. Materials and Methods

2.1 Raw materials: Jackfruit was procured from the Roha and Kolad local market. Jackfruit peel was separated and washed it then dried it in convective hot air 50 °C.

2.2 Extraction process: The acid extraction method for extraction of pectin from Jackfruit peel powder prepared from convective hot air drying and solar drying was carried out as per the procedure (Nurdjanah *et al*., 2013) [15].

Samples (10 g) (a) Convective hot air-dried jackfruit peel powder and (b) Solar air-dried jackfruit peel powder separately of dried ground cell wall materials (Jackfruit rind powder) were dispersed in 150 mL 0.1 M HCl. The dispersion was stirred for 10 min and kept in water bath at temperature (a) 85 °C, (b) 90 °C, (c) 95 °C and at pH level of (a) 1.5, (b) 2.0, (c) 2.5 for 90 min separately. The hot extract was filtered through four folds of nylon cloth, cooled at room temperature. After allowing to cool it at 4°C and for 15-20 min, the suspensions were centrifuged for 30 min at 4000 rpm in a centrifuge (Make: Remi Elecktrotechnik Ltd. Vasai, India). Then the same volume of 85% Isopropyl alcohol was added, the mixture was stirred for 5 minutes and allowed to settle for 2 h. The mixture was then again centrifuged at 4000 rpm for 30 min and the pectin residue washed with 70, 80, 90%, Isopropyl alcohol successively (until the decant water became colorless). Finally, the extracted purified pectin was pressed by muslin cloth and then dried using 40 °C for 5 hours in tray dryer, the dried sample was than ground to 0.50 mm particles and then stored at normal atmospheric temperature in a polythene pouch (300 gauge).

3. Physio-chemical Parameters for determination of quality of pectin

3.1 Yield of Pectin, (%)

The yield of pectin was determined as per the procedure of Lin *et al*., (2018) [12] The pectin yield based on the total peel used for extraction was calculated using the Eq (3.1).

$$\text{Pectin Yield} = \frac{\text{Weight of dried pectin(g)}}{\text{Initial weight of dried jackfruit rind powder (g)}} \times 100 \ldots (3.1)$$

3.2 Moisture content, (%)

As indicated in section Eq (3.2), 1 g of pectin was weighed and dried for 24 hours at 105 °C in a hot air oven (AOAC, 2010) [1].

$$\text{Moisture Content (\% db)} = \frac{W_2 - W_1}{W_3 - W_1} \times 100 \ldots (3.2)$$

Where,
W_1=Weight of moisture box, g
W_2=Weight of moisture box + Sample, g
W_3=Weight of moisture box + Oven dried sample, g

3.3 Ash content, (%)

1 gram of pectin was weighed in a crucible and burned for four hours at 550 degrees Celsius in a Muffle furnace to determine the amount of ash content. After being chilled in a desiccator, the residue was weighed. The Association of Official Analytical Chemists (AOAC, 2010) [1] assessed the amount of ash. The following formula (3.3) was used to calculate the ash content.

$$\text{Ash content (\%)} = \frac{\text{Weight of crucible with ash} - \text{weight of crucible}}{\text{weight of sample in g}} \times 100 \ldots (3.3)$$

3.4 Equivalent weight, (%)

According to Ranganna's (1995) [16], the equivalent weight for pectin samples derived from various pectin extraction methods was determined. A 250 ml conical flask weighed with a 0.5 g pectin sample was soaked with 5 ml ethanol. After adding 1.0g of NaCl to the mixture, 100ml of distilled water, and six drops of phenol red indicator, an aliquot was added. Using 0.1 M NaOH, the solution was titrated until a pink color was achieved.

Equivalent weight was used for the determination of anhydrouronic acid (AUA) and the degree of esterification (DE). Equivalent weight was calculated by following formula (3.4).

$$\text{Equivalent weight (\%)} = \frac{\text{Weight of sample (g)} \times 1000}{\text{Volume of alkali} \times \text{Normality of alkali}} \ldots (3.4)$$

3.5 Methoxyl Content (MeO), (%)

Methoxyl content (MeO) of pectin sample prepared for each extraction process was calculated using Girma and Worku's (2016) [9] approach. This was accomplished by saponifying pectin and titrating the released acid, using the neutralized solution from equivalent weight determination (section 3.4.4). After adding 25 milliliters of 0.25 milliliters of NaOH to neutralize the solution used to calculate equivalent weight, the mixture was well mixed and left to stand at room temperature for half an hour. It was mixed with 25 ml of 0.25 N HCL and titrated with 0.1 N NaOH. Brown color was achieved as the solution's end point. The following formula (3.5) was used to calculate the methoxyl content (MeO).

$$\text{Methoxyl Content \%} = \frac{\text{ml of alkali} \times \text{Normality of Alkali} \times 3.1}{\text{Weight of sample pectin}} \ldots (3.5)$$

3.5 Anhydrouronic Acid content (AUA), (%)

Using formula (3.6), which was documented in Mohamed and Hasan's 1995 [14] literature, the anhydrouronic acid content (AUA) was determined. Anhydrouronic acid (AUA) content was calculated using the alkali milli-equivalents derived from equivalent weight and methoxyl content. Using the following formula (3.6), the anhydrouronic acid (AUA) was calculated.

$$\text{\% of AUA} = \frac{176 \times 0.1z \times 100}{w \times 1000} - \frac{176 \times 0.1y \times 100}{w \times 1000} \ldots (3.6)$$

When molecular unit of AUA (1 unit) = 176g

Where,
z = ml (titre) of NaOH from equivalent weight determination.
y = ml (titre) of NaOH from methoyl content determination.
w = Weight of sample, g

3.6 Degree of Esterification (DE), (%)
All pectin samples that were extracted for each treatment had their degree of esterification assessed in accordance with the protocol. Daud and Associates, 2019.According to the following equation, the DE of extracted pectin was determined using the quantity of methoxyl and anhydrouronic acid (3.7).

$$\% \text{ DE } = \frac{176 \times \% \text{MeO}}{31 \times \% \text{ AUA}} \times 100 \qquad \ldots(3.7)$$

Where,
% MeO =Methoxyl Content
% AUA= Anhydrouronic acid

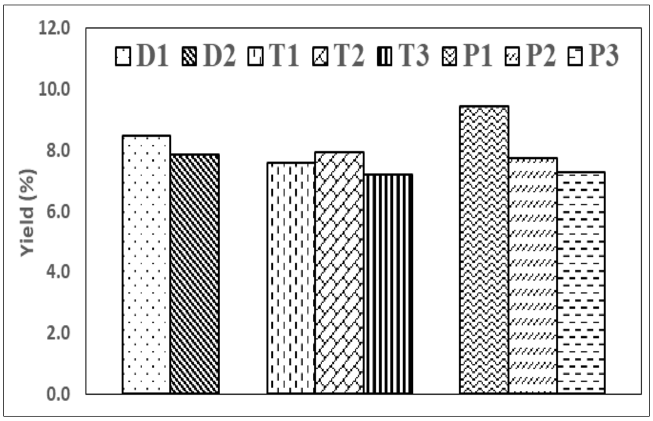
3.7 Galacturonic acid, (%)
The galacturonic acid (GalA) content was ascertained in the light of carbazole-sulfuric acid colourimetric titration with some modifications. The galacturonic acid (GalA) was determined for the developed pectin sample from all those methods as per the procedure of Dische 1946 [5]. 1 mL pectin solution in distilled water (200 µg/mL) was fully reacted with 5 mL concentrated sulfuric acid and hydrolysed for about 20 min in a water bath of 75 ℃. Afterwards, alcohol-based carbazole solution (200 µL, 0.15%, w/v) was added to the cooled reaction, and the end point of the mixture was left to colour in a dark environment for about 2 h. The absorbance was recorded at 530 nm using spectrophotometer (Make: Labindia Analytical, India) (Min *et al*., 2021) [13].

4. Results and Discussion
The experiment consisted of one extraction method (Acid Extraction) two drying method i.e. (Convective hot air dryer and solar dryer), three extraction temperature (85 ℃, 90 ℃, 95 ℃) and three extraction pH (1.5, 2.0, 2.5) Conditions. The experimental data was analyzed statistically using Completely Randomized Design (CRD). The observations on the changes in physical, chemical parameters of pectin samples were recorded i.e. yield, moisture content, ash content, pH, methoxyl content, anhydraunic adic, equivalent weight, degree of esterification, galacturonic acid, intrinsic viscosity, spreadability, colour (L), colour (a), colour (b) etc.

4.1 Yield, %
Figure 1 and Table 1 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 ℃, 90 ℃,95 ℃) and pH (1.5, 2.0, 2.5) on the yield of pectin from the jackfruit peel waste. The yield (%) present in the sample were in the range of 7.194-9.450
The most common factor influencing the amount of pectin is temperature. The results shown increases in temperature decreases the yield of pectin. According to (Girma *et al*., 2016) [9] that the pectin yield was found to be increased up to some extent (up to certain temperature); later decreased upon increasing the temperature during the extraction of pectin. Temperature increases have the potential to disrupt ester and hydrogen bonding, which would enhance pectin solubility and solvent diffusion into plant tissues while also raising pectin extraction yield. Nevertheless, the yield of pectin decreases with additional temperature increases. Pectin molecules may break at a higher temperature, which would enhance the de-esterification of polygalacturonic chains. Additionally, its quality decreases when pectin powder becomes on a dark brown colour.
The yield of pectin increases as the pH decreases. According to (Zakaria, *et al*., 2021) [19], the pH indicates that increased pectin results and extracted pectin purity were observed at lower pH values. This finding showed a similar result with the previous investigation, which found that pH 2.0 yielded the maximum pectin result. This might be the result of as pH decreasing, hydrogen ions increase, which neutralises more of the pectin's carboxylic groups and raises pectin yield. At pH was around to be 2.00 shows the increasing pectin yield the pH value increases may cause the decreasing the pectin yield. The lower acidic pH value of extraction solvent can have the ability to conduct with the insoluble form of pectin is hydrolysis to converted the soluble form of pectin to increases the pectin yield.

Table 1: Effect of Drying Method, Temperature (℃), and pH on Yield (%) of Pectin

Factors	Average Yield			F-Ratio	CD (5%)
Drying Method	8.482	7.855	-	307.020	0.073
Temperature	7.569	7.942	7.194	568.785	0.089
pH	9.450	7.756	7.298	1,340.250	0.089
Int. A X B				194.966	0.126
Int. A X C				5.764	0.126
Int. B X C				102.627	0.154
Int. A X B X C				20.476	0.218



(D1= Convective hot air dryer; D2= Solar dryer; T1= 85 ℃; T2= 90 ℃; T3= 95 ℃; P1= 1.5, P2= 2.0, P3= 2.5)

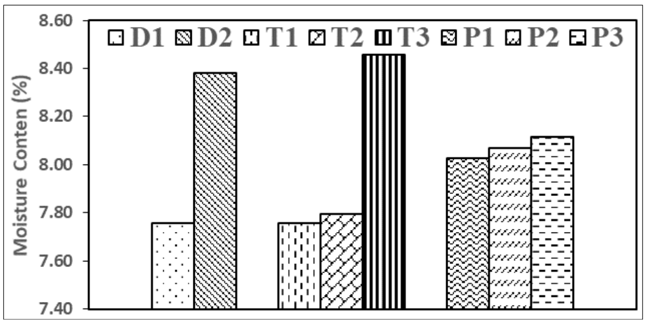
Fig 1: Effect of Drying Method, Temperature (℃), and pH on Yield (%) of Pectin

4.2 Moisture Content, (%)
Figure 2 and Table 2 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 ℃, 90 ℃, 95 ℃) and pH (1.5, 2.0, 2.5) on the moisture content (%) of pectin from the jackfruit peel waste. The moisture Content (%) present in the sample were in the range of 7.758 – 8.456%.
Moisture content is also affected by the pH (1.5, 2.0, 2.5) of the extraction. The moisture content of pectin at different temperatures (1.5, 2.0, and 2.5) are 7.758, 7.796 and 8.456%

respectively. The lowest moisture content was observed at 1.5 pH (8.025%), and the highest moisture content was observed at 2.5 pH (8.115%). The moisture content of pectin by different extractions pH was significant at ($p<0.05$).
According to the quality standards of commercial pectin or IPPA (International Pectin Producers Association) standard maximum acceptable limit of moisture is 12%. That means that pectin moisture content might not exceed 12%. Pectin must have a low to moderate moisture level in order to be stored safely. Owing to the action of pectinase enzymes, elevated moisture level might impact pectin quality by accelerating the growth of microorganisms. This makes elevated moisture content an indication of spoiling.

Table 2: Effect of Drying Method, Temperature (°C), and pH on Moisture Content (%) of Pectin

Factors	Average Moisture Content			F-Ratio	CD (5%)
Drying Method	7.758	8.381	-	280.336	0.076
Temperature	7.758	7.796	8.456	113.889	0.093
pH	8.025	8.069	8.115	1.896	N/A
Int. A X B				43.937	0.131
Int. A X C				69.696	0.131
Int. B X C				9.088	0.16
Int. A X B X C				9.182	0.227



(D1= Convective hot air dryer; D2= Solar dryer; T1= 85 °C; T2= 90 °C; T3= 95 °C; P1= 1.5, P2= 2.0, P3= 2.5)

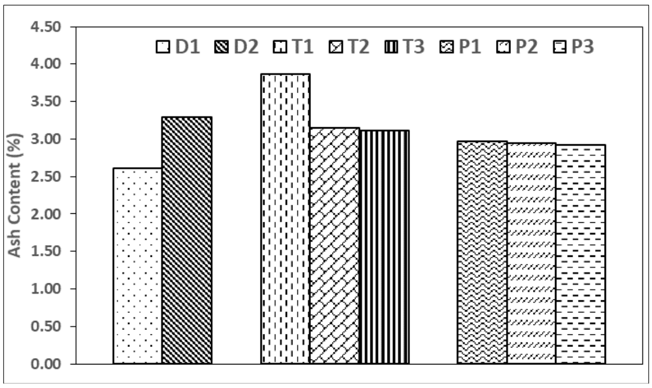
Fig 2: Effect of Drying Method, Temperature (°C), and pH on Moisture Content (%) of Pectin

4.3 Ash Content (%)

Figure 3 and Table 3 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 °C, 90 °C,95 °C) and pH (1.5,2.0,2.5) on the ash Content (%) of pectin from the jackfruit peel waste. The ash Content (%) present in the sample were in the range of 2.604-3.870%.
Ash content is also affected by the pH (1.5, 2.0, 2.5) of the extraction. The lowest ash content was observed at 2.5 pH (2.922%), and the highest ash content was observed at 1.5 pH (2.974%). The ash content of pectin by different extractions pH was significant at ($p<0.05$). The marked difference between the values attributed to the of solvent used for extraction and the purification process carried out. Isopropyl alcohol showed that the total ash content higher than other those precipitated by solvent. However, because of its decreased ash level, the pectin extracted in this study is thought to be of good quality for enhancing gel formation functionality. As a result, the use of pectin determines the desired ash content.

Table 3: Effect of Drying Method, Temperature (°C), and pH on Ash Content (%) of Pectin

Factors	Average Ash Content (%)			F-Ratio	CD (5%)
Drying Method	2.604	3.293	-	373.128	0.072
Temperature	3.110	3.150	3.870	57.882	0.089
pH	2.922	2.950	2.974	0.71	N/A
Int. A X B				79.09	0.125
Int. A X C				7.607	0.125
Int. B X C				2.515	N/A
Int. A X B X C				10.17	0.217



(D1= Convective hot air dryer; D2= Solar dryer; T1= 85 °C; T2= 90 °C; T3= 95 °C; P1= 1.5, P2= 2.0, P3= 2.5)

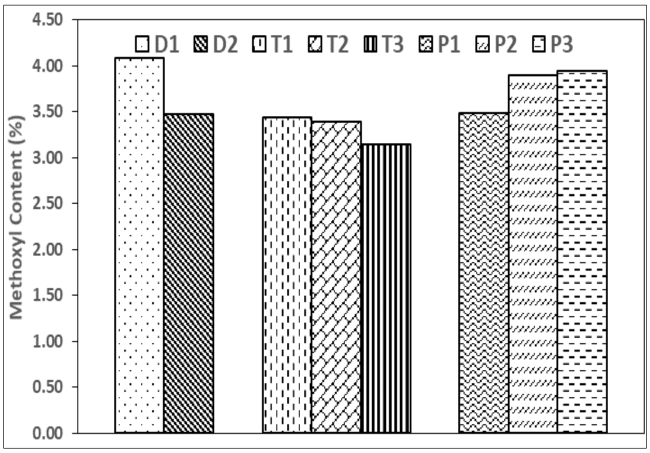
Fig 3: Effect of Drying Method, Temperature (°C), and pH on Ash Content (%) of Pectin

4.4 Methoxyl content, (%)

Figure 4 and Table 4 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 °C, 90 °C,95 °C) and pH (1.5,2.0,2.5) on the methoxyl content (%) of pectin from the jackfruit peel waste. The methoxyl Content (%) present in the sample were in the range of 3.143-4.084%.
The methoxyl content of pectin is greatly influenced by the extraction temperature; different temperature levels produced methoxyl contents in pectin ranging from 3.146 to 3.433 percent. The methoxyl content decreases as the extraction temperature rises. states that although raising the temperature and lengthening the extraction time may boost yield, increasing esters hydrolysis in the methoxylated carboxyl groups appears to reduce the methoxyls percentage, which is directly correlated with pectin quality.
The extraction pH had an impact on the methoxyl values, and it was found that the methoxyl content increased with decreasing pH. This is in contrast to the findings of who found that the methoxyl content decreased with decreasing pH, showing 1.47% at pH 2.0 (66% lower compared to that obtained at pH 3.0). Pectin's methoxy groups are preserved in low pH circumstances, which raises the methoxyl concentration. Elevated pH levels cause pectin to become demethylated, which lowers the amount of methoxyl it contains. Therefore, acidic circumstances are advantageous for high methoxyl content pectin.

Table 4: Effect of Drying Method, Temperature (°C), and pH on Methoxyl Content (%) of Pectin

Factors	Average Methoxyl Content			F-Ratio	CD (5%)
Drying Method	4.084	3.473	-	3454.56	0.021
Temperature	3.433	3.390	3.143	197.135	0.026
pH	3.487	3.899	3.949	793.57	0.026
Int. A X B				134.614	0.036
Int. A X C				232.102	0.036
Int. B X C				218.336	0.045
Int. A X B X C				291.119	0.063

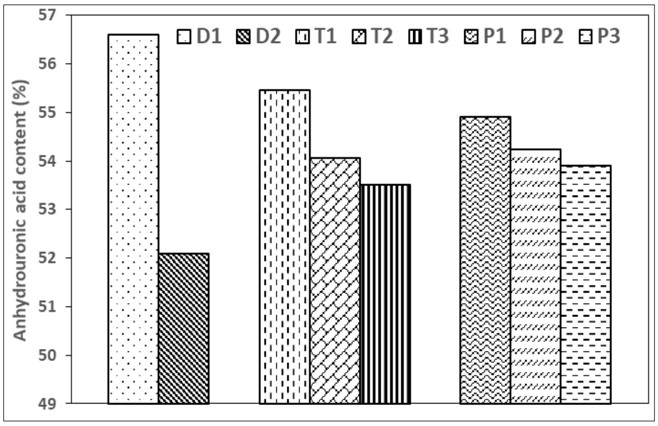


(D1= Convective hot air dryer; D2= Solar dryer; T1= 85 °C; T2= 90 °C; T3= 95 °C; P1= 1.5, P2= 2.0, P3= 2.5)

Fig 4: Effect of Drying Method, Temperature (°C), and pH on Methoxyl Content (%) of Pectin

Table 5: Effect of Drying Method, Temperature (°C), and pH on Anhydrouronic acid content (%) of Pectin

Factors	Average Anhydrouronic acid content (%)			F-Ratio	CD (5%)
Drying Method	56.607	52.085	-	44188.78	0.044
Temperature	55.46	54.068	53.51	2906.44	0.053
pH	54.898	54.235	53.905	738.181	0.053
Int. A X B				5508.87	0.076
Int. A X C				1087.54	0.076
Int. B X C				12555.62	0.093
Int. A X B X C				4608.76	0.131



(D1= Convective hot air dryer; D2= Solar dryer; T1= 85 °C; T2= 90 °C; T3= 95 °C; P1= 1.5, P2= 2.0, P3= 2.5)

Fig 5: Effect of Drying Method, Temperature (°C), and pH on Anhydrouronic acid content (%) of Pectin

4.5 Anhydrouronic acid content, (%)

Figure 5 and Table 5 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 °C, 90 °C, 95 °C) and pH (1.5,2.0,2.5) on the moisture content (%) of pectin from the jackfruit peel waste. The anhydrouronic acid content (%) present in the sample were in the range of 52.085-55.460%.

AUA of pectin significantly influenced by temperature, higher temperatures can lead to the degradation or breakdown of chemical compounds, including AUA. This might result in changes to the structural and functional properties of pectin. Higher temperatures, potentially causing hydrolysis or other thermal degradation of AUA in pectin. This can lead to a decrease in molecular weight and altered physicochemical properties, affecting its gelling or thickening abilities. Monitoring and controlling temperature during the processing or storage of pectin-containing products is crucial to maintaining the desired quality and functionality of the pectin.

pH significantly affected on the AUA at Low pH, AUA in pectin tends to increase. At low pH, the acidic environment promotes the ionization of carboxyl groups present in AUA of pectin. This ionization results in increased negative charges on the pectin molecules, which contributes to improved interactions with positively charged ions. This enhanced interaction, often through gel formation, is favorable for pectin's functionality in applications such as jams and jellies. Therefore, low pH conditions facilitate the strengthening of the gel network formed by pectin, making it more effective in providing structure and texture to products. Similar result reported by Begum *et al*. (2017) [20], who obtained anhydrouronic acid 56.11% by acid-hydrolyzed jackfruit waste pectin.

4.6 Equivalent Weight, (mg/mol)

Figure 6 and Table 6 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 °C, 90 °C,95 °C) and pH (1.5,2.0,2.5) on the moisture content (%) of pectin from the jackfruit peel waste. The equivalent Weight (mg/mol) present in the sample were in the range of 448.213-474.352%.

A higher gel-forming influence is indicated by a higher Equivalent Weight number. The equivalent weight of pectin indicates the amount of free galacturonic acid present. A higher or lower equivalent weight may be associated with the amount of free acid.

Extraction temperature significantly affected the equivalent weight of pectin, because the equivalent weight of pectin generally decreases with an increase in temperature. This is because higher temperatures can lead to increased molecular mobility, making it easier for chemical reactions to occur. As a result, the effective molecular weight of pectin decreases, leading to a lower equivalent weight.

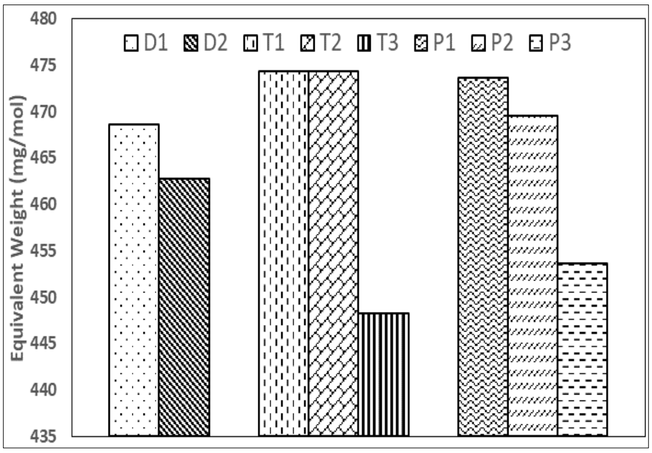
pH also significantly influenced the equivalent weight of pectin. The equivalent weight tends to decrease as the pH increases. This is because pectin molecules undergo ionization at different pH levels. At higher pH, pectin carboxyl groups are more likely to be ionized, reducing the effective molecular weight and leading to a lower equivalent weight.

Similar to the equal weight value of pectin was identified in this investigation, reported for 477.89 0.43 from citrus limetta peel; but slightly lower than, reported for 652.14 ±0.21 from kinnow peel.

Equivalent weight the equivalent weight was calculated in order to analyze the stability, emulsion potential and to assess the amount of free acid contained in the pectin molecule.

Table 6: Effect of Drying Method, Temperature (°C), and pH on Equivalent Weight (mg/mol) of Pectin

Factors	Average Equivalent Weight (mg/mol)			F-Ratio	CD (5%)
Drying Method	468.567	462.704	-	10.463	3.673
Temperature	474.352	474.341	448.213	92.574	4.499
pH	473.700	469.542	453.663	45.468	4.499
Int. A X B				18.349	6.362
Int. A X C				4.073	6.362
Int. B X C				22.409	7.792
Int. A X B X C				11.951	11.02



(D1= Convective hot air dryer; D2= Solar dryer; T1= 85 °C; T2= 90 °C; T3= 95 °C; P1= 1.5, P2= 2.0, P3= 2.5)

Fig 6: Effect of Drying Method, Temperature (°C), and pH on Equivalent Weight (mg/mol) of Pectin

4.8 Degree of Esterification, (%)

Figure 7 and Table 7 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 °C, 90 °C,95 °C) and pH (1.5,2.0,2.5) on the degree of esterification (%) of pectin from the jackfruit peel waste. The degree of esterification (%) present in the sample were in the range of 30.580-34.913(%)

The DE is highly influenced by temperature; a high temperature indicates a low DE. There was a high equivalent weight of the pectin extracted at low temperature. The findings showed that while pectin output increased with increasing extraction temperature, equivalent weight dropped. This could be the result of pectin partially breaking down. Comparable findings revealed that there was little DE in the pectin derived from jackfruit waste material (Garna *et al*., 2007) [18]. Lower DE pectin was obtained by raising the temperature of pectin extraction using hydrochloric acid at pH 2.5 from 50 to 95 °C. The hydrolysis of acetic acid groups from galacturonic acids under extreme extraction conditions could be the cause of this.

This study showed that there was additional deesterification of pectin during extraction as a result of temperature rise, since higher temperatures provide more thermal energy available to hydrolyze ester bonds. Previous research on citrus peels revealed similar findings.

The pH has a significant impact on DE; when pH rises, there are insufficient H+ ions to de-esterify pectin during extraction, which is indicated by a sharp increase in DE up to pH 2.5 and a gradual increase up to pH 3.7. Consequently, the DE value rises with increasing pH and falls with decreasing pH. Because more thermal energy is available to hydrolyze the ester bonds at higher temperatures, this study demonstrated that there was increased de-esterification of pectin during extraction. Similar results were found in earlier research on citrus peels, mango peels and banana peels.

Table 7: Effect of Drying Method, Temperature (°C), and pH on Degree of Esterification (%) of Pectin

Factors	Average Degree of Esterification (%)			F-Ratio	CD (5%)
Drying Method	34.913	32.891	-	15615.21	0.033
Temperature	34.777	34.470	30.580	1020.23	0.04
pH	33.652	33.710	34.344	751.786	0.04
Int. A X B				2881.17	0.057
Int. A X C				16.628	0.057
Int. B X C				3448.11	0.07
Int. A X B X C				1727.11	0.098

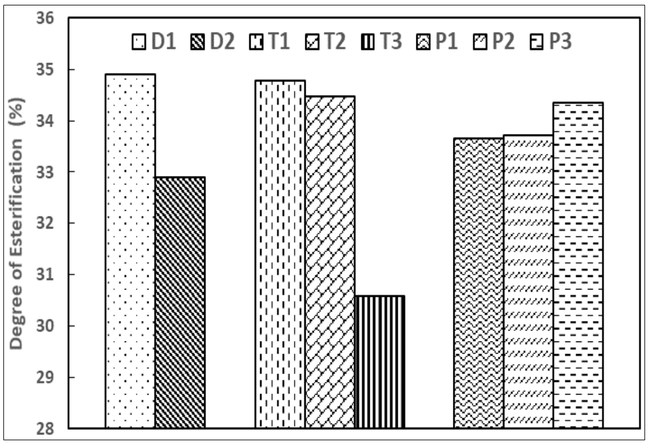


Fig 7: Effect of Drying Method, Temperature (°C), and pH on Degree of Esterification (%) of Pectin

4.8 Galacturonic acid content, (%)

Figure 8 and Table 8 shows the effect of drying method (Convective hot air dryer and solar dryer), extraction condition i.e. temperature (85 °C, 90 °C,95 °C) and pH (1.5,2.0,2.5) on the galacturonic acid content (%) of pectin from the jackfruit peel waste. The galacturonic acid content (%) present in the sample were in the range of 42.140-45.347%

One of the most crucial characteristics of pectin that determines its purity is its GalA content. The FAO recommends that GalA values of pectin should be higher than 65% to be accepted as a food additive and for pharmaceutical purposes.

As pH drops and temperature rises, galacturonic acid levels rise. Fraeye *et al.* (2009) [8] suggested that this might be explained by the side chains of pectin sugar hydrolyzing more quickly in an acidic environment. According to Garna *et al*. (2007) [18], chemical hydrolysis of pectin with acid at a high temperature (100 °C) appears to combine two simultaneous phenomena: the release of sugars as a byproduct of pectin hydrolysis, and the subsequent destruction of those sugars due to the combined effects of heat and acid. They demonstrated that the breakdown of the side chains of pectin sugar occurred less frequently at 80 °C than at 100 °C.

Similar findings were reported by Chan (2013) [15]. Pectin with a greater galacturonic acid concentration was obtained by raising the extraction temperature while employing hydrochloric acid at pH 2.5 or citric acid at pH 4.0. According to Garna *et al*. (2007) [18], when apple pectin was extracted using sulfuric acid at pH 1.5 or 2.0, the amount of galacturonic acid that was recovered was always larger at 90 °C than at 80 °C.

Table 8: Effect of Drying Method, Temperature (°C), and pH on Galacturonic acid content (%) of Pectin

Factors	Average Galacturonic acid content (%)			F-Ratio	CD (5%)
Drying Method	45.347	42.140	-	10.308	2.026
Temperature	42.814	43.685	44.732	1.232	N/A
pH	44.917	43.965	42.349	2.252	N/A
Int. A X B				4.103	3.509
Int. A X C				0.649	N/A
Int. B X C				2.130	N/A
Int. A X B X C				1.438	N/A

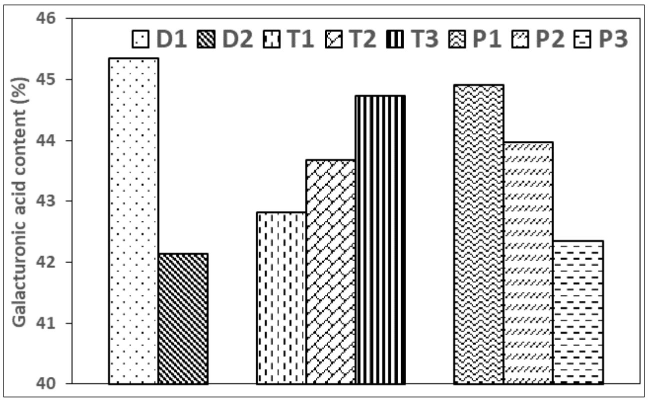


Fig 8: Effect of Drying Method, Temperature (°C), and pH on Galacturonic acid content of Pectin

5. Conclusion

Following conclusion can be drawn from the present study.

1. The rind of fully ripe jackfruit were procured for experimentation from the Roha and Kolad Local market. The rind was washed with tap water to remove dirt, dust adhered. The surface moisture of the jackfruit rind removed with the help of muslin cloth. The rinds were cut into small pieces of 4 mm thickness. Then the cut pieces of jackfruit rind were dried in (a) Convective hot air dryer at 50 °C and (b) solar dryer. The rind were dried in a thin layer in a convective hot air dryer at 50 °C ±1 °C.
2. Pectin extraction form Acid extraction method, the temperature 85 °C showed the best result where yield (7.569%), moisture content (7.758%), ash content (3.110%), methoxyl Content (3.433%), anhydronic acid (55.460), equivalent weight (474.362), degree of esterification (34.777), galacturonic acid (44.732).
3. Pectin extraction form Acid extraction method, the1.5 pH showed the best result where yield (9.450%), moisture content (8.025%), ash content (2.922%), methoxyl Content (3.949%), anhydronic acid (54.898), equivalent weight (473.700), degree of esterification (34.344), galacturonic acid (44.917).

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