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Effect of maturity levels and blanching temperature on extraction of pectin from jackfruit rags and study its properties

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Abstract

In the present investigation effect of different maturity stage i.e. Middle stage (5 to 13 week) and Ripe (14 to 18 week) and different blanching temperature (75 °C, 85 °C and 95 °C) on extraction of jackfruit rags pectin was carried out. The result indicated that blanching as a pretreatment plays a significant role $p \leq 0.05$. Thus, the middle stage jackfruit and blanched sample at 95 °C for 5 min given favorably higher values in terms of tested properties and yields. The Yield (16.179%), Moisture content (8.518%), Ash content (1.249%), pH (5.338), Methoxyl content (3.849%), Anhydronaunic acid (55.035%), Equivalent weight (483.325 mg/mol), Degree of esterification (39.662%), Galucteronic acid (62.267%) and Intrinsic viscosity (2.856 dL/g). Jackfruit rags is better source of pectin at middle stage and 95 °C blanching as pretreatment. Thus, sourcing pectin from natural fruit rags like jackfruit waste could also add economic value to the rural economy and promote sustainable development.

Keywords: Pectin, jackfruit rags, maturity, blanching, yield, methoxyl content, anhydrouronic acid, equivalent weight, degree of esterification, galacturonic acid, intrinsic viscosity

Introduction

The jackfruit (*Artocarpus heterophyllus*) is a large, edible tropical fruit that grows on trees, is a member of the *Moraceae* family. The fruit has an abundance of nutrients, including vitamins, flavonoids, protein, minerals, antioxidants, and digestible starch, which makes it a nutritious food option. Particularly in humid, wet coastal areas with high yearly rainfall, jackfruit can be found. India produces the highest jackfruit followed by Bangladesh, which comes second and claims jackfruit as its national fruit. The jackfruit industry is also important in Nepal, Thailand, and Indonesia. If jackfruit isn't consumed right away or preserved, it will quickly spoiled. It is a crop that is underutilized, but because of its nutritional advantages, demand has grown recently. According to reports, between 25 and 35 percent of jackfruit are utilized for human consumption, while 75 to 65 percent of the fruit is wasted. This fruit's non-edible parts include the peel, rags, and the center core (Pathak *et al.* 2022) [51].

Subburamu *et al.* (1992) [62] reported the distribution of jackfruit waste, outer prickly rind (54%), inner perigones (non-edible perianth), and central core (6%), which are unutilized waste, make up 60% of the fruit. Jackfruit peel is currently not being used for any value-added processes, making it available for disposal as solid waste. This is owing to limited research efforts focusing on potential conversion of the waste into other valuable items. But the outer peel, which is mainly fibrous and rich in calcium and pectin, makes up the majority of the mature fruit, or about 59% of it. When jackfruit is processed, rags-a latex-like filament found outside the jackfruit bulb-are used as a by-product. Its composition is as follows: 19.77% carbohydrates, 20.5% cellulose, 0.3-0.6% protein, 1.76-4.50% reducing sugar, and 1.3-6.8% total sugar (Dam and Nguyen, 2012) [10]. Fruit cell walls, which include pectin, are primarily made of polysaccharides. A large portion of the pectin undergoes a transformation during ripening from a water-insoluble form to a soluble one by certain degrading enzymes (Duan *et al.*, 2008) [14].

Complex polysaccharides called pectins are found in the cell wall, particularly in the middle lamella. Homogalacturonan (HG), a linear polymer consisting of d-galacturonic acids (GalAs) connected by α-1,4 glycoside linkages, is the main constituent of pectins. A methyl-esterified carboxyl group is present in certain GalAs containing HG units, and they aid in the development of intra- and intermolecular pectin networks (Zhan *et al*., 1998) [76]. Low-methyl-esterification pectin, for instance, forms a gel by connecting intra- and intermolecularly via Ca2+ (Thibault and Rinaudo, 1985) [66]. As a result, the cell wall gets stronger. However, pectin hydrolysis and β-elimination are caused by heating in solution and the actions of enzymes including pectin methylesterase (PME), polygalacturonase (PG), and pectin lyase (PL), which soften the cell wall (Sila *et al*., 2009) [60]. Prior work shows changes in pectin and softening caused by blanching (Imaizumi *et al*., 2017; Wang *et al*., 2018) [23, 73].

The amount of pectin in a fruit depends on its maturity level and the type of fruit, the under ripe fruits contains more pectin than ripe fruits, for half ripe fruits, the fruit peel is more tender, making the pectin more accessible for extraction. The amount of pectin decreases as the fruit ripens, and the pectin changes into non-gelling form. As the fruit ripens the enzymes like polygalacturonase, pectin methyl esterase and pectate lyase breakdown the pectin chain, which may decrease the yield of pectin. The texture of plant foods can be attributed to the structure and chemical composition of the cell wall, the middle lamella, and to the turgor generated within leaving cells by osmosis (Jackman and stanley, 1995) [27]. Metabolic changes involving modification of these structural elements will influence tissue mechanical properties. For many fruit species, it has been observed the post harvest ripening is generally accomplished by increased pectin solubility and non glucose neutral sugar losses, probably arrising from pectic polysaccharides (Gross and Sams, 1984; Redgwell *et al*., 1992) [22, 54].

Nidhina *et al*., 2003 [45] reported that when the fruit become older, the yield of jackfruit pectin increased from stage I (0-3 weeks) i.e. 9.7%. to stage IV (13-17 weeks) i.e. 21.5% also the functional properties of jackfruit pectin were similar to commercial apple pectin. Blanching is a unit operation being used prior to freezing, canning or drying in which fruits and vegetables are heated for the purpose of inactivation of enzymes, modifying texture, preserving colour, flavour and nutritional value and removing trapped air. Hot water blanching and steam blanching are the most commonly used methods. This helps to cleanse the surface of food, brightness the colour, retard loss of vitamin, soften vegetables and make them easier to pack.In case of pectin extraction substantial losses in yield as well as quality of pectin were observed during drying of pomace. Blanching treatment before drying is an effective method for shortening drying time an inactivation of undesirable enzymes (Wang *et al*. 2021) [72]. Primary objective of the blanching treatment was to inactivate enzymes that deteriorate products during processing and storage in addition, this treatment improve the drying time because the cell membrane break and the moisture–moving rate is enhanced (Shinde *et al*., 2024) [58].

Generally blanching is done using hot water temperature above 80 °C, various researchers has used blanching and suggested and effective technique for extraction of pectin from Mango peel, Carrots, Apple pomace by Geerkens *et al*. 2015 [19]; Lo *et al*. 2002 [34]; Sharma *et al*. 2015 [57] respectively. Blanching the material before drying is one efficient way to reduce drying time (Wang *et al*., 2021) [72]. The main goal of the blanching treatment, which is often applied with hot water that is above 80 °C, is to inactivate enzymes that may cause items to deteriorate during processing and storage (Imaizumi *et al*., 2017) [23]. Furthermore, this treatment improves the drying period by breaking cell membranes and increasing the rate at which moisture is moved (Ando *et al*., 2016; Arévalo-Pinedo and Murr, 2006) [1, 3]. Because blanching increases the quantity of galacturonic acid, pectin purity is improved (Geerkens *et al*., 2015) [19].

Materials and Methods

Jackfruit waste requited for experimentation was utilized from the jackfruit waste collected at Department of Post Harvest Engineering, P.G. Institute of Post Harvest Technology and Management, Killa – Roha. The jackfruit waste from fresh cleaned undamaged fruits was taken for the experiments. The bulbs and seeds are edible portions and hence removed. The 60% of the fruit part of Jackfruit is inedible consisting of the outer prickly rind (54%), inner perigones (nonedible perianth) and central core (6%), which are unutilized waste. The bulbs and seeds are edible portions and hence removed.

Sample preparation

Fig.1 (a) shows the Middle jackfruit Rags (at maturity 5 to 13 weeks) of 3 mm thickness was takes into 5 liters vessel. The sample shreds to water ratio was 1:5. The Blanching of the tender jackfruit Rags was carried out in autoclave at 75, 85 and 95 °C separately for 5 minutes and the sample was taken out and cooled at room temperature and are dried at 50 °C 12 to 14 hours and grounded for particle size 0.5 mm in a pulverizer.

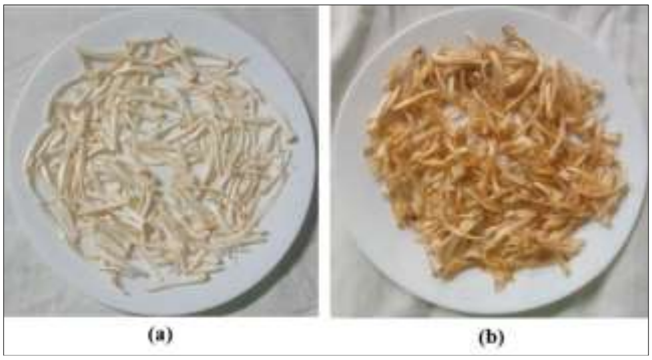


Fig 1: (a) Middle Stage Jackfruit Rags, (b) Ripe Stage Jackfruit Rags

Fig.1 (b) Shows the jackfruit Rags at ripe stage (at maturity 14 to 18 weeks) of 3 mm was taken for the study and similar procedure as presented above was exposed for blanching at 75, 85, 95 °C for 5 minutes separately and dried the sample at 50 °C for 12 to 14 hours and grounded to a particle size 0.5 mm was used for pectin extraction.

Extraction Process

Extraction of pectin from jackfruit Rags was done as per procedure of Nurdjanah *et al*., (2013) [47]. Samples (10 g) of dried jackfruit Rags powder separately were dispersed in 150 mL 0.1 M HCl. The dispersion was stirred for 10 min and kept in water bath at temperature 85 °C and at pH level of 1.5 for 60 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 a tray dryer, ground, and then stored at normal atmospheric temperature in polyethylene pouches (300 gauge).

Physio-chemical Parameters for determination of the quality of pectin

1. Yield of Pectin, (%)

The yield of pectin prepared for both maturity levels of jackfruit Rags (i.e. Middle stage and Ripe stage) and at various blanching temperature (75, 85 and 95 °C) were determined as per the procedure of Lin *et al*. (2018) [33]. The pectin yield based on the total Rags used for extraction was calculated using the Eq (1).

$$\text{Pectin Yield} = \frac{\text{Weight of dried pectin (g)}}{\text{Initial weight of dried jackfruit rind powder (g)}} \times 100 \quad (1)$$

2. Moisture content, (% db):

According to AOAC (2010), Pectin (1 g) prepared for both maturity levels of jackfruit Rags (i.e. Middle and Ripe) and at various blanching temperature (75, 85 and 95 °C) were weighed, using the hot air oven method, the moisture content was measured over a 24-hour period at 105 °C±1 °C. After a full day, the dried pectin sample's final weight was noted. Using the following formula Eq (2), the moisture content of the dried pectin was calculated.

$$\text{Moisture Content (\% db)} = \frac{w_2 - w_1}{w_3 - w_1} \times 100 \quad (2)$$

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. Ash content, (%)

For ash content, 1 g of pectin prepared for both maturity levels of jackfruit Rags (i.e. Middle and Ripe) and at various blanching temperature (75, 85 and 95 °C) were weighed in a crucible and then incinerated in a Muffle furnace at 550° for four hours. The residue was cooled in a desiccator and weighed. Ash were determined by AOAC (Association of Official Analytical Chemists 2010) [2]. Ash content was determined as per the following formula (3);

$$\text{Ash content (\%)} = \frac{\text{Weight of crucible with ash} - \text{weight of crucible}}{\text{weight of sample in g}} \times 100 \quad (3)$$

4. Determination of pH

The pH for the extracted pectin sample using various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) was determined according to the methods of (AOAC 2010) using a digital pH meter (A standard pH meter). Exactly 1 gram of pectin was added to 10 ml of distilled water in a beaker. The pH was measured by direct immersion of the electrode into the sample. A digital pH meter (LAB India Instruments Pvt. Ltd., Mumbai) was used. pH meter was calibrated before use with a standard buffer solution at 30°C each day before use buffer solutions of pH 4.0 and 7.0 were used to standardize the pH meter, and pH measurements were carried out in duplicate.

5. Equivalent weight (%)

Equivalent weight for pectin sample obtained from various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) were used for determination of Equivalent weight (%) as per the procedure Ranganna's (1986) [53]. Pectin sample (0.5 g) was weighed into 250 ml conical flask and moistened with 5 ml ethanol. A 1.0 g NaCl was added to the mixture followed by addition of 100 ml distilled water and to this aliquot 6 drops of phenol red indicator was added. The solution was titrated with 0.1 M NaOH to an end point where pink colour was obtained.

Equivalent weight determined for various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) were used for the determination of anhydrouronic acid (AUA) and the degree of esterification (DE).

Equivalent weight was calculated by following formula (4).

$$\text{Equivalent weight (\%)} = \frac{\text{Weight of sample (g)} \times 1000}{\text{Volume of alkali} \times \text{Normality of alkali}} \quad (4)$$

6. Methoxyl Content (MeO) (%):

Methoxyl content (MeO) of pectin sample obtained from various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) were determined as per the method described by Girma and Worku (2016) [21]. This was done using the neutralized solution from equivalent weight determination (Eq 4), by the saponification of pectin followed by titration of the liberated acid. 25 ml of 0.25 M NaOH was added to neutralize solution which was used for determination of equivalent weight was used and the mixture was stirred thoroughly and allowed to stand for 30 min at room temperature. A 25 ml of 0.25 N HCL was added to it and titrated with 0.1 N NaOH. The end point for the solution was brown colour was obtained. The methoxyl content (MeO) was determined as per the following formula (5)

$$\text{Methoxyl Content\%} = \frac{\text{ml of alkali} \times \text{Normality of Alkali} \times 3.1}{\text{Weight of sample pectin (g)}} \quad (5)$$

7. Anhydrouronic Acid content (AUA) (%):

The Anhydrouronic acid content (AUA) was determined for the pectin obtained from various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) by using the formula (6) that was reported in the literature by Mohamed and Hasan 1995 [39]. The alkali milli-equivalents from equivalent weight and methoxyl content were taken to calculate anhydrouronic acid (AUA) content for the various samples of maturity levels of jackfruit Rags (i.e. Tender, Middle and Ripe stage) and at various temperature (75, 85 and 95 °C). The anhydrouronic acid (AUA) was determined as per the following formula (6)

$$\% \text{ of AUA} = \frac{176\times 0.1z\times 100}{w\times 1000} - \frac{176\times 0.1y\times 100}{w\times 1000} \qquad (6)$$

When molecular unit of AUA (1 unit) = 176 g
Where,
z = ml (titre) of NaOH from equivalent weight determination.
y = ml (titre) of NaOH from methoyl content determination.
w = Weight of sample, g

8. Degree of Esterification (DE), (%)

The degree of esterification for all pectin samples determined for the various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) were determined as per the procedure Daud *et al*., 2019 [12]. The DE of extracted pectin calculated from methoxyl and anhydrouronic acid content as per the following equation descried (7).

$$\% \text{ DE } = \frac{176\times \%\text{MeO}}{31\times \%\text{ AUA}} \times 100 \qquad (7)$$

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

9. Galacturonic acid, (%)

The galacturonic acid (GalA) content for all pectin samples determined for the various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) 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 [13]; Filisetti-Cozzi and Carpita, 1991 [16]; Galambos 1967 [17]; Li *et al*., 2007 [32]. 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 ◦C. 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: M/S Labindia Analytical, India).

10. Intrinsic viscosity, (dl/g)

The viscosity of pectin extracted from jackfruit waste from various treatments of maturity levels of jackfruit Rags (i.e. Middle and Ripe stage) and at various temperature (75, 85 and 95 °C) was determined using an Ostwlad capillary viscometer (Make: Physilab, India) using Iglesias and Lozano, 2004 procedure. The specific viscosity (η_{sp}) was measured by recording pectin solution flow time in an Ostwlad capillary viscometer at 25±0.1 °C. The temperature was maintained by immersing the viscometer in a temperature-controlled water bath. Different concentrations of pectin solutions (0.005–0.02 g/L) were prepared in an aqueous solution with continuous stirring at room temperature. Pectin solutions and solvent were filtered using 0.45 µm membrane filters before viscosity was measured. The relative viscosity (η_{rel}) was measured from the ratio of the viscosity of the solvent (5.844 g/L NaCl) and that of the pectin solution. The intrinsic viscosity (η) was estimated from the relative viscosity of pectin solutions by extrapolation of Kraemer and Huggins curves to zero concentration (Kraemer, 1938 and Billmeyer, 1984) [29, 7].

Optimization of the maturity levels and blanching temperature for jackfruit rags

The desirable properties of jackfruit rags pectin are the pectin should have higher yield (%), lower moisture content (%), higher ash content (%), higher pH, higher methoxyl content (%), lower anhydrouronic acid (%), higher equivalent weight (mg/mol) and higher intrinsic viscosity (dL/g).

Stastistical Analysis

Two jackfruit maturity (Middle and Ripe), three blanching temperature (75, 85 and 95 °C) for jackfruit part Rags were used in the experiment. Completely Randomized Design (CRD) was used to statistically analyse the experimental data. Significant changes between treatment means at a 5% level of significance allowed for drawing of valid finding. This was done as per the procedure of Panse and Sukhatme, (1954) [49]. The yield, moisture content, ash content, pH, methoxyl content, anhydrouronic acid, equivalent weight, degree of esterification, galacturonic acid, intrinsic viscosity and other physical and chemical parameters of the pectin samples were noted along with the changes in these parameters.

Results and Discussion

1. Yield (%)

Figure 2 (a) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 °C, 85 °C and 95 °C) on yield (%) of jackfruit rags pectin. The yield of rags pectin ranged between 10.829±0.058 to 16.179±0.056%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin yield (%) varied from 13.171±0.054 to 10.829±0.058%; 14.611±0.004 to 11.506±0.061%; 16.179±0.056 to 13.17±0.013% at blanching temperature 75 °C, 85 °C and 95 °C respectively. Lower jackfruit rags pectin yield (%) was observed at ripe stage (10.829±0.058 to 13.17±0.013%), highest jackfruit rags pectin yield (13.171±0.054 to 16.179±0.056%) was observed at middle stage, for all the blanching temperature which can be seen from Fig.2 (a). As the blanching temperature varied from 75 °C to 95 °C the jackfruit rags pectin yield (%) was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on yield (%) of jackfruit rags pectin was showing increasing trend followed by decreasing which can be seen from Fig.2 (a). Effect of maturity level on yield (%) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on yield (%) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on yield (%) of jackfruit rags pectin was also significant at $p \leq 0.05$.

According to Islam *et al*. (2023) [25], the yield of pectin from jackfruit tandem is 28.21±0.34%, which is higher than what the experiment revealed. The reduced pectin yield percentage could be caused by the type of fruit and the development conditions (Shamseera *et al*., 2022) [56]. A larger yield might be obtained by adjusting for temperature, time, pH, solubilizing agents, and availability of cell wall breakdown into smaller pectin particles during the extraction process (Begum *et al*., 2014; Sundarraj *et al*.,

2018) [5, 63]. When utilizing microwave assistance for extraction, the yield of pectin from jackfruit rags might vary between 12.92 and 29.63%. (Tran *et al*., 2023) [68].

Fruit's pectin production may drop as it ripens because pectin is broken down by enzymes such as pectate lyase (PL), polygalacturonase (PG), and pectin methyl esterase (PME) (Otu *et al*., 2024) [48]. Verma (1965) [70] studied effect of growth and maturity of two varieties of guava (Safeda Alahabad and Red flesh) on yield of pectin. They picked fruits at weekly interval (1st week to 9th week) from fruit set to slightly advance stage to maturity. The increase in the total pectin content in Safeda Allahabad yield range from 0.59% to 1.10% while the lower pectin yield (0.59%) was observed at 1st week, the highest pectin yield (1.10%) was observed in 8th week followed by 9th week (0.69%). Similarly, Red-Fleshed ranged from 0.43% to 1.07%. Further, there was an abrupt decrease in the total pectin content after attaining the peak.

Pectin yield and quality losses can be minimized by blanching prior to drying. Blanching renders pectinolytic enzymes inactive, which prevents pectin from being broken down (Sharma *et al*., 2015) [57]. Blanching treatment aim to inactivate enzymes that deteriorates products during processing and storage in addition, this treatment improves the drying time because of cell membrane rupture and enhance moisture movement rate during drying (Shinde *et al*., 2024) [58]. Effect of blanching on extraction yield of fruit pectin reported in the literature was higher than the unblanched peel, i.e. for apple peel it was (11%) for hydrochloric acid extraction for blanched compared with (6.75%) with unblanched; apple peel nitric acid extraction (11.75%) for blanched and (5.17%) for unblanched. Blanching imparts higher yield compared with unblanched peels (Kumar *et al.,* 2020) [30]. Zielinska *et al.,* 2022 [77] reported the highest yield (5.7±0.4%) of pectin in okra pods for high-humidity hot air impingement blanching for 60sec, compared with unblanched (3.6±0.3%) yield.

2. Moisture (%db)

Figure 2 (b) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 ℃, 85 ℃ and 95 ℃) on moisture (%db) of jackfruit rags pectin. The moisture of rags pectin ranged between 8.518±0.048 to 9.694±0.060%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin moisture (%db) varied from 8.888±0.034 to 9.694±0.060%; 8.612±0.012 to 9.56±0.056%; 8.518±0.048 to 9.300±0.020% at blanching temperature 75 ℃, 85 ℃ and 95 ℃ respectively. Lower jackfruit rags pectin moisture (%db) was observed at middle stage (8.518±0.048 to 8.888±0.034%), highest jackfruit rags pectin moisture (9.3±0.020 to 9.694±0.060%) was observed at ripe stage, for all the blanching temperature which can be seen from Fig.2 (b). As the blanching temperature varied from 75 ℃ to 95 ℃ the jackfruit rags pectin moisture (%db) was decreased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on moisture (%db) of jackfruit rags pectin was showing decreasing which can be seen from Fig.2 (b). Effect of maturity level on moisture (%db) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on moisture (%db) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on moisture (%db) of jackfruit rags pectin was also significant at $p \leq 0.05$.

Islam *et al*. (2023) [25] reported that the pectin recovered from the tandem or rags had a moisture level of 10.94±0.43%. The IPPA (2014) [24] rules state that pectin with a moisture content of ≤ 12% is acceptable. In this experiment, the moisture levels of the pectin that was extracted from jackfruit rags within the permissible range. The moisture content of food products is a critical factor influencing their durability, as it correlates with microbial activity in stored items. Food products with less moisture content exhibit greater stability and extended shelf-life compared to those with high moisture content (Susanti, 2021) [64]. The moisture levels in the lemon pomace samples ranged from 11.49±0.55 to 13.40±0.79% at different maturity stages (Pre-mature, Mature and Over-ripe), as reported by Azad *et al.,* (2014) [4]. Similar findings were presented by Ismail *et al.,* (2012) [26], who noted a moisture content range of 11.13 to 11.33% in dragon fruit pectin. It was observed that premature samples had lower moisture content than over-ripened ones. It is important to consider that high moisture content could promote the growth of microorganisms and the production of pectinase enzymes, which could impact the quality of the pectin (Muhamadzadeh *et al.,* 2010).

According to More and Khodke (2023) [40], blanching can reduce moisture content, particularly when done over prolonged periods of time. This is because cellular fluid may seep out of broken cell membranes due to the heat generated during blanching. Tadesse *et al.,* (2023) [65] reported the effect of blanching on moisture content of Dawrach leaf was lower than the unblanched dawrach leaf. The moisture of unblanched dawrach leaf was 10.77±0.40% and blanched dawrach leaf moisture varied from 7.69±0.15 to 9.99±0.40% at 50 ℃, 60 ℃, 70 ℃, 80 ℃ and 90 ℃ blanching temperature. Lower moisture content was observed at 90 ℃ (7.69±0.15%) while higher moisture content observed at 50 ℃ (9.99±0.40).

3. Ash (%)

Figure 2 (c) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 ℃, 85 ℃ and 95 ℃) on ash (%) of jackfruit rags pectin. The ash of rags pectin ranged between 1.249±0.051 to 1.782±0.011%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin ash (%) varied from 1.393±0.025 to 1.782±0.011%; 1.256±0.052 to 1.652±0.057%; 1.249±0.051 to 1.457±0.055% at blanching temperature 75 ℃, 85 ℃ and 95 ℃ respectively. Lower jackfruit rags pectin ash (%) was observed at middle stage (1.249±0.051 to 1.393±0.025%), highest jackfruit rags pectin ash (1.457±0.055 to 1.782±0.011%) was observed at ripe stage, for all the blanching temperature which can be seen from Fig.2 (c). As the blanching temperature varied from 75 ℃ to 95 ℃ the jackfruit rags pectin ash (%) was decreased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on ash (%) of jackfruit rags pectin was showing decreasing trend which can be seen from Fig.2 (c). Effect of maturity level on ash (%) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on ash (%) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on ash (%) of jackfruit rags pectin was also significant at $p \leq 0.05$.

According to Islam *et al*. (2023) [25], the ash level of tandem or rags pectin was 1.30±0.17%. This indicates that the pectin contains accessible inorganic minerals such as potassium, sodium, magnesium, and iron. When pectin has low ash content, it can be regarded as pure, superior grade, and capable of gelling (Begum *et al*., 2014) [5]. Many studies, using various extraction solvents, revealed varying ash contents of the pectin from various fruit by-products, such as pomelo peel: 3.4 to 5.4% (Gamonpilas *et al*., 2021) [18], mango peel: 3.53% (Valdivia-Rivera *et al*., 2021) [69] and jackfruit waste: 3.71 to 8.15% (Begum *et al*., 2014) [5].

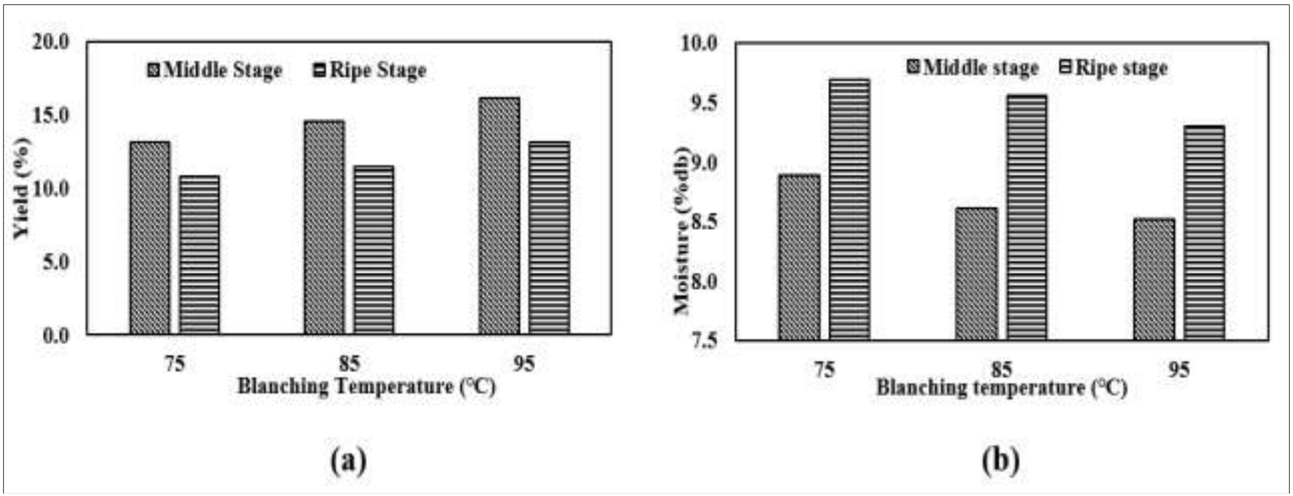
When the pectin output declines, the ash content rises, suggesting that the fruit's ripening has caused a major increase in sugar and other constituents. In terms of food grade, high quality pectin has an ash concentration range of 1% to 10%. As a result, the experiment's ash content reveals the pectin's purity. The pectin isolated from bael fruit has an ash concentration of 1.24%. Ash content rises as pectin yield declines, showing that fruit ripening has caused a large increase in sugar content and other constituents (Maskey *et al*., 2018) [37].

According to Manzoor *et al*. (2019) [35], when the drying temperature increased, the ash content of both blanched and unblanched dried green beans dropped considerably ($p \leq 0.05$) from 4.87-4.33% and 4.41-3.96%, respectively. This lower ash content at high temperatures could be the result of micronutrients degrading at high drying temperatures. Reis *et al*. (2013) [55], who investigated the impact of drying temperatures on the nutritional and antioxidant characteristics of cumari peppers (Chinese capsicum), also discovered a similar tendency. Compared to unblanched dried samples, blanched dried samples had a considerably ($p \leq 0.05$) decreased ash content; this impact may have resulted from the minerals in the samples moving to the boiling water (Nnamani *et al*. 2009) [46].

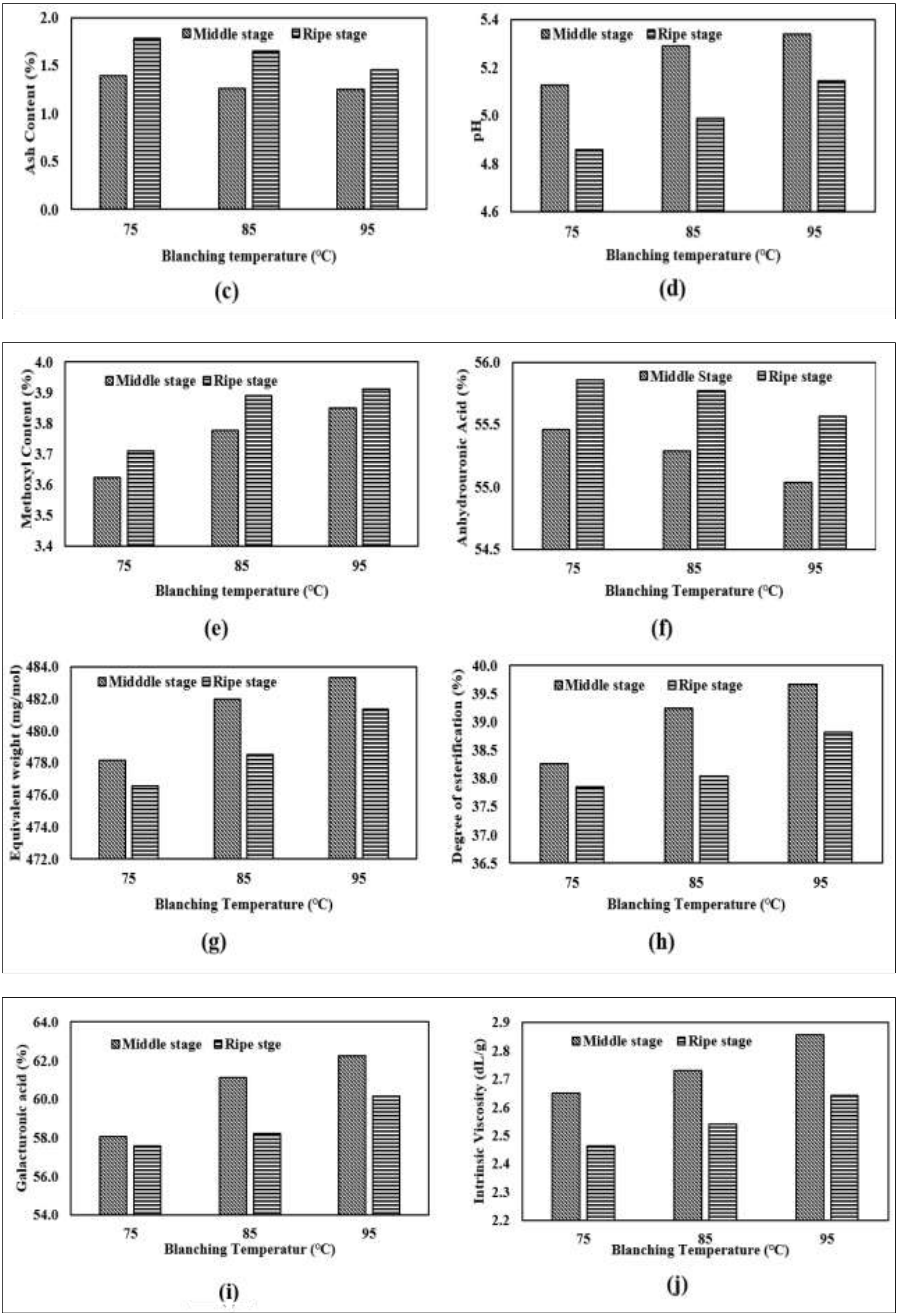
4. pH

Figure 2 (d) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 °C, 85 °C and 95 °C) on pH of jackfruit rags pectin. The pH of rags pectin ranged between 4.857±0.031 to 5.338±0.041; As maturity varied from middle stage to ripe stage the jackfruit rags pectin pH varied from 4.857±0.031 to 5.126±0.027; 4.989±0.005 to 5.29±0.008; 5.145±0.036 to 5.338±0.041 at blanching temperature 75 °C, 85 °C and 95 °C respectively. Lower jackfruit rags pectin pH was observed at ripe stage (4.857±0.031 to 5.145±0.036), highest jackfruit rags pectin pH (5.126±0.027 to 5.338±0.041) was observed at middle stage, for all the blanching temperature which can be seen from Fig.2 (d). As the blanching temperature varied from 75 °C to 95 °C the jackfruit rags pectin pH was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on pH of jackfruit rags pectin was showing increasing which can be seen from Fig.2 (d). Effect of maturity level on pH of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on pH of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on pH of jackfruit rags pectin was also significant at $p \leq 0.05$. According to Tran *et al*. (2023) [68], 1.35 was the optimized pH for pectin extraction from jackfruit rags by microwave heating. According to Almeida and Huber (1999), the pH of the apoplastic fluid in tomato fruit drops from 6.7 in immature stages to 4.4 in fully ripe fruit. Reported that the pH of jackfruit ranges from 4.70 to 5.72. The pH value was lowest in the unripe jackfruit and increase significantly during the ripening stages, followed by a significant decrease at full ripe stage.

Fresh turnip greens, without blanching or freezing, had pH values ranging from 6.27 to 6.33. After being blanched for 1 minute, the pH values slightly increased to 6.56±0.05. This rise in pH could be attributed to a greater extraction of soluble compounds during blanching and the loss of organic acids in the blanching water (Martínez *et al*., 2013) [36]. Pervin *et al*., (2017) [52] reported that the pH of unblanched pea was 7.08. Blanched pea pH ranged between 7.12 to 7.29 at 80 °C for 1 min to 7 min, the pea were blanched at 80 °C for 7 min was highest pH (7.29) and lower pH (7.12) was observed at 80 °C for 1 min.



(a) (b)



(c) (d)

(e) (f)

(g) (h)

(i) (j)

Fig 2: Effect of Maturity Level and Blanching Temperature on (a) yield (%), (b) Moisture (% db), (c) Ash (%), (d) pH, (e) Methoxyl content (%), (f) Anhydrouronic Acid (%), (g) Equivalent weight (mg/mol), (h) Degree of esterification (%), (i) Galacturonic acid (%) and (j) Intrinsic Viscosity (dL/g) of Jackfruit Rags pectin

5. Methoxyl content (%)

Figure 2 (e) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 °C, 85 °C and 95 °C) on methoxyl content (%) of jackfruit rags pectin. The methoxyl content of rags pectin ranged between 3.624±0.010 to 3.912±0.04%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin methoxyl content (%) varied from 3.624±0.010 to 3.709±0.011%; 3.776±0.006 to 3.890±0.005%; 3.849±0.007 to 3.912±0.04% at blanching temperature 75 °C, 85 °C and 95 °C respectively. Lower jackfruit rags pectin methoxyl content (%) was observed at middle stage (3.624±0.010 to 3.849±0.007%), highest jackfruit rags pectin methoxyl content (3.709±0.011 to 3.912±0.04%) was observed at ripe stage, for all the blanching temperature which can be seen from Fig. 2 (e). As the blanching temperature varied from 75 °C to 95 °C the jackfruit rags pectin methoxyl content (%) was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on methoxyl content (%) of jackfruit rags pectin was showing increasing which can be seen from Fig. 2 (e). Effect of maturity level on methoxyl content (%) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on methoxyl content (%) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on methoxyl content (%) of jackfruit rags pectin was also significant at $p \leq 0.05$.

According to Islam *et al*. (2023) [25], the methoxyl concentration of pectin derived from rags or tandem was found to be 3.87±0.17. According to Wongkaew *et al.* (2020) [75], methoxyl concentration is a crucial determinant of pectin's setting time, ability to combine with metallic ions, ability to distribute in water and gels, and other advantageous qualities. According to reports, pectin derived from various plant materials and extracted under various conditions can have a methoxyl concentration ranging from 0.2 to 12% (Kute *et al*., 2020) [31]. Furthermore, according to Islam *et al*. (2023) [25], pectin with a methoxyl content of less than 7% is classified as low methoxyl content, whereas pectin with a methoxyl content of 8–12% is classified as high methoxyl pectin. The results of this research indicate that the pectin isolated from jackfruit rags has a low methoxyl concentration, which means it can be utilized to make low-sugar food products since it doesn't need sugar to produce gels (Panwar *et al*., 2022) [50].

Castillo-Israel *et al*., (2015) [8] studied characteristics of pectin from Saba banana peels and concluded that methoxyl content of Saba Banana peel pectin was 5.25% and 6.4% in unripe and ripe bananas, respectively. Methoxyl content is important in controlling setting time of pectin, sensitivity to polyvalent metal cations and also determines the functional properties of the pectin-gel texture (Constenla and Lozano, 2003) [10].

Mugampoza *et al*., (2020) [41] studied on extracted pectin from bananas at five stages of ripening, stages 0 (green maturity), 1, 2, 5 and 7 i.e. every after 8 hour interval. Extracted pectin at stages 2, 5 and 7 was characterized. The methoxyl content of pectin from ripening banana pulp and peel was not significantly different ($p > 0.05$) and generally increased through the ripening stages. Methoxyl content of pectin from banana peel ranged between 4.07 to 11.02% while that from banana pulp ranged between 3.67 to 8.21% across ripening stages. Methoxyl content of pectin from banana pulp at stage 2 of ripening for all the three cultivars did not differ significantly ($p > 0.05$) i.e. Nakitembe (5.37%), Musakala (5.12%) and Mpologoma (4.07%). At stage 5, methoxyl content was 4.73% for Nakitembe, 7.27% for Musakala and 5.73% for Mpologoma and was not significantly different ($p > 0.05$). At stage 7 of ripening, methoxyl content of pectin from Nakitembe was 11.02%, from Musakala was 8.76% and Mpologoma 7.88%. The pectin from banana peel at stage 2 of ripening had low methoxyl content of 4.02% for Nakitembe, 5.86% for Musakala and 4.03% for Mpologoma. At stages 5 and 7, the respective methoxyl contents of the pectin extracts were 5.87 and 3.67% for Mpologoma; 4.02 and 8.21% for Nakitembe and 7.13 and 7.75% for Musakala.

According to Chaliha *et al*. (1963) [9], the methoxyl concentration of pectin recovered from dried, washed, and unblanched apple peel and pomace was 8.0%, but it was 8.74% in blanched apple peel. The methoxyl content of blanched passion fruit peel was higher than that of non-blanched peel. Methoxyl content from blanched passion fruit peel of yellow and purple variety was 7.02±0.16 g to 7.89b±0.48 g/100 g of pectin and 8.96±0.19 g to 7.83±0.40 g/100 g of pectin, respectively, which was higher than non-blanched (6.35±0.21 g to 7.15±0.03 g/100 g of pectin and 4.31±0.33 g to 5.97±0.22 g/100 g of pectin) passion fruit peel of yellow and purple variety (Wickramasinghe *et al*., 2022) [74].

6. Anhydrouronic Acid (%) (AUA)

Figure 2 (f) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 °C, 85 °C and 95 °C) on anhydrouronic acid (%) of jackfruit rags pectin. The anhydrouronic acid of rags pectin ranged between 55.035±0.107 to 55.858±0.511%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin anhydrouronic acid (%) varied from 55.460±0.110 to 55.858±0.511%; 55.285±0.206 to 55.773±0.305%; 55.035±0.107 to 55.568±0.145% at blanching temperature 75 °C, 85 °C and 95 °C respectively. Lower jackfruit rags pectin anhydrouronic acid (%) was observed at middle stage (55.460±0.110 to 55.035±0.107%), highest jackfruit rags pectin anhydrouronic acid (55.858±0.511 to 55.568±0.145%) was observed at ripe stage, for all the blanching temperature which can be seen from Fig.2 (f). As the blanching temperature varied from 75 °C to 95 °C the jackfruit rags pectin anhydrouronic acid (%) was decreased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on anhydrouronic acid (%) of jackfruit rags pectin was showing decreasing which can be seen from Fig.2 (f). Effect of maturity level on anhydrouronic acid (%) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on anhydrouronic acid (%) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on anhydrouronic acid (%) of jackfruit rags pectin was also significant at $p \leq 0.05$.

Sook *et al*. (2023) [61] reported that the AUA content of rags made from jackfruit was 31.12%. According to Ismail *et al*. (2012) [26], the low AUA level may be caused by the pectin's high protein or sugar content. The primary characteristic that determines the purity of extracted pectin and affects its gelling properties is its AUA content. According to guidelines defined by the Food and Agricultural

Organization (FAO) and Food Chemical Codex (FCC, 1996) [15], the recommended value of AUA for pectin used as food additives or medicinal agents on an ash and moisture-free basis should not be less than 65%. Islam *et al*. (2023) [25] reported that 40.48±0.45% of the AUA concentration was found in the pectin that was isolated from jackfruit tandem or rags.

Mugampoza *et al*., (2020) [41] extracted pectin from the bananas at five stages of ripening i.e. stages-1 (All Green), stages-2 (Green with a trace of Yellow), stages-5(Yellow with a trace of green) and stages-7(All Yellow with Brown spackles). The AUA of pectin extracted at stages 2 and 5 was comparatively lower than that of stage 7 extraction. The majority of the results showed that pectin extracted at ripening stage 7 had a higher AUA, suggesting that purity increased with ripening. Depending on the cultivar of banana, the AUA concentration of pectin in ripening bananas varied from 24.51 to 67.38%, mainly rising with ripening stage. In the case of the Nakitembe cultivar, for example, the AUA of pectin grew from 39.41 to 67.38%, while that of Musakala increased from 37.67 to 58.57%, and that of Mpologoma increased from 24.51 to 48.64%. The pectin from the peel of Nakitembe and Musakala increased in AUA from 26.48 to 53.49% and 43.15 to 53.94%, respectively, while the pectin from Mpologoma was relatively unchanged at 24.64 to 23.60%. According to a study done by Mugampoza *et al*. (2020) [41], the AUA values of pectin from green mature and ripe bananas studied were in agreement with values obtained by Castillo-Israel *et al*. (2015) [8] of 57.3% and 39.68% for ripe and unripe banana peels, respectively.

Wickramasinghe *et al*. (2022) [74] isolated pectin from a yellow variety of passion fruit. The sample that under blanching as a pre-treatment had an AUA that was decreased (65.38±1.99% to 70.49±2.88%) than the sample that was not blanched (72.34±0.35% to 74.80±0.73%).

7. Equivalent weight (mg/mol)

Figure 2(g) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 ℃, 85 ℃ and 95 ℃) on equivalent weight (mg/mol) of jackfruit rags pectin. The equivalent weight (mg/mol) of rags pectin ranged between 476.55±0.349 to 483.325±0.267 mg/mol; As maturity varied from middle stage to ripe stage the jackfruit rags pectin equivalent weight (mg/mol) varied from 476.55±0.349 to 478.134±0.126 mg/mol; 478.541±0.191 to 481.988±0.643 mg/mol; 481.367±0.355 to 483.325±0.267 mg/mol at blanching temperature 75 ℃, 85 ℃ and 95 ℃ respectively. Lower jackfruit rags pectin equivalent weight (mg/mol) was observed at ripe stage (476.55±0.349 to 481.367±0.355 mg/mol), highest jackfruit rags pectin equivalent weight (mg/mol) (478.134±0.126 to 483.325±0.267 mg/mol) was observed at middle stage, for all the blanching temperature which can be seen from Fig.2(g). As the blanching temperature varied from 75 ℃ to 95 ℃ the jackfruit rags pectin equivalent weight (mg/mol) was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on equivalent weight (mg/mol) of jackfruit rags pectin was showing increasing which can be seen from Fig.2(g). Effect of maturity level on equivalent weight (mg/mol) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on equivalent weight (mg/mol) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on equivalent weight (mg/mol) of jackfruit rags pectin was also significant at $p \leq 0.05$.

Pectin's equivalent weight serves as a gauge for the quantity of free galacturonic acid present; a rise or fall in this weight may be related to the concentration of free acid (Siddiqui *et al*., 2021) [59]. According to Islam *et al*. (2023) [25], 555.56±1.23 mg/mol was the equivalent weight (mg/mol) of pectin recovered from jackfruit tandem or rags. The gel-forming ability of pectin can be measured by its equivalent weight. Because of the quantity of galacturonic acid residues in the molecule, higher equivalent weight results in higher gel strength and higher-quality pectin. According to a study done by Torres-Gallo *et al*. (2022) [67], the equivalent weight of pectin extracted from mango peels decreased dramatically ($p \leq 0.05$) when the mangos reached a ripening stage; that is, from 754 mg to 1295 mg at stage 0 and 500 mg to 876 mg at stage 4. The drop in the equivalent weight of pectin was caused by the breakup of the galacturonic acid chains during the fruit ripening process, which resulted in a reduction in the quantity of esterified carboxyls being converted into free carboxyls. According to Azad *et al*. (2014) [4], at the mature stage, there was a significant different ($p<0.05$) in equivalent weight. The mature extracted sample showed the maximum equivalent weight (1632±137), while the overripe extracted pectin showed a lower equivalent weight (368±3). A higher partial breakdown of pectin could be the cause of the decreased equivalent weight. The amount of free acid may also have an impact on the equivalent weight's increase or decrease (Nazaruddin and Asmawati, 2011) [42].

The value for yellow-blanched, yellow-non blanched, purple-blanched, purple-non blanched are 696.51, 550.29, 1171.94 and 583.39 respectively. It can also be said that the blanching condition (100 ℃ for 3 min) is more effective for the equivalent weight thus the blanched samples have given higher values than non-blanched samples in both varieties (Wickramasinghe *et al*., 2022) [74].

8. Degree of esterification (%)

Figure 2(h) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 ℃, 85 ℃ and 95 ℃) on degree of esterification (%) of jackfruit rags pectin. The degree of esterification of rags pectin ranged between 37.851±0.291 to 39.662±0.167%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin degree of esterification (%) varied from 37.851±0.291 to 38.263±0.126%; 38.047±0.191 to 39.236±0.143%; 38.818±0.155 to 39.662±0.167% at blanching temperature 75 ℃, 85 ℃ and 95 ℃ respectively. Lower jackfruit rags pectin degree of esterification (%) was observed at ripe stage (37.851±0.291 to 38.818±0.155%), highest jackfruit rags pectin degree of esterification (38.263±0.126 to 39.662±0.167%) was observed at middle stage, for all the blanching temperature which can be seen from Fig.2(h). As the blanching temperature varied from 75 ℃ to 95 ℃ the jackfruit rags pectin degree of esterification (%) was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on degree of esterification (%) of jackfruit rags pectin was showing increasing which can be seen from Fig.2(h). Effect of maturity level on degree of esterification (%) of jackfruit rags pectin was significant at

$p \leq 0.05$. Similarly, the effect of blanching temperature on degree of esterification (%) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on degree of esterification (%) of jackfruit rags pectin was also significant at $p \leq 0.05$.

According to Islam *et al*. (2023) [25], the pectin isolated from jackfruit tandem has a degree of esterification (DE) of 28.21±0.34%. Pectin isolated from the peel and core of jackfruit had a higher DE (35.13±0.49%) than that of tandem (25.35±0.21%). The degree of esterification (DE) can theoretically range from 0% to 100%. According to Walter (1991) [71], pectins classified as high methoxyl (HM) have a degree of esterification DE greater than 50%, whereas pectins classified as low methoxyl (LM) have a degree of esterification DE less than 50%. The amount of pectin methyl esterification in tomatoes reduced from 90% in mature green fruit to 35% in red, ripe fruit during the ripening process (Koch and Nevins, 1989) [28].

Wickramasinghe *et al*., (2022) [74] reported that the degree of esterification (%) of pectin from yellow and purple passion fruit peels by ultrasonic extraction method, both varieties yellow and purple passion fruit peel pectin have shown higher DE 79.17±0.26 and 85.14±1.3 values for the blanched samples than for the non-blanched samples 70.37±1.70 and 78.23±1.32 respectively.

9. Galacturonic acid (%)

Figure 2(i) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 ℃, 85 ℃ and 95 ℃) on galacturonic acid (%) of jackfruit rags pectin. The galacturonic acid of rags pectin ranged between 57.562±0.291 to 62.267±0.167%; As maturity varied from middle stage to ripe stage the jackfruit rags pectin galacturonic acid (%) varied from 57.562±0.291 to 58.055±0.126%; 58.238±0.191 to 61.137±0.143%; 60.165±0.155 to 62.267±0.167% at blanching temperature 75 ℃, 85 ℃ and 95 ℃ respectively. Lower jackfruit rags pectin galacturonic acid (%) was observed at ripe stage (57.562±0.291 to 60.165±0.155%), highest jackfruit rags pectin galacturonic acid (58.055±0.126 to 62.267±0.167%) was observed at middle stage, for all the blanching temperature which can be seen from Fig.2(i). As the blanching temperature varied from 75 ℃ to 95 ℃ the jackfruit rags pectin galacturonic acid (%) was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on galacturonic acid (%) of jackfruit rags pectin was showing increasing which can be seen from Fig.2(i). Effect of maturity level on galacturonic acid (%) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on galacturonic acid (%) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on galacturonic acid (%) of jackfruit rags pectin was also significant at $p \leq 0.05$.

Galacturonic acid content of Jackfruit rags pectin obtained through Microwave-assisted extraction was 61.53% (Tran *et al*., 2023) [68]. Ghai *et al*. (2016) [20] reported that, From the unripe to the ripe stage of trewia nudiflora Linn, the amount of galacturonic acid decreased from 25.31±2.51% to 19.09±1.58%. Plant cell walls can release more galacturonic acid when they are blanched. This could happen as a result of enzymes that break down cell wall polysaccharides activating or the structure of the cell wall being disrupted (Neri *et al*., 2011) [43].

Geerkens *et al*., (2015) [19] reported that by implementing peel blanching the galacturonic acid content of a sample of cv. Palmer was increased to 65%, reaching the minimum legal requirement of pectin for food use. The galacturonic acid content of alcohol insoluble solids (AIS) from blanched peels (34.38 g/100 g) exceeded that from unblanched peels (28.36 g/100 g). Blanching prior to drying reduced arabinogalactan and ash impurities, whereas galacturonic acid contents were increased.

10. Intrinsic Viscosity (dL/g)

Figure 2(j) shows the effect of maturity level (Middle stage and Ripe stage) and blanching temperature (75 ℃, 85 ℃ and 95 ℃) on intrinsic viscosity (dL/g) of jackfruit rags pectin. The intrinsic viscosity (dL/g) of rags pectin ranged between 2.464±0.042 to 2.856±0.042 dL/g; As maturity varied from middle stage to ripe stage the jackfruit rags pectin intrinsic viscosity (dL/g) varied from 2.464±0.042 to 2.650±0.033dL/g; 2.541±0.029 to 2.729±0.028dL/g; 2.643±0.024 to 2.856±0.042 dL/g at blanching temperature 75 ℃, 85 ℃ and 95 ℃ respectively. Lower jackfruit rags pectin intrinsic viscosity (dL/g) was observed at ripe stage (2.464±0.042 to 2.643±0.024 dL/g), highest jackfruit rags pectin intrinsic viscosity (dL/g) (2.650±0.033 to 2.856±0.042 dL/g) was observed at middle stage, for all the blanching temperature which can be seen from Fig.2(j). As the blanching temperature varied from 75 ℃ to 95 ℃ the jackfruit rags pectin intrinsic viscosity (dL/g) was increased, for both the maturity stages. Combined effect of maturity level (Middle stage and Ripe stage) and blanching temperature on intrinsic viscosity (dL/g) of jackfruit rags pectin was showing increasing which can be seen from Fig.2(j). Effect of maturity level on intrinsic viscosity (dL/g) of jackfruit rags pectin was significant at $p \leq 0.05$. Similarly, the effect of blanching temperature on intrinsic viscosity (dL/g) of jackfruit rags pectin was also significant at $p \leq 0.05$. The interaction effect of maturity level of jackfruit and blanching temperature on intrinsic viscosity (dL/g) of jackfruit rags pectin was non-significant at $p \leq 0.05$.

According to Begum *et al*. (2021) [6], the results of the pectin solution's intrinsic viscosity analysis showed that analytical grade pectin (AGP) had the highest intrinsic viscosity at 3.39 dl/g. Commercial grade pectin (CGP) came in second with 3.27 dl/g, followed by ammonium oxalate-extracted jackfruit waste pectin (AOJP) at 2.19 dl/g, and acid-hydrolyzed jackfruit waste pectin (AHJP) at 2.14 dl/g.

Similar results have been reported by Nguyen *et al*. (2019) [44] for pectin extracted from Vietnamese mango peels. They studied three varieties of Vietnamese mango and reported that intrinsic viscosity increased from pre-mature to mature and then reduced as fruit ripened. For example, Ghep was one variety that Nguyen *et al*. (2019) [44] studied, and the result was that intrinsic viscosity for pre-mature, mature, and ripe mango was 46.3±0.1 mL/g, 50.3±0.2 mL/g, and 50.1±0.2 mL/g, respectively.

Conclusion

The choice of maturity and blanching temperature for pectin extraction significantly impacts the yield and quality of the extracted pectin. These factors influence the composition and structure of the plant cell walls, affecting the accessibility of pectin molecules to the extraction solvent.

As fruits mature, the pectin content in their cell walls decreasing. The structure of the cell wall becomes more rigid as fruits mature. This can make it more difficult to extract pectin. Blanching helps to disrupt the cell wall structure, making pectin more accessible to the extraction solvent. The desirable best results were obtained at Middle stage (5 to 13 weeks) and 95 ℃ blanching temperature condition as; Yield (16.179%), Moisture content (8.518%), Ash content (1.249%), pH (5.338%), Methoxyl content (3.849%), Anhydronaunic acid (55.035%), Equivalent weight (483.325 mg/mol), Degree of esterification (39.662%), Galucteronic acid (62.267%) and Intrinsic viscosity (2.856 dl/g).

References

1. Ando Y, Maeda Y, Mizutani K, Wakatsuki N, Hagiwara S, Nabetani H. Impact of blanching and freeze-thaw pretreatment on drying rate of carrot roots in relation to changes in cell membrane function and cell wall structure. LWT - Food Science and Technology. 2016;71:40-46.
2. Association of Official Analytical Chemists (AOAC). Official Methods of Analysis of the Association of Analytical Chemists; c2010.
3. Arévalo-Pinedo A, Murr FE. Kinetics of vacuum drying of pumpkin (*Cucurbita maxima*): modeling with shrinkage. Journal of Food Engineering. 2006;76(4):562-567.
4. Azad AKM, Ali MA, Akter MS, Rahman MJ, Ahmed M. Isolation and characterization of pectin extracted from lemon pomace during ripening. Journal of Food and Nutrition Science. 2014;2(2):30-35.
5. Begum R, Aziz MG, Uddin MB, Yusof YA. Characterization of jackfruit (*Artocarpus heterophyllus*) waste pectin as influenced by various extraction conditions. Agriculture and Agricultural Science Procedia. 2014;2:244-251.
6. Begum R, Aziz MG, Yusof YA, Saifullah M, Uddin MB. Evaluation of gelation properties of jackfruit (*Artocarpus heterophyllus*) waste pectin. Carbohydrate Polymers Technology and Applications. 2021;2:100160.
7. Billmeyer FW. Textbook of Polymer Science. New York: John Wiley & Sons; c1984. p. 212-214.
8. Castillo-Israel K, Diasanta S, Lizardo M, Dizon R, Mejico M. Extraction and characterization of pectin from Saba banana [*Musa 'saba'* (*Musa acuminata* x *Musa balbisiana*)] peel wastes: a preliminary study. International Food Research Journal. 2015;22(1):202-207.
9. Chaliha BP, Barua AD, Siddappa GS. Assam limon as a source of pectin. Indian Food Packer; c1963.
10. Constenla D, Lozano J. Kinetic model of pectin demethylation. Latin American Applied Research. 2003;33:91-96.
11. Dam SM, Nguyen NT. Production of fermented beverage from fruit rags of jackfruit (*Artocarpus heterophyllus*). In: Southeast Asia Symposium on Quality Management in Postharvest Systems and Asia Pacific Symposium on Postharvest Quality; 2012 Feb; 989:285-292.
12. Daud S, Said J, Jafar Y, Kusrini, Usman. pH dependent yield and physicochemical properties of pectin isolated from *Citrus maxima*. Chemical Engineering Journal. 2019;10(1):1131-1139.
13. Dische Z. A new specific color reaction of hexuronic acids. Journal of Biological Chemistry. 1946;167:189-198.
14. Duan X, Cheng G, Yang E, Yi C, Ruenroengklin N, Lu W, *et al*. Modification of pectin polysaccharides during ripening of postharvest banana fruit. Food Chemistry. 2008;111(1):144-149.
15. Food Chemical Codex. Monographs. Washington, DC: National Academy Press; c1996. p. 4:283.
16. Filisetti-Cozzi TM, Carpita NC. Measurement of uronic acids without interference from neutral sugars. Analytical Biochemistry. 1991;197:157-162.
17. Galambos JT. The reaction of carbazole with carbohydrates. Analytical Biochemistry. 1967;19:133-143.
18. Gamonpilas C, Buathongjan C, Kirdsawasd T, Rattanaprasert M, Klomtun M, Phonsatta N, *et al*. Pomelo pectin and fiber: some perspectives and applications in food industry. Food Hydrocolloids. 2021;120:106981.
19. Geerkens CH, Nagel A, Just KM, Miller-Rostek P, Kammerer DR, Schweiggert RM, *et al*. Mango pectin quality as influenced by cultivar, ripeness, peel particle size, blanching, drying, and irradiation. Food Hydrocolloids. 2015;51:241-251.
20. Ghai K, Gupta PK, Gupta AK. Physiochemical behaviour changes during ripening in fruits of *Trewia nudiflora* Linn. Perspectives in Science. 2016;8:596-598.
21. Girma A, Worku M. Extraction and characterization of pectin from selected fruit peel waste. International Journal of Scientific Research and Publications. 2016;6(2):447-454.
22. Gross KC, Sams CE. Changes in cell wall neutral sugar composition during fruit ripening: a species survey. Phytochemistry. 1984;23(11):2457-2461.
23. Imaizumi T, Szymańska-Chargot M, Pieczywek PM, Chylińska M, Kozioł A, Ganczarenko D, *et al*. Evaluation of pectin nanostructure by atomic force microscopy in blanched carrot. LWT - Food Science and Technology. 2017;84:658-667.
24. International Pectin Producers Association. Pectin commercial production and pectin in organic food products. 2014.
25. Islam MR, Biswas MMH, Esham MKH, Roy P, Hasan SK. Jackfruit (*Artocarpus heterophyllus*) by-products a novel source of pectin: studies on physicochemical characterization and its application in soup formulation as a thickener. Food Chemistry Advances. 2023;2:100273.
26. Ismail NSM, Ramli N, Hani NM, Meon ZJSM. Extraction and characterization of pectin from dragon fruit (*Hylocereus polyrhizus*) using various extraction conditions. Sains Malaysiana. 2012;41(1):41-45.
27. Jackman RL, Stanley DW. Perspectives in the textural evaluation of plant foods. Trends in Food Science & Technology. 1995;6(6):187-194.
28. Koch JL, Nevins DJ. Tomato fruit cell wall: I. Use of purified tomato polygalacturonase and pectinmethylesterase to identify developmental changes in pectins. Plant Physiology. 1989;91(3):816-822.

29. Kraemer EO. Molecular weight of celluloses and cellulose derivatives. Journal of Industrial and Engineering Chemistry. 1938;30:1200-1203.
30. Kumar S, Ozukum R, Mathad GM. Extraction, characterization and utilization of pectin from apple peels. Journal of Pharmacognosy and Phytochemistry. 2020;9(5):2599-2604.
31. Kute AB, Mohapatra D, Kotwaliwale N, Giri SK, Sawant BP. Characterization of pectin extracted from orange peel powder using microwave-assisted and acid extraction methods. Agricultural Research. 2020;9:241-248.
32. Li J, Kisara K, Danielsson S, Lindstrom ME, Gellerstedt G. An improved methodology for the quantification of uronic acid units in xylans and other polysaccharides. Carbohydrate Research. 2007;342:1442-1449.
33. Lin B, Chua K, Ng A, Amena. Ultrasound assisted extraction of pectin from dragon fruit peels. Journal of Engineering Science and Technology. 2018;13:65-81.
34. Lo CM, Grün IU, Taylor TA, Kramer H, Fernando LN. Blanching effects on the chemical composition and the cellular distribution of pectins in carrots. Journal of Food Science. 2002;67(9):3321-3328.
35. Manzoor N, Dar AH, Khan S, Hakeem HR, Makroo HA. Effect of blanching and drying temperatures on various physico-chemical characteristics of green beans. Asian Journal of Dairy and Food Research. 2019;38(3):213-223.
36. Martínez S, Pérez N, Carballo J, Franco I. Effect of blanching methods and frozen storage on some quality parameters of turnip greens ("grelos"). LWT-Food Science and Technology. 2013;51(1):383-392.
37. Maskey B, Dhakal D, Pradhananga M, Shrestha NK. Extraction and process optimization of bael fruit pectin. Food Science & Nutrition. 2018;6(7):1927-1932.
38. Mohamadzadeh J, Sadeghi-Mahoonak AR, Yaghbani M, Aalami M. Extraction of pectin from sunflower head residues of selected Iranian cultivars.
39. Mohamed S, Hasan Z. Extraction and characterisation of pectin from tropical agrowastes. ASEAN Food Journal. 1995;10(2):43-50.
40. More PG, Khodke SU. Effect of blanching time on quality parameter of blanched carrot slices. The Pharma Innovation Journal. 2023;12(1):1699-1702.
41. Mugampoza D, Gafuma S, Kyosaba P, Namakajjo R. Characterization of pectin from pulp and peel of Ugandan cooking bananas at different stages of ripening. Journal of Food Research. 2020;9(5):67-77.
42. Nazaruddin Ramli NR, Asmawati A. Effect of ammonium oxalate and acetic acid at several extraction time and pH on some physicochemical properties of pectin from cocoa husks (*Theobroma cacao*).
43. Neri L, Hernando IH, Pérez-Munuera I, Sacchetti G, Pittia P. Effect of blanching in water and sugar solutions on texture and microstructure of sliced carrots. Journal of Food Science. 2011;76(1).
44. Nguyen HH, Nguyen HV, Savage GP. Properties of pectin extracted from Vietnamese mango peels. Foods. 2019;8(12):629.
45. Nidhina K, Abraham B, Fontes-Candia C, Martínez-Abad A, Martínez-Sanz M, Nisha P, *et al*. Physicochemical and functional properties of pectin extracted from the edible portions of jackfruit at different stages of maturity. Journal of the Science of Food and Agriculture. 2023;103(6):3194-3204.
46. Nnamani CV, Oselebe HO, Agbatutu A. Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. African Journal of Biotechnology. 2009;8(10).
47. Nurdjanah S, Hook J, Paton J, Paterson J. Galacturonic acid content and degree of esterification of pectin from sweet potato starch residue detected using C CP/MAS solid state NMR. European Journal of Food Research and Review. 2013;3:16-37.
48. Otu DAB, Owusu FW, Acquah PGJ, Boakye-Gyasi ME, Edzor-Agbo Y, Johnson R, *et al*. Effect of ripening and extraction method on the physicochemical properties of pectin extracted from peels of apem and apantu plantain cultivars in Ghana. Journal of Chemistry. 2024;2024(1):6677179.
49. Panse VG, Sukhatme PV. Statistical methods for agricultural workers; c1954.
50. Panwar D, Panesar PS, Chopra HK. Green extraction of pectin from Citrus limetta peels using organic acid and its characterization. Biomass Conversion and Biorefinery. c2022. p. 1-13.
51. Pathak N, Singh S, Singh P, Singh PK, Singh R, Bala S, Thirumalesh BV, Gaur R, Tripathi M. Valorization of jackfruit waste into value added products and their potential applications. Frontiers in Nutrition. 2022;9:1061098.
52. Pervin S, Miaruddin M, Islam MS, Khan MHH, Rahman MM. Blanching effect on the quality and shelf life of pea. Journal of Postharvest Technology. 2017;5(2):47-54.
53. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education; 1986.
54. Redgwell RJ, Melton LD, Brasch DJ. Cell wall dissolution in ripening kiwifruit (*Actinidia deliciosa*): solubilization of the pectic polymers. Plant Physiology. 1992;98(1):71-81.
55. Reis RC, Castro VC, Devilla IA, Oliveira CA, Barbosa LS, Rodovalho R. Effect of drying temperature on the nutritional and antioxidant qualities of cumari peppers from Pará (*Capsicum chinense* Jacqui). Brazilian Journal of Chemical Engineering. 2013;30:337-343.
56. Shamsheera KO, Prasad AR, Arshad M, Joseph A. A sustainable method of mitigating acid corrosion of mild steel using jackfruit pectin (JP) as green inhibitor: theoretical and electrochemical studies. Journal of the Indian Chemical Society. 2022;99(1):100271.
57. Sharma PC, Gupta A, Kaushal P. Optimization of method for extraction of pectin from apple pomace. Indian Journal of Natural Products and Resources. 2015;5(2):184-189.
58. Shinde GB, Swami SB, Zambre S, Venkatesh KV. Effect of pretreatment on extraction yield and quality of fruit pectin: a review. International Journal of Food and Fermentation Technology. 2024;14(01):423-437.
59. Siddiqui A, Chand K, Shahi NC. Effect of process parameters on extraction of pectin from sweet lime peels. Journal of The Institution of Engineers (India): Series A. 2021;102:469-478.
60. Sila DN, Van Buggenhout S, Duvetter T, Fraeye I, De Roeck A, Van Loey A, *et al*. Pectins in processed fruits and vegetables: Part II—Structure–function

relationships. Comprehensive Reviews in Food Science and Food Safety. 2009;8(2):86-104.

61. Sook Wah C, Ching Enn H, Chin Ping T, Yih Phing K, Zaixiang L. Ultrasound-assisted extraction of pectin from jackfruit (*Artocarpus heterophyllus*) rags: optimization, characterization, and application in model food gel. Current Research in Nutrition and Food Science Journal. 2023;11(3):991-1007.
62. Subburamu K, Singaravelu M, Nazar A, Irulappan I. A study on the utilization of jackfruit waste. Bioresource Technology. 1992;40(1):85-6.
63. Sundarraj AA, Vasudevan RT, Sriramulu G. Optimized extraction and characterization of pectin from jackfruit (*Artocarpus integer*) wastes using response surface methodology. International Journal of Biological Macromolecules. 2018;106:698-703.
64. Susanti S. Comparing the chemical characteristics of pectin isolated from various Indonesian fruit peels. [No additional details provided].
65. Tadesse AY, Mohammed HH, Andersa KN. Proximate composition and selected phytochemical components of Dawrach (*Raphanus raphanistrum* L.) as affected by blanching temperature. Heliyon. 2023;9(8).
66. Thibault JF, Rinaudo M. Interactions of mono- and divalent counterions with alkali- and enzyme-deesterified pectins in salt-free solutions. Biopolymers: Original Research on Biomolecules. 1985;24(11):2131-43.
67. Torres-Gallo R, Bayuelo-Bonilla S, Carpio-Ortiz L, Barreto-Rodríguez G, Tirado DF. High-intensity ultrasound-assisted extraction of pectin from mango wastes at different maturity. International Journal of Food Science. 2022;2022(1):4606024.
68. Tran NTK, Nguyen VB, Van Tran T, Nguyen TTT. Microwave-assisted extraction of pectin from jackfruit rags: optimization, physicochemical properties, and antibacterial activities. Food Chemistry. 2023;418:135807.
69. Valdivia-Rivera S, Herrera-Pool IE, Ayora-Talavera T, Lizardi-Jiménez MA, García-Cruz U, Cuevas-Bernardino JC, *et al*. Kinetic, thermodynamic, physicochemical, and economical characterization of pectin from *Mangifera indica* L. cv. Haden residues. Foods. 2021;10(9):2093.
70. Verma AR, Srivastava JC. Pectin in guava during growth and maturity. Indian Journal of Horticulture. 1965;22(3-4):318-21.
71. Walter RH. Analytical and graphical methods for pectin. In: The Chemistry and Technology of Pectin. 1991. p. 189-225.
72. Wang H, Fang XM, Sutar PP, Meng JS, Wang J, Yu XL, *et al*. Effects of vacuum-steam pulsed blanching on drying kinetics, colour, phytochemical contents, antioxidant capacity of carrot, and the mechanism of carrot quality changes revealed by texture, microstructure, and ultrastructure. Food Chemistry. 2021;338:127799.
73. Wang J, Mujumdar AS, Deng LZ, Gao ZJ, Xiao HW, Raghavan GSV. High-humidity hot air impingement blanching alters texture, cell-wall polysaccharides, water status, and distribution of seedless grape. Carbohydrate Polymers. 2018;194:9-17.
74. Wickramasinghe UL, Marapana RAUJ, Anuradha PAV. Extraction, characterization, and comparison of pectin from purple (*Passiflora edulis*) and yellow (*Passiflora edulis* f. flavicarpa) varieties of passion fruit peel by ultrasonic extraction method under two pretreatment conditions. International Journal of Food Science and Nutrition. 2022;7(3):124-33.
75. Wongkaew M, Sommano SR, Tangpao T, Rachtanapun P, Jantanasakulwong K. Mango peel pectin by microwave-assisted extraction and its use as fat replacement in dried Chinese sausage. Foods. 2020;9(4):450.
76. Zhan D, Janssen P, Mort AJ. Scarcity or complete lack of single rhamnose residues interspersed within the homogalacturonan regions of citrus pectin. Carbohydrate Research. 1998;308(3-4):373-80.
77. Zielinska S, Cybulska J, Pieczywek P, Zdunek A, Kurzyna-Szklarek M, Liu ZL, *et al*. The effect of high humidity hot air impingement blanching on the changes in molecular and rheological characteristics of pectin fractions extracted from okra pods. Food Hydrocolloids. 2022;123:107199.