



Research article

PECTIC SUBSTANCES FROM THE LEAVES OF *MELIA AZEDARACH* FOR THE PRODUCTION OF LOW-SUGAR FRUIT JELLY

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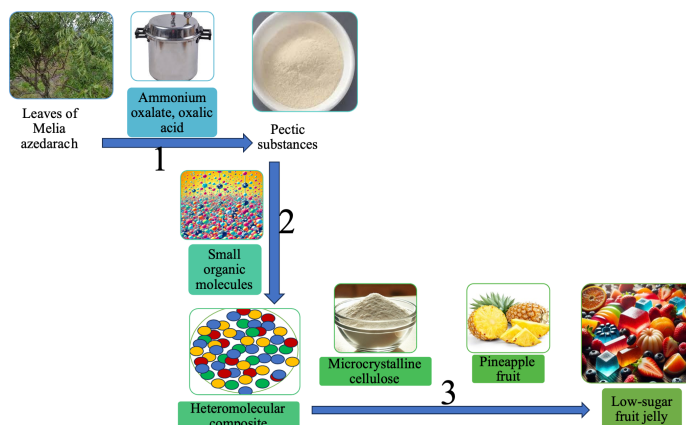
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Keywords

Pectic substances,
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Abstract

Pectic substances, extracted from the leaves of *Melia azedarach*, were used to prepare low-sugar fruit jelly using sucrose, boric acid, glucuronic acid, microcrystalline cellulose, and pineapple fruit. The jelly was characterized by spectroscopic, rheological, and textural methods. A heteromolecular composite with high viscosity was formed during the process from the pectic substances, sucrose, boric acid, and glucuronic acid. Spectroscopic studies revealed that the formation of the jelly involved chemical interactions at the level of the molecules. The microcrystalline cellulose had a decisive role in the textural properties. The conditions for extracting pectic substances and forming heteromolecular composite were optimized using the Response Surface Methodology in Minitab. The finished product contained only 0.8 % sugar and is therefore suitable in diabetic conditions. Fruit jellies with desired textural properties may be produced using this method. When amalgamated with suitable small organic molecules, leaf-based pectic substances may be used to make fruit jellies



Graphical abstract

1. Introduction

Consumer choice of food materials is greatly influenced by potential impact on health (Imami et al., 2025). The tendency to minimize the use of sugary materials is thus increasing worldwide. While fruit jellies (Sivaraj et al., 2025) have become an essential part of food almost universally, higher concentrations of sugars, such as sucrose, force people to think twice before consuming them. Therefore, any formulation of fruit jelly (Da Silveira et al., 2025) containing lower sugar content will be most welcome in any consumer society. This article describes the production of fruit jelly that contains only 0.8% of sucrose in the final product.

Large polymers of galacturonic acids called pectin, obtained from plants, are often used as gelling agents in food and other industries (Babaoglu Farzaliev & Ökten, 2025). Even though, pectin is usually obtained from the waste of the fruit industry (Phayel et al., 2025), (Iqbal et al., 2025), ever-increasing applications (Laybidi et al., 2025), (El Habbasha et al., 2025) have forced researchers to look for alternate sources such as leaves (Deng et al., 2025) of plants as potential sources of pectin. The extraction of pectic substances from the leaves of *Melia azedarach* and its use in the production of low-sugar fruit jellies is reported in this article. This plant was selected after experimenting with many plants (data not shown). The degree of methyl esterification and galacturonic acid content in the extracted pectic substances were studied.

Melia azedarach of the family Meliaceae is widely distributed in different parts of the world (Kasuya et al., 2025) and is widely studied and utilized for its medicinal properties (De Sousa et al., 2025). However, extraction of pectic substances from its leaves is not seen in published literature.

The gelling capability of any pectin-based preparation is a limiting factor in its applications (Xie et al., 2025). Often the gelling capability may be improved by converting it into a composite (Li et al., 2025) consisting of many components that interact together

chemically to interlink with one another, thereby increasing the viscosity of the product. This article describes for the first time the use of pectic substances from the leaves of *Melia azedarach*, sucrose, boric acid, and glucuronic acid to increase the apparent viscosity of the low-sugar fruit jelly. These components were selected after trials with different types of components (data not shown) and were transformed into a heteromolecular composite. Thereafter, microcrystalline cellulose was used as a filler, as it does not contribute to the sugar content of the blood. The property of microcrystalline cellulose to form a network with other molecules has been experimentally demonstrated recently (Hernandez-Ruiz et al., 2025). Ripe pineapple was used as the fruit in this work. This would be a better formulation since the earlier starch-based jellies are not preferred in diabetic conditions (Zhou et al., 2025). At the same time, this proposed low-sugar fruit jelly, which is based on microcrystalline cellulose, retains the benefits of the traditional polysaccharide-based jellies (C. Zhao et al., 2026).

The conditions for extracting pectic substances from the raw materials and the concentration of pectic substances, sucrose, boric acid, and glucuronic acid, required to form the heteromolecular composite with the highest apparent viscosity were optimized in Central composite Design using Response Surface Methodology in Minitab. The mechanism involved in the formation of the jelly was studied using FTIR – ATR. The effect of the microcrystalline cellulose on the texture, which plays an important role in consumer acceptance (Qiu et al., 2024), of the product was studied using texture profile analysis. The apparent viscosity of the heteromolecular composite and the jelly was investigated using a rheometer throughout the experiment.

2. Materials and methods

All reagents used in this work were purchased from Merck, India.

2.1. Extraction of pectic substances

Leaves of *Melia azedarach* (family Meliaceae, order Sapindales) were collected from Palakkad district in Kerala state, India. A herbarium specimen of this plant is kept as No. 27, in the Digital Flora of Peninsular India, Herbarium JCB, Indian Institute of Science, Bangalore, India, and it can be reached by the link

[http://peninsula.ces.iisc.ac.in/plants.php?name=Melia azedarach](http://peninsula.ces.iisc.ac.in/plants.php?name=Melia%20azedarach). Weighed amounts of the sun-dried leaves were mixed with the extractant liquid, consisting of ammonium oxalate (Han et al., 2024) and oxalic acid, in different values of

pH, concentration of ammonium oxalate, and liquid-to-solid ratios, and heated in a pressure cooker at 121°C and 15 psi pressure for various periods, filtered first using a cheesecloth and then Whatman No.1 filter paper. The pectic substances were precipitated with an equal volume of isopropyl alcohol. Then the precipitate was resuspended in water, again precipitated as before, and this process was repeated five times. The final precipitate was used for analysis and experiments. Table 1 shows the conditions used to extract the pectic substances from the leaves of *Melia azedarach*.

Table 1. Different conditions used for the extraction of pectic substances from the leaves of *Melia azedarach*

Conditions affecting extraction	Values				
Liquid (ml) to solid (g) ratio	30	40	50	60	70
Concentration of Ammonium oxalate (%)	0.4	0.6	0.8	1	1.2
Time (min)	8	10	12	14	16
pH	4.5	5	5.5	6	6.5

2.2. Estimation of the degree of esterification

A small amount of the above pectic substances is transformed into a pellet with KBr, and the FTIR-ATR spectrum in the transmission mode was obtained in the range of 4000-400 cm^{-1} using a PerkinElmer machine. The ratio of methylated carboxyl groups (peak at 1745 cm^{-1}) to the total number of carboxyl groups (peaks at 1745 and 1630 cm^{-1}) was used to calculate the degree of methyl esterification (F. Wang et al., 2021).

2.3. Estimation of galacturonic acid content

50mg of the pectic substances and 20 mL of 2 M trifluoroacetic acid were heated at 105°C for 3 hours. Then the acid was evaporated using nitrogen. 5 mL of isopropyl alcohol was added, mixed well, and evaporated. Then 1 mL of water and 1 mL of buffered copper solution were added and heated at 102°C for 45 minutes, cooled, and 16 mL of Folin-Ciocalteu reagent (prepared by mixing 2 mL of 2N Folin-Ciocalteu reagent

and 78 mL of water) was added. It was then mixed well and the optical density was measured at 750 nm using a UV-VIS Spectrophotometer (Perkin Elmer Model: Lambda 650). Citrus pectin containing 74% galacturonic acid was used as the standard, and a solution without pectin was used as the control (Anthon & Barrett, 2008).

2.4. Preparation of the heteromolecular composite

Pectic substances were made into a suspension with water to reach a final concentration of 0.225g/mL. Aqueous solutions of sucrose, boric acid, and glucuronic acid were prepared. Predetermined volumes of the above preparations, each containing a particular concentration, were mixed in a pre-weighed beaker and then boiled on a flame to reach a particular weight and packed for further studies. Details of the preparation of the heteromolecular composite gels are given in table 2.

Table 2. Concentrations of the components used for the preparation of the heteromolecular composite gels using pectic substances from the leaves of *Melia azedarach*. All gels had a final weight of 5g.

Sl. No.	Name of component	Range of concentrations in the finished gel (%)				
1	Pectic substances	0	0.2	0.4	0.6	0.8
2	Sucrose	0	1	2	3	4
3	Boric acid	0	0.1	0.2	0.3	0.4
4	Glucuronic acid	0	0.1	0.2	0.3	0.4

2.5. Preparation of the low-sugar fruit jelly

Ripe pineapple fruits purchased from the local market were cut into small pieces and pulverized well using a mixer grinder. Fixed quantities of it are mixed with the selected volume of the heteromolecular composite and

pre-determined quantities of microcrystalline cellulose in a pre-weighed beaker, kept overnight, boiled on a flame to a final weight of 50g, and packed for further studies. Different compositions of the low-sugar fruit jelly are shown in table 3.

Table 3. Different compositions of the low-sugar fruit jelly. The heteromolecular composite with the highest average apparent viscosity from the previous experiments was selected for this work.

No.	Weight of component (g)	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
1	Pectic substances (g)	0.08	0	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2	Sucrose (g)	0.4	0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3	Boric acid (g)	0.02	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
4	Glucuronic acid (g)	0.06	0	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
5	Microcrystalline cellulose (g)	0	0.5	0.5	1	1.5	2	2.5	3	3.5	4
6	Pineapple fruit (g)	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.94
7	Water (g)	34.5	34.6	34	33.5	33	32.5	32	31.5	31	30.5
8	Total weight of jam (g)	50	50	50	50	50	50	50	50	50	50

2.6. FTIR – ATR

To identify the mechanism involved in the formation of the low-sugar fruit jelly, all components mentioned in table 3, the heteromolecular composite, and the jelly itself

were analyzed by FTIR – ATR (PerkinElmer) in transmission mode, in the range of 4100-400 cm^{-1} using a KBr cell.

2.7. Rheological analysis

The apparent viscosity of the heteromolecular composite and the low-sugar fruit jelly was measured with a Rotational Rheometer Model RheolabQC (Anton Paar, Austria) using a 1 mL cylinder measuring cup.

2.8. Texture profile analysis

To identify the effect of varying concentrations of microcrystalline cellulose on the texture of the low-sugar fruit jelly, its texture profile was measured using a CT 3 Texture Analyzer, (make CT 3 Brookfield Engineering from Brookfield AMETEK), at a speed of 1 mm/sec, using Texture Pro CT V1.7 Build 29 software.

2.9. Statistical analysis

Response surface methodology (RSM) in Minitab was used to optimize the extraction conditions for pectic substances from leaf dust and the concentration of components in the heteromolecular composite. All tests were prepared in triplicates.

3. Results and discussions

3.1. Optimised yield of pectic substances

As per the prediction from RSM – Minitab analysis, the optimum conditions were LSR – 50.4 ml of the extractant fluid per gram of the leaf dust, pH – 5.5, concentration of ammonium oxalate – 0.9%, and time – 13 minutes, with a potential yield of 9.8%. However, when the work was performed under this set of conditions, the actual yield obtained was 11.7%. The contour plots of response optimization for yield are given in figure 1.

3.2. Degree of esterification and Galacturonic acid content

The degree of esterification, as calculated from the FTIR – ATR spectrum of the pectic substances obtained from the leaves of *Melia azedarach* was found to be 44.8%. Therefore, it is of low-methyl type. The content of galacturonic acid in the extracted pectic substances was found to be 55.3%.

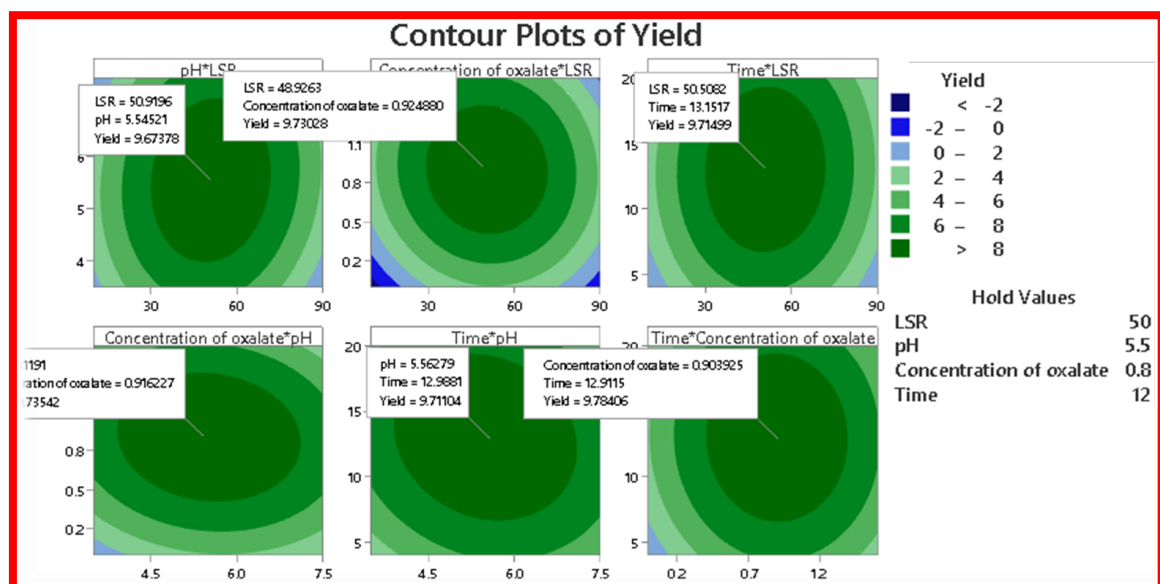


Figure 1. Contour plots of response optimization for yield of pectic substances from leaves of *Melia azedarach*

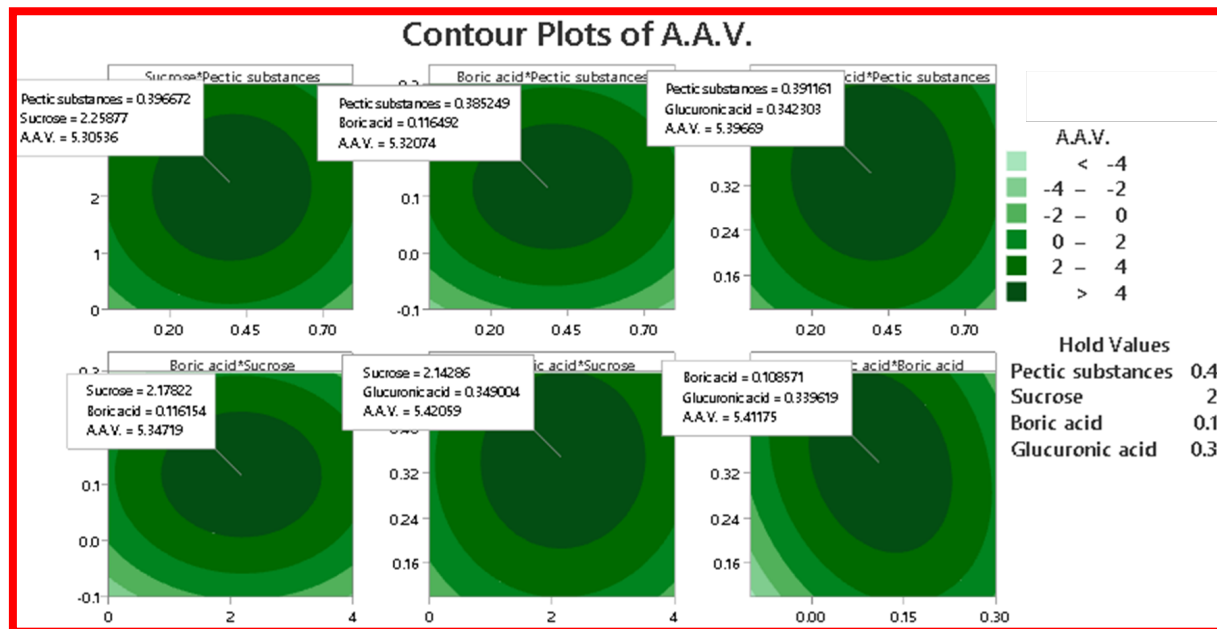


Figure 2. Contour plots of the heteromolecular composite's average apparent viscosity (A.A.V.) as a function of the concentration of pectic substances, sucrose, boric acid, and glucuronic acid

3.3. Optimized composition of the heteromolecular composite

As per the optimized data from the RSM–Minitab analysis, the highest average apparent viscosity was observed when the gel contained 0.4% by weight of pectic substances, 2% by weight of sucrose, 0.1% by weight of boric acid, and 0.3% by weight of glucuronic acid. Figure 2 shows the contour plots of the average apparent viscosity of the heteromolecular composite as a function of the concentration of pectic substances, sucrose, boric acid, and glucuronic acid in it.

3.4. FTIR – ATR studies

Evidence of chemical interactions among the components is seen in the FTIR - ATR of both the heteromolecular composite and the low-sugar fruit jelly. Analysis of the FTIR – ATR spectra given in figure 3 shows that many peaks of all the components disappeared during

the formation of the heteromolecular composite. A detailed list of such peaks is given in table 4. At the same time, many peaks of the components were modified to form new peaks in the heteromolecular composite. Table 5 shows a list of such peaks.

The FTIR – ATR spectra of various components of the low-sugar fruit jelly are given in figure 4. The spectra of the heteromolecular composite, the microcrystalline cellulose, and the fruit jelly are strikingly similar. The peak at 2163.04 cm^{-1} of the pectic substances disappeared during the formation of the heteromolecular composite but reappeared during the formation of the fruit jelly. All peaks of microcrystalline cellulose appeared modified in the spectrum of the fruit jelly, while the peak at 576 cm^{-1} of the pectic substances, 1589.5 cm^{-1} , 1442.26 cm^{-1} , and 515.56 cm^{-1} of the pineapple fruit disappeared completely in the spectrum of the fruit jelly.

Table 4. Peaks of the components disappeared in the FTIR – ATR spectra, during the formation of the heteromolecular composite. Pectic substances were obtained from the leaves of *Melia azedarach*

Sl. No.	Component	Peaks
1	Pectic substances	2163.04 cm ⁻¹ , 576 cm ⁻¹
2	Sucrose	3559.29 cm ⁻¹ , 3380.79 cm ⁻¹ , 3321.05 cm ⁻¹ (all O-H stretching(Hauswirth et al., 2022)) 2937.37 cm ⁻¹ (stretching vibration of C-H groups(Han et al., 2024)), 1570.85 cm ⁻¹ , 1346.39 cm ⁻¹ , 1046.66 cm ⁻¹ , 986.85 cm ⁻¹ , 908.76 cm ⁻¹ (all vibrations of -C-H(Hauswirth et al., 2022)) 521.69 cm ⁻¹ , 468.98 cm ⁻¹
3	Glucuronic acid	3559.78 cm ⁻¹ , 3380.96 cm ⁻¹ , 3323.84 cm ⁻¹ , 2937.54 cm ⁻¹ , 1571.68 cm ⁻¹ (COO- stretching(Mirzayeva et al., 2021)), 1346.91 cm ⁻¹ , 1230.56 cm ⁻¹ , 985.1 cm ⁻¹ , 908.81 cm ⁻¹ , 522.28 cm ⁻¹ , 468.18 cm ⁻¹
4	Boric acid	3220.01 cm ⁻¹ (O-H stretching vibration(Kannigar DATERAKSA, 2021)), 2260.42 cm ⁻¹ , 1582.27 cm ⁻¹ , 1195.22 cm ⁻¹ , 987.12 cm ⁻¹ (all B-O stretching vibrations(Suryawanshi et al., 2023)), 695.32 cm ⁻¹ , 633.14 cm ⁻¹ (both B-O-H bending vibrations(Suryawanshi et al., 2023)), 471.05 cm ⁻¹

Table 5. Peaks of the components modified in the FTIR – ATR spectra, during the formation of the heteromolecular composite and the fruit jelly. Pectic substances were obtained from the leaves of *Melia azedarach*. MCC = microcrystalline cellulose

Peaks of components modified				Resultant peaks of heteromolecular composite	Remarks
Pectic substances	Sucrose	Glucuronic acid	Boric acid		
3343.87 cm ⁻¹				3339.16 cm ⁻¹	
1738.1 cm ⁻¹ (stretching vibration of carbonyl group (Han et al.,	1740.15 cm ⁻¹ (vibrations of -C-H(Hauswirth et al., 2022))	1739.62 cm ⁻¹ (stretching vibration of the carbonyl group	1739.9 cm ⁻¹ (B-O stretching vibrations(Sur	1738.99 cm ⁻¹	C=O bond stretching

2024))			(Han et al., al., 2023))		
1643.89 cm ⁻¹			2024))	1643.73 cm ⁻¹	
1437.14 cm ⁻¹	1428.08 cm ⁻¹ (vibrations of -C-H(Hauswirth et al., 2022))	1429.81 cm ⁻¹	1430.26 cm ⁻¹ (B-O stretching vibrations(Suryawanshi et al., 2023))	1431.99 cm ⁻¹	
1367.11 cm ⁻¹ (vibrations of -C-H(Hauswirth et al., 2022))	1367.58 cm ⁻¹ (vibrations of -C-H(Hauswirth et al., 2022))	1366.06 cm ⁻¹ (vibrations of -C-H(Hauswirth et al., 2022))	1370.87 cm ⁻¹ (B-O stretching vibrations(Suryawanshi et al., 2023))	1367.77 cm ⁻¹	(all vibrations of -C-H(Hauswirth et al., 2022))
1214.22 cm ⁻¹				1216.42 cm ⁻¹	
998.33 cm ⁻¹				997.79 cm ⁻¹	
685.14 cm ⁻¹				684.26 cm ⁻¹	
610.27 cm ⁻¹				610.04 cm ⁻¹	
			543.73 cm ⁻¹ (O-B-O vibrations (Kannigar DATERAKS A, 2021))	542.73 cm ⁻¹	
Peaks of components modified	Heteromolecular composite	MCC	Fruit	Resultant peaks of Fruit Jelly	
Pectic substances					
3343.87 cm ⁻¹	3339.16 cm ⁻¹	3340.52 cm ⁻¹	3341.06 cm ⁻¹	3340.95 cm ⁻¹	
2163.04 cm ⁻¹				2162.97 cm ⁻¹	
1738.1 cm ⁻¹	1738.99 cm ⁻¹	1738.9 cm ⁻¹	1740.21 cm ⁻¹	1739.08 cm ⁻¹	C=O bond stretching
1643.89 cm ⁻¹	1643.73 cm ⁻¹	1643.54 cm ⁻¹	1644.57 cm ⁻¹	1643.93 cm ⁻¹	
1437.14 cm ⁻¹	1431.99 cm ⁻¹	1433.54 cm ⁻¹		1433.65 cm ⁻¹	-CH ₂ bending (Mirzayeva et al., 2021)
1367.11 cm ⁻¹	1367.77 cm ⁻¹	1367.13 cm ⁻¹	1366.1 cm ⁻¹	1367.41 cm ⁻¹	
1214.22 cm ⁻¹	1216.42 cm ⁻¹	1216.13 cm ⁻¹	1218.94 cm ⁻¹	1215.89 cm ⁻¹	
			1073.39 cm ⁻¹	1079.98 cm ⁻¹	C-O-C bond vibration

998.33 cm ⁻¹	997.79 cm ⁻¹	998.86 cm ⁻¹		996.01 cm ⁻¹	n(Derksen et al., 2023) C-O-C bond vibration
685.14 cm ⁻¹	684.26 cm ⁻¹	684.73 cm ⁻¹		686.33 cm ⁻¹	
610.27 cm ⁻¹	610.04 cm ⁻¹	609.73 cm ⁻¹	612.72 cm ⁻¹	610.15 cm ⁻¹	
	542.73 cm ⁻¹	543.08 cm ⁻¹		541.78 cm ⁻¹	

A comparison of the spectra in figures 3 and 4 reveals that the same peaks of the same components disappeared/modified during the formation of the composite and jelly.

3.5. Rheological analysis of the low-sugar fruit jelly

Fruit jelly, prepared using the heteromolecular composite and the fruit alone, had a certain amount of apparent viscosity. But, when the heteromolecular composite was replaced with 1% microcrystalline cellulose, the average apparent viscosity increased. Supplementing this jelly with the heteromolecular composite, resulted in a higher average apparent viscosity. Thereafter, the average apparent viscosity increased with the concentration of the microcrystalline cellulose. These findings indicate that both the heteromolecular composite and the microcrystalline cellulose contributed to the apparent viscosity of the fruit jelly. Recently, the use of non-pectin molecules to modulate the rheological properties of pectin-based food gels has been experimented successfully (X. Zhao et al., 2024). Finally, the presence of 7% microcrystalline cellulose in the finished low-sugar fruit jelly was found to contribute the highest average apparent viscosity to the fruit jelly. The concentration of sucrose in this jelly was 0.8%. Figure 5 shows the trend of change in the average apparent viscosity of the low-

sugar fruit jelly with increasing concentrations of microcrystalline cellulose.

3.6. Texture profile analysis of the low-sugar fruit jelly

Earlier works indicate that the concentration of some or all the components affects the textural properties of fruit jellies (Putri et al., 2024). The fruit jelly prepared using heteromolecular composite and fruit alone had the highest hardness, gumminess, and chewiness. Adding microcrystalline cellulose, which is rich in hydroxyl groups, to the jelly decreased both these values due to the chemical interactions like H bonds among the components, as is evident from the FTIR spectra (Z. Wang et al., 2024). These parameters were further reduced with increasing concentrations of microcrystalline cellulose. Replacing the heteromolecular composite with microcrystalline cellulose also decreased hardness, gumminess, and chewiness. The presence of the heteromolecular composite and the microcrystalline cellulose had a cumulative effect on the textural properties. This knowledge can be used to design low-sugar fruit jelly with any required hardness, gumminess, and chewiness to suit the particular requirements of people with various pathophysiological conditions (Özder et al., 2024). The trend in the variation of textural properties with increasing concentrations of microcrystalline cellulose is shown in figure 6.

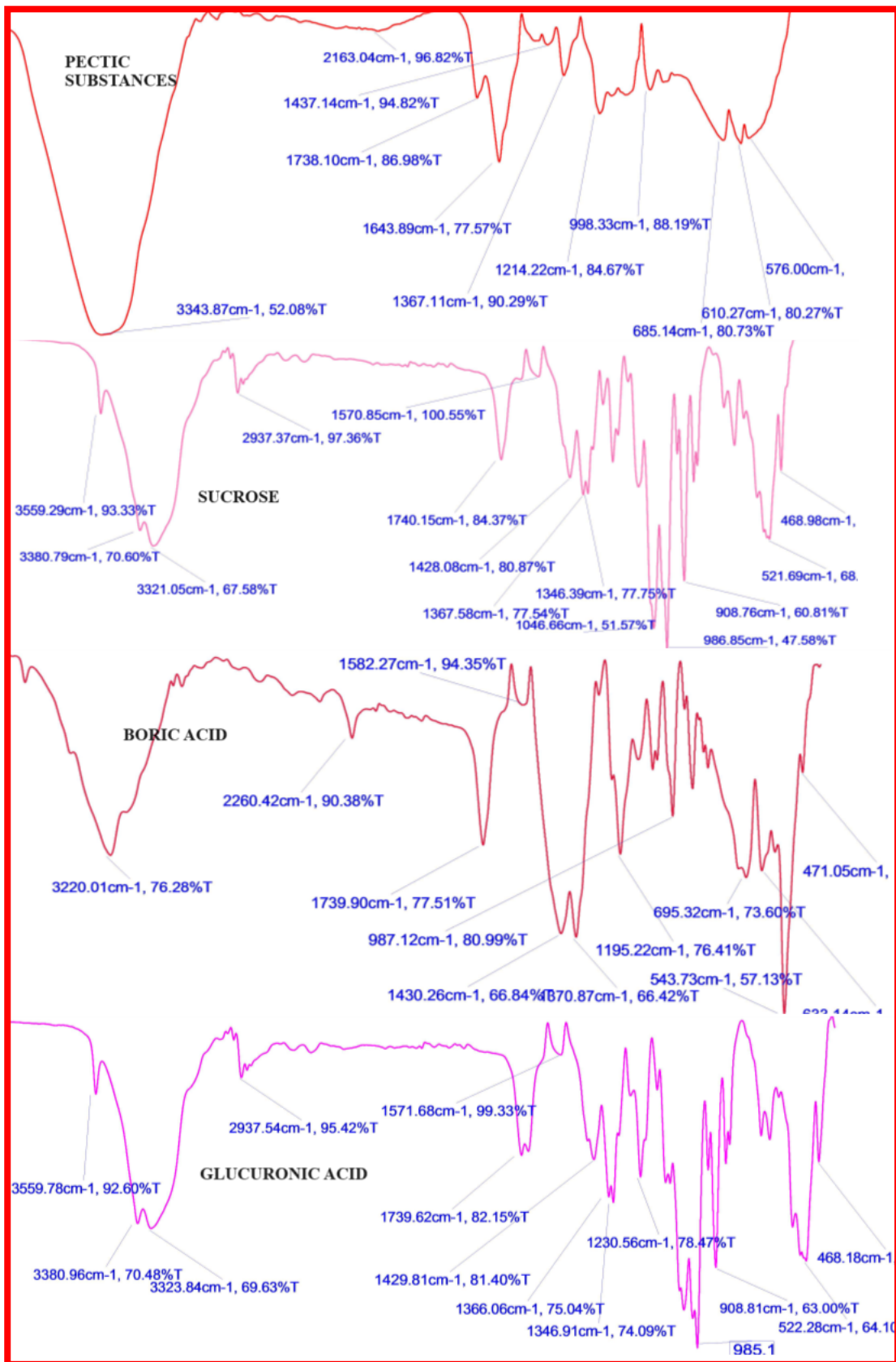


Figure 3. FTIR – ATR spectra of the components of the heteromolecular composite

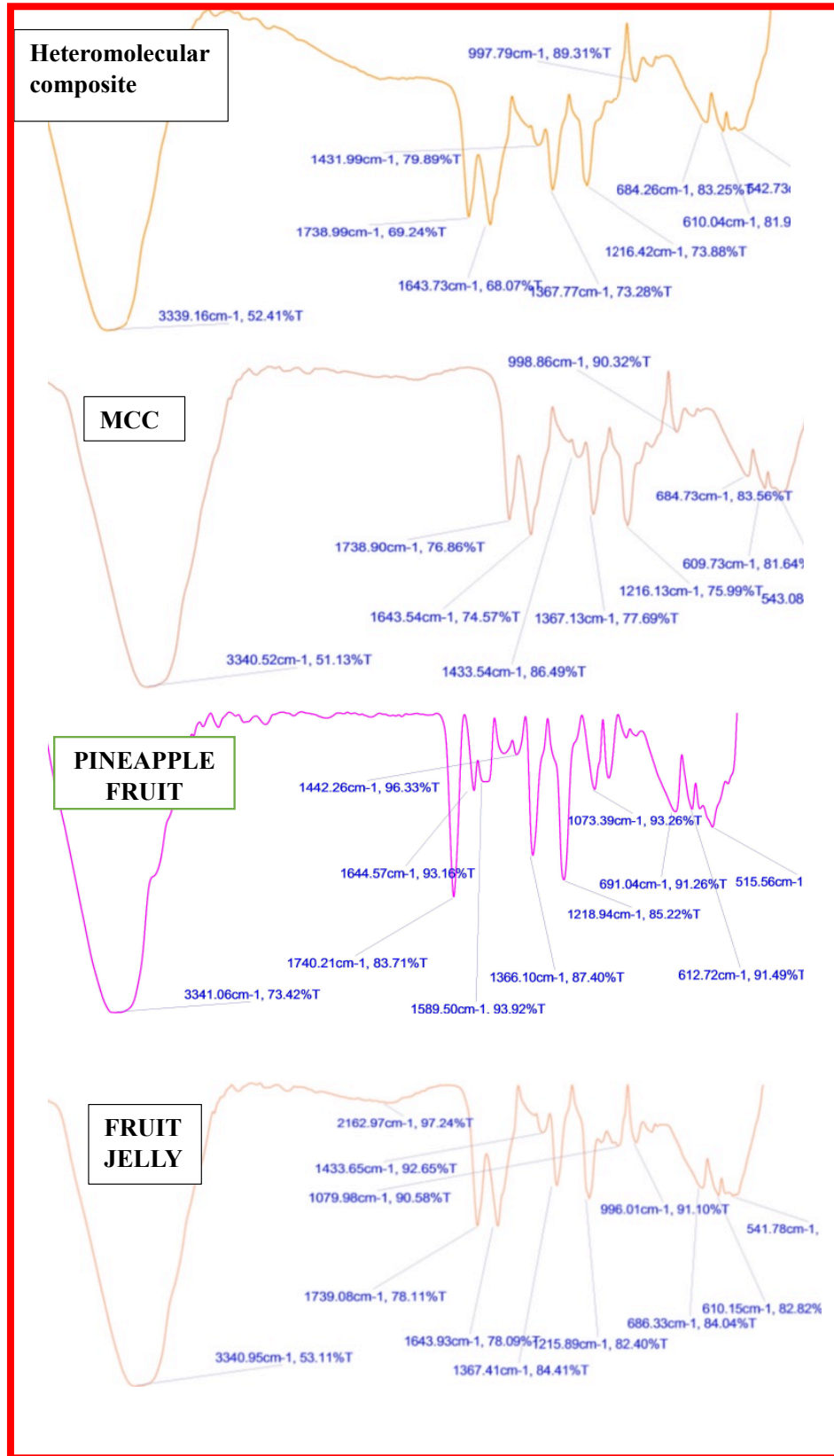


Figure 4. FTIR – ATR spectra of the low-sugar fruit jelly and its components. MCC = microcrystalline cellulose

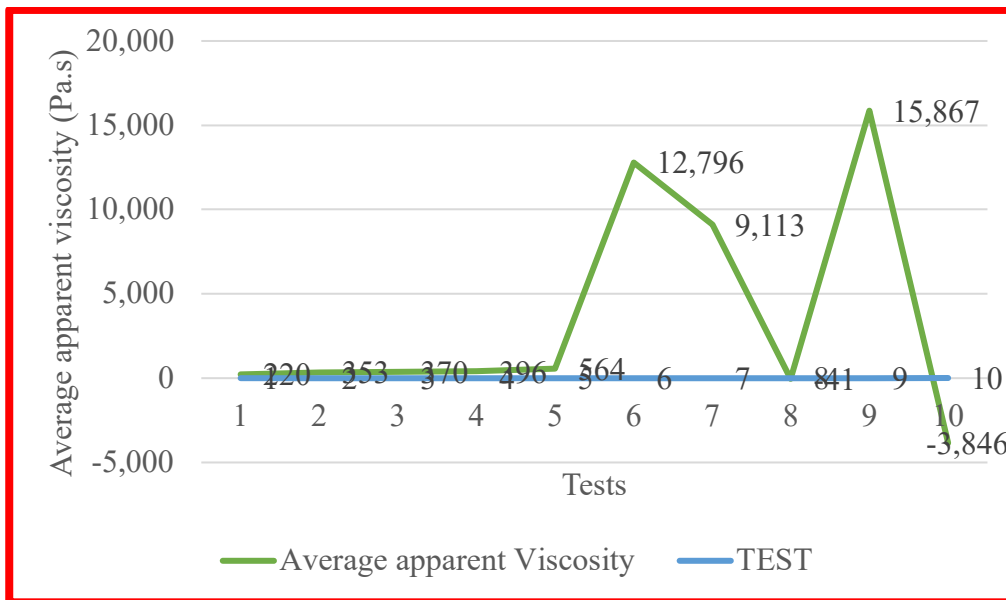


Figure 5. Average apparent viscosity of the low-sugar fruit jelly as a function of concentration of microcrystalline cellulose. Conditions for the preparation of the fruit jelly are given in table 3

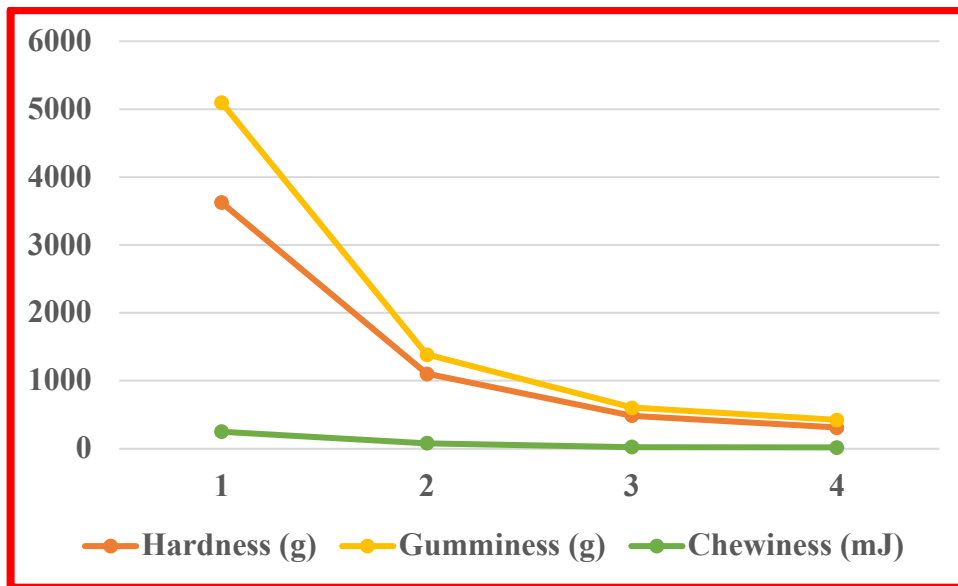


Figure 6. The trend in the variation of textural properties with increasing concentrations of microcrystalline cellulose

4. Conclusions

Thus, even though pectic substances extracted from the leaves of *Melia azedarach*, contain less galacturonic acid compared with pectin from traditional sources, it is a good candidate for use as a gelling agent when amalgamated with the right types of molecules. The heteromolecular composite obtained using the pectic substances, sucrose, boric acid, and

galacturonic acid interacts effectively with the microcrystalline cellulose and the pineapple fruit to form the low-sugar fruit jelly. Since the plant is widely distributed in nature and does not need to be cultivated, using this plant as the raw material does not result in polluting the environment. Adopting this knowledge for commercial production may benefit individuals with diabetes mellitus, those experiencing

chewing difficulties, and others, while also creating employment opportunities in rural communities.

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