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Research Article

Pectin Isolation from Interdonato Lemon (*Citrus-limon*) Using Various Solvents and Its Application in Pineapple Jelly

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Abstract: Interdonato lemon (*Citrus limon*) is a rich source of pectin. However, commercial extraction and application in jam and jelly have not been performed yet. The study's objective was to use ethanol and acetone precipitation to extract pectin from Interdonato lemon. Interdonato lemon was taken and passed through preliminary treatment to obtain albedo and dried in a dryer at 65 °C for 12 hr. To extract pectin, the dried albedo was heated in acidic water (pH 1 for both ethanol and acetone extraction maintained with citric acid) at 88 °C for 45 minutes. The resulting slurry was then filtered using muslin cloth, rinsed with hot water (88 °C), and filtered using Whatman No. 41 filter paper. Finally, the filtrate was precipitated using 95% ethanol and acetone in a ratio of 2:1 (sample: solvent), and centrifuged at 4,500 rpm for 20 min. The pectin was scrapped and dried in a hot air oven at 48 to 52 °C for 15 hr (ethanol) and a similar temperature for 18 hr (acetone). Ethanol-extracted pectin was superior in terms of chemical and physical analysis. Statistical analysis showed significant differences ($p < 0.05$) in all parameters of ethanol and acetone-extracted pectin except anhydrouronic acid (AUA) % and ash content. Moreover, the best pectin was utilized in the preparation of three pineapple jelly samples prepared with different extracted pectin concentrations (0.75%, 1%, and 1.5%) and coded as A, B, and C and compared with pineapple jelly prepared with Analytical Reagent (AR) grade pectin (100 grade) coded with sample D. From the sensory evaluations, sample B showed superior in terms of color, appearance, taste, texture, and overall acceptance. Hence, the findings highlighted actionable recommendations for commercially extracted pectin from the Interdonato lemon fruit albedo portion and applied to different food and pharmaceutical products.

***Keywords*:** pectin, precipitation, characterization, chemical analysis, pineapple jelly, sensory evaluation

1. Introduction

Lemons are spherical, tart, vivid green citrus fruits. They are nutrient-dense powerhouses that are loaded with antioxidants, vitamin C, and other necessary elements [1]. Among fruit crops, citrus fruit (genus Citrus in the family *Rutaceae*) is unique since it is widely cultivated and in high demand, even though its origin and history remain a mystery. China's Cochin region is home to the citrus reticulate. All around the subtropical world, it is widely cultivated.

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Among the Indian states with abundant agricultural land are Assam, Sikkim, Punjab, Central India, and Coorg [2]. Native to tropical and subtropical areas of Asia, such as China, the Philippines, India, Nepal, and Iran, are citrus lemon trees [3].

Acid lime, or Citrus aurantifolia Swingle, is a large commercial fruit that has traditionally been produced in most of Nepal's districts, according to the National Citrus Research Programmed of Dhankuta-Nepal. It is also known as "Kagati". In Nepal, sixteen percent of all fruit harvests are grown on lemon plantations [4]. Although there is a year-round market for lemons, lemon production in Nepal primarily occurs from September to November [5]. At the moment, citrus is cultivated in over 137 nations on six continents, mostly in tropical and subtropical climates, and it brings in over 105 billion US dollars a year to the worldwide fruit market [6]. After processing, it yields 50% juice, 29% peel, 20% residue, and 1% seed suit [7, 8]. Foods, drinks, and confections can all be flavored with citrus lemon juice. Lemon fruit is an essential ingredient in many chutneys and pickles. Limeade and other lemon-flavored drinks have a completely different flavor and scent from those made with real lemons [9].

Pectin is a polysaccharide that is often used in the food and pharmaceutical sectors. It acts as a thickening and gelling agent. Its medicinal uses include antidiarrheal, detoxifying, and blood sugar reduction [10]. Pectin is composed of a linear backbone of joined d-galacturonic acid units and a branching region of neutral sugars. Galactosaccharide's carboxyl group can be either free or methyl-esterified, resulting in high- and low-methoxyl forms of pectin depending on the degree of esterification. Peels from citrus fruits, such as orange, lemon, and lime fruits, are well recognized to be traditional sources of pectin used in commercial applications [11].

Pectin is composed of extended stretches of partially methyl-esterified (1→4)-linked α-D-galacturonate residues, sometimes known as the "smooth" region. D-xylose, D-glucose, L-rhamnose, L-arabinose, and D-galactose are among the sugars with faults that disrupt these sequences. High methoxyl pectin and low methoxyl pectin are the two categories of pectin based on the degree of esterification. D-galacturonic acid units make up pectin [12]. Pectin is traditionally produced in two steps: first, raw materials are extracted using water, and then the extracted solution is precipitated with alcohol to separate the pectin from the extracted solution. Protopectin is hydrolyzed with acid to extract commercial pectin at high temperatures. High temperature and low pH extraction generally produce higher yields [11].

Pectin is a sugar present in plant walls that is utilized as a gelling agent, especially in jams and jellies. Pectin accounts for around 30% of citrus fruit peels. Consuming pectin influences blood cholesterol levels and aids in blood sugar regulation [13]. Interdonato lemon (*Citrus limon*) is a citrus fruit, whose flavedo is a good source of pectin, accounting for up to 35% [14]. The most popular techniques for obtaining pectin from raw materials include aqueous extraction, which includes direct boiling, acid, enzyme, and alcohol extraction, as well as microwave, ultrasonic, autoclave, and electromagnetic induction. All of these pectin extraction techniques contribute to a certain degree of pectin quality degradation, so the quality enhancement techniques are still in the research [15]. The variables that impact the production of pectin include temperature, extraction time, pH level, and source material [16].

Scientific research has been done on a variety of fruit peels, but not on the flavedo portion of the fruit as of yet. Research and improvement deficiencies are major barriers to promotion. The primary problem with the product (jelly) is its chemical makeup, nutritional value, and process optimization, which have not received enough attention in the study on Interdonato lemon flavedo pectin-based goods [17]. The main goal of our scientific study is the extraction of pectin from Interdonato lemons (*Citrus limon*) using various solvents, utilized for the production of pineapple jelly. From a broader perspective, we encouraged the farmer to commercially produce Interdonato lemons (*Citrus limon*), and the food industry should adopt the production of pectin and apply it to jam and jelly production.

2. Materials and methods

2.1 *Description of the study area*

The research was performed from June 2023 to July 2023 in the research lab of Birat Multiple Campus, Biratnagar, Nepal. Geographically, the experimental area is situated at Latitude 26° 26′ 59.64″ N, and Longitude 87° 16′ 21.36″ E with an average altitude of 74 m (243 ft.). The minimum and maximum temperatures range from 11 °C and 43 °C respectively, and the average annual precipitation falls 1,542.43 mm.

2.2 *Raw materials*

Interdonato lemon (*Citrus Limon*) a citrus fruit, was obtained from the local market of Khotang district. Sugar and pineapple (*Ananas comosus*) were obtained from the local market of Biratnagar, and water was supplied by Birat Multiple College, Biratnagar.

2.3 *Experimental layout*

The work layout of the research is summarized in Figure 1.

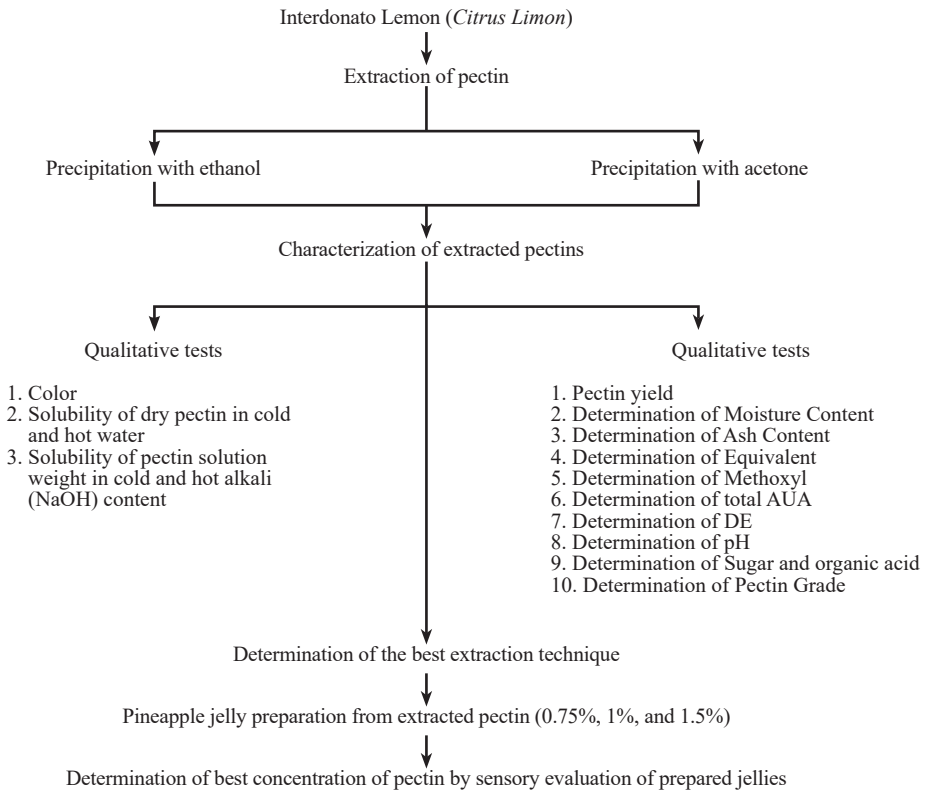

Figure 1. Work layout of the scientific research

2.4 *Methodologies*

2.4.1 *Extraction of pectin*

After heating the Interdonato lemon albedo with water, the cell walls are broken down by the addition of citric acid during the extraction process. To assist in dissolving pectin, the mixture was heated to 88 °C with a pH of 1. After further filtering, separate acetone and ethanol precipitations were made, and the pectin was centrifuged, and then dried. The ethanol and acetone extraction processes [18, 19], provided some minor modifications to the pH, solvent ratio, drying time, and temperature throughout the extraction process. In addition, the centrifugation procedure following precipitation was included; Figure 2 and Figure 3 showcase this process.

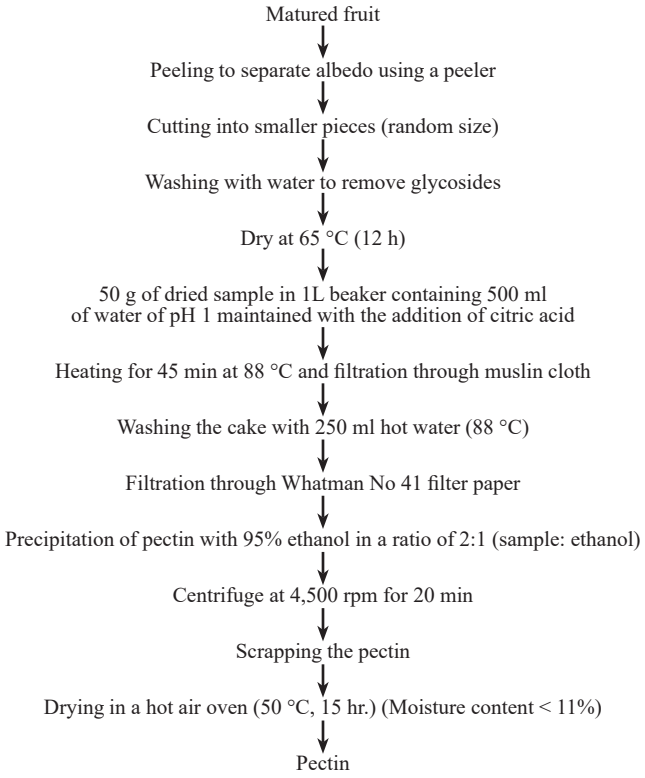

Figure 2. Flow chart for the extraction of pectin by precipitation with ethanol

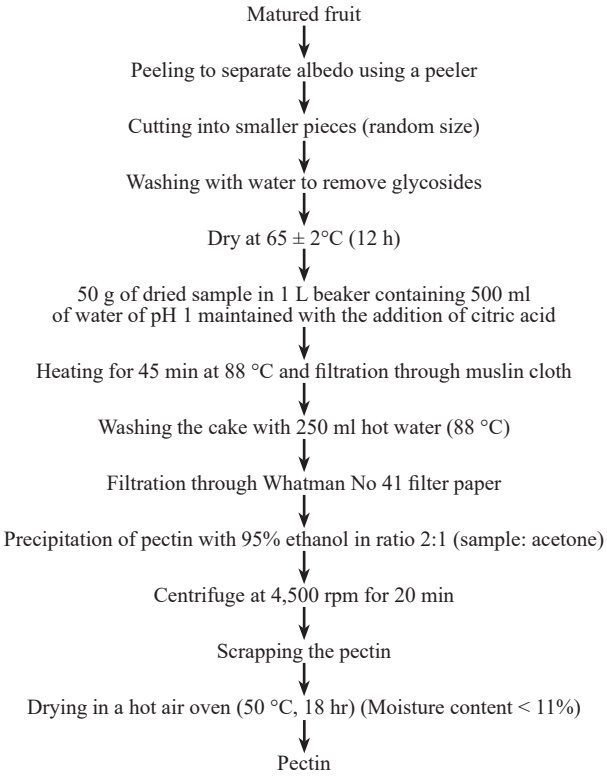

Figure 3. Flow chart for the extraction of pectin by precipitation with acetone

2.4.2 *Characterization of pectin*

To ascertain its properties, the dried pectin that was isolated from Interdonato lemon peels underwent the following qualitative and quantitative testing. The qualitative analysis is presented in Table 1.

Table 1. Qualitative analysis of pectin

Qualitative analysis	Procedure	References
Color	Visual observation	-
Solubility of pectin (cold and hot water)	Ten milliliters of 95% ethanol, fifty milliliters of distilled water, and 0.25% w/w of the pectin samples. The mixture was heated for about 15 minutes at a temperature of 85 and 95 °C	[20]
Solubility of pectin solution (cold/ hot alkali NaOH)	After adding 1 ml of 0.1 N NaOH to 5 ml of pectin solution, the mixture was heated for 15 minutes at 85-90 °C	[20]

2.4.2.1 *Quantitative analysis*

Pectin yield

Pectin yield was determined as given by the Ranganna [21].

$$\text{Pectin } (g\backslash 100g) = \frac{\text{weight of dried pectin}}{\text{weight of dried peel powder taken}} \times 100\%$$

Determination of moisture content

Based on the Ranganna [21], moisture content was calculated. For four hours, 1 gram of the material was dried at 100 to 105 °C. Weigh after cooling in a desiccator.

Determination of ash content

To calculate the ash content, two grams of the sample were placed in a dry crucible, heated to 600 °C for three to four hours, cooled in a desiccator, and then weighed [21].

$$\text{Ash\%} = \frac{Wt.\,of\ ash \times 100}{Wt\ of\ sample}$$

Determination of equivalent weight

One of the pectin's most significant physical characteristics is equivalent weight. It is the feature that matters most in figuring out how pectin functions. The gelling power of individual pectins is highly correlated with their equivalent weight. Ranganna determined equivalent weight [21]. A 250 ml conical flask was filled with a 0.5 g sample, and 5 ml of ethanol was added. There was an addition of 1 g of sodium chloride and 100 ml of distilled water. Six drops of phenol red were then added, and the mixture was titrated against 0.1 N NaOH. The hue pink represented the titration point. This neutralized solution was kept to determine the methoxyl content.

Equivalent weight was calculated by following the formula:

$$\text{Equivalent weight} = \frac{\text{weight of sample} \times 1{,}000}{\text{ml of alkali} \times \text{normality of alkali}}$$

Determination of methoxyl content (MeO)

MeO was determined using the Ranganna [21] Technique. After the equivalent weight was determined, the neutral solution was collected, and 25 ml of sodium hydroxide (0.25 N) was added. The combined mixture was well-mixed and allowed to stand at room temperature for half an hour. Following a half hour, 25 milliliters of 0.25 N hydrochloric acid were added and titrated against 0.1 N NaOH. Methoxyl content was calculated by applying the formula:

$$\text{Methoxyl content } (\%) = \frac{\text{ml of alkali normality} \times 3.1}{\text{weight of sample}} \times 100\%$$

Determination of total Anhydrouronic acid content (AUA)

Pectin's total AUA was determined in accordance with Ranganna [21], Using the subsequent formula:

$$\%\text{ of } AUA = \frac{176 \times 0.1z \times 100w \times 1,000 + 176 \times 0.1y \times 100w \times 1,000}{w \times 1,000} \times 1,000$$

z = ml of NaOH from equivalent weight determination.

Y = ml of NaOH from methoxyl content determination.

W = weight of sample.

Determination of degree of esterification (DE)

Based on the methoxyl and AUA levels, the DE of pectin was determined using the formula provided by Ranganna [21].

$$\%\text{ of } DE = \frac{176 \times \%\, MeO}{31 \times \%\, AUA} \times 100\%$$

Determination of pH

A pH meter was used to measure it immediately. By utilizing buffer solutions with pH values of 7 and 4 at the necessary temperature, the pH meter was standardized by Ranganna [21].

Determination of sugar and organic acid (OA) content

In each 500 mL flask, one gram of the pectin sample was added, along with five milliliters of ethanol and one hundred milliliters of water. The flasks were then quickly shaken and left to stand for ten minutes. This solution was combined with 100 ml of ethanol containing 0.3 ml of hydrochloric acid, quickly filtered, and the filtrate was metered out into a 25 ml conical flask. The residue was dried in an oven at 50 °C for two hours, while the liquid evaporated in a steam bath [21].

$$\%\text{ Sugar and OA} = \frac{\text{weight before dry} - \text{weight after dry}}{\text{weight of sample}} \times 100\%$$

Determination of pectin grade

Based on Ranganna [21], the pectin grade was ascertained. Test samples with varying concentrations of pectin were used to make jellies, which were then compared to a standard 100-grade pectin sample prepared under comparable circumstances to determine the grade. Compiling a comparison requires the following:

(1). 65% Sugar jelly.

(2). pH 3 ± 0.05.

(3). For both unknown and standard, the time lapsed after jelly-making was eighteen hours.

Procedure:

In addition to measuring the empty vessel's weight, 65 g of sugar and 35 ml of water were also measured. After adding five times the weight of sugar (pectin: sugar = 1:5) and boiling, five different quantities of test pectin were applied. All of the sugar was then added. Upon reaching a weight of 100 ± 2 g, 0.5 ml of citric acid and 1 ml of sodium citrate were added. The mixture was then brought to a boil once more, at which point the heat was turned off and a petri dish was covered. The mixture was left for 18 hours, during which the jelly was compared to normal jelly. The pectin grade was

then determined.

$$\text{Pectin grade} = \frac{weight\ of\ sugar}{weght\ of\ pectin}$$

2.4.3 *Comparison of extracted pectin*

Upon finding a significant difference, the extracted pectin was compared using both qualitative and quantitative tests in SPSS (IBM Statistics 27). The ideal extraction method was determined to be the precipitation solvent that extracts the highest-quality pectin. Thus, more pineapple preparation was applied to the highest quality pectin. Since pineapple has a relatively low proportion of pectin, it was used for jelly manufacturing [22].

2.4.4 *Sample preparation*

The samples prepared are presented in Table 2.

Table 2. Coding of different sample

S.N.	Code	Pectin concentration
1.	A	0.75%
2.	B	1%
3.	C	1.5%
4.	D	AR Grade

AR: Analytical Reagent

2.4.5 *Preparation of jelly using extracted pectin*

Using a crusher, the pineapple juice was removed. 12% TSS and 0.5% acidity from citric acid were present in the extracted pineapple juice. After that, pineapple jellies were made by boiling 45% juice and 55% sugar, then adding 1.05 g of citric acid and different concentrations of extracted pectin (0.75%, 1%, and 1.5%) as well as AR grade pectin (100 grade), albeit with minor modifications from Nwosu JN et al. [23]. In Table 3, the recipe table is displayed.

Table 3. Recipe for jelly preparation

Sample	Juice (ml)	Acid (g)	Pectin (g)	Sugar (g)
A	100	1.05	1.66	130
B	100	1.05	2.22	128
C	100	1.05	3.33	127
D	100	1.05	2.22	128

2.4.6 *Preparation of pineapple jelly*

For the preparation of pineapple jelly, the process was followed by Nwosu JN et al. [23] with slight modifications. Initially, Fresh matured pineapple was sorted and taken for juice extraction, Firstly, the preliminary treatment was carried out which involved cleaning, peeling, and cutting into required pieces. Following, the juice was extracted by crushing and maintaining TSS 12 °Brix and 0.5% acidity as a citric acid. After that, the boiling of juice was carried out where the juice was 45% and sugar was 55%, with the addition of 1 g of citric acid to maintain the acidity of the juice. Subsequently, the addition of pectin takes place 0.75% at first and gradually 1 and 1.5%. Next, the judgment of the endpoint of jelly takes place and finally maintains at 65 degrees with the help of a hand refractometer. Finally, the colling and setting of jelly is stored in a glass jar.

2.4.7 *Sensory evaluation*

After being extracted at various concentrations (0.75%, 1%, and 1.5%), the final pineapple jelly was made and put through a sensory assessment in comparison to normal AR grade (100 pectin grade) pectin. Using nine hedonic rating scales, fifteen semi-trained panelists evaluated the sensory aspects of color, appearance, texture, taste, and overall acceptability.

2.4.8 *Statistical analysis*

The experiment was run in triplicate, and all measurements were done so as well. Genstat Discovery Edition 12.1 was used to statistically assess the gathered data for Analysis of Variance (ANOVA) at a significance level of 5% [24]. Similarly, with regard to an independent t-test, equality of variances and means at a 95% confidence interval were applied using IBM SPSS 20 (IMB Corporation, Marlborough, MA, USA) [25].

3. Results and discussion

After peeling and separating the albedo part of an Interdonato lemon (*Citrus limon*), pectin was extracted using acetone and ethanol. The pectin that precipitated in ethanol and acetone was examined chemically and physically. After undergoing qualitative and quantitative testing, the best-extracted pectin was used to manufacture pineapple jelly.

3.1 *Albedo content of Interdonato lemon*

Fruit byproducts are processed to extract pectin for usage in goods. The albedo concentration of Interdonato lemons was determined to be 30.51% on a dry basis. The finest sources of pectin are the peels from citrus fruits, albedo, and flavedo ingredients. Pectin production increases with a quantitative increase in albedo content. The albedo percentage of a normal Interdonato lemon fruit is between thirty and forty percent. During the extraction of pectin from citrus fruits the albedo content was *citrus limon*, 35% [26], apple 8.43% [27], orange 38.45% [28].

3.2 *Chemical composition of albedo portion*

The proximate composition of the albedo portion of Interdonato lemon is presented in Table 4.

Table 4. Proximate composition of albedo portion of Interdonato lemon

Parameters	Value (% wb)
Moisture	14.73 ± 0.2
Ash	6.25 ± 0.04

Table 4. (cont.)

Parameters	Value (% wb)
Crude protein	9.40 ± 0.15
Crude fat	5.01 ± 0.21
Crude fiber	15.15 ± 0.07
Total Carbohydrate	63.16 ± 0.65

* Values are the means of three determinations standard deviations. Wb = wet basis

3.3 *Pectin yield from the albedo*

Pectin yields for ethanol and acetone precipitation were 29.98 ± 1.57 and 32.79 ± 2.06, respectively, given in Figure 4, on a wet basis (%). Interdonato lemons often have a fruit albedo of 16-35% pectin. Algae occupied 33% of the Interdonato lemon's surface area. The slight variation in pectin content from the albedo may be explained by the type of Interdonato lemon you select or how they are treated [28].

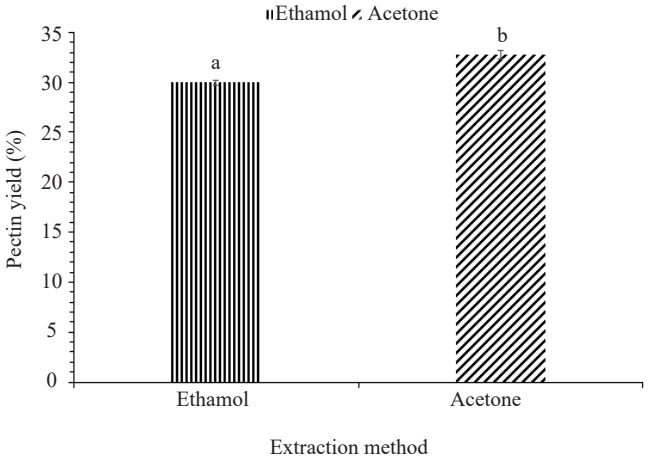

Figure 4. Pectin yield from the albedo portion

Where a and b are the significant differences between the samples.

3.4 *Analysis of pectin*

The Interdonato lemon albedo portion's pectin, which had been extracted using ethanol and acetone solvent, was analyzed both qualitatively and quantitatively.

3.4.1 *Qualitative analysis*

The physical analysis of extracted pectin is presented in Table 5.

Table 5. Qualitative analysis of pectin extracted from the albedo portion of Interdonato lemon

Parameter	Ethanol	Acetone
Color	Brown	Dark brown
Solubility		
a. Cold water	Insoluble	Insoluble
b. Hot water	Soluble	Soluble
c. Cold alkali (NaOH)	Slightly soluble (yellow color)	Slightly soluble (yellow color)
d. Hot alkali (NaOH)	Soluble	Soluble

In general, pectin has a pale hue [29]. Surface contamination, environmental factors, the types of fruits used, and human error may have all contributed to the discrepancy in color. This may be due to the higher time pectin drying after the scrapping. Table 4. All had the characteristic color of brown pectin. Pectin shows a brown color after drying [30].

Pectin solubility is influenced by temperature, pH, molecular weight, degree of esterification, and ions in the solution. Low solubility was seen in cold water, but pectin was soluble in hot water due to acetone's aprotic polar solvent and disfavoring hydrogen bonding [31]. Pectin solubility is influenced by temperature, pH, molecular weight, degree of esterification, and ions in the solution. Low solubility was seen in cold water, but pectin was soluble in hot water due to acetone's aprotic polar solvent and disfavoring hydrogen bonding [32].

3.4.2 *Quantitative analysis*

The values of chemical components of Interdonato lemon pectins on a wet basis (%) are presented in Table 6.

Table 6. Quantitative analysis of pectin extracted from the albedo portion of Interdonato lemon

Parameter	Ethanol	Acetone
Moisture content %	$9.78^{a} \pm 0.15$	$9.47^{b} \pm 0.04$
Sugar and organic acid %	$2.07^{a} \pm 0.0.08$	$1.85^{b} \pm 0.05$
pH	$4.0^{a} \pm 0.1$	$4.31^{b} \pm 0.07$
Ash content %	$6.04^{a} \pm 0.08$	$6.45^{a} \pm 0.41$
Equivalent weight	$626.47^{a} \pm 9.58$	$598.10^{b} \pm 2.33$
Methoxyl content %	$6.05^{a} \pm 0.47$	$5.20^{b} \pm 0.02$
Pectin grade	$108.25^{a} \pm 2.5$	$83.12^{b} \pm 1.64$
Anhydrouronic acid (AUA) %	$62.49^{a} \pm 2.27$	$59.11^{a} \pm 0.23$
Degree of esterification (DE) %	$54.92^{a} \pm 2.38$	$50.06^{b} \pm 0.05$

* Values are the means of three determinations standard deviation. Mean sharing the same letter within a column is non-significant. Means followed by different letters within each column are significant and tested at a 5% level of significance

In comparison between the pectin extracted from ethanol and acetone, statistical analysis showed that there is a significant difference ($p < 0.05$) between the moisture content, sugar and organic acid, pH, equivalent weight, methoxyl

content %, pectin grade, and degree of esterification (DE) % in contrast, anhydrouronic acid (AUA %) and ash content % show no significant difference ($p > 0.05$). The moisture content of 9.4-11.3% for commercial pectin [19], and the moisture content of pectin extracted and precipitated with ethanol and acetone were found to be 9.78% and 9.47%, respectively which shows similar results. Due to its high hygroscopicity, pectin must be maintained in an enclosed, dry environment. The moisture percentage of pectin derived from dragon fruit and other citrus peels such as Kinnow, Musambi, Malta, and Feutral ranges from 9.4 to 11.3 percent [28]. The sugar and organic acid content of the pectin precipitated with ethanol and acetone was found to be 2.07% and 1.85% respectively while the pH was found to be 4.0 and 4.31 respectively. The pectin grade was determined to be 108.25 and 83.12 respectively for pectin precipitated with ethanol and acetone.

The ash contents of pectin precipitated with ethanol and acetone were found to be 6.04% and 6.45%, respectively, while commercial pectin had an ash concentration of roughly less than 10% [29]. The ash level of various fruits ranged from 6.9 to 11.6% (dragon fruit), to Musambi, Malta, and Feutral, and from 6.5 to 8.9% in orange peels. The method and characteristics of the citrus fruits utilized for extraction might be to blame for the vast range of variance. The equivalent weights of pectin precipitated with ethanol and acetone were determined to be 626.47 and 598.10, respectively, falling within the same range as that of cocoa husk pectin [30]. However, the equivalent weight of pectin from apple pomace was found to be 833.33-1,666.30, which was higher as revealed by Nazaruddin Ramli et al. [33]. More gel formation would be the outcome of a higher equivalent weight. The reduced equivalent weight might be the result of higher pectin partial breakdown. The amount of free acid present may also have an impact on whether the equivalent weight rises or falls [34]. The methoxyl content of pectin precipitated with ethanol and acetone was determined to be 6.05% and 5.20%, respectively. These results were higher than dragon fruit pectin (2.98% to 4.34%) but slightly equivalent to those found for mango peel (7.33%), banana peel (7.03%), pomelo peel (8.57%), lime peel (9.92%), and passion fruit peel (8.81%-9.61%) [35]. The amount of methyl content greatly influences pectin's setting time and gel-forming capacity [36]. Premature samples had the greatest methoxyl content, followed by mature and overripe samples. Pectin's capacity to distribute and bind sugar raises the concentration of methyl groups [36].

The AUA concentration of the pectin that precipitated with acetone and ethanol was discovered to be 62.49% and 59.11%, respectively. The AUA (2.98% to 4.34%) of commercial apple pectin and dragon fruit pectin, respectively, ranges from 59.52 to 70.50% and 45.25 to 52.45% [33], but is higher in commercial apple pectin (8.81%-9.61%) [37]. Estimating the anhydrouronic acid concentration allows for the evaluation of the physical attributes, purity, and esterification level [20]. Low AUA values suggest that there may be a significant concentration of protein, starch, and sugars in the precipitated pectin [37]. After the extracted pectin precipitated with acetone and ethanol, its DE was determined to be 54.92% and 50.06%, respectively. Pectin may be categorized into two groups based on DE: low methoxyl (< 50% DE) and high methoxyl (> 50% DE). Fruits lose some of their esterification as they get older. The reduced DE might be caused by the increasing sugar content during fruit growth, which softens the fruit. According to Allwyn et al. [38], DE is solely dependent on species, tissue, and stages of development.

3.4.3 *Comparison of extracted pectin for pineapple jelly preparation*

The extracted pectin employing ethanol and acetone solvents was compared qualitatively. The qualitative study did not reveal many differences, but the quantitative analysis was comparable. The statistical analysis was performed for a comparison with a significant difference at the 5% level. Pectin with ethanol precipitation performed better in terms of equivalent weight, methoxyl content, AUA, DE, and pectin grade.

3.4.4 *Sensory evaluation of pineapple jelly from Interdonato lemon peel*

Initially, three distinct samples of pineapple jelly were created. The samples had varying pectin concentrations (0.75, 1%, and 1.5%) and were classified with A, B, and C, respectively (Figure 5). They were compared to pineapple jelly made from normal AR-grade pectin, which was coded with sample D.

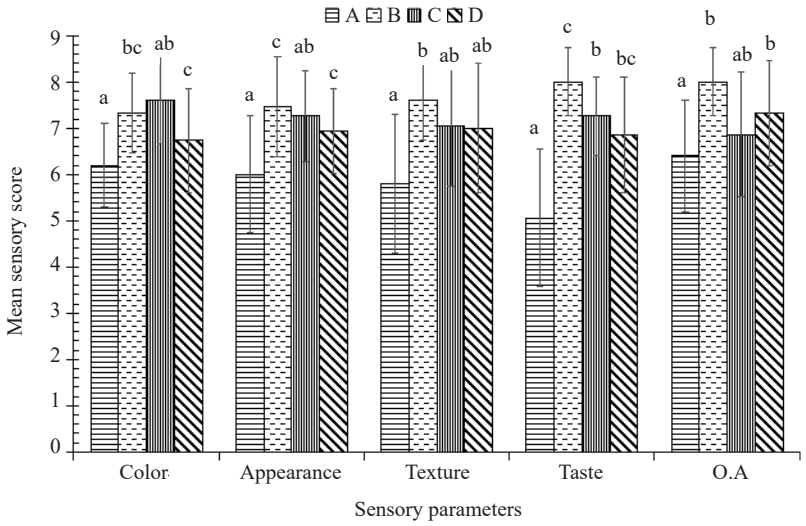

Figure 5. Effect of different pectin utilization on the sensory parameters of pineapple jelly
*A comparable alphabet above the bar shows no significant difference ($p > 0.05$), whereas a different alphabet indicates a significant difference. The error bars indicate the standard deviation.

3.4.4.1 *Effect of pectin on the color of pineapple jelly*

The color sensory scores for samples A, B, C, and D were 6.20 ± 0.90, 7.33 ± 0.86, 7.60 ± 0.95, and 6.73 ± 1.12, respectively, as shown in Figure 5. Sample C had the highest mean score (7.60 ± 0.95). Samples A & D showed a significant difference ($p < 0.05$) at the 5% level of significance in the sensory score analysis, but samples B & C and B & D did not vary substantially ($p > 0.05$). Devi [19] and Fernandes et al. [39] reported that the jelly made from the pectin extracted from the citrus peel gave an excellent color to the lab-grade pectin.

3.4.4.2 *Effect of pectin on the appearance of pineapple jelly*

Figure 5 illustrates that samples A, B, C, and D had mean sensory scores of 6.00 ± 1.26, 7.46 ± 1.08, 7.20 ± 0.99, and 6.93 ± 0.92, respectively. Sample B showed the highest mean score (7.46 ± 1.08). The sensory score analysis revealed significant differences ($p < 0.05$) between samples A & D, B & C, and C & D, but not between A & C and B & D ($p > 0.05$) at a 5% level of significance. Devi [19] and Fernandes et al. [39] reported that the jelly made from the pectin extracted from the citrus peel showed a better appearance.

3.4.4.3 *Effect of pectin on the texture of pineapple jelly*

As shown in Figure 5, the mean sensory score for the texture of samples A, B, C, and D were 5.80 ± 1.51, 7.60 ± 0.87, 7.06 ± 1.33, and 7.00 ± 1.14. Sample B had the highest mean score (7.60 ± 0.87). The sensory score analysis revealed significant differences ($p < 0.05$) between samples A and B, but not between A and C, A and D, B and C, or B and D ($p > 0.05$) at the 5% level of significance. Fernandes et al. [39] reported similar results in different fruit-extracted pectin jelly which stated that the jelly had great texture but the flavor was a bit undesirable of jelly made from citrus peel.

3.4.4.4 *Effect of pectin on the taste of pineapple jelly*

Samples A, B, C, and D had mean sensory scores of 5.06 ± 1.48, 8.00 ± 0.73, 7.26 ± 0.85, and 6.86 ± 1.25, respectively (Figure 5). Sample B exhibited the highest mean score (8.00 ± 0.73). The sensory score analysis revealed significant differences ($p < 0.05$) between samples A, B, and C, but not between B and D or C and D ($p > 0.05$) at the 5% level of significance. Devi [19] and Fernandes et al. [39] revealed that the jelly made from the pectin extracted from the citrus peel gave an excellent taste to the lab-grade pectin.

3.4.4.5 *Effect of pectin on overall acceptance of pineapple jelly*

Figure 5 shows the mean sensory scores for samples A, B, C, and D for overall acceptance: 6.40 ± 1.20, 8.00 ± 0.721, 6.80 ± 1.35, and 7.33 ± 1.13. Sample C showed the highest mean score (8.00 ± 0.72). The sensory score analysis revealed significant differences ($p < 0.05$) between samples A & B and A & D, but no significant differences ($p > 0.05$) at the 5% level of significance. Thus, sample B (1% pectin concentration) closely matched sample D (AR grade pectin jelly). So, the B sample was confirmed to be the best. Devi [19] and Fernandes et al. [39] revealed that the jelly made from the pectin extracted from the citrus peel showed a greater acceptance level than the lab-grade pectin.

3.5 *Chemical composition of pineapple jelly*

The proximate composition of pineapple jelly was determined and presented in Table 7 The analyzed results were within the ranges revealed by the various researchers [19, 39].

Table 7. Proximate composition of pineapple jelly

Parameters	Value
Moisture	35.8 ± 5.03
Ash	0.44 ± 0.02
Protein	0.36 ± 0.04
Carbohydrate	63.38 ± 5.02

* Values are the means of three determinations standard deviation

3.6 *Limitations and recommendations*

Based on our research, only a single variety of citrus fruit was taken for pectin extraction. Next, the extraction was done only at a single time and temperature. We recommended different varieties of fruits, available in various locations, can be used to extract high-quality pectin and create affordable, nutrient-dense food products. Secondly, by applying various extraction techniques and upholding various appropriate parameters (pH, temperature, time, process), it is possible to boost the extraction quality and yield percentage.

4. Conclusions

With regards to our study, Pectin yield using ethanol as a solvent was found to be 29.98%, and using acetone as a solvent was found to be 32.79%, respectively. The extracted pectin using ethanol solvent showed superior quality in terms of physical and chemical analysis. From sensory analysis, the pineapple jelly prepared using 1% extracted pectin concentration was very similar to AR-grade pectin jelly and found to be superior concerning appearance, color, texture, taste, and overall acceptance as scored by the semi-trained sensory panelist.

Authors' contribution

Kiran Phayel: Writing-original draft, Conceptualization, Formal analysis Methodology, Investigation, Data Curation, Software, Resource collection, Investigation. Ganga Sangroula: Writing-original draft, Reviewing & editing Conceptualizing, Visualizing, software, analyzing, methodology, Supervising, and Investigating. Adit Sangroula:

Conceptualization, Visualization, and software Prabina Niraula: Resource collection, Visualization, and Reviewing-editing.

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Conflict of interest

The authors disclose no conflicts of interest, and everyone contributed equally to the manuscript's development and final approval.

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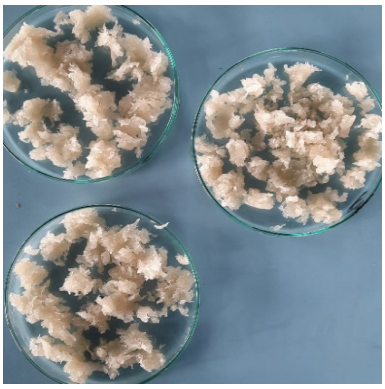
Appendix

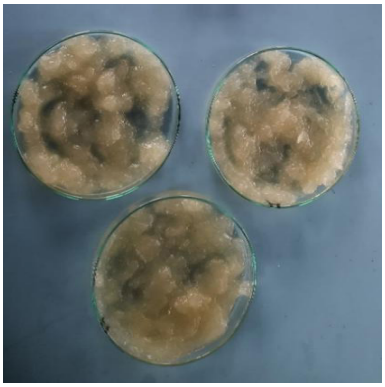
Photo gallery

P.1 Interdonato lemon

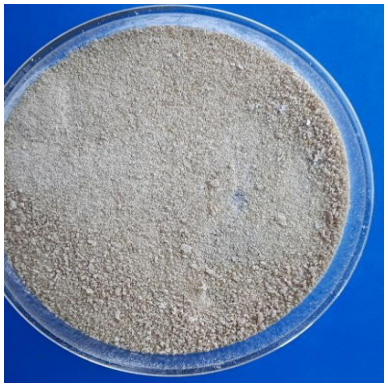
P.2 Dried albedo portion



P.3 Ethanol extracted pectin before drying



P.4 Acetone extracted pectin before drying



P.5 Ethanol extracted pectin after drying

P.6 Acetone extracted pectin after drying