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Extraction and characterization of pectin from Colombo lemon (*Citrus limon*) peel

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ABSTRACT

The study investigated the effect of temperature, time, and pH on pectin extraction from Colombo lemon peel. The extracted pectin was analyzed for it's physicochemical characteristics. The functional groups of the pectin were located using Fourier transform infrared (FTIR) spectroscopy. Pectin from the dried peel powder was extracted in water at different combinations of time (20 mins, 40 mins and 60 mins), temperature (60°C, 80°C and 100°C), and pH (2, 2.5 and 3.0) using 95% ethanol. The optimal conditions for pectin extraction from Colombo lemon peel were determined at 80°C heating temperature, 60 min heating time, and pH 2 yielding 15.2% pectin. The moisture content, ash content, equivalent weight, methoxyl content, anhydrouronic acid content, degree of esterification, acetyl value and water activity of the extracted pectin were 13.30%, 2.45%, 819.67 mg/mol, 7.25%, 62.66%, 65.60%, 0.45%, 0.46 respectively. The findings of these characteristic studies suggest the suitability of the extracted pectin to be used in food preparation such as jam and jelly.

Introduction

Complete utilization of fruit waste has been a major challenge faced by the food industry. With increased health awareness production and consumption of fruits and vegetables have increased, resulted in the increased generation of waste or by-products. The wastes are not limited from cultivation stage but also from processing plant (Ferreira *et al.*, 2015; Salim Singh, and Raghavan 2017). Fruit wastes and by-products are often discarded, even though these are rich in different bioactive compounds, phytochemicals, essential oils, pectin, and dietary fibers etc. (Chavan *et al.*, 2018; Rahmani *et al.* 2020; Garcia and Raghavan 2022).

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Pectin is a family of complex, acid-rich polysaccharides from plant cell walls. They are widely used as gelling and stabilizing agents in the food, pharmaceuticals and cosmetic industries (May 1990; Mohanasundaram *et al.*, 2023). The composition of pectin depends on the plant source and conditions employed during pectin isolation and purification. As such, extraction is an important step in the recovery of pectin, and the choice of extraction conditions depends upon the raw material and the desired product (Dranca and Oroian, 2018).

The main sources for commercial pectin production are apple pomace and citrus peels (Buljeta *et al.*, 2023). Various agricultural by-products have been studied as potential sources of pectin, including beet pulp (Levigne *et al.*, 2002; B. Yapo *et al.*, 2007), soy hull (Kalapathy and Proctor, 2001), sunflower residues (Iglesias and Lozano, 2004), ambarella peels (Koubala *et al.*, 2008), cocoa bean husks (Mollea *et al.*, 2008), banana peels (Emaga *et al.*, 2008) and so many others agricultural by-products including mango peel, guava pulp, figs, passion fruit peel, faba bean, cocoa hulls, watermelon rind, banana, and pomegranate peels (Liew *et al.*, 2014; Marić *et al.* 2018; Buljeta *et al.* 2023).

Colombo lemon (*Citrus limon*) is a popular citrus fruit, naturally a rich source of pectin (Mahajan and Sadana, 2023). This fruit is familiar for its extraordinary aroma and size, and has been popularizing as a domestic tree in the yard garden. The fruit peels of the lemon family reportedly contain a high amount of pectin such as lemon peel contains 15.25% and orange peel contains 20.75% pectin (Sulieman *et al.* 2013). Due to a high yield performance, size and attractive fragrance the cultivation of Colombo lemon has been increased dramatically. This has opened the window to use the lemon peels to be used for pectin production. However, the quantity and quality of pectin depend on a series of factors such as plant source, extraction media and extraction conditions employed during isolation and purification.

Therefore, this study was focused on extraction and characterization of pectin from Colombo lemon peel. In the run, the study focused on the following objectives: a) determining the moisture, ash and crude fiber contents in Colombo lemon peel powder. b) developing an optimal extraction process for pectin from Colombo lemon peel and c) characterization of the extracted pectin.

Materials and Methods

Materials

Fresh and mature Colombo lemons were collected from the local market and orchards of Gazipur and district during the season. Fruit peels were chopped with sharp knife and dried in a cabinet dryer to prepare the peel for pectin extraction (Fig. 1).

Methods

Preparation of Colombo Lemon Peel Powder

The Colombo lemons were washed to remove adhered materials from fruit surface and sliced into 2 to 3 mm thick pieces. The peels were separated from inner portion, chopped into small pieces, blended, and dried at 50°C for 48 hours in a cabinet drier. The dried blend was ground into powder using a blender. The powder was sieved using a stainless-steel sieve (Sieve no. MIC-300) and stored in a glass jar at room temperature (25 ± 2°C) for future uses.

Extraction of Pectin from Colombo Lemon Peel Powder

The extraction of pectin was carried out based on the method as stated by Liew, Chin, and Yusof (2014). Hundred gram of peel powder was mixed in 3 L water. Different pH, temperatures and heating times (Table 1) were investigated to get an optimum extraction condition of pectin. pH was adjusted to 2, 2.5 and 3 using 0.1N HCl. The mixtures were heated at 60°C, 80°C and 100°C for 20, 40 and 60 min respectively in a cooking pan. The suspensions were filtered and pressed to recover the extract. Pectin was precipitated by adding ethanol (95%) at a ratio of 1:1 (1 part extract and 1 part

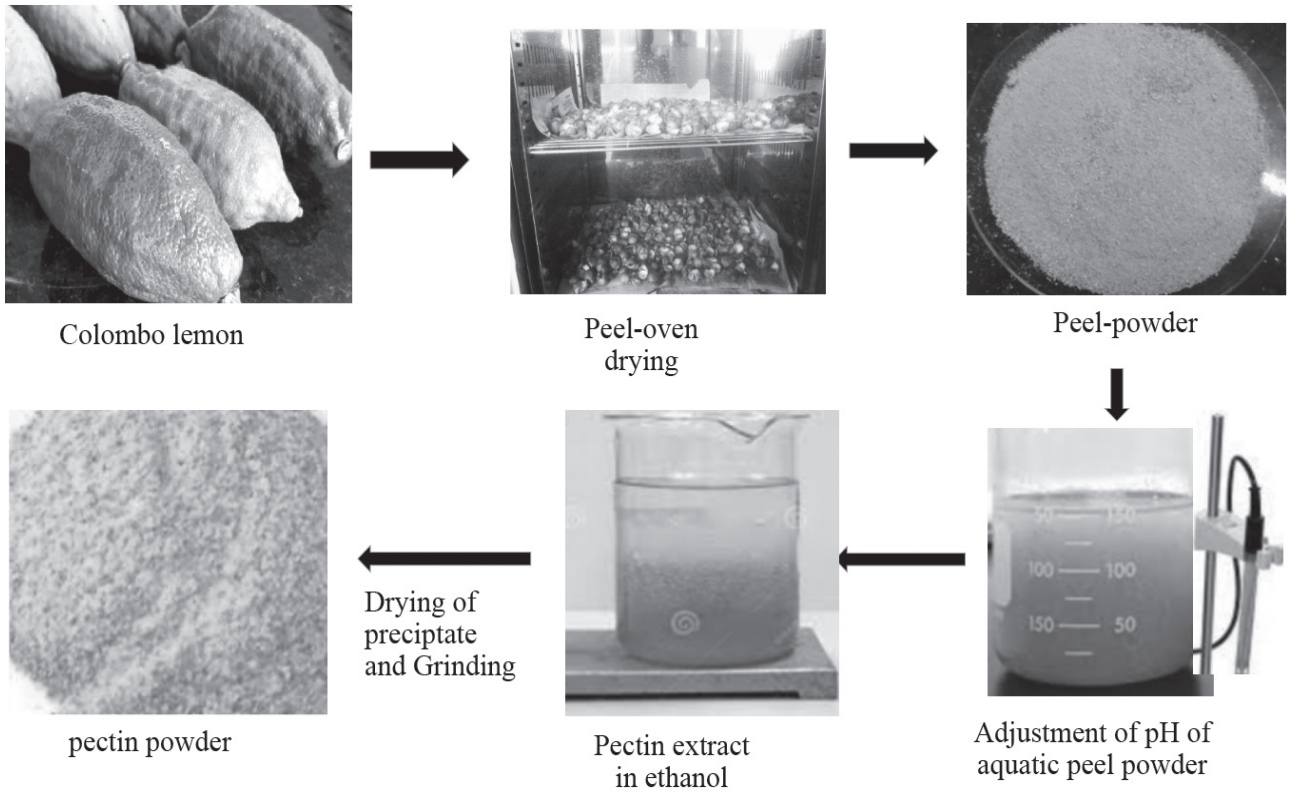

Fig. 1. A flow diagram presenting the overall approach of pectin preparation from Colombo lemon peel.

ethanol) and left at room temperature overnight. The precipitated pectin was filtered through Whatman No. 1 filter paper and dried in a cabinet drier at 60°C for 24 h. The extracted pectin was stored in a glass bottle at room temperature (25 ± 2°C) for further analyses.

Proximate Composition Analysis of Peel Powder

Determination of Moisture Content

Moisture content was determined using the Standard Official Methods of Analysis of AOAC (2005) from the difference in weight after drying at 105°C for 24 h.

Determination of Total Ash Content

Ash content was determined by the procedures stated by (Ranganna, 1986), from the difference in weight after burning 5g sample at 550°C for 6 h using a muffle furnace.

Determination of Crude Fiber

Total crude fiber content in Colombo lemon peel was determined by using the method of International Organization for Standardization (2000) with slight modifications. The crude fiber was calculated using the following equation.

$$\text{Crude fiber} = \frac{\text{Weight of dried residue before ashing-weight of residual ash}}{\text{Weight of sample}} \times 100$$

Characterization of Pectin

The dried pectin sample obtained from the peel was further analyzed for characterization.

Table 1. Experimental design presenting the conditions induced for extracting pectin from Colombo lemon peel powder.

Sample	Extraction conditions		
	pH	Heating temperature (°C)	Heating time (Min)
Colombo lemon peel powder solution in water	2.0	60	20 40 60
		80	20 40 60
		100	20 40 60
	2.5	60	20 40 60
		80	20 40 60
		100	20 40 60
	3.0	60	20 40 60
		80	20 40 60
		100	20 40 60

Pectin Yield

The yield of extracted pectin was calculated using the following equation.

$$\text{Pectin yield (\%)} = \frac{\text{Weight of dried pectin}}{\text{Weight of dried peel powder used in extraction}} \times 100$$

Determination of Equivalent Weight

Equivalent weight was determined using the method as stated by Ranganna (1986). The equivalent weight of the pectin was calculated by the following equation.

$$\text{Equivalent weight (mg/mole)} = \frac{\text{Weight of sample} \times 1000}{\text{Milliliter of Alkali} \times \text{Normality of Alkali}} \times 100$$

Determination of Methoxyl Content (MeO)

The methoxyl content in the extracted pectin was determined following the method as stated by Ranganna (1986), and the neutral solution remained after determination of equivalent weight was used there as the sample. 25 ml 0.25 N sodium hydroxide was added to the solution and stirred thoroughly followed by allowing to stand for 30 min at room temperature (25 ± 2°C). Then 25 ml of 0.25 N hydrochloric acid was added to it and titrated against 0.1 N NaOH. The end point was indicated by purple color. Methoxyl content was calculated using the following equation.

$$\text{Methoxyl content (\%)} = \frac{\text{Milliliter of Alkali} \times \text{Normality of Alkali} \times 31}{\text{Weight of sample} \times 1000} \times 100$$

Where the number 31 indicates the molecular weight of methoxyl group.

Determination of Total Anhydrouronic Acid Content (AUA)

Total anhydrouronic acid content (AUA) of pectin was calculated using following equation from Suhaila and Zahariah (1995).

$$\text{Anhydrouronic acid (\%)} = \left(\frac{176 \times 0.1z \times 100}{w \times 1000}\right) + \left(\frac{176 \times 0.1y \times 100}{w \times 1000}\right)$$

Here, the molecular unit of AUA (1 unit) equals to 176 g, and z = ml (titre) of NaOH from equivalent weight determination; y = ml (titre) of NaOH from methoxyl content determination; w = weight of sample (g).

Determination of Degree of Esterification

The degree of esterification (DE) was determined by a method described by Silva et al., (2008). A dried pectin sample weighing 20 mg was moistened with ethanol and dissolved in 20 ml of deionized water at 40°C. To this solution, phenolphthalein indicator was added, and titration against 0.5 M NaOH was continued until a color change was noticed at the endpoint. The volume of NaOH solution utilized was noted as the initial titer. Following this, 10 ml of 0.5 M NaOH was added to the solution and left to rest for 15 minutes. Subsequently, 10 ml of 0.5 M HCl was added and the solution was vigorously agitated until the pink color disappeared. The solution was then titrated against 0.5 M NaOH, and the volume used was recorded as the saponification titer or final titer. The DE was computed using the following equation:

$$DE(\%) = \left(\frac{V_2}{V_1 + V_2}\right) \times 100$$

Where, V_1 = initial titer volume (ml); V_2 = final titer volume (ml)

Determination of Acetyl Value

Determination of acetyl value was done by following the procedure as stated by Ranganna (1986). A 0.5 g of pectin and 25 ml of 0.1 M NaOH were mixed, dissolved by stirring, and allowed to stand overnight. The mixture was then diluted to 250 ml with deionized water. An aliquot of 20 ml was placed into the distillation apparatus along with 20 ml magnesium sulphate-sulphuric acid solution (100 g of magnesium sulphate was added to 1.5 g sulfuric acid and diluted to 180 ml) and distilled. About 100 ml of distillate was collected. The distillate was titrated against 0.5 NaOH (0.05 M) using phenol red indicator, and the acetyle value was determined by the following equation.

$$\text{Acetyle value (\%)} = \frac{\text{Milliliter of Alkali} \times \text{Normality of Alkali} \times 4.3}{\text{Weight of aliquot (g)}}$$

Determination of Water Activity

The water activity (a_w) was determined using an Aqualab 3 analyzer (Decagon Devices, Pullman, WA) at 25°C after stabilization of the samples at this temperature for 1 hour.

Determination of Color

Color measurement was carried out by a hand colorimeter following the method described by Ansorena et al. (1997). The surface color of the samples was evaluated with a hand spectrophotometer (CM2500d, Konica, Minolta Optics Inc., Japan) based on the CIE L*a*b* color space where the values of L* represents brightness, a* corresponds to the red-green color gradient, and b* indicates the yellow-blue color gradient. Three measurements were conducted in each sample.

Functional Groups of Colombo Lemon Pectin

The IR spectra were acquired through Perkin Elmer FTIR (Spectrum-2) instrument operated by CPU32M

software. The isolated pectin was scanned within 650 to 4000 cm^{-1} using triglycine sulphate (TGS) detector. A total of 8 scans at 4 cm^{-1} resolution were accumulated at 0.2 cm/sec scanning speed. The spectra were analyzed by using Perkin Elmer's proprietary software (Version 10.05.03)

Statistical Analysis

All measurements were carried out triplicate for each individual sample. Results were expressed as mean values ± standard deviation. Data were statistically analyzed using MSTAT-C by windows version 2.10.

Results and Discussion

Moisture, Ash and Crude Fiber Content in Colombo Lemon Peel Powder

The Colombo lemon peel powder was analyzed to determine the moisture, ash and crude fiber contents in it. The results are presented in Table 2 and discussed below.

Table 2. Moisture, ash and crude fiber contents in Colombo lemon peel powder

Composition	Content (mean ± SD*)
Moisture (%)	10.20 ± 1.06
Ash (%)	4.95 ± 0.93
Crude fiber (%)	31.52 ± 1.96

*SD = Standard deviation

Moisture Content

The moisture level in the experimental Colombo lemon peel powder (CLPP) is a significant factor in determining its storage stability. As per Table 2, the moisture content in CLPP was 10.20%. The moisture content of CLPP is comparable with the moisture content of other fruit peel powders such as banana (9.8%), orange (7.9%), citrus (7.58%), and jackfruit (6.48%) reported by Pathak *et al.,* (2017).

Total Ash Content

According to Table 2 the ash content in Colombo lemon peel powder was 4.95% which is approximately similar to that as reported by Romelle *et al.* (2016) who found 4.39%, 5.17%, 3.24% and 5.03% total ash in dry peels of pine apple, orange, mango and watermelon respectively.

Crude Fiber Content

The Colombo lemon peel comprises approximately 31.52% crude fiber (Table 2) which is consistent with the previous study. The literatures describe that the dry peels of pineapple exhibited 11.66%, avocado 53.14%, orange 20.14%, and passion fruit 32.85% crude fiber (Dias *et al.*, 2020)which is a nuisance to the environment as a solid waste. The aim of this study was to ascertain the chemical composition, physicochemical properties, and technological properties of selected such fruit peels to determine their suitability for use as natural food ingredients. Peels from four fruit varieties namely pineapple (PP. The variations in fiber contents in dry peels of different fruits might be due to the variations in varieties, soil conditions, fruiting seasons, maturity at harvesting time, sand climatic conditions (Dias *et al.*, 2020)which is a nuisance to the environment as a solid waste. The aim of this study was to ascertain the chemical composition, physicochemical properties, and technological properties of selected such fruit peels to determine their suitability for use as natural food ingredients. Peels from four fruit varieties namely pineapple (PP.

Pectin Yield

The yield of Colombo lemon peel pectin, expressed as percentage, exhibited variations depending on extraction conditions. At pH 2 it ranged from 7.80% to 15.20%, at pH 2.5 from 6.70% to 11.90%, and at pH 3 from 5.97% to 10.3%. The pectin yield was greatly affected by the temperature and periods of extraction. In this study the highest yield (15.20 %) was obtained at pH 2 and temperature 80°C by an extraction period for 60 min where the lowest one (5.97%) was at pH

3, temperature 100°C, and by an extraction for 20 min (Fig.2).

The result obtained in this study for pectin yield is consistent with previous studies where 10 to 13% pectin yield was found in ambarella fruits, 4.60 to 18.50% in mango (Koubala *et al.*, 2008), and 7.50% in passion fruit (Yapo and Koffi, 2006). Rha *et al.* (2011) reported 22% pectin yield in golden apple. The pectin yield is tremendously influenced by the pectin sources, varieties, extraction methods as well as extraction conditions (Koubala *et al.*, 2008).

Effect of Time, Temperature, and pH on Pectin Yield

The pectin yield from the Colombo lemon peel showed an increase in rising temperature up to 80°C (Fig. 2). The increase in temperature tends to enhance the solubility of extracted pectin, thereby facilitating a higher extraction rate. However, the increase in temperature beyond 80°C exhibited a declining trend in pectin yield. Studies by Girma and Worku (2016) suggested that elevated temperatures might lead to the breakdown of pectin molecules, as they consist of α-(1-4) linked units of galacturonic acid or methyl ester. However, higher temperature contributes to increased extraction costs due to energy loss through vaporization. A study by Muhidinov *et al.* (2010) suggested that lower temperatures can result in inadequate diffusion between phases and slower extraction due to the increased viscosity of pectin.

The pectin yield showed a significant increase against extended extraction times (Fig. 2). Nevertheless, findings from Girma and Worku (2016) indicated that prolonged extraction may lead to thermal degradation and reduced yield of pectin. Prolonged extraction could result in darker extracts requiring a thorough washing with alcohol. As the concentration of pectin in the solution rises, the extraction rate diminishes, and the solution becomes more viscous.

Moreover, pH levels also influenced the pectin yield in this study. Colombo lemon peel exhibited the highest yield at pH 2. Subsequent increases in pH levels resulted in decreased pectin yield. This phenomenon could be attributed to a potential disruption of hydrogen bonds and ester linkages between pectin and the cell wall due to the high temperature and low pH, promoting to an increased diffusion and pectin extraction (Hamidon and Zaidel, 2017).

Considering the above results, the optimal conditions for pectin extraction are concluded as 80°C heating temperature, 60 min heating time and pH 2 for Colombo lemon peel yielding 15.2% pectin.

Characterization of Pectin

The characteristic parameters were determined of the pectin sample extracted using the optimized conditions 2.0, 80°C and 60 mins of pH, heating temperature and heating time respectively.

The extracted pectin was characterised in terms of moisture content, ash content, equivalent weight, methoxyl content, anhydrouronic acid, degree of esterification, acetyl value and water activity as shown in Table 3.

Moisture Content of Pectin

In this study the moisture content of Colombo lemon peel was obtained 13.30% (Table 3) which is consistent to the findings of previous studies where 7.08% moisture content was reported in Assam lemon and 13.40% in lemon pomace (Azad *et al.*, 2014). According to Mohamadzadeh *et al.* (2010), elevated moisture content can potentially deteriorate the pectin quality by fostering microbial growth and production of pectinase enzymes.

Ash Content

To have low ash content in pectin (below 10%) is more advantageous to ensure the purity of pectin and its functionality (Ismail *et al.,* 2012). The ash content (2.45%) of pectin obtained in this study (Table 3) is consistent to literature where Azad *et al.* (2014) found

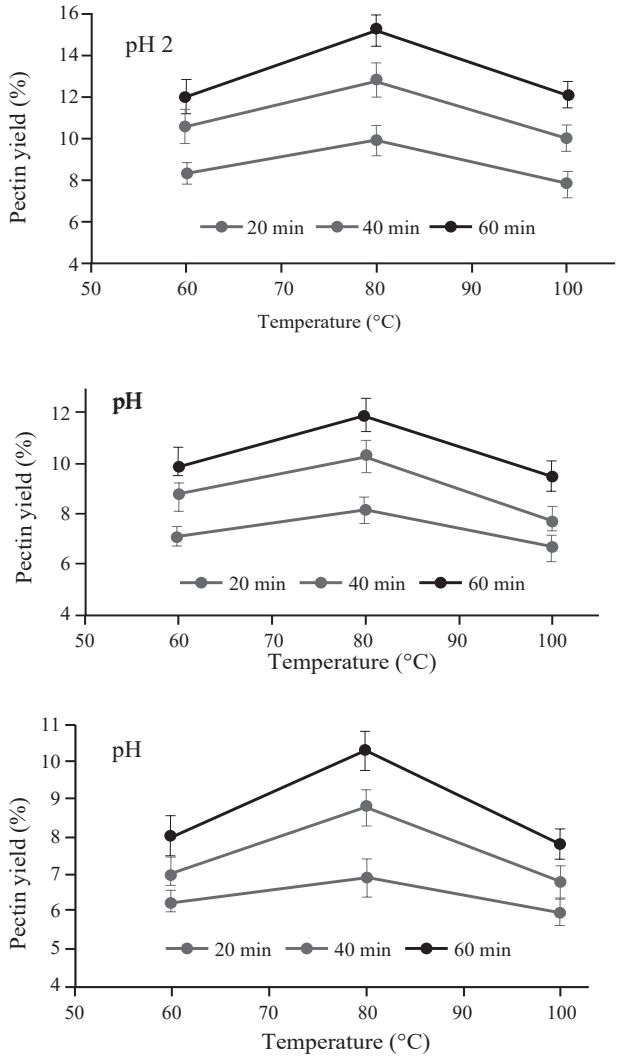

Fig. 2. Effect of pH, temperature, and time on pectin yield from Colombo lemon peel powder. The X-axis indicates temperature (ºC) and Y-axis indicates pectin yield (%). The graphs are presented differently for pH investigations and the color of graphs presents the period of extraction.

Table 3. Characteristics of pectin extracted from Colombo lemon peel

Characteristics	Amount (mean ± SD*)
Moisture (%)	13.30 ± 0.86
Ash (%)	2.45 ± 0.32
Equivalent weight (mg/mol)	819.67 ± 13.77
Methoxyl content (%)	7.25 ± 0.87
Anhydrouronic acid (%)	62.66 ± 3.96
Degree of esterification (%)	65.60 ± 1.77
Acetyl value (%)	0.45 ± 0.06
Water activity	0.46 ± 0.08

*SD = Standard deviation

2.41% ash in premature lemon peel, and 4.60% in over ripe lemon peel. The ash content in pectin varies according to the maturity statges of lemon pomace and the immature lemon contains lower percentage of ash in pectin than that of ripe lemon peel pectin (Azad *et al.*, 2014).

Equivalent Weight

As shown in Table 3, the equivalent weight of pectin obtained from Colombo lemon peel was 819.67 mg/mol which is significantly lower than that of Kumar and Chauhan (2010) who found 1666.30 mg/mol equivalent weight of pectin extracted from apple pomace. On the other hand, the equivalent weight of pectin (819.67 mg/mol) found in this study (Table 3) is significantly high as compared to that found by Nazaruddin and Asmawati (2011) who extracted pectin of 645.19 mg/mol equivalent weight from cocoa husk. The variation in equivalent weight of pectin might be due to the variation in pectin sources, extraction methods, maturity stages, and species. A higher equivalent weight is associated with enhanced stability and improved emulsion capacity of the pectin.

Methoxyl Content

In this study, the obtained methoxyl content was 7.25% (Table 3) which is approximately similar to the previous report where Apsara and Pushpalatha (2002) mentioned 7.33% methoxyl content in mango peel, 7.03% in banana peel, 8.57% in pumelo peel, and 8.81-9.61% in passion fruit. However, in another study Ismail *et al.* (2012) have reported a significantly lower percentage of methoxyl contents in dragon fruit pectin ranging from 2.98% to 4.34%.

Total Anhydrouronic Acid Content

Suitable anhydrouronic acid content of pectin implies the appropriateness of pectin to use in food preparation such as jam and jelly. The anhydrouronic acid (AUA) content of the extracted pectin was 62.67% (Table 3) which is comparable with the AUA content obtained by Ismail *et al.* (2012) in commercial apple pectin (61.72%) and dragon fruit pectin (45.25% to 52.45%).

Degree of Esterification

In this study, the degree of esterification (DE) of the extracted pectin was 65.60% (Table 3) which is consistent with the previous studies. According to literatures the pomelo peel pectin shows 59.40 - 70.70% DE (Methacanon *et al.*, 2014), *Citrus maxima* shows 76.30% (Sotanaphun *et al.*, 2012), and apple pomace pectin shows 83.41% (Wang et al., 2014). However, pectins having DE <50% form rigid gels by the action of calcium or multivalent cations through cross-linking the galacturonic acid chains. This property of pectin is very useful in designing controlled release dosage of drug manufacturing since the lower the DE, the greater the time for releasing the drugs (Sungthongjeen *et al.*, 2004).

Acetyl Value

The obtained acetyl value of the pectin was 0.45% (Table 3). Reduced acetyl values are advantageous in the manufacturing of jams, jellies, and various food products as acetyl groups can hinder jelly formation (Jindal *et al.*, 2013). According to Virk and Sogi (2004) there is a slight variation in acetyl values between apple's peel pectin and commercial pectin which are 0.62% and 0.50% respectively. Furthermore, the acetyl value (0.45%) obtained in this study similar to the result found by Sharma *et al.* (1985) who stated 0.46% acetyl value in partially ripe apple.

Water Activity

According to Table 3, the determined water activity (a_w) of the extracted pectin 0.46 is extremely low to propagate the microorganisms. Generally, no microorganism can grow at $a_w = 0.6$. Therefore, the a_w (0.46) obtained in this study is very effective to inhibit the growth of any microorganisms like bacteria, yeast and molds (Koerber, 2000).

Table 4. L*a*b* color values of Colombo lemon peel pectin

Sample	L* (mean ± SD)	a* (mean ± SD)	b* (mean ± SD*)
Colombo lemon peel pectin	50.56 ± 1.35	15.23 ± 0.38	13.65 ± 1.27

*SD = Standard deviation

Color Measurement

In terms of color, the Colombo lemon peel pectin exhibited a lightness (L* value) of 50.56 (Table 4) indicating a moderate level of lightness.

The redness (a* value) was recorded at 15.23, while the yellowness (b* value) was measured as 13.65 (Table 4) which indicates a relatively reduced yellowish tint in the obtained pectin powder. The color characteristics obtained in this study (Table 4) from L*a*b* color space approximately similar to those observed by Masmoudi *et al.* (2012) who stated a* = 3.5 to 6.0 in lemon pectin derived from lemon by-products. From this result it can be stated that the color of Colombo lemon peel pectin looks redder than that of lemon pectin derived from lemon by-products.

Functional Groups of Colombo Lemon Pectin

The distinctive absorption peaks for Colombo lemon peel pectin are presented in Fig. 3. The broad band centering at 3314.54 cm^{-1} represents the O-H stretching vibration, where is the absorption around 2928.24 cm^{-1} is caused by the C–H stretching vibrations from CH, CH_2, and CH_3 (Joel *et al.*, 2018; Karnik *et al.*, 2016). The functional peaks of the pectin are also appeared as C=O stretching vibration 1732.72 cm-1, C=C stretching vibration at 1623.47 cm^{-1}, vibration from sp3 CH_2 of the methylene bridge is around 1329.70, the vibration at 1228 cm^{-1} through 1329.70 cm^{-1} corresponds to –CH_3CO displacements and varying intensities among the samples (López-Mercado *et al.*, 2018). C-O stretching from glycosidic bonds is responsible for the peak at 1013 cm^{-1}. The shoulder at 1128 cm^{-1} is linked to pyranose rings (Alba *et al.*, 2015).

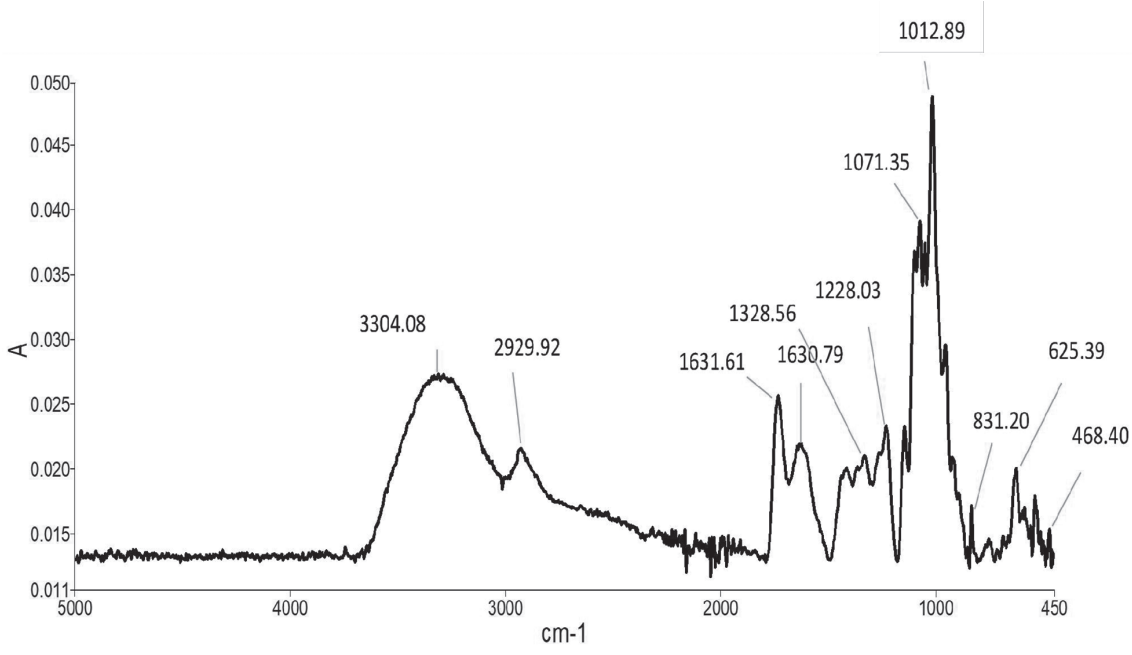

Fig. 3. FTIR spectrum of the extracted dried pectin from Colombo lemon peel. The band locations are presented along to X-axis (cm^{-1}) and corresponding absorbances are along to Y-axis.

Conclusion

This study investigated the effect of the conditional parameters temperature, time and pH on the yield of pectin extracted from Colombo lemon peel. Using an ethanolic extraction method, it was observed that the yield of pectin significantly varied due to variation of the conditional parameters. Low pH of the solvent was found preferable, whereas, medium temperature and an extended time resulted in higher yield of the pectin. The optimal extraction condition was found at 80°C for 60 min heating time at pH 2. This process resulted in the highest pectin yield 15.2%, while the lowest extraction is 5.97% at 100 °C for 20 min at pH 3. The FTIR study suggests the important functional groups of the Colombo lemon peel pectin. The physicochemical properties such as Equivalent Weight, Methoxyl Content, Anhydrouronic Acid Content and Degree of esterification of the extracted pectin affirmed its potential to provide gelling, thickening and stabilizing parameters of various food preparations. Hence, the study strongly advocates for Colombo lemon peels as a promising source for commercial pectin extraction. However, more study is recommended on using this pectin in real food preparation and pilot-scale study is suggested before switching to commercial production of pectin from Colombo lemon peel.

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Conflict of Interest

The authors affirm that no financial or commercial relationships that might be construed as a potential conflict of interest existed during the course of the research.

Author Contributions

Md. Masud Rana: Writing major portion of the original draft, editing final draft; Md Akram Hossain: Writing a part of the draft, editing overall; Razia Sultana: Writing a part of the draft, editing overall; Md. Aslam Ali: Writing a part of the draft, editing overall; Md. Ahiduzzaman: Writing a part of the draft, editing overall; M. Amdadul Haque: Conceptualization, writing original draft, editing final draft.

References

Alba, K., A.P. Laws and V. Kontogiorgos. 2015. Isolation and characterization of acetylated LM-pectins extracted from okra pods. *Food Hydrocoll.* 43: 726-735.

Ansorena-Artieda, D., M. P. Peña, I. Astiasarán and J. Bello. 1997. Colour evaluation of chorizo de Pamplona, a Spanish dry fermented sausage: Comparison between the CIE L (*) a (*) b (*) and the Hunter lab systems with illuminants D65 and C. *Meat Sci.* 46: 313-318.

Apsara, M. and P. B. Pushpalatha. 2002. Characterization of pectin extracted from different fruit wastes. *J. Trop. Agric.* 40: 53-55.

Azad, A. K. M., M. A. Ali, M. S. Akter, M. J. Rahman and M. Ahmed. 2014. Isolation and characterization of pectin extracted from lemon pomace during ripening. *J. Food Nutr. Sci*. *2*(2): 30-35.

Buljeta, I., D. Šubarić, J. Babić, A. Pichler, J. Šimunović and M. Kopjar. 2023. Extraction of Dietary Fibers from Plant-Based Industry Waste: A Comprehensive Review. *Appl. Sci.* 13(16): 9309-9328.

Chavan, P., A. K. Singh and G. Kaur. 2018. Recent progress in the utilization of industrial waste and by-products of citrus fruits: A review. *J. Food Process. Eng.* 41(8): 12895-905.

Dias, P. G. I., J. W. A. Sajiwanie and R.M.U.S.K. Rathnayaka. 2020. Chemical composition, physicochemical and technological properties

of selected fruit peels as a potential food source. *Int. J. Fruit Sci.* 20: 240-251.

Dranca, F. and M. Oroian. 2018. Extraction, purification and characterization of pectin from alternative sources with potential technological applications. *Food Res. Int.* 113: 327-350.

Emaga, T. H., C. Robert, S. N. Ronkart, B. Wathelet and M. Paquot. 2008. Dietary fibre components and pectin chemical features of peels during ripening in banana and plantain varieties. *Bioresour. Technol.* 99(10): 4346-4354.

Ferreira, M. S., M. C. Santos, T. M. Moro, G. J. Basto, R. M. Andrade and E. C. Gonçalves. 2015. Formulation and characterization of functional foods based on fruit and vegetable residue flour. *J. Food Sci. Technol.* 52: 822-830.

Girma, E. and W. Teshome. 2016. "Extraction and Characterization of Pectin from Selected Fruit Peel Waste." *Int. J. Sci. Res. Publ.* 6(2): 447-54.

Hamidon, N. H. and D. N. A. Zaidel. 2017. Effect of extraction conditions on pectin yield extracted from sweet potato peels residues using hydrochloric acid. *Chem. Eng. Trans.* 56: 979-984.

Iglesias, M. T. and J. E. Lozano. 2004. Extraction and characterization of sunflower pectin. *J. Food Eng.* 62(3): 215-223.

International Organization for Standardization. 2000. "Animal Feeding Stuffs—Determination of Crude Fibre Content—Method with Intermediate Filtration (ISO Method No 6865:2000)." Geneva, Switzerland: International Organization for Standardization. https://www.iso.org/standard/13377.html.

Ismail, N. S. M., N. Ramli, N. M. Hani and Z. J. S. M. Meon. 2012. Extraction and characterization of pectin from dragon fruit (*Hylocereus polyrhizus*) using various extraction conditions. *Sains Malays.* 41(1): 41-45.

Jindal, M., V. Kumar, V. Rana and A. K. Tiwary. 2013. Aegle marmelos fruit pectin for food and pharmaceuticals: Physico-chemical, rheological and functional performance. *Carbohydr. Polym.* 93(2): 386-394.

Joel, J. M., J. T. Barminas, E. Y. Riki, J. M. Yelwa and F. Edeh. 2018. Extraction and characterization of hydrocolloid pectin from goron tula (*Azanza garckeana*) fruit. *World Sci. News*. 101: 157-171.

Kalapathy, U. and A. Proctor. 2001. Effect of acid extraction and alcohol precipitation conditions on the yield and purity of soy hull pectin. *Food Chem.* 73(4): 393-396.

Karnik, D., J. Jung, S. Hawking and L. Wicker. 2016. Sugar beet pectin fractionated using isopropanol differs in galacturonic acid, protein, ferulic acid and surface hydrophobicity. *Food Hydrocoll.* 60: 179-185.

Koerber, S. 2000. Humectants and Water Activity. *Water Activity News*.

Koubala, B. B., L. I. Mbome, G. Kansci, F. T. Mbiapo, M. J. Crepeau, J. F. Thibault and M. C. Ralet. 2008. Physicochemical properties of pectins from ambarella peels (Spondias cytherea) obtained using different extraction conditions. *Food Chem.* 106(3): 1202-1207.

Kumar, A. and G. S. Chauhan. 2010. Extraction and characterization of pectin from apple pomace and its evaluation as lipase (steapsin) inhibitor. *Carbohydr. Polym.* 82(2): 454-459.

Levigne, S., M. C. Ralet and J. F. Thibault. 2002. Characterisation of pectins extracted from fresh sugar beet under different conditions using an experimental design. *Carbohydr. Polym.* 49(2): 145-153.

Liew, S. Q., N. L. Chin and Y. A. Yusof. 2014. Extraction and characterization of pectin from passion fruit peels. *Agri. Agric. Sci. Procedia*. 2: 231-236.

López-Mercado, J., A. Nambo, M. E. Toribio-Nava, O. Melgoza-Sevilla, L. Cázarez-Barragán, L. Cajero-Zul, L. G. Guerrero-Ramírez, B. E. Handy and M. G. Cardenas-Galindo. 2018. High and low esterification degree pectins decomposition by hydrolysis and modified Maillard reactions for furfural production. *Clean Technol. Environ. Policy*. 20: 1413-1422.

Mahajan, M. and R. Sadana. 2023. Citrus based food products and their shelf life. Pp. 367-393. In Recent Advances in Citrus Fruits. Cham: Springer International Publishing.

Marić, M., A. N Grassino, Z. Zhu, F. Z. Barba, M. Brnčić and S. R. Brnčić. 2018. An overview of the traditional and innovative approaches for pectin extraction from plant food wastes and by-products: Ultrasound-, microwaves-, and enzyme-assisted extraction. *Trends Food Sci. Technol.* 76: 28-37.

Masmoudi, M., S. Besbes, F. Abbes, C. Robert, M. Paquot, C. Blecker and H. Attia. 2012. Pectin extraction from lemon by-product with acidified date juice: Effect of extraction conditions on chemical composition of pectins. *Food Bioproc. Tech.* 5: 687-695.

May, C. D. 1990. Industrial pectins: Sources, production and applications. *Carbohydr. Polym.* 12(1): 79-99.

Methacanon, P., J. Krongsin and C. Gamonpilas. 2014. Pomelo (*Citrus maxima)* pectin: Effects of extraction parameters and its properties. *Food Hydrocoll.* 35: 383-391.

Mohamadzadeh, J., A. R. Sadeghi-Mahoonak, M. Yaghbani and M. Aalami. 2010. Extraction of pectin from sunflower head residues of selected Iranian cultivars. *World Appl. Sci. J.* 8(1): 21-24.

Mohanasundaram, S., B. Singh, N. G. Suradkar, S. Venkatesa Prabhu, G. Chinnasamy, M. Goel and J. M. Khaled. 2023. Extraction of pectin from Ethiopian prickly pear fruit peel and its potency for preparing of cellulose-reinforced biofilm. *Biomass. Convers. Biorefin.* 1-15.

Mollea, C., F. Chiampo and R. Conti. 2008. Extraction and characterization of pectins from cocoa husks: a preliminary study. *Food Chem.107*(3): 1353-1356.

Muhidinov, Z.K., M.L. Fishman, K.K. Avloev, M.T. Norova, M, A.S. Nasriddinov and D.K. Khalikov. 2010. Effect of temperature on the intrinsic viscosity and conformation of different pectins. *Polym. Sci. Ser. A*. 52: 1257-1263.

Nazaruddin, R. 2011. Effect of ammonium oxalate and acetic acid at several extraction time and pH on some physicochemical properties of pectin from cocoa husks (*Theobroma cacao*). *Afr. J. Food Sci*. 5(15): 790-798.

Pathak, P. D., S. A. Mandavgane and B.D. Kulkarni. 2017. Fruit peel waste: characterization and its potential uses. *Curr. Sci*. 113: 444-454.

Rahmani, Z., F. Khodaiyan, M. Kazemi and A. Sharifan. 2020. Optimization of microwave-assisted extraction and structural characterization of pectin from sweet lemon peel. *Int. J. Biol. Macromol.* 147: 1107-1115.

Ranganna, S. 1986. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education.

Rha, H. J., I. Y. Bae, S. Lee, S. H. Yoo, P. S. Chang and H. G. Lee. 2011. Enhancement of anti-radical activity of pectin from apple pomace by hydroxamation. *Food Hydrocoll.* 25(3): 545-548.

Garcia, R. S. L. and V. Raghavan, 2022. Green extraction techniques from fruit and vegetable waste to obtain bioactive compounds—A review. *Crit. Rev. Food Sci. Nutr*, 62(23): 6446-6466.

Romelle, F. D., A. Rani and R. S. Manohar. 2016. Chemical composition of some selected fruit peels. *Eur. J. Food Sci. Technol.* 4(4): 12-21.

Salim, N. S. M., A. Singh and V. Raghavan. 2017. Potential utilization of fruit and vegetable wastes for food through drying or extraction techniques. *Nov. Tech. Nutr. Food Sci*. 1(2): 1-12.

Sharma, T. R., B. Lal, B. Kumar. and A. K Goswami. 1985. Pectin from different varieties of Himachal Pradesh apples. *Indian Food Pack*. 39(4): 53-57.

Silva, I. M., L. V. Gonzaga, E. R. Amante, R. F. Teófilo, M. M. Ferreira and R. D. Amboni. 2008. Optimization of extraction of high-ester pectin from passion fruit peel (Passiflora edulis flavicarpa) with citric acid by using response surface methodology. *Bioresour. Technol*. 99(13): 5561-5566.

Sotanaphun, U., A. Chaidedgumjorn, N. Kitcharoen, M. Satiraphan, P. Asavapichayont and P. Sriamornsak. 2012. Preparation of pectin from fruit peel of Citrus maxima. *Sci. Eng. Health Stud*. 6: 42-48.

Suhaila, M. and H. Zahariah. 1995. Extraction and characterisation of pectin from various tropical agrowastes. *ASEAN Food J.* 10(2): 43-50.

Sulieman, A. M. E., K. M. Khodari and Z. A. Salih. 2013. Extraction of pectin from lemon and orange fruits peels and its utilization in jam making. *Int. J. Food Sci. and Nutr. Eng.* 3(5): 81-84.

Sungthongjeen, S., Sriamornsak, P., Pitaksuteepong, T., Somsiri, A., and Puttipipatkhachorn, S. 2004. Effect of degree of esterification of pectin and calcium amount on drug release from pectin-based matrix tablets. *AAPS Pharmaceuticals Science and Technology*, 5: 1–8.

Virk, B. S. and D. S. Sogi. 2004. Extraction and characterization of pectin from apple (Malus Pumila. Cv Amri) peel waste. *Int. J. Food Prop*. *7*(3): 693-703.

Walter, R. H. 1991. "Analytical and Graphical Methods for Pectin." *Chem. Technol. Pectin*. 189–225.

Wang, X., Q. Chen, and X. Lu. 2014. Pectin extracted from apple pomace and citrus peel by subcritical water. *Food Hydrocoll.* 38: 129–137.

Yapo, B. M. and K. L. Koffi. 2006. Yellow passion fruit rind a potential source of low-methoxyl pectin. *J. Agric. Food Chem*. 54(7): 2738-2744.

Yapo, B. M., C. Robert, E. Isabella. B. Wathele and M. Paquot. 2007. Effect of extraction conditions on the yield, purity and surface properties of sugar beet pulp pectin extracts. *Food Chem.* 100(4): 1356-1364.