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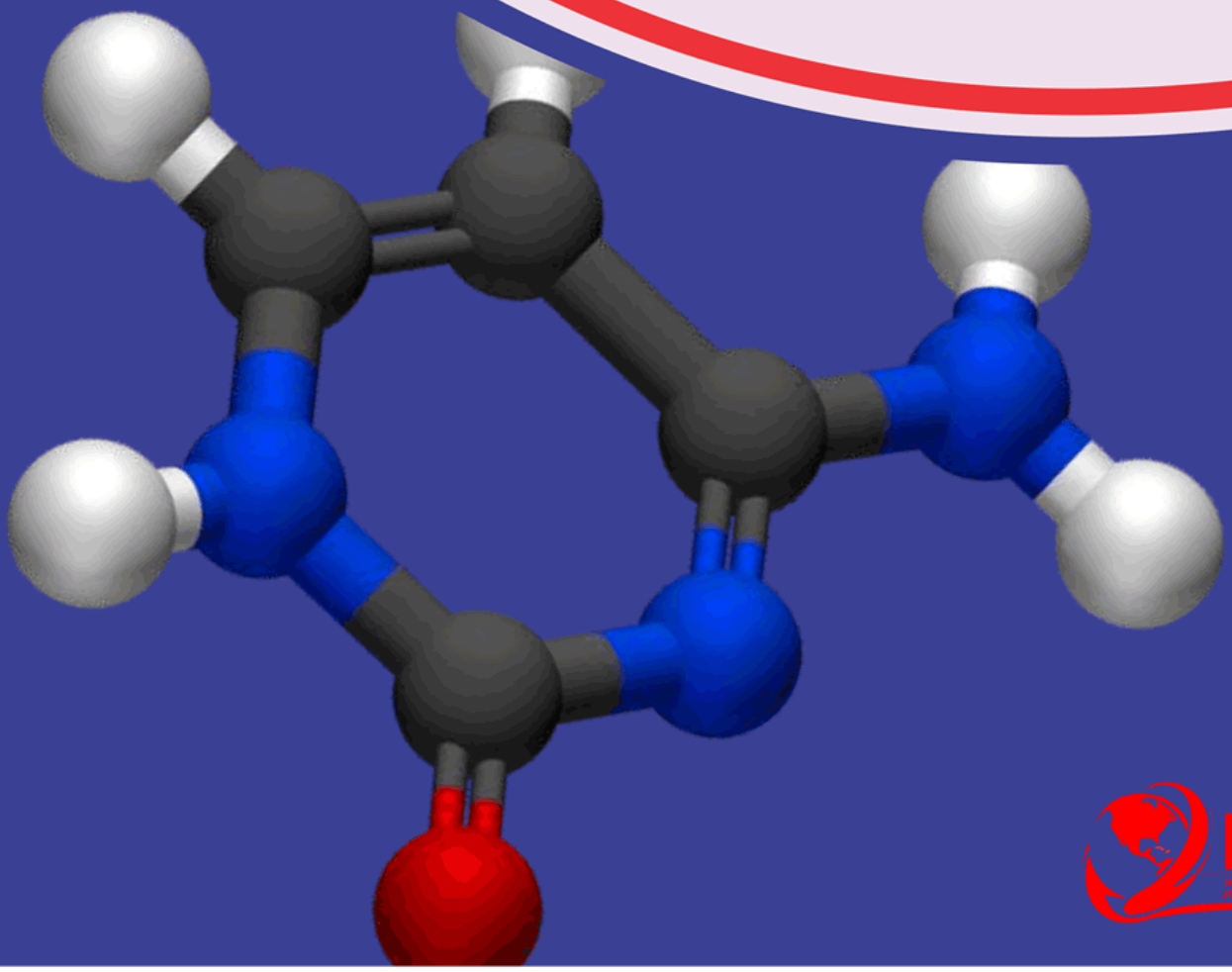

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Extraction and Characterization of Pectin from Orange (*Citrus sinensis*), Lemon (*Citrus limon*) and Tangerine (*Citrus tangerina*)

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Abstract

Purpose: The study focused on the extraction and characterization of pectin from orange (*Citrus sinensis*), lemon (*Citrus limon*), and tangerine (*Citrus tangerina*)

Methodology: Pectin was extracted from lemon *(Citrus limon)*, tangerine (*Citrus tangerina*) and orange (*Citrus sinensis*) peels. The feasibility of the citrus peel pectin for use in food processing was assessed. Pectin from these citrus fruit peels was extracted under the same extraction conditions. The pectin extraction was carried out using hydrochloric acid (0.05N, pH 2.22; 0.04N, pH 1.54 and 0.03N, pH 1.27).

Findings: Pectin from the acidified fruit peels was extracted at 70℃ ± 0.5°C for 1 hour at the different pH values. The highest pectin yield from all fruit peels was obtained at pH of 1.27, with lemons having the highest yield followed by oranges and lastly tangerine in the order; 16.61%, 16.01% and 15.23% respectively. Second highest yield was obtained at pH 1.54 in the same order; lemon (15.65%), orange (15.23%) and tangerine (13.87%). The least yield was obtained at a pH of 2.22; lemon (10.52%), oranges (11.01%) and tangerine (9.45%). The average yield was highest in lemon, orange and lastly in tangerine with percentages of 14.36%, 14.08% and 12.82% respectively. Chemical characterization of the citrus peel pectin revealed that the equivalent weight of pectin from all samples was generally low as compared to that of commercial pectin. The average equivalent weight in mg/mL was found to be 150.43, 116.78 and 97.15% for lemon, orange and tangerine respectively. Methoxyl content showed that the pectin obtained for all the samples was high (HM); lemon (11.49%), orange (14.94%) and tangerine (12.02%). Anhydrouronic acid (AUA) values were lemon (76.92%), orange (100.03%) and tangerine (86.38%) which are above the minimum of 65% set by FAO, while the degree of esterification (DE) was high for all; lemon (84.54%), orange (84.68%) and tangerine (78.88%) indicating that all were rapid-setting pectin. The colors of pectin obtained from lemon and orange were pale yellow while that obtained from tangerine was brown.

Unique Contribution to Theory, Practice and Policy: Depending on the AUA, lemon pectin was the purest of all the three samples, followed by tangerine and lastly orange peels. For commercial use of this pectin, lemon pectin is most suitable then tangerine and lastly orange basing on the methoxyl content. It is recommended that for better yields, pectin should be extracted on a dry basis instead of a wet basis.

Keywords: *Pectins*; *Lemon (Citrus Limon), Tangerine (Citrus Tangerina) and Orange (Citrus Sinensis) Peels; Pectin Yield; Degree of Pectin Esterification; Anhydrouronic Acid and Methoxyl Contents*

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INTRODUCTION

Among the other polysaccharides, which are extracted from the plant materials, pectin is an extremely complex polysaccharide and is used widely as functional ingredients in pharmaceutical and food industries. Pectin is used in food technology as gelling and thickening agent. Its medical uses are detoxification, blood glucose reducer, and anti-diarrhoeal effect (Voragen *et al.*, 1995). The global annual pectin consumption is approximately 45 000 tons per year, occupying global market value of no less than 400 million Euros (Savary *et al.*, 2003). Pectins consist of units of D–galacturonic acid and is classified into 2 groups: low methoxyl pectin (LMP) and high methoxyl pectin (HMP), depending on the degree of esterification (DE). Many sources of pectin in nature exist, such as apple pomace, dragon fruit peel, citrus peel, pomelo peel, sugar beets, among others. Apart from citrus peel and apple pomace which are most common commercial sources for pectin production; another novel sources, such as sunflower heads and sugar beets, have also been explored (Joye & Luzio, 2000).

The extraction of pectin often makes use of 2 kinds of solvents; organic acid solvent such as oxalic, tartaric or acetic acid, and inorganic acid solvent such as hydrochloric, sulphuric or nitric acid. All make use of traditional heating. However, it was reported that microwave extraction reduces the pectin extraction time, also lessens the solvent consumption and gives higher yields than conventional method (Seixas *et al.*, 2014). Also the microwave can be used to aid the heating process with tartaric acid as solvent to pectin extraction from orange peel (Liang *et al.*, 2011) and passion fruit (Seixas *et al.*, 2014). In a study of 44 severely ill, tube-fed adults receiving antibiotics, a trend toward decreased diarrhoea in those receiving fibre and pectin was reported. Pectin stimulates the epithelial growth in the colon, as a result lessens diarrhoea (Ashby-Hughes et al, 2000). Additional suggested mechanisms of action in the gastrointestinal (GI) tract include the effect of peptic oligosaccharides on the intestinal micro flora (Jelinek et al, 2005).

Pectin has also been explored for its other pharmaceutical applications such as binding, thickening, suspending properties. Pectin, together with other polysaccharides, can be used to improve the functional properties of food formulations, including the water and oil absorption capacities, gelling capacity, thickening ability, etc. (Awuchi *et al.*, 2019; Awuchi, 2019a). Medicinally, pectin has not only been used in anti-diarrheal products, but also; used to lower blood lipoprotein levels; as agglutinator in blood therapy; people use pectin for high cholesterol, high triglycerides, and to prevent colon cancer and prostate cancer (Vitamin Supplements, 2014); used for diabetes and gastro esophageal reflux disease (GERD); used to prevent poisoning caused by lead, strontium, and other heavy metals; application on the skin to protect raw or ulcerated mouth and throat sores. Use of pectin together with medicinal plants may be effective to managing some health issues such as diarrhoea, gastric diseases, etc. (Awuchi, 2019b) Other industrial uses of Pectin; as a gelling agent, thickening agent and stabilizer in food; as a thickening agent in the medium used for canning meat; in food as gelling agent mostly in jams and jellies; in treatment of regimens involving contamination with heavy metals. Pectins of most configurations show affinity for complexation with metal ions in aqueous solutions.

For extraction purposes, the source of pectin is the peels. The citrus processing industry can get a complete makeover if due importance is given for separation of useful ingredient from lemon peel. Researchers and Scientists have been working on the separation of pectin from lemon peel and reporting their findings in journals of repute. The market potential can be analysed on the basis of the growth prospects of its user industries. The food processing units

have been mushrooming at a rapid pace. Apart from the indigenous consumption, there is a demand of pectin in export markets. Therefore, this industry may prove to be a good foreign exchange earner. Fruit wastes which are highly perishable and seasonal are a problem in the processing industries and pollution monitoring agencies.

The rise in population, industrialization and urbanization over the years has led to the big growth of the food processing sector. With this growth, the beverage industry alone accounts for the highest waste production in the form of fruit peelings and pulp, which ought to be properly managed (Awuchi and Igwe, 2017). Citrus peels if treated as waste materials create environmental problems for local communities due to the presence of biomaterials in the peelings. During citrus juice production, only around half of the fresh citrus weight is transformed into juice, thereby generating great amounts of residue (peel, pulp, seeds, citrus leaves and whole citrus fruits) that do not reach the quality requirements. This huge amount of waste is, in most cases, spread on soil in areas adjacent to the production locations, thereby becoming an environmental hazard. This problem could be turned into an asset, if potentially marketable bio products such as pectin could be extracted from the peels. After extraction, the peels could also be sold as a high protein stock feed in dry form, increasing the potential return for the citrus juice industry and reducing the pollution load to the environment. Subsequently the pectin extracted from different citrus fruit peels can be used as a raw material in pharmaceuticals (as an excipient, dietary fibre or even as a drug itself and in food processing industries (for jam and yoghurt production) thus significantly reducing on the high costs of importation of pectin as a raw material in Uganda.

The overall objective of this project was to extract and compare pectin yield from different citrus fruit peels (lemons, oranges and tangerines) by water based extraction, extract pectin from the peelings of oranges, lemons and tangerines, determine the percentage yield of extracted pectin, determine the methoxyl content of extracted pectin, determine the equivalent weight of the extracted pectin, determine the anhydrouronic acid content of the extracted pectin, and determine the degree of esterification of the extracted pectin.

The scope of the study was limited to the peelings of oranges, lemons and tangerines. This research was intended to show that citrus species, if exploited effectively, have the potential to give the maximum pectin yield enough to compete in the food and chemical industries. In addition, citrus peels are the major solid by-products of the juice production process. Citrus peels are the major source of pectin, which can be used for various industrial applications. In order to produce good quality of extracts of pectin from the citrus peel waste, the most appropriate extraction technology must be applied.

METHODOLOGY

Materials and Equipment

The materials used for the study include fresh citrus peels of orange (*Citrus sinensis*), lemon (*Citrus limon*), and tangerine (*Citrus tangerina*). Distilled water, Pestle and motor, Digital weighing balance, Muslin cloth, Sodium hydroxide, Sodium Chloride, Phenol red, Aluminum foil, Air drier, Blender, Water bath, Polythene bags, pH meter, Suction pump, Dilute mineral acid (hydrochloric acid), and 95% Isopropoanol.

Sample Preparation

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Mature Lemon, tangerine and Orange fruits were purchased from Kansanga Market. The fruits were physically examined to ascertain their wholesomeness. Each of the fruits; Lemon (Citrus limon), tangerine (Citrus tangerina) and Orange (Citrus sinensis) were split/cut into four parts and the peels removed (a soft white substance inside the skin of citrus fruits). The peels were cut further into smaller pieces for easy drying and then washed with large volume of water to remove glycosides, the bitter taste of the peels, and also to remove the residues of the pesticide spray. Afterwards, they were air dried for 24 hours, blended and kept in a polythene bag for future use.

Pectin Extraction from the Prepared Sample

The peel powder was measured (30 g) and transferred into a beaker (1000 mL) containing 450 mL of water, and 2.6 mL hydrochloric acid was added to give a pH of 1.27. Each of the fruit peel samples were then boiled for one hour. Thereafter, the residues were removed from the extracts by filtering through a cheese cloth. The cakes were washed with 250 ml boiled water and the combined filtrate was allowed to cool to 25°C to reduce heat degradation of the pectin. Extracted pectin was precipitated by the addition of 200 ml 95% isopropanol to 100 ml of the extracted pectin with thorough stirring, and left for 30 min to allow the pectin float on the surface. The gelatinous pectin flocculants were then filtered off. The pectin extract was purified by washing in 200 ml isopropanol and pressed on nylon cloth to remove residue HCl and universal salt. The resulting pectin was weighed, shredded into small pieces and air dried. Lastly, the dried pectin was reduced further into smaller pieces using pestle and mortar and weighed using a digital weighing balance.

Percentage Yield of Pectin

The pectin yield was calculated using equation below.

$$\text{Ypec}(\%) = \frac{\text{P}}{\text{Bi}} \times 100$$

Where, y pec (%) is the extracted pectin yield in percent (%), P is the amount of extracted pectin in grams and Bi is the initial amount of orange or lime peel (30g).

Equivalent Weight

Pectin sample of 0.5 g was weighed into 250 ml conical flask and moistened using 5 mL ethanol; 1.0 g NaCl was added to the mixture, followed by 100 ml distilled water and a few drops of phenol red indicator. Care was taken at this point to ensure that all the pectin had dissolved and that no clumping occurred on the sides of the flask before the solution was then slowly titrated (to avoid possible de-esterification) with 0.1 M NaOH to a pink colour at the endpoint.

Equivalent weight was calculated using the equation below:

$$\text{Equivalent weight (EW)} = \frac{\text{weight of sample (g)x 100\%}}{\text{ml of alkali x N of alkali}}$$

Methoxyl Content

Methoxyl content is a significant factor in controlling the sensitivity to polyvalent cations, the pectins setting time, and their usefulness in the preparation of low solid gels, fibers, and films. It was determined by saponification of pectin and titration of the liberated carboxyl group. To a neutral solution titrated for the equivalent weight containing 0.5g of pectic substances, 25mL

of 0.25N sodium hydroxide (NaOH) was added, thoroughly shook and was allowed to stand for 30 mins at room temperature in a flask with stopper. A 25mL portions of 0.25N HCl (or an amount equivalent to the added base) were added and was titrated with 0.1N sodium hydroxide (NaOH) to the same endpoint as the previous one (Titration B). Methoxyl content was calculated using the following equation:

$$\% \text{ Methoxyl content } = \frac{\text{mL alkali x N alkali x 3.1}}{\text{weight of sample(g)}}$$

Anhydrouronic Acid (AUA)

Estimation of AUA content is essential to determine purity, degree of esterification (DE), and in the evaluation of pectin physical properties. Pectin, a partly esterified polygalacturonide, contains at least 10% organic material composed of galactose, arabinose, and other sugars. Making use of equivalent weight, methoxyl content, and the alkalinity of the ash data, the anhydrouronic acid was calculated using;

$$\text{AUA (\%)} = \frac{176 \text{ x } 0.1z \text{ x } 100\%}{w \text{ x } 1000} + \frac{176 \text{ x } 0.1y \text{ x} 100\%}{w \text{ x } 1000}$$

Where 176 is the molecular weight of anhydrouronic acid

y = ml (titer) of NaOH from methoxyl content determination.

z = ml (titer) of NaOH from equivalent weight determination.

w = weight of sample

Degree of Esterification (DE)

The DE of pectin was determined according to the formula below (Shaha *et al.*, 2013):

$$\text{DE (\%)} = \frac{176 \text{ x MeC(\%) x } 100}{31 \text{ x AUA (\%)}}$$

FINDINGS AND DISCUSSIONS

The summary of the average results of the yield, methoxyl content, DE, AUA, colour, and EW obtained are shown in Table 1.

Table 1: Overview of average results obtained in this study

	Colour	EW (%)	MeC (%)	AUA	DE (%)	Yield (%)
Lemon	Pale yellow	150.43	11.49	76.92	84.54	14.26
Orange	Pale yellow	116.78	14.94	100.03	84.68	14.08
Tangerine	Slightly brownish	97.15	12.02	86.38	78.88	12.82

Yield

The percent pectin yield is shown in Table 2.

Table 2: Yield of Pectin

Sample	pH	Mass of sample (g)	Mass of pectin (g)	Yield of pectin (%)
Lemon	2.22	10.0147	1.0535	10.52
	1.54	20.0218	3.1334	15.65
	1.27	30.0072	4.9842	16.61
Orange	2.22	10.0125	1.1024	11.01
	1.54	20.0272	3.0501	15.23
	1.27	30.0112	4.8048	16.01
Tangerine	2.22	10.0112	9.4306	9.45
	1.54	20.0241	2.7773	13.87
	1.27	30.0084	4.5433	15.14

On average, %yield of pectin obtained from lemon, orange and tangerine was 14.26, 14.08 and 12.82 respectively. Generally, the yield obtained from all three samples was low as compared to what is stated in the above theoretical statistics (25-30%). Phaviphu *et al.* (2018) reported that the yields of pectin extracted from different sources were significantly different and varied from 10.91 to 24.08%. The highest pectin yield was obtained from banana peel namely Kluai Leb Mu Nang (24.08%) while the low yield was obtained from apple pomace (10.91%). This deviation could have been brought about by factors such as surface contamination, environmental factors and types of fruits used (the species). Also, this could have been brought about by the amount of alcohol used for precipitation and purification during the experiment not being enough (McGready (1996). Uzma *et al.* (2015) reported that the yield of papaya peel pectin expressed as the dry weight of extract varied from 2.8% to 16% and that using citric acid varied from 1.9% - 9.9%. Consequentially, extraction of pectin is influenced by several variables such as extraction time, pH, temperature, solid/solvent ratio (May, 1990), irradiation time and irradiation power (Wang *et al.*, 2007; Seixas*et al.*, 2014). Previous studies have shown that pectin yield decreases with increase in fruit maturation (Phaviphu *et al.*, 2018).

Having kept the temperature and extraction time constant, pH caused the biggest variations in the yield. In Table 2, the pectin yield increases, as the pH decreases. The highest yield for lemon was 16.61% at pH = 1.27 and the low yield was 10.52% at pH = 2.22. The highest yield from orange was 16.01% at pH=1.27 and lowest yield was 11.01 at pH=2.22. Tangerine's highest yield was 15.14 at pH=1.27 and the lowest was 9.45 at pH=2.22. Generally, the yield from lemon was highest followed by orange and lastly tangerine. Increase in pH results in

decrease in pectin yield (Uzma *et al.*, 2015). The lower the pH values were, the greater the presence of H^+ ions, hence this would increase the hydrolysis of protopectin (Kertész, 1951). In addition, reducing the pH value may promote the release of pectin molecules from the raw peel because the linkage of pectin with hemicellulose was separated (Rombouts and Thibault., 1996).

Colour

Figure 1: Precipitation of pectin after addition of alcohol

Figure 2: Floating of the pectin after mixture settling for 30 minutes

Figure 3: Dried samples of pectin; from tangerine on the left, lemon in the middle and orange at the right

From Figure 1 to 3, the characteristic color of pectin obtained from lemon and orange was pale yellow while that obtained from tangerine was slightly brownish. According to IPPA (2009), pectins are usually light in color, types of fruits as a factor may have contributed to the discrepancy in color for the tangerine. Phaviphu *et al.*, (2018) reported that pectins extracted from banana peels showed a higher lightness than citrus peel and apple pomace pectins, and also stated that the redness and yellowness of the apple pomace and citrus peel pectins were greater than banana peel pectins; this would be reflected from different color component contained in the raw materials.

3.3 Equivalent weight

The equivalent weight of the pectins is shown in Table 3.

Table 3: Equivalent weight

Sample	Weight of sample (g)	Initial titre (Cm^3)	Final titre (cm^3)	Volume of NaOH used (cm^3)	Equivalent weight
	0.5043	13.00	16.30	3.30	152.82

Lemon pectin	0.5010	0.00	3.30	3.30	151.18
	0.5008	0.00	3.40	3.40	147.29
Orange pectin	0.5028	7.00	11.70	4.70	106.98
	0.5020	5.00	9.50	4.50	111.56
	0.5014	0.00	3.80	3.80	131.79
Tangerine pectin	0.5032	0.00	5.20	5.20	96.77
	0.5012	5.00	10.20	5.20	96.38
	0.5014	0.00	5.10	5.10	98.31

The average equivalent weight in mg/ml was found to be 150.43, 116.78 and 97.15% for lemon, orange and tangerine respectively. Uzma *et al.* (2015) reported that the equivalent weight of the pectin extracted using HCl and Citric acids was 912.17 and 455.1 respectively. The equivalent weight of pectins in this study was relatively lower compared to the work of Uzma *et al.* (2015). The high equivalent weight would have higher gel-forming effect. The lower equivalent weight may be as a result of higher partial degradation of pectin. The decreased equivalent weight could also be dependent upon the amount of free acid (Ramli and Asmawati, 2011). The equivalent weight of the pectin is total content of free galacturonic acid (unesterified) in the molecular chains of pectin. Pectin produced at a low pH has higher equivalent weight, because a low pH can cause pectin polymerization into longer chain, and in turn reduces the free acid content (Uzma *et al.*, 2015).

Methoxyl Content

Table 4: Methoxyl content

Sample	Weight of sample (g)	Initial titre (Cm^3)	Final titre (cm^3)	Volume of NaOH used (cm^3)	Methoxyl content (%)
Lemon pectin	0.5043	0.00	14.70	14.7	9.04
	0.5010	0.00	20.50	20.50	12.68
	0.5008	4.00	24.60	20.60	12.75
Orange pectin	0.5028	17.00	38.2	21.20	13.07
	0.5020	0.00	25.50	25.50	15.75
	0.5014	4.00	29.9	25.90	16.01
Tangerine pectin	0.5032	0.00	16.80	16.80	10.35
	0.5012	0.00	20.70	20.70	12.80
	0.5014	0.00	20.90	20.90	12.92

The % methoxyl content determined from the three fruits, lemon, orange and tangerine, were 11.49, 14.94 and 12.02, respectively. Uzman *et al.* (2015) reported that the methoxyl content of papaya peel pectins derived using HCl was 7.5% and that derived using citric acids was 6.2%. Methoxyl content is the number of moles of methyl alcohol (methanol) in 100 mol galacturonic acid. The methoxyl content of pectin is key to controlling the setting time, the gel strength, the sensitivity to metal ions, and determine the functional properties of pectin solution and pectin gel texture (Uzma *et al.*, 2015). Methoxyl content also influences dispersibility of

pectin in water, the higher methoxyl content being more readily dispersible in water than that with less than 7.0% methoxyl content (Rouse *et al.*, 1962). Methoxyl content is a key factor in controlling the setting time of pectins and the ability of the pectin to form gels (Constenla and Lozano, 2003). Spreading quality and sugar-binding capacity of pectin is increased with increase methoxyl content (Madhav and Pushpalatha, 2002). Since lower methoxyl content is preferred, the order of preference of pectin from these citrus fruits is lemon, tangerine and lastly orange.

Anhydrouronic Acid (AUA)

Table 5: Anhydrouronic acid

Sample	Weight of sample (g)	Titration A (Cm^3)	Titration B (cm^3)	Z	AUA (%)
Lemon pectin	0.5043	3.30	14.7	0.02801667	62.81975
	0.5010	3.30	20.50	0.02105042	83.60878
	0.5008	3.40	20.60	0.02086667	84.34505
Orange pectin	0.5028	4.70	21.20	0.01941313	90.6603
	0.5020	4.50	25.50	0.01673333	105.1793
	0.5014	3.80	25.90	0.01688215	104.2521
Tangerine pectin	0.5032	5.20	16.80	0.02287273	76.94754
	0.5012	5.20	20.70	0.01935135	90.94972
	0.5014	5.10	20.90	0.01928462	91.26446

The content of anhydrouronic acid (AUA) indicates the purity of the extracted pectin with a recommended value of not less than 65% for pectin used as food additives or for pharmaceutical purpose (Phaviphu *et al.*, 2018). A minimum value of 65 percent AUA for commercial pectins has been specified by FAO. This requirement has limited the potential sources of food and pharmaceutical pectins. The search for alternative pectin sources for commercial production using hot dilute acid extraction technique which is the most convenient approach for industrial extraction of pectin has been the topic of many studies (Phaviphu *et al.*, 2018). The average AUA of lemon, orange and tangerine were 76.92%, 100.03% and 86.38%, respectively, which meet the UN FAO requirement of a minimum of 65%. These values were higher than the values of 34.56% to 66.67% of the AUA contents of banana peel pectins reported by Phaviphu *et al.* (2018). The anhydrouronic acid content indicates purity of extracted pectin if not less than 65% (Food Chemical Codex, 1996). The AUA content of less than 65% may indicate impurities due to the presence of proteins, starch and sugars in the precipitated pectin (Norazelina and Nazarrudin, 2012). Pectin, which is a partly esterified polygalacturonide, contains at least 10% organic materials composed of arabinose, galactose and other sugars. AUA (%) is essential to determine the purity and the degree of esterification and to evaluate physical properties (Ranganna, 1986). The higher galacturonic acid and lower

ash content are the two criteria governing its purity (Hwang *et al.*, 1992). In this study, the purity of the pectin obtained from lemon is highest, followed by tangerines and lastly oranges.

Degree of Esterification (DE)

Table 6: Degree of esterification

Sample	Methoxyl content (%)	AUA (%)	DE (%)
Lemon pectin	9.04	62.81975	81.70021505
	12.68	83.60878	86.10300895
	12.75	84.34505	85.82258065
Orange pectin	13.07	90.6603	81.84825009
	15.75	105.1793	85.01612903
	16.01	104.2521	87.18816118
Tangerine pectin	10.35	76.94754	76.36539589
	12.80	90.94972	79.90235397
	12.92	91.26446	80.37330025

Degree of Esterification is the ratio of esterified galacturonic acid groups to total galacturonic acid groups present. DE is an important property that determines the gelling nature of pectin (Uzman *et al.*, 2015). Depending on the degree of esterification, pectin is divided into two groups: pectin with DE higher than 50% is known as high methoxyl pectin while low methoxyl pectin has a DE lower than 50% (Phaviphu *et al.*, 2018). The values for the degree of esterification obtained in this study were 84.54, 84.68 and 78.88% for lemon, orange and tangerine respectively. Phaviphu *et al.*, 2018 reported that the degree of esterification of extracted pectins from various banana varieties ranged between 63.15 and 72.03%, indicating that all banana peel pectins were categorized as high methoxyl pectin similar to those from citrus peel (62.83%) and apple pomace (58.44%). Degree of esterification, (DE) values obtained in a study done by Shaha *et al.* (2013) were within the range of 60 to 90%, which is generally found in tissues (Shaha *et al.*, 2013). The values of Shaha *et al.* (2013) were similar to the values obtained in this study. Pectin could be classified as rapid-set (DE >72%) and slow-set (DE 58-65%), which describes the rate of gel formation (Shaha *et al.*, 2013). The obtained pectin was all rapid-set. In 2015, Uzman *et al.* reported that the pectins extracted using hydrochloric acid has higher DE compared to that extracted using citric acid.

CONCLUSIONS

The above results were obtained from the extraction of pectin on dry basis since the yield is greater when extracted on a dry basis. Generally, the yield from lemon was highest, followed by oranges and lastly tangerine. This is due to the thick white pith on these citrus peels in that same order. Depending on the AUA, lemon pectin was the most pure of all the three samples, followed by tangerine and lastly orange peels. For commercial use of this pectin, lemon pectin is most suitable then tangerine and lastly orange basing on the methoxyl content. In terms of the pectin colour, the lemon and orange pectin had a better appearance than the tangerine pectin. Based on this study, the pectin obtained from the three samples was rapid set. It is recommended that for better yields, pectin should be extracted on a dry basis instead of a wet basis. This is so because in this study, the extraction of pectin on a dry basis yielded more pectin while hardly any pectin was obtained from the extraction carried out on the wet basis. It is also recommended that blending should be carried out because blending the dried pectin increases the surface area, thus improving on the efficiency of extraction. Instead of industrial sectors disposing of citrus fruit peels as wastes, more research should be carried out on the importance of the peels as waste and put to use.

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