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Valorisation of fruit by-products: Production characterization of pectins from fruit peels

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ABSTRACT

The aim of the study is to determine the physical, chemical, structural and thermal properties of the pectins obtained from melon rinds, kiwifruit and pomeganate peels and compared with the pectins obtained from apple and orange peel used in the commercial pectin production process. Pectins extractions from these wastes were performed with citric acid, at 80 °C and 60 min. All pectins, extracted, were found to be high methoxyl pectines. The water holding capacity of the melon rind, kiwifruit and pomegranate peels pectins were lower than the orange and apple peel pectins while the thermal stability of the kiwifruit peel pectin was close to the apple and orange peel pectins. The morphological structures of the extracted pectins showed that they had micro-fractures and hollow openings. The crystallinity of the melon rinds, kiwifruit and pomegranate peel pectins were smilar to orange peel pectin. The result of this study showed that the kiwifruit peel had advantages in terms of commercial pectin production due to its high pectin yield, water holding capacity, esterification degree and thermal stability.

1. Introduction

Pectin is a component of the cell wall of plant that imparts flexibility and mechanical strength to plants by interacting with other cell wall elements (Rosenbohm et al., 2003) and it is composed of backbone of α-galacturonic acid residues that are partly esterified with methyl or acetyl ester groups with a small proportion of L-rhamnose units (Wang et al., 2016). It is widely used as thickening, texturizing, emulsifying, stabilizing and gelling agents in food, cosmetic and pharmaceutical industries (Liu et al., 2006). It has various biological activities such as healing wound (Hokputsa et al., 2004), reducing lipase activity (Edashige et al., 2008), inhibiting growth of human cancer cell, inducing cell apoptosis (Jackson et al., 2007) and decreasing cholesterol level (Yamada, 1996).

Pectins are classified as low and high esterification grade pectin, according the amount of methanol-esterified galacturonic acid content. High methoxyl pectins are methylated more than 50% of the carboxyl groups and low methoxyl pectins are less methylated (Sharma et al., 2006). The gel-forming properties of aqueous solutions of pectins with acid and sugar vary according to the esterification degree. As the esterification degree increases, the amount of sugar and pH required for gelation increases and the time required for gelation decreases (Saldamli, 2005).

Commercially, apple pomace, citrus peels, sunflower head and sugar beet pulps are used for the pectin productions (Ranganna, 2008) and the properties of the pectin varies according to the source that is isolated from. Apple pectin produces a harder and more viscous gel, which is suitable for the bakery products, while citrus pectins are preferred for the candy and jellies because they have light-color (May, 1990). Although pectin is widely found in plant tissues, the production of it from every source is not feasible due to the production cost or the properties of the pectin (Cemeroğlu and Acar, 1986). There have been various studies on the extraction of pectin from different plant sources such as passion fruit peel, banana peel (Oliveira et al., 2016) and cacao peel (Sarah et al., 2018), but finding other alternative sources are necessary that can compete with the production cost and properties of the commercial pectin if the resulting product is going to be used in food application.

Food waste refers to discarded or lost of the uneaten part of the food that can be occurred entire food supply chain. It is estimated as around

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1.6 billion tonnes per year, and fruits and vegetables have the highest wastage rates among the food waste (FAO, 2016). In this study, melon rinds, kiwifruit, apple, pomegranate and orange peels, widely cultivated in Turkey were evaluated for the pectin production. In Turkey, the amount of kiwifruit, melon, apple, pomegranate and orange production in 2017 were 56,164 tons, 1,813,422 tons, 3032 164 tons, 502,606 tons and 1950,000 tons, respectively (TUIK, 2018), and in 2016, Turkey ranked 2nd and 4th in the world melon and apple production, respectively (FAO, 2017). While some of the agricultural and industrial wastes can be used as animal feed or fertilizer (Ashoush and Gadallah, 2011), wastes such as kernels, roots, peels and leaves are mostly discarded, which is a serious problem in the food and agriculture sector. For this reason, studies are needed to convert these wastes into high value-added products, such as pectins, to be used in industry.

Pectin is generally extracted with acidified hot water. For the acidification of water, the use of mineral acid can cause corrosion of the equipment as well as can be harmful to the environment (Hosseini et al., 2016). Instead of mineral acid, the use of organic acid is a more proper approach, environmentally, and due to the low dissociation capacity, it causes less depolymerisation of the pectin (Oliveira et al., 2016). The aim of this study is to determinate the pectin production capacity of melon rinds, kiwifruit, apple, pomegranate and orange peels with citric acid extraction, examine the physical, chemical, structural and thermal properties and compare properties of the extracted pectins to orange and apple peel pectins.

2. Materials and methods

2.1. Material

The kiwifruit, melon, apple, pomegranate and orange were obtained from local markets. Fresh fruits were peeled, and peels and rinds were dried (48 h, 60 °C), ground (Bosch MKM 600, Germany) and stored at 4 °C.

2.2. Extraction of pectin

Pectin extraction was performed with the modification of the method provided by Kliemann et al. (2009). Citric acid solution (pH 1) (100 mL) was mixed with 10 g of peels and extractions were carried out (80 °C, 60 min) in shaking water bath. After the extraction, the extracts were filtered and cooled to 4 °C, and extracted pectins were precipitated with 96% ethanol, separated by filtration, and washed with 20 mL of 70% acidic ethanol (contain 0.5% HCl), 20 mL of 70% (two times) and 20 mL of 96% ethanol. The isolated pectin was dried at 50 °C for 24 h and stored at 4 °C.

2.3. Moisture, ash, liquid holding capacity and solubility of pectins

Moisture and ash contents of dried pectins were determined gravimetrically (AOAC, 1989). For the solubility test, 250 mg pectin and 5 mL sodium hydroxide (1 M)/methanol (96%)/acetone were mixed for 2 min and their solubility was monitored (Halib et al., 2012). For the determination of the liquid holding capacity (LHC), pectins (1 g) were mixed with water/acetone/dimethyl sulphoxide/ acetic acid (40 g), allowed to stand for 2 h and centrifuged at 3500 rpm for 30 min and weighed, and LHC calculated by the following equation (Tappi, 1991).

$$\mathrm{LHC}(\%) = (B - A)/A \times 100 \quad (1)$$

LHC: liquid holding capacity, A: the dry weight of pectin (g), B: the wet weight of pectin (g).

2.4. Esterification, amidation and galacturonic acid contents of pectins

The esterification, amidation and galacturonic acid contents of pectins were determined (FAO JECFA, 2009). Pectins (5 g) were mixed with 60% ethyl alcohol (100 mL) and 2.7 M HCl (5 mL) solutions, filtered, washed with the same alcohol-acid solution (6 times, 15 mL) and ethanol (96%, 20 mL) and dried at 105 °C. Ethanol (2 mL) and water (100 mL) were added to 1/10 of the dried sample and the mixture was titrated against 0.1 M of NaOH. The spent volume of the titration was recorded as V1. NaOH (0.5 M, 20 mL) and HCl (0.5 M, 20 mL) were added to the solution and the mixture was titrated against 0.1 M NaOH. The spent volume of the titration was recorded as V2. NaOH (10%, 20 mL) was added to the solution, the mixture was distilled and titrated against 0.1 M of NaOH and the spent volume of the titration was recorded as S1. For the blank determination, HCl (0.1 M, 20 mL) was titrated against 0.1 M of NaOH and spent volume was recorded as B1 and the B1-S1 difference (mL) was recorded as V3. Dried samples (1/10 of the dried sample weight) were mixed with ethanol (2 mL), dissolved in NaOH (0.125 M, 25 mL) for saponification and filled with distilled water to 50 mL. This solution was mixed with of Clark's solution (20 mL) and distilled. The distillate was titrated against 0.05 M NaOH and volume was recorded as S2. Water (20 mL) was used for the blank determination, titrated and volume of NaOH (mL) was recorded as B2 and S2-B2 difference (mL) was recorded as V4. The ratio of the esterification, amidation and total galacturonic acid were calculated according equations below (FAO JECFA, 2009). The results were calculated by taking the average of at 3 replications and expressed as mean ± standard deviation.

$$\mathrm{DE}\%(w/w) = [V2/(V1 + V2)] \times 100 \quad (2)$$

$$\mathrm{DA}\%(w/w) = [V3/(V1 + V2 + V3 - V4)] \times 100 \quad (3)$$

$$\mathrm{GA}(mg) = (V1 + V2 + V3 - V4) \times 19.41 \quad (4)$$

DE: esterification degree, DA: the degree of amidation, GA: the amount of galacturonic acid.

2.5. Fourier transform infrared (FTIR) spectroscopy

FTIR analysis of pectins (prepared as KBr pellets) was performed on Jasco FT/IR-430 spectrophotometer (Japan). The esterification degree (DE) of the samples were calculated by determining the peak area values of the free carboxyl groups (1630 cm^{-1}) and the esterified groups (1740 cm^{-1}) by following equation (Pappas et al., 2004).

$$\mathrm{DE} = 124.7 \times R + 2.2013 \quad (5)$$

$$R = A_{1740}/(A_{1740} + A_{1630}) \times 100 \quad (6)$$

DE: esterification degree, A_{1740} and $A_{1630:}$ the absorbance densities at 1740 cm^{-1} and 1630 cm^{-1}, respectively.

2.6. Thermogravimetric analysis (TG–DTA)

PRIS Diamond TG/DTA thermal analyser (USA) was used for the determination of thermal properties of the pectins. In a nitrogen atmosphere, the pectins were heated from 20 °C to 650 °C in the rate of 10 °C/min.

Table 1 – Chemical and physicochemical properties of pectins.

		KP	MP	PP	AP	OP
Pectin yield (% w/w)		8.03 ± 0.09^{b}	6.54 ± 0.02^{b}	6.13 ± 0.26^{b}	13.30 ± 0.18^{a}	11.46 ± 0.14^{a}
Moisture (% w/w)		12.06 ± 0.09^{a}	14.81 ± 0.54^{a}	10.31 ± 0.15^{ab}	4.67 ± 3.71^{b}	10.18 ± 1.14^{ab}
Ash (% w/w)		1.14 ± 0.01^{a}	1.35 ± 0.20^{a}	1.15 ± 0.02^{a}	1.08 ± 0.06^{a}	1.19 ± 0.06^{a}
LHC	Water (% w/w)	268.76 ± 4.83^{c}	161.63 ± 2.30^{e}	235.25 ± 1.82^{d}	454.10 ± 0.46^{b}	491.32 ± 1.07^{a}
	Acetone (% w/w)	62.05 ± 1.49^{b}	54.13 ± 2.40^{c}	82.04 ± 1.74^{a}	85.55 ± 0.61^{a}	65.11 ± 2.20^{b}
	DMSO (% w/w)	200.60 ± 2.24^{e}	217.40 ± 2.64^{d}	276.72 ± 1.94^{c}	384.56 ± 0.79^{b}	419.39 ± 1.93^{a}
	Acetic acid (%, w/w)	176.01 ± 7.32^{c}	154.09 ± 0.23^{d}	192.06 ± 1.52^{b}	261.47 ± 3.18^{a}	151.95 ± 1.42^{d}
Esterification (%)		84.72 ± 1.60^{a}	71.98 ± 3.74^{b}	56.74 ± 1.95^{c}	77.62 ± 0.67^{ab}	69.67 ± 3.35^{b}
Amidation (%)		0.79 ± 0.19^{b}	0.77 ± 0.01^{b}	3.75 ± 0.07^{a}	0.96 ± 0.03^{b}	0.65 ± 0.02^{b}
Galacturonic acid (%)		94.75 ± 1.06^{a}	92.97 ± 1.37^{a}	78.48 ± 1.60^{b}	79.78 ± 1.37^{b}	76.32 ± 1.68^{b}
Solubility	1 M NaOH	+	+	+	+	+
	Methanol	–	–	–	–	–
	Acetone	–	–	–	–	–

Pectin from melon rind (MP), kiwifruit (KP); pomegranate (PP), apple (AP) and orange (OP) peels. Liquid holding capacity (LHC); dimethyl sulfoxide (DMSO); insoluble (–), soluble (+).
[a,b,c,d,e]Means followed by different letters within the same line represent significant differences ($p < 0.05$). Data are the average of triplicates.

2.7. *Scanning electron microscope (SEM) analysis*

Scanning electron microscope (QUANTA 450 Field Emission Gun-FEG, SEM High Resolution Scanning Electron Microscope, USA) was used for the examination of the structural and morphological characteristics of the pectins. Different magnification images (×2000, ×1000 and ×500) were recorded.

2.8. *X-ray diffraction (XRD) analysis*

X-ray diffraction (XRD) analysis of pectins was performed with Panalytical Empyrean High Performance Diffractometer (Netherlands). The pectins were analysed in Cu X-ray tube device with Ni filter between $2\theta = 10–50^{\circ}$ at 5°/min.

2.9. *Statistical analysis*

SPSS statistical program (SPSS, Inc., Chicago, IL, USA) was used, variance analysis of the results (ANOVA) was performed and the differences between the groups were assessed statistically at a 95% confidence interval by the Duncan multiple comparison test.

3. Results and discussion

3.1. *Physicochemical properties*

The pectin yields of the melon rinds (MP), kiwifruit (KP), pomegranate (PP), apple (AP) and orange (OP) peels were determined as 8.03%, 6.54%, 6.13%, 13.30% and 11.46%, respectively (Table 1). Among them, the highest pectin yield was obtained from the apple peel followed by the orange peel, kiwifruit peel, melon rind and pomegranate peel. In the previous studies, it was found that the pectin yields were between 3.62 and 4.48% for kiwifruit pomace (Yuliarti et al., 2015a), 11.46 and 22.09% for citrus (lemon, mandarin, orange and grapefruit) peels (Güzel and Akpınar, 2017), 2.8% and 8.8% for banana and mango peels, respectively (Panchami and Gunasekaran, 2017), 1.99 and 2.86% for quince (Açıkgöz and Poyraz, 2006) and 4.7% for cocoa husks (Mollea et al., 2008). Pectin yields of all the peels investigated in this study were higher than kiwifruit pomace, banana peels, quince and cocoa husks reported in the literature, and they could be used for the production of pectin.

The moisture contents of the pectins were varied from 4.67% to 14.81% and their ash contents were between 1.08% and 1.35% (Table 1). Previous studies showed that the ash content of pectins varied according to the plant materials and the extraction methods. It was reported that the ash contents were determined as 1.05–12.87% for kiwifruit pectins (Yuliarti et al., 2015a, b), 1.84% for apple pomace pectin (Johar et al., 1960), 0.50% for mandarin peel pectin (Pruthi et al., 1961) and for 0.70% lemon pectin (Dang, 1968). Since low ash content is an important criterion for the purity of pectin (Miyamoto and Chang, 1992), according to these results, it can be stated that the pectins obtained in this study have high purity.

Liquid holding capacities of the extracted pectins were presented in Table 1. A polymer, which has a high liquid holding capacity, has the function of increasing the volume of the food while decreasing the calorie content of it. It also directly affects the texture and viscosity of the food. Therefore the liquid holding capacity of the material is important both physiologically and technologically for food (Rodriguez et al., 2006). The water and dimethyl sulfoxide holding capacities of all the pectins were found to be higher than their acetic acid and acetone holding capacities. Among them, AP and OP had higher water holding capacities than other pectins. In the literature studies, the water holding capacities of the pectins were reported as 34–187% (w/w) for olive oil byproducts, 1035% (w/w) for commercial citrus pectin and 200% (w/w) for commercial apple pectin (Senent et al., 2015). It was found that, except MP, all the extracted pectins had higher water holding capacities than the olive oil byproducts and the apple pomace pectins, while lower than the commercial citrus peel pectin.

The solubilities of pectins in different solvents were presented in Table 1. All the pectins were soluble in NaOH (1 M), but not soluble in methanol and acetone. The previous study about the orange peel pectin (Tyagi, 2016) reported the insolubility of the pectin in methanol and acetone, as in our study. The studies investigating the solubility of pectins from lemon, grapefruit and orange peels (Aina et al., 2012) were reported that all the pectins formed yellow solutions in cold alkaline (20 °C, 0.1 N NaOH), and dissolved and turned into milky structures in hot alkaline (85–95 °C, 0.1 N NaOH).

The esterification degrees of the pectins were ranged from 56.74 to 84.72%, so all the isolated pectins were high methoxyl pectins and the esterification degree of KP was the highest among them (Table 1). In the previous studies, it was

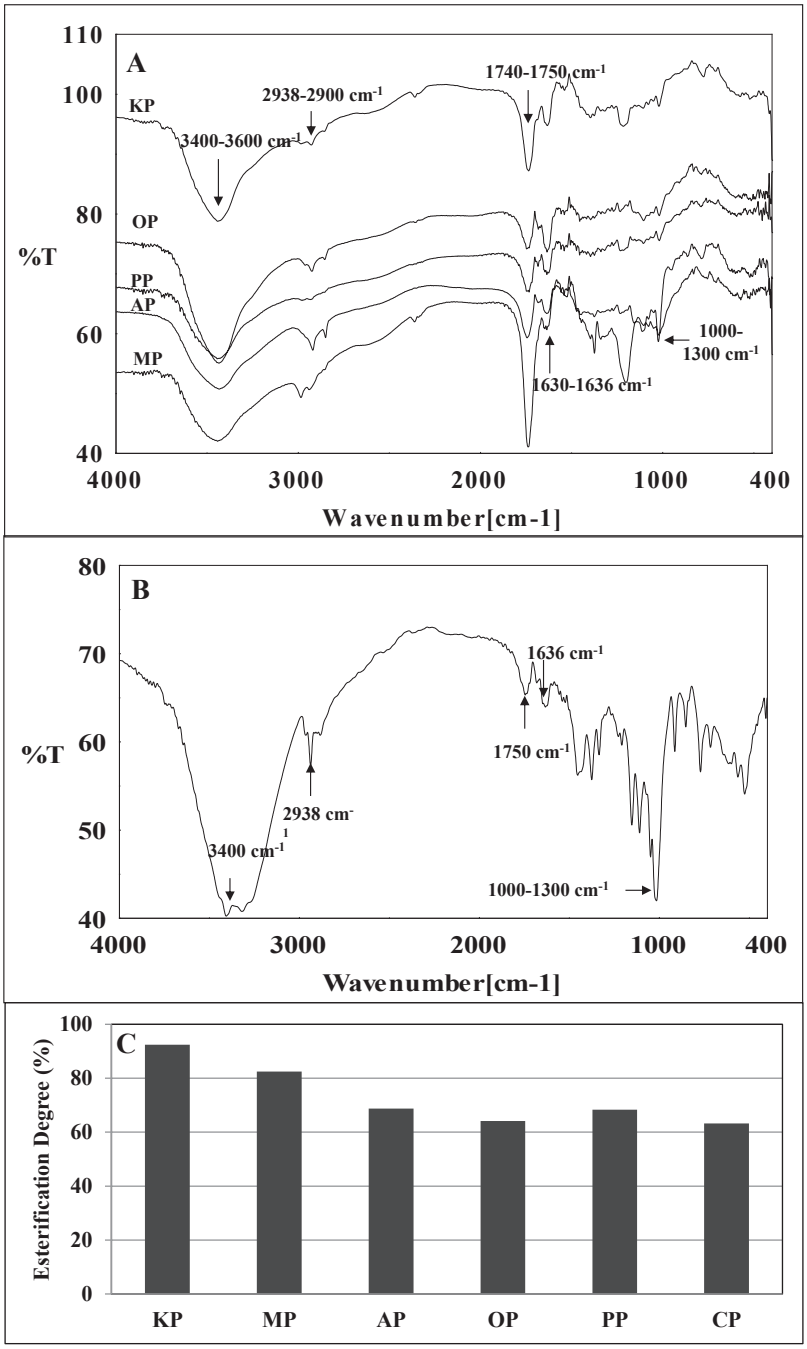

Fig. 1 – FTIR spectrum and esterification degrees of pectins, A: FTIR spectrum of pectin from kiwifruit (KP); melon (MP), apple (AP), orange (OP) and pomegranate (PP) peels; B: FTIR spectra of commercial pectin (CP); C: esterification degrees of KP, MP, AP, OP, PP, CP.

found that the maturation degree of the fruits and extraction methods affected the esterification degree of pectins (Azad et al., 2014; Yuliarti et al., 2015b) and the esterification degrees were reported as 82% and 90% for kiwifruit pectins (Yuliarti et al., 2015b), 63% and 75% for orange peel pectins (Georgiev et al., 2012; Venzon et al., 2015), 55.61% for lemon peel pectin (Georgiev et al., 2012) and 56.56–57.54% for grapefruit peel pectins (Mohamed and Mohamed, 2015). The esterification degrees of all the pectins extracted in this study were consistent with the literature studies.

The amidation degrees of KP, MP, OP and AP, which were important for the elasticity and gelling for the low methoxylated pectins (Lootens et al., 2003), were found to be similar to each other and PP had the highest amidation degree. Galacturonic acid contents of pectins ranged 78.48% and 94.75% and among them KP had the highest galacturonic acid content (Table 1). When the results were compared to the previous studies, it was found that the amidation degrees of KP, MP, AP and OP were lower than the pectins from orange (2.20%) and lemon peels (1.44%) (Georgiev et al., 2012), but galacturonic acid of all pectins extracted were higher than the that of gold kiwifruit pectin (28.96%–58.57%) (Yuliarti et al., 2015a).

3.2. *FT-IR analysis*

In Fig. 1, FT-IR spectra of all the extracted pectins were presented. Non-associate OH peaks in their spectra were observed at 3600–3400 cm^{-1}. These are characteristic peaks for the poly-

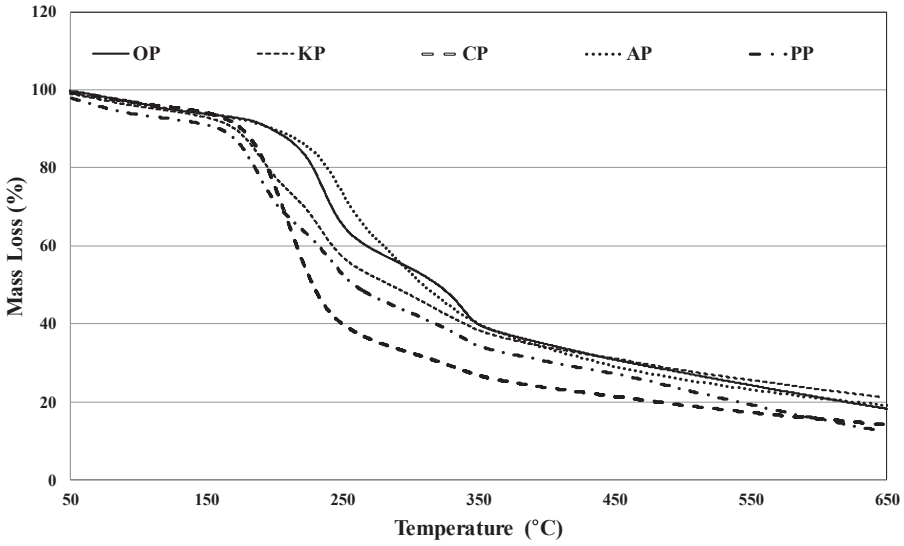

Fig. 2 – TGA curves of KP, MP, AP, OP and PP.

hydroxy compounds, and they indicate the presence of a large number of OH groups. The absorbance at about 2900 cm^{-1} belongs to the —CH, —CH_2, and —CH_3 stretches of galacturonic acid methyl esters. The peak at 1740 cm^{-1} is the C=O stretch observed in the ester and derived from acetyl ($COCH_3$) group. The peak at 1630 cm^{-1} is related to the —OH tensile vibration band, and the bands at 1380–1445 cm^{-1} indicate the presence of —CH_3 groups. The bands at 1015–1100 cm^{-1} belong to C—O bending or stretching (Fig. 1) (Ferreira et al., 2001; Nesic et al., 2011; Fajardo et al., 2012). It was observed that the FT-IR spectra of all the pectins had characteristic pectin peaks and KP, MP and PP spectra were similar to the AP and OP spectra that are also used commercially. Based on the areas of the peaks at 1740 cm^{-1} and 1630 cm^{-1} of the FT-IR spectra of all the pectins, their esterification degrees were calculated and presented in Fig. 1. It was found that all pectins had high esterification degrees (DE > 50), and the results were found to be compatible with the results of the titration method (Table 1).

3.3. *Thermal analysis*

In the thermal analysis of pectins, the decreases in pectins mass against temperature were determined and the results were given in Fig. 2. It was observed that the thermogravimetric curves of all the pectins were similar to each other, and they had three regions (50–190 °C, 190–400 °C and 400–650 °C) that also reported in other studies (Combo et al., 2013; Wang et al., 2016). A slow weight loss occurred due to the evaporation of water in the first region (50–190 °C). In the second region (190–400 °C), a quick weight loss (~50%) occurred due to the decomposition of the polysaccharide. In the third region (400–650 °C), slow weight loss was observed due to the decomposition of the char (Wang et al., 2016).

The DTG_{max}, at which the decomposition rate was maximum temperature, was determined as ranged from 210 °C to 249 °C for all the pectins. The DTG_{max} of PP was higher than OP, but lower than AP. It was determined that $T_{\%50}$, a temperature of 50% of the mass lost, was determined to range from 226 °C to 319 °C $T_{\%50}$ of KP, PP and MP were lower than the AP (306 °C) and OP (319 °C). The total mass loss at 650 °C was ranged from 80% to 88% (Table 2). Pectin with high thermal stability is preferred in food industry due to the suitability of the use as an additive in high temperature treated food products such as cakes, breads and pastries (Combo et al., 2013). Among the pectins studied, MP had the lowest thermal stability while OP and AP showed the highest thermal stabilities, followed by KP. The results showed that pectins obtained from different sources can have different thermal properties and stabilities.

Table 2 – Thermal degradation measurement of pectins.

TGA	$T_{\%50}$ (°C)	DTG_{max} (°C)	Mass Loss (650 °C) (%)
KP	280	234	80
MP	226	210	86
PP	255	240	88
AP	306	249	80
OP	319	236	80

Pectin from melon rind (MP), kiwifruit (KP); pomegranate (PP), apple (AP) and orange (OP) peels.

3.4. *SEM analysis*

The surface morphologies of the pectins were examined by scanning electron microscope (SEM) at different magnification degress and the images were presented in Fig. 3. The roughness difference between the pectin surfaces had been detected. When the images were examined, it was observed that the morphological structures of pectins had some micro-fractures and hollow openings and these micro-fractures and hollow openings of AP and OP were similar to each other but less than those of other pectins.

3.5. *XRD analysis*

XRD (X-ray diffraction) diffractograms of the pectins were presented in Fig. 4 and provided information about the structure of the polymers. In XRD (X-ray diffraction) diffractograms, the crystalline material shows the series of sharp peaks, while amorphous product produces a broad background pattern (Combo et al., 2013). In the previous studies, it has been

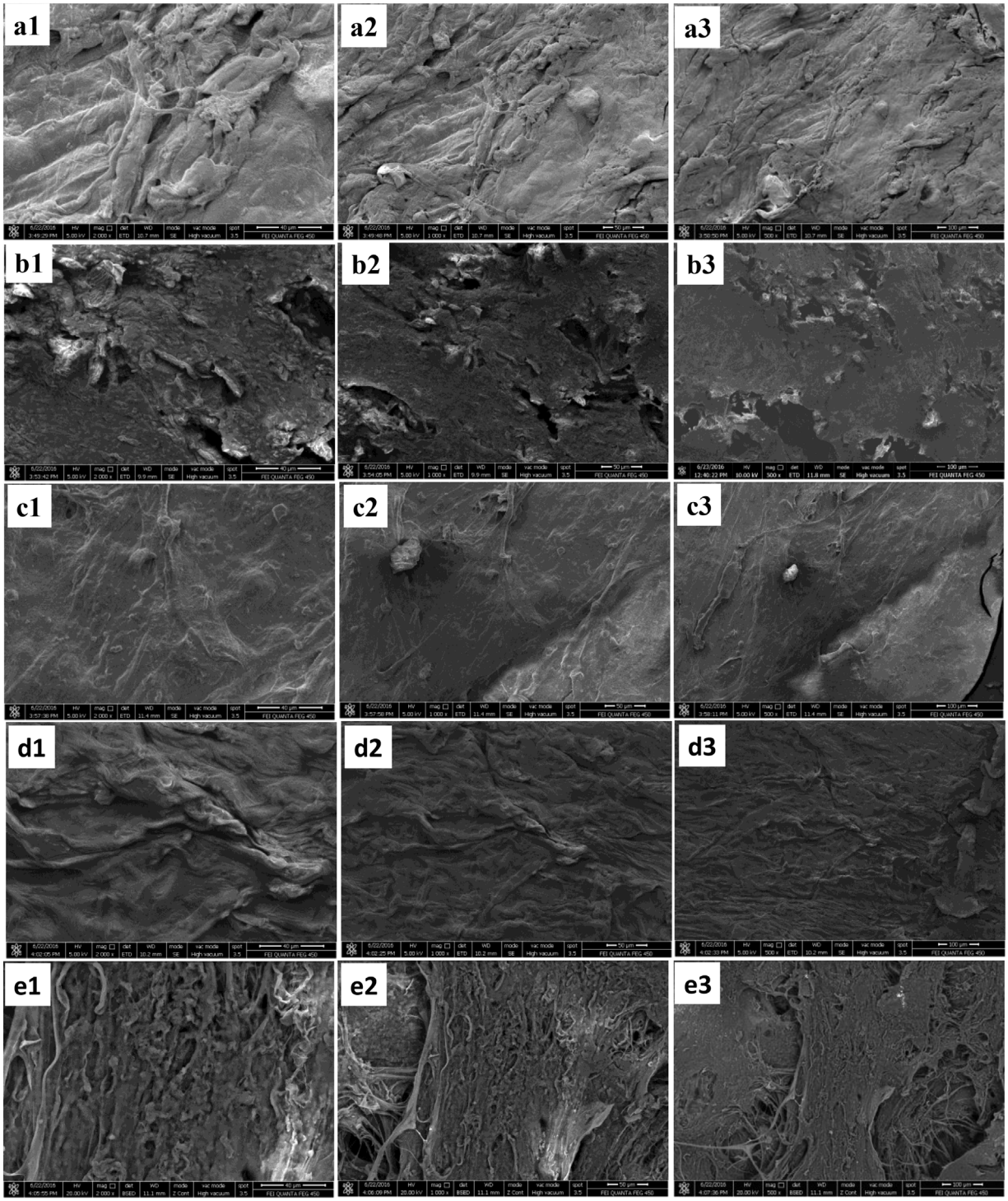

Fig. 3 – SEM of KP (a); MP (b), AP (c), OP (d) and PP (e); 2000× (1), 1000× (2) and 500× (3) magnification.

reported that pectin has characteristic peaks in the X-ray diffractogram associated with the pure pectin crystallinity at 13.56°, 22.56° (Sharma and Ahuja, 2011), 9°, 12.7°, 18.42°, 28.22°, 40.14° (Mishra et al., 2008), 12.72°, 16.30°, 18.45°, 25.32° and 40.14° (2θ) (Nisar et al., 2018). The sharper and narrower diffraction peaks show the crystallinity of pectin (Khodzhaeva et al., 2003; Kumar and Chauhan, 2010). It was observed that all pectins had similar peaks to the peaks reported in the literature and showed amorphous nature. Among them it was observed that AP had sharp and narrow diffraction peaks, and the other pectins showed the similar crystalline structures to the OP that was used also as commercial pectin.

4. Conclusion

This study showed that the kiwifruit peel, pomegranate peels and melon rind could be used for the pectin production like orange and apple peel. All the pectins had high esterification degrees and water holding capacities. Among them kiwifruit peel has advantages in terms of commercial pectin production

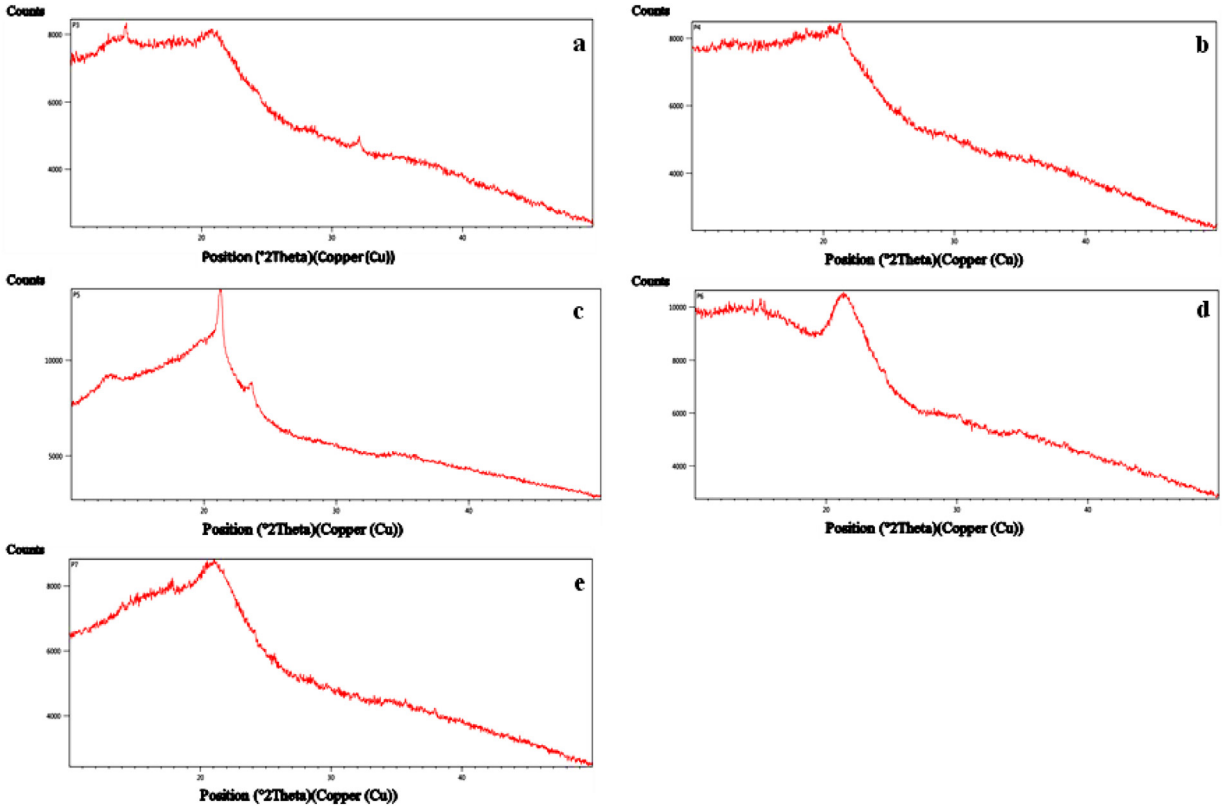

Fig. 4 – X-ray diffractogram of KP (a); MP (b), AP (c), OP (d) and PP (e).

due to its high pectin content, water holding capacity, esterification degree and thermal stability, so it has a potential for the commercial pectin production that can be used in the food industry.

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References

Açıkgöz, Ç., Poyraz, Z., 2006. Extraction and characterization of pectin obtained from quince (cydonia vulgaris pers.). J. Sci. Tech. Dumlupınar Univ. 12, 27–34.

Aina, V.O., Barau, M.M., Mamman, O.A., Zakari, A., Haruna, H., Hauwa Umar, M.S., Abba, Y.B., 2012. Extraction and characterization of pectin from peels of lemon (Citrus lemon), grape fruit (Citrus paradise) and sweet orange (Citrus sinensis). Br. J. Pharmacol. Toxicol. 3 (6), 259–262.

AOAC, 1989. Official Methods of Analysis, 14th Edition. Association of Official Analytical Chemists, Washington DC, USA.

Ashoush, I.S., Gadallah, M.G.E., 2011. Utilization of mango peels and seed kernels powders as sources of phytochemicals in biscuit. World J. Dairy Food Sci. 6 (1), 35–42.

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

Cemeroğlu, B., Acar, J., 1986. Meyve Sebze İşleme Teknolojisi. Gıda Teknolojisi Derneği, Ankara.

Combo, A.M.M., Aguedo, M., Quiévy, N., Danthine, S., Goffin, D., Jacquet, N., Blecker, C., Devaux, J., Paquot, M., 2013. Characterization of sugar beet pectic-derived oligosaccharides obtained by enzymatic hydrolysis. Int. J. Biol. Macromol. 52, 148–156.

Dang, R.L., 1968. Better utilization of galgal. Indian Food Pack. 22 (6), 16–24.

Edashige, Y., Murakami, N., Tsujita, T., 2008. Inhibitory effect of pectin from the segment membrane of citrus fruits on lipase activity. J. Nutr. Sci. Vitaminol. 54 (5), 409–415.

Fajardo, A.R., Lopes, L.C., Pereira, A.G.B., Rubira, A.F., Muniz, E.C., 2012. Polyelectrolyte complexes based on pectin–NH2 and chondroitin sulfate. Carbohydr. Polym. 87 (3), 1950–1955.

FAO, 2016. Food Wastage: Key Facts and Figures,. (Accessed 16 March 2018) http://www.fao.org/news/story/pt/item/196402/icode/.

FAO, 2017. The Food and Agriculture Organization,. (Accessed 12 November 2018) http://www.fao.org/faostat/en/#rankings/countries_by_commodity.

FAO JECFA, 2009. Compendium of Food Additive Specifications (71st JECFA), 7. FAO JECFA Monographs, . (Accessed 16 March 2018) http://www.fao.org/3/a-i0971e.pdf.

Ferreira, D., Barros, A., Coimbra, M.A., Delgadillo, I., 2001. Use of FT-IR spectroscopy to follow the effect of the processing in cell wall polysaccharide extracts of the sun dried pear. Carbohydr. Polym. 45 (2), 175–182.

Georgiev, Y., Ognyanov, M., Yanakieva, I., Kussovski, V., Kratchanova, M., 2012. Isolation, characterization, and modification of citrus pectins. J. Biosci. Biotech. 1 (3), 223–233.

Güzel, M., Akpınar, Ö., 2017. Characterization and physicochemical properties of pectins obtained from citrus peels. Academic Food J. 15 (1), 17–28, http://dx.doi.org/10.24323/akademik-gida.304274.

Halib, N., Iqbal, M.C., Amin, M., Ahmad, I., 2012. Physicochemical properties and characterization of nata de coco from local food industries as a source of cellulose. Sains Malays. 41 (2), 205–211.

Hokputsa, S., Gerddit, W., Pongsamart, S., Inngjerdingen, K., Heinze, T., Koschella, A., Harding, S.E., Paulsen, B.S., 2004. Water-soluble polysaccharides with pharmaceutical importance from Durian rinds (Durio zibethinus Murr.): isolation, fractionation, characterisation and bioactivity. Carbohydr. Polym. 56 (4), 471–481.

Hosseini, S.S., Khodaiyan, F., Yarmand, M.S., 2016. Optimization of microwave assisted extraction of pectin from sour orange peel and its physicochemical properties. Carbohydr. Polym. 140, 59–65.
Jackson, C.L., Dreaden, T.M., Theobald, L.K., Tran, N.M., Beal, T.L., Eid, M., Gao, M.Y., Shirley, R.B., Stoffel, M.T., Kumar, M.V., Mohnen, D., 2007. Pectin induces apoptosis in human prostate cancer cells: correlation of apoptotic function with pectin structure. Glycobiology 17 (8), 805–819.
Johar, D.S., Krishnamurthy, G.V., Bhatia, B.S., 1960. Utilization of apple pomace. Food Sci. 9, 82–84.
Khodzhaeva, M.A., Turakhozhaev, M.T., Khachaturova, R.V., Burkhanova, N.D., Yugai, S.M., Yunusov, M.Y., Nikonovich, G.V., 2003. Properties of the polycomplex of apple pectin with benzimidazolyl-2-methylcarbamate hydrochloride after micronization. Chem. Nat. Comp. 39 (1), 41–45.
Kliemann, E., Simas, K.N., Amante, E.R., Prudencio, E.S., Teofilo, R.F., Ferreira, M.C., Renata Amboni, D.M.C., 2009. Optimisation of pectin acid extraction from passion fruit peel (*Passiflora edulis* flavicarpa) using response surface methodology. Int. J. Food Sci. Tech. 44 (3), 476–483.
Kumar, A., Chauhan, G.S., 2010. Extraction and characterization of pectin from apple pomace and its evaluation as lipase (steapsin) inhibitor. Carbohydr. Polym. 82, 454–459.
Liu, L.S., Kende, M., Ruthel, G., Fishman, M.L., Hicks, K.B., 2006. Pectin/zein beads for potential colon-specific drugdelivery: synthesis and in vitro evaluation. Drug Deliv. 13 (6), 417–423.
Lootens, D., Capel, F., Durand, D., Nicolai, T., Boulenguer, P., Langendorff, V., 2003. Influence of pH, Ca concentration, temperature and amidation on the gelation of low methoxyl pectin. Food Hydrocoll. 17, 237–244.
May, C.D., 1990. Industrial pectins: sources, production and applications. Carbohydr. Polym. 12, 79–99.
Mishra, R.K., Datt, M., Banthia, A.K., 2008. Synthesis and characterization of pectin/pVP hydrogel membranes for drug delivery system. AAPS. Pharm. Sci. Tech. 9 (2), 395–403.
Miyamoto, A., Chang, K.C., 1992. Extraction and physicochemical characterization of pectin from sunflower head residues. J. Food Sci. 57 (6), 1439–1443.
Mohamed, H.A., Mohamed, B.E.W., 2015. Fractionation and physicochemical properties of pectic substances extracted from grapefruit peels. J. Food Process. Tech. 6 (8).
Mollea, C., Chiampo, F., Conti, R., 2008. Extraction and characterization of pectins from cocoa husks: a preliminary study. Food Chem. 107, 1353–1356.
Nesic, A.R., Trifunovic, S.S., Grujic, A.S., Velickovic, S.J., Antonovic, D.G., 2011. Complexation of amidated pectin with poly (itaconic acid) as a polycarboxylic polymer model compound. Carbohydr. Res. 346 (15), 2463–2468.
Nisar, T., Wang, Z., Yang, X., Tian, Y., Iqbal, M., Guo, Y., 2018. Characterization of citrus pectin films integrated with clove bud essential oil: physical, thermal, barrier, antioxidant and antibacterial properties. Int. J. Biol. Macromol. 106, 670–680.
Oliveira, T.S., Rosa, M.F., Cavalcante, F.L., Pereira, P.H.F., Moates, G.K., Wellner, N., Mazzetto, S.E., Waldron, K.W., Henriette, M., Azeredo, C., 2016. Optimization of pectin extraction from banana peels withccitric acid by using response surface methodology. Food Chem. 198, 113–118.
Panchami, P.S., Gunasekaran, S., 2017. Extraction and characterization of pectin from fruit waste. Int. J. Curr. Microbiol. App. Sci. 6 (8), 943–948.
Pappas, C.S., Malovikova, A., Hromadkova, Z., Tarantilis, P.A., Ebringerova, A., Polissiou, M., 2004. Determination of the degree of esterification of pectinates with decyl and benzyl ester groups by diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) and curve-fitting deconvolution method. Carbohydr. Polym. 56 (4), 465–469.
Pruthi, J.S., Parekh, C.M., Lal, G., 1961. An integrated process for the recovery of essential oil and pectin from mandarin orange waste. Food Sci. 10 (11), 372–378.
Ranganna, S., 2008. Pectin, Handbook of Analysis And Quality Control For Fruit and Vegetable Products. Tata McGraw Hill, New Delhi, India, pp. 31–66.
Rodriguez, R., Jiménez, R., Fernández-Bolaños, J., Guillén, R., Heredia, A., 2006. Dietary fibre from vegetable products as source of functional ingredients. Trends Food Sci. Tech. 17 (1), 3–15.
Rosenbohm, C., Lundt, I., Christensen, T.I., Young, N.G., 2003. Chemically methylated and reduced pectins: preparation, characterisation by 1H NMR spectroscopy, enzymatic degradation, and gelling properties. Carbohydr. Res. 338 (7), 637–649.
Saldamli, İ., 2005. Gıda KimYası. Hacettepe University Publications, Ankara, Turkey.
Sarah, M., Hanum, F., Rizky, M., Hisham, M.F., 2018. Microwave-assisted extraction of pectin from cocoa peel. IOP Conference Series: Earth and Environmental Science 122, http://dx.doi.org/10.1088/1755-1315/122/1/012079.
Senent, F., Rodríguez-Gutiérrez, G., Lama-Muñoz, A., Fernández-Bolaños, J., 2015. Pectin extracted from thermally treated olive oil by-products: characterization, physico-chemical properties, in vitro bile acid and glucose binding. Food Hydrocoll. 43, 311–321.
Sharma, R., Ahuja, M., 2011. Thiolated pectin: synthesis, characterization and evaluation as a mucoadhesive polymer. Carbohydr. Polym. 85 (3), 658–663.
Sharma, B.R., Naresh, L., Dhuldhoya, N.C., Merchant, S.U., Merchant, U.C., 2006. An overview on pectins. Times Food Process. J. 23, 44–51.
Tappi, 1991. Tappi useful method UM256. In: Water Retention Value (WRV), Tappi Useful Methods. Tappi Press, Atlanta, USA.
TUIK, 2018. Crop Production Statistics (Accessed 16 March 2018) http://www.tuik.gov.tr/UstMenu.do?metod=temelist.
Tyagi, S., 2016. Extraction, characterization and evaluation of pectin from orange peels as pharmaceutical excipient. Global J. Pharm. Pharm. Sci. 10 (2), 41–44.
Venzon, S.S., Canteri, M.H.G., Granato, D., Junior, B.D., Maciel, G.M., Stafussa, A.P., Haminiuk, C.W.I., 2015. Physicochemical properties of modified citrus pectins extracted from orange pomace. J. Food Sci. Tech. 52 (7), 4102–4112.
Wang, M., Huang, B., Fan, C., Zhao, K., Hu, H., Xu, X., Pan, S., Liu, F., 2016. Characterization and functional properties of mango peel pectin extracted by ultrasound assisted citric acid. Int. J. Biol. Macromol. 91, 794–803.
Yamada, H., 1996. Contribution of pectins on health care. Prog. Biotech. 14, 173–190.
Yuliarti, O., Goh, K.K.T., Matia-Merino, L., Mawson, J., Brennan, C., 2015a. Extraction and characterization of pomace pectin from gold kiwifruit (*Actinidia chinensis*). Food Chem. 187, 290–296.
Yuliarti, O., Merino, L., Goh, K., Mawson, J., Williams, M., Brennan, C., 2015b. Characterization of gold kiwifruit pectin from fruit of different maturities and extraction methods. Food Chem. 166, 479–485.