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## ORIGINAL ARTICLE

# A new approach for pectin extraction: Electromagnetic induction heating

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## KEYWORDS

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**Abstract** Electromagnetic induction (EMI) and conventional (CV) heating have been employed to extract pectin from citrange (*Citrus sinensis* × *Poncirus trifoliata*) albedos under the same extraction conditions (pH 1.2, temperature 80 °C and extraction time 90 min). The electromagnetic induction heating process was investigated at different extraction times (10, 20, 30, 40, 50, 60 and 90 min) and at different power levels. The high pectin yield obtained with this process was found to be 29% (w/w) of dried albedos, which was almost equal to that found using conventional heating (24% (w/w)). However, a considerable reduction in the extraction time was observed. It was found that 30 min of electromagnetic induction extraction of pectin from dried albedos yielded the same amount (24% (w/w)) of pectin obtained by conventional heating process for 90 min. Also, the electromagnetic induction heating at higher power and for only 2.09 min gave half the amount of pectin extracted by conventional heating for 90 min. Moreover, it was found that both extracted pectins showed almost similar compositions and physicochemical properties, presenting a galacturonic acid content of 29.10–29.40% and an esterification degree of 61.00–62.50%. The average molecular weight for both pectins extracted by EMI and CV heating ranged from  $0.84 \times 10^5$  to  $1.63 \times 10^5$ . Hence, the electromagnetic induction heating can be suggested as a promising method for the extraction of pectin from citrange albedos at a short time, with a remarkable yield and keeping the composition and the physicochemical properties of the pectin unchanged.

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## 1. Introduction

For over 50 years, many scientific reports have described the composition of pectins extracted from various plants (Voragen et al., 1995; Mohnen, 2008; Ele-Ekouna et al., 2011). Pectic substances are heterogeneous complex polysaccharides, consisting mainly of α (1–4) D-galacturonic acid residues, organized on a linear backbone. The linear structure of pectin is partly interrupted by (1,2)-linked side-chains consisting of L-rhamnose

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residues and some other neutral sugars (Schols and Voragen, 1996). Pectic polysaccharides are of high molecular weight and closely connected with other polymer components in the cell walls, which inhibit their release from the cell matrix (Kratchanova et al., 2004). Therefore, the used protocols must be sufficient to allow selective extraction of privileged pectins. They must also have the ability to protect the integrity of the molecular structures by limiting their degradation.

Several methods of pectin extraction have already been reported in the literature (Zhiwei et al., 2002; Sahari et al., 2003; Thomas et al., 2003; Singthong et al., 2004; Mesbahi et al., 2005; Zhongdong et al., 2006; Prabasari et al., 2011). The usual used techniques of extraction include principally, direct boiling and microwave heating (Fishman et al., 2000; Joye and Luzio, 2000; Zouambia et al., 2009). However, these methods give rise to some degradation of the extracted pectins. Direct boiling is the most common method employed for the extraction of pectic substances, which takes up to approximately 2 h to obtain a good yield of pectin. Thereby, it is considered as a time consuming process (El-Nawawi and Shehata, 1987). Therefore, it is necessary to establish a new method, by which the pectin could be extracted in a shorter time with better quality.

The use of microwave for extraction of constituents from plant material has shown tremendous research interest and potential. Microwave heating extraction takes less than 15 min to extract a satisfactory amount of pectin (Fishman et al., 2000). This process is generally more effective in terms of pectin yield and gives better quality products (Kratchanova et al., 2004). Flash pectin extraction from orange albedo by microwave heating under pressure indicated that molar mass, size and intrinsic viscosity were increased as compared with pectin extracted by conventional heating techniques (Fishman et al., 2000). It must be noted that this heating method allows obtaining excellent performances; however the cost of such technique is usually very high. So, research is directed to the development of new heating processes based on physical and electrical properties of acidic and basic solutions. It is the appearance of electromagnetic induction heating.

The technology of plant extraction using direct induction heating assisted by magnetic field has been investigated only in the case of producing parietal fractions and fractions of secondary metabolites from wheat straw, madder roots and caraway seeds (Lagunez Rivera and Vilarem, 2007). By comparison with conventional systems, in the case of caraway essential oil, the hydrodistillation method supported by direct induction showed the best results for rapidity and chemical selectivity.

The aim of this work was to introduce the electromagnetic induction heating, as a new approach, for the extraction of pectin from citrange albedos. In this study, extraction yield, composition and physicochemical characteristics of pectin extracted by electromagnetic induction heating were studied and compared with those obtained by conventional heating method (direct boiling).

## 2. Material and methods

### 2.1. Chemical reagents

The chemical reagents used in the present work were purchased from Sigma Aldrich (Switzerland) and were of analytical grade, and they were used without further purification.

Commercial citrus pectin was procured from Sigma life science (Switzerland).

### 2.2. Raw material

The citrange fruit which is a crossing between *Citrus sinensis* and *Poncirus trifoliata* i.e. a sweet orange crossing with *P. trifoliata* was used as raw material for pectin extraction. These local fruits (Medea region, Algeria) were collected at the end of their maturity and they were carefully selected. The fruits, weighing between 80 and 120 g, were peeled in order to recover only the albedos of the fruit. The recovered albedos were dried in an oven at 50 °C until their weight was unchanged. The dried peels were then mechanically ground and sifted to get a powder of the same particle sizes of which the diameter ranged between 0.63 and 1.25 mm. The ground albedos were packaged in a polyethylene bag and stored at room temperature.

### 2.3. Pretreatment and preparation of alcohol insoluble solids

The pretreatment of the raw material is of great importance to remove low molecular carbohydrates, color pigments, organic compounds and to inactivate pectic enzymes. Pretreatment of the albedos was carried out in two steps by making a combination between the two methods proposed by Kar and Arslan (1999a,b) and Taboada et al. (2010) respectively with slight modifications.

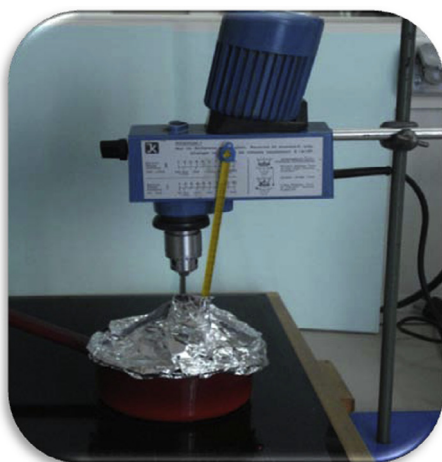
In the first step, the albedos were washed in water and blanched at 90 °C for 10 min using a solid/liquid ratio 1:25 (w/v). The mixture was then filtered using a two-layered cheesecloth. The residual plant material was dried in an air convection oven at 50 °C.

In the second step, the dried residues were treated thereafter with 85% ethanol at 70 °C in water bath for 20 min using a solid/liquid ratio 1:5 (w/v). Finally, the mixture was filtered and the solid phase was dried at 50 °C in a conventional oven during 16 h to give alcohol insoluble solids (AIS).

### 2.4. Pectin extraction and purification

Extraction of pectin from citrange albedos was chosen on the basis of various studies (Buchholt et al., 2004; Mesbahi et al., 2005) which suggested that acid hydrolysis is the most used method for pectin extraction. Pectin was extracted with two different modes of heating: conventional (CV) heating in water bath and electromagnetic induction (EMI) heating. For each extraction, 10 g of AIS was suspended in distilled water using a solid/liquid ratio 1:50 (w/v). The aqueous solution was adjusted to pH 1.2 with a solution of 1 M H<sub>2</sub>SO<sub>4</sub>. The mixture was then heated to 80 ± 2 °C and extraction was carried out with continuous stirring for 90 min.

For CV heating, extraction was performed in a conical flask placed in a water bath under continuous stirring. Whereas for EMI heating, extraction was carried out in magnetizable and enameled containers placed on an induction plate. This apparatus contains 9 levels; each level corresponds to a defined power which gives a known temperature. For example, level 2 is used to reach the temperature of 80 °C. The experimental device used for EMI heating is shown in Fig. 1. The extraction time was varied for 10, 20, 30, 40, 50, 60 and 90 min.



**Figure 1** Experimental device used for electromagnetic induction heating.

### 2.5. Correlation between time and electromagnetic power

To evaluate the effect of EMI power on pectin yield and esterification degree, the extraction was carried out using various power levels (4, 5, 6, 7, 8, and 9). The necessary time to reach a temperature of 80 °C corresponding to each power level is given in [Table 1](#). It should be noted that beyond this time the temperature exceeds 80 °C and can reach more than 120 °C for example for level 9.

### 2.6. Morphology analysis

In order to visualize the effect of heating mode on the destruction of plant tissue used for the extraction of pectin, an analysis by scanning electron microscopy (SEM) of alcohol insoluble solids before extraction and those remaining after extraction was performed. The prepared samples were observed using a FEI Quanta 200 at an accelerating voltage of 30 kV.

### 2.7. Determination of pectin yield

Pectin yield was calculated as follows:

$$\text{Pectin yield (\%)} = \frac{\text{weight (g) of dried pectin}}{\text{weight (g) of dried peel taken for extraction}} \times 100 \quad (1)$$

### 2.8. Determination of moisture and ash content

The moisture content was calculated as the weight loss after drying at 105 °C until constant weight. Ash content was

determined by incinerating 1 g of sample in a furnace at 600 °C for 4 h. The subsequent ash was cooled and stored in a desiccator until weighting.

### 2.9. Determination of esterification degree

The degree of esterification (DE) of pectin samples was determined by potentiometric method titration according to [Pinheiro et al. \(2008\)](#) with a slight modification. The dried sample (200 mg) was transferred to a 250 mL flask, wetted with ethanol and dissolved in 20 mL of carbon dioxide-free water. Later, the sample was left under continuous stirring until complete dissolution. The resulting solution was titrated with 0.5 M NaOH in the presence of three drops of phenolphthalein and the result was recorded as initial titer (IT). Then, 10 mL of 0.5 M NaOH was added; the sample was shaken vigorously, and allowed to stand under continuous stirring for 2 h to saponify the polymer ester groups. Then 10 mL of 0.5 M HCl was added and the sample was shaken until the pink color disappeared. Phenolphthalein (three drops) was added and the solution was titrated with 0.5 M NaOH to a faint pink color that persisted after vigorous shaking (end-point). This volume of titration was recorded as the saponification titer named final titer (FT).

DE was calculated by using the following formula:

$$\text{DE (\%)} = \frac{\text{FT}}{\text{IT} + \text{FT}} \times 100 \quad (2)$$

### 2.10. Determination of methoxyl percentage

The methoxyl percentage (MeO%) was determined according to the procedure of Gee, McComb, McCready (1958) reported by [Kar and Arslan \(1999a,b\)](#). Since the amount of methoxyl in 100% of esterified pectin is 16.32%, the methoxyl percentage was calculated from the following equation:

$$\text{MeO\%} = \frac{16.32}{100} \times \text{DE} \quad (3)$$

### 2.11. Determination of galacturonic acid and total sugar content

Galacturonic acid was determined by m-hydroxydiphenyl method ([Blumenkrantz and Asboe-Hansen, 1973](#)). Samples (200 µL) were mixed thoroughly with 1.2 mL of 0.125 M sodium tetraborate solution (in concentrated sulfuric acid) in an ice bath. The mixtures were heated in a boiling bath for 5 min and subsequently cooled in an ice bath. The mixtures were added with 20 µL of 0.15% m-hydroxydiphenyl (in 0.5% NaOH) and mixed. A pink color develops during 5 min. After that, the absorbances were recorded at 520 nm using an UV spectrophotometer (Shimadzu UV mini, 1240). A standard curve was obtained using galacturonic acid at 25, 50, 100 and 200 µg mL<sup>-1</sup>.

The content of total sugars of pectin was determined by the phenol-sulfuric acid method ([Dubois et al., 1956](#)). Samples (200 µL) were mixed thoroughly with 200 µL of aqueous solution of phenol of 5%. Then 1 mL of concentrated sulfuric acid was quickly introduced into the reactional medium. After homogenization, the mixtures were heated in a boiling bath for 5 min, cooled in an ice bath and placed in the dark for 30 min. An orange color appears. The absorbance was

**Table 1** Correlation between heating levels of the induction plate used and time to reach a temperature of 80 °C for aqueous solution used in the extraction of pectin.

Level	4	5	6	7	8	9
Time (min)	10.36	6.49	5.43	4.15	3.50	2.09



recorded at 492 nm. A standard curve was obtained using glucose at 25, 50, 100 and 200  $\mu\text{g mL}^{-1}$ .

### 2.12. Intrinsic viscosity determination and estimation of average molecular weight

Intrinsic viscosity was determined using the method proposed by Kar and Arslan (1999a,b). Pectin solutions at the concentrations of 0.25, 0.5, 0.75, 1, 1.5 and 2 g/L were prepared using 1% of sodium hexametaphosphate buffer solution (pH = 7) instead of water as solvent. The mixture was then allowed to stand with mixing at ambient temperature for 12 h. The viscosity values of pectin solutions at different concentrations were determined at 20 °C using an Ubbelohde viscometer (No.13, ID: 0.84 mm). Specific, reduced and intrinsic viscosities were calculated by the following equations:

$$\text{Specific viscosity : } \eta_{sp} = \frac{t - t_0}{t_0} \quad (4)$$

$$\text{Reduced viscosity : } \eta_{red} = \frac{\eta_{sp}}{C} \quad (5)$$

$$\text{Intrinsic viscosity : } \eta_i = \lim_{C \rightarrow 0} \frac{\eta_{sp}}{C} \quad (6)$$

where  $t$  is the time taken by the solution to flow in viscosimeter (s);  $t_0$  is the time taken by the solvent to flow in viscosimeter (s);  $C$  is the concentration of the solution (g/L).

The molecular weight is estimated by applying the Mark Houwink equation:

$$\eta_i = k \overline{M}_v^a \quad (7)$$

The above equation shows the relation between intrinsic viscosity ( $\eta_i$ ) and viscosity-average molecular weight ( $\overline{M}_v$ ) where the values of the constants,  $k$  and  $a$  of pectin, are  $9.55 \times 10^{-2}$  mL/g and 0.73 respectively at 25 °C (Hiorth et al., 2003).

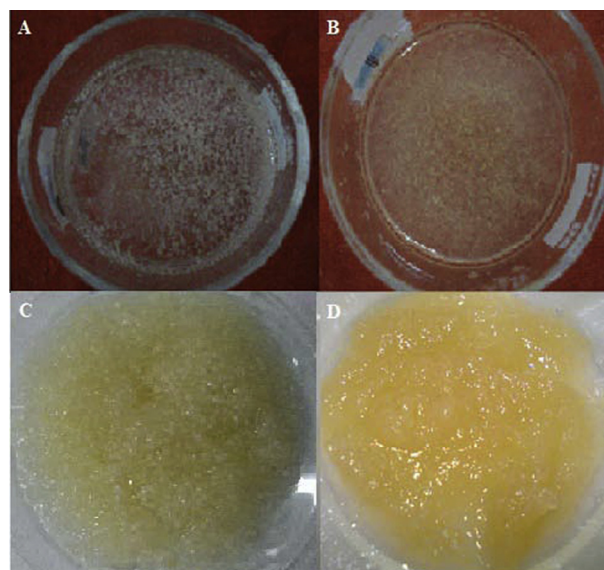
### 2.13. Fourier transform infrared spectroscopy

All samples were dried and stored in desiccators prior to their analysis by infrared spectroscopy (FT-IR) analysis. FT-IR spectra of pectin polysaccharides were recorded on KBr (spectroscopic grade) disks using a 90:10 KBr/pectin proportion. FT-IR spectra were collected at the absorbance mode from 4000 to 400  $\text{cm}^{-1}$  using a Shimadzu-8400 spectrophotometer at the resolution of 4  $\text{cm}^{-1}$  and 128 scans were collected to obtain a high signal-to-noise ratio.

## 3. Results and discussion

### 3.1. Effect of heating modes on the pectin yield

The effect of the heating mode on the extraction yield was investigated. The yield values of pectin extracted by CV heating in water bath and by EMI heating, at the same extraction conditions (pH, temperature and extraction time) were found to be equal respectively to 24 and 29% (w/w) of dried AIS. So, by using the electromagnetic induction heating, 5% (w/w) of pectin was extracted in comparison with the use of conventional heating. This result could be explained by the homogeneity and the rapidity of heating produced within material heated by electromagnetic induction. However, it should be noted that a difference of 5% (w/w) on pectin yield



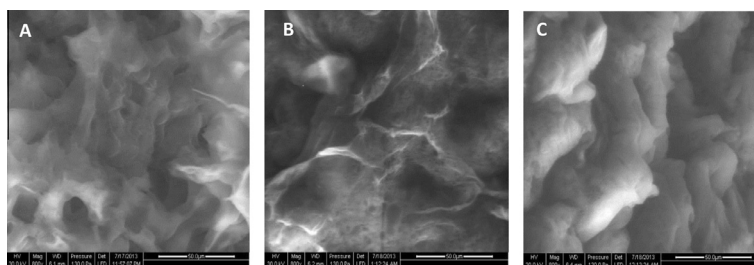
**Figure 2** Tissue morphology of albedo residues remained after pectin extraction; (a) albedos before filtration for CV heating extraction, (b) albedos before filtration for EMI heating extraction, (c) and (d) residues after filtration for CV and EMI heating respectively.

does not really justify the effectiveness of this heating mode. Nevertheless, the results of the kinetics study of EMI assisted-extraction of pectin (see Section 3.3) at different regular time intervals show clearly the advantages of such heating technique.

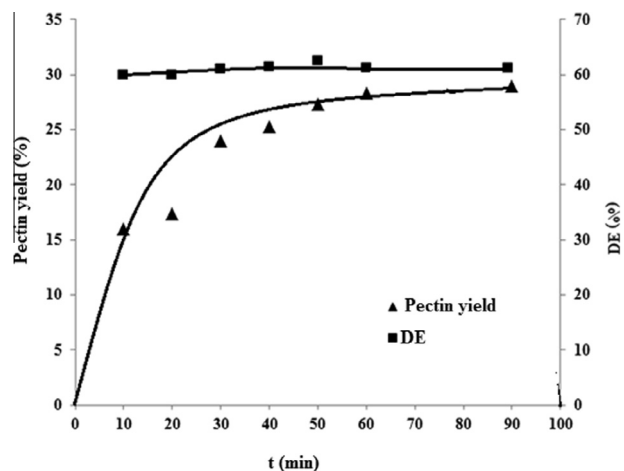
### 3.2. Effect of heating modes on the structural properties of citrange albedos tissues

After extraction by the two heating modes, some morphological modifications of the raw material were observed. Fig. 2 shows the tissue morphologies of albedos remaining after pectin extraction using CV and EMI-assisted heating, before and after filtration. As shown in Fig. 2a, the solvent-albedos mixture obtained after CV heating extraction was still a typical suspension system which was easy to separate. However, the mixture obtained after EMI assisted-extraction (Fig. 2b) became a relatively consistent system, in which the hydrated and swelled plant tissues are distributed all across the system. Fig. 2c and d represents the tissue residues after the filtration of solvent-albedos mixtures for CV and EMI heating respectively. The residues of EMI extraction show obvious swelling behavior compared to that of those obtained by CV extraction.

SEM images (with a magnification factor of 800) of dried citrange albedos, before (a) and after (b and c) undergoing the extraction process are shown in Fig. 3. Fig. 3a which shows citrange albedos before extraction and Fig. 3b of citrange residues after CV heating extraction are almost identical. This indicates that the structure of citrange albedo tissue was still complete and compact after CV heating extraction. However, the tissue treated by EMI heating (Fig. 3c) was greatly disintegrated and, the surface morphology was visibly changed. Hence, the tissue treated by EMI heating became much looser than that by CV heating. From these results, it can be noticed that an increase in temperature from EMI heating may cause a rupture of the parenchymal cells of the plant material. The



**Figure 3** Scanning electron micrographs of citrange albedos; (a) Albedos before extraction, (b) Albedos after extraction with CV heating, (c) Albedos after extraction with EMI heating.



**Figure 4** Evolution of pectin yield and esterification degree according to extraction time for electromagnetic induction heating. (▲) pectin yield (■) DE.

damage of the plant tissue could be explained by the increase in intracellular spaces. So the cell will split and the pectin can easily release itself.

### 3.3. Effect of extraction time for EMI heating compared to CV heating

In this part, the effect of extraction time on pectin yield and esterification degree was studied. The evolutions of pectin yield and DE according to the extraction time are illustrated in Fig. 4. It was noted that the amount of the extracted pectin increases progressively with the extraction time. In the first 10 min, the pectin yield was found about 16% (w/w) of dried albedos which increased to 28.33% (w/w) at 60 min of extraction. However, increasing extraction time to 90 min did not increase pectin yield significantly, it reaches about 29.00% (w/w) of albedos. Thus, the optimum extraction time leading to maximum pectin yield was found to be 60 min. Similar results, in terms of effect of extraction time, were reported on pectin extracted by CV heating from passion fruit peel by Kulkarni and Vijayanand (2010). It was also observed in this case, that pectin yield at 30 min of extraction was 24% (w/w) which is the same yield obtained for 90 min of extraction with a CV heating. These results indicate that the rapid heating with EMI energy has the potential to increase the yield of extracted pectin at a shorter time compared to CV heating. This can be explained by the principle of the heating process assisted by magnetic induction using the properties of the electrical

conductivity of acidic and basic solutions. Then, the most plausible explanation is that, for conductive liquids (dilute sulfuric acid in our case), the application of an electromagnetic field generates an agitation of ions ( $H^+$ ,  $SO_4^{2-}$ ) and electrolyte compounds such as metal salts and galacturonic acid which lead to the increase of temperature of the aqueous solution. After a few minutes, the aqueous solution initiates a motion with the solids and then the boiling starts. During extraction, boiling is homogeneous throughout the liquid volume. This specificity of homogeneity allows greater heat transfer, and consequently the extraction rate increases.

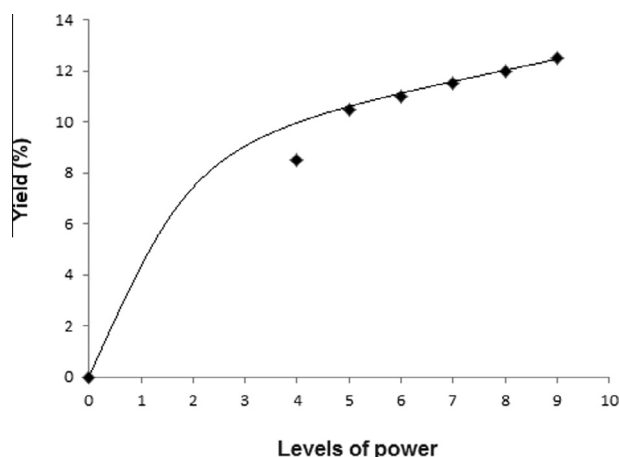
The evolution of DE according to extraction time indicates that the DE of the extracted pectin increases with the extraction time, but with small degrees. The higher DE was found to be 62.50% at 50 min, which decreases slightly at 60 min and thereafter remains almost constant.

It is also obvious from Fig. 4, that the DE of pectin extracted by EMI heating at 90 min is 61% which is almost the same value (62.5%) of the DE obtained for the pectin extracted by CV heating under the same conditions of extraction. As a result, it can be concluded that heating mode does not have a significant influence on the DE of the extracted pectin; however it strongly affects the pectin yield.

### 3.4. Effect of EMI power on pectin yield compared to CV heating

Pectin yield was evaluated by using EMI heating with different powers which are represented by different levels (Table 1). The induction plate contains 9 levels but the only ones used in this study are 4, 5, 6, 7, 8 and 9 obtained by the determination of reasonable time necessary for heating extraction solution to 80 °C. We have observed, for this induction plate, that levels lower than the level 4 are not able to reach this temperature in acceptable time (over 30 min). Fig. 5 shows the yield of extracted pectin as a function of different levels. In this test, the pectin yield was found to increase with the increasing power. An increase of 2% (w/w) (from 8.55% to 10.50% (w/w)) was observed on the pectin yield when the level passes from level 4 to level 5 and with a reduction in the extraction time by 40%. Nevertheless, a relatively high pectin yield (12.50% (w/w)) was found for the higher level 9 for the shorter time of 2.09 min. These results show that the increase in power leads to an increase of pectin yield and an appreciable decrease of the extraction time.

Compared with conventional heating extraction, the EMI heating extraction reduced considerably the extraction time. For EMI heating, 2.09 min is enough to give an extraction

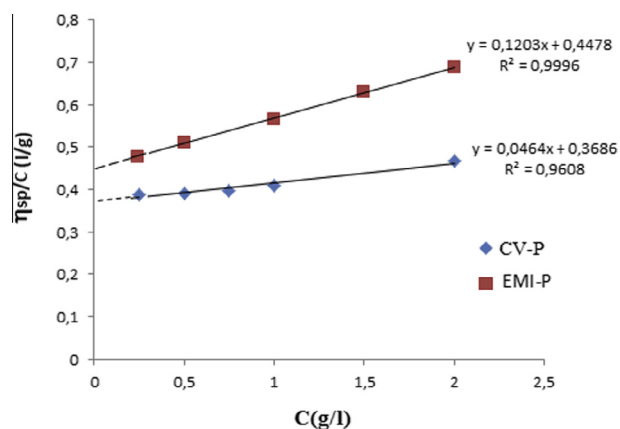


**Figure 5** Evolution of pectin yield according to different power levels used for electromagnetic induction heating.

yield (12.50% (w/w)) of pectin equal to half of that obtained with 90 min by conventional heating extraction (24% (w/w)). The significant reduction in extraction time using EMI heating is due to the physical changes in the citrange swelled albedos tissues. Indeed, during EMI heating considerable thermal energy generates at the core of the raw material. Then, this high thermal energy modifies the physical properties of the citrange albedos tissues, breaking down the cell structure as confirmed by the SEM analysis (Fig. 3). This feature allows better penetration of extracting solvent into the tissues, improving the subsequent extraction of pectin. These results show clearly the rapidity and homogeneity of heating produced by EMI energy.

### 3.5. Molecular properties of extracted pectin

The average molecular weight of extracted pectin was determined using the Mark Houwink equation based on its intrinsic viscosity. Fig. 6 shows the variation of the ratio of specific viscosity to the concentration ( $\eta_{sp}/C$ ) versus pectin concentration. Based on this figure, the intercept for EMI-P was 447 mL/g. Using the Mark Houwink equation, the calculated average



**Figure 6** Specific viscosity/concentration ( $\eta_{sp}/C$ ) versus concentration of pectins.

molecular weight ( $M_v$ ) for the pectin extracted by EMI was  $1.06 \times 10^5$ . On the other hand, the intercept for CV-P was 376 mL/g; and, the calculated  $M_v$  for the conventional heating pectin was about  $0.84 \times 10^5$ . These results are in agreement with those found for citrus pectin ( $1.63 \times 10^5$ ) by Ho et al. (2010). However, the difference observed between the two extracted pectins is probably justified by the use of two different heating methods for their extraction (CV and EMI heating). The molecular weight is related to the chain length, so the CV heating can cause a little depolymerization of the pectin chains.

### 3.6. Chemical composition of extracted pectins

The chemical features of pectin extracted by CV and EMI heating are presented in Table 2. The ash contents of pectin obtained by EMI heating (EMI-P) and CV heating (CV-P) were similar. They are about 5.90 and 4.40% respectively and are similar to those found for citrus peel pectin (4–5%) (Kurita et al., 2008). The moistures obtained from both types of pectin are less than 11% what allows a better conservation of the powders of these pectins. These values are in agreement with those reported for citrus peel (8–9%) (Kurita et al., 2008), sugar beet pulp (4–6%) (Yapo et al., 2007), sunflower head residues (7–11%) (Iglesias and Lozano, 2004), and soy hull (8–10%) (Kurita et al., 2008).

Galacturonic acid constitutes the main component of pectic polysaccharides. It was about 29.4% for EMI-P which is almost the same for CV-P (29.1%). So, EMI heating does not have a significant effect on pectin backbone.

Furthermore, pectin extracted by EMI heating has the highest proportions of total sugar compared with those found for pectin extracted by the conventional one. A difference of about 5% in total sugar between the two extracted pectins (24.9% for EMI-P and 19.5% for CV-P) was recorded. According to the total sugar composition of the extracted pectins, it was deduced that the pectin extracted by EMI heating was a bit ramified than that extracted by CV heating.

The main results for different characteristic tests of the two pectins are grouped in Fig. 7. From the analysis of this figure, the following conclusions can be made: (i) the extraction assisted by EMI leads to an improvement of the extraction yield, (ii) for EMI heating, the extraction time was considerably reduced compared to CV heating, (iii) EMI Heating does not have a significant effect on the pectin backbone, (iv) the extraction assisted by EMI can lead to obtain ramified pectins in comparison with those obtained by CV heating.

**Table 2** Comparison of chemical composition between the two extracted pectins: EMI-P and CV-P.

Chemical tests	Pectin type	
	CV-P	EMI-P
Ash (%)	04.40	05.90
Moisture (%)	10.01	11.05
DE (%)	62.50	61.00
MeO (%)	10.20	09.95
GlaA (%)	29.10	29.40
Total sugar (%)	19.50	24.90



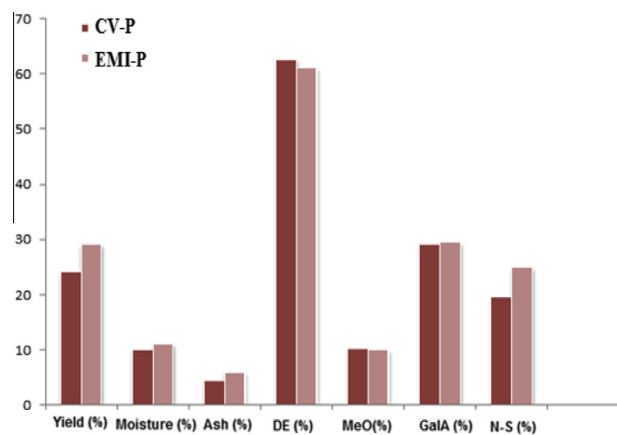


Figure 7 Comparison between EMI-P and CV-P.

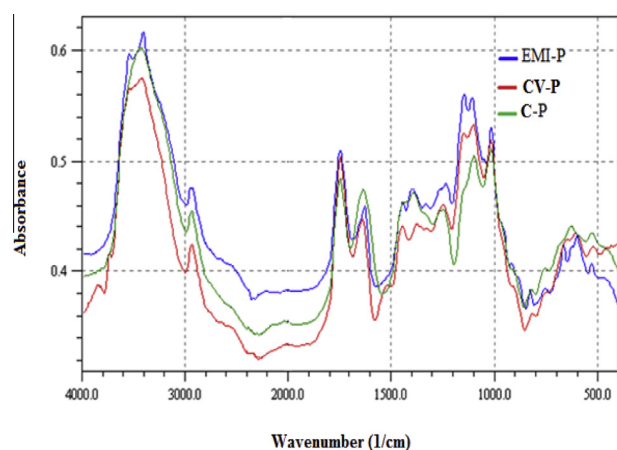


Figure 8 FTIR spectra of pectin samples.

### 3.7. Structural analysis

The infrared spectroscopy is a fast and convenient method for investigation of functional groups of polysaccharides. In order to confirm the pectin identity and to show the effect of heating mode on the structural properties of extracted pectins, the samples were analyzed by Fourier Transform Infrared Spectroscopy (FT-IR) and compared to commercial pectin (Citrus pectin or C-P). FT-IR spectra of the studied pectins are presented in Fig. 8. It was found that both extracted pectins spectra exhibited similarities in their absorption patterns to those of commercial pectin. FT-IR spectra in the wavelength range from 950 to 1200  $\text{cm}^{-1}$  are considered as the 'finger print' region for carbohydrates as it allows the identification of major chemical groups in polysaccharides (Cerná et al., 2003). Similarities of the extracted pectin spectra with those of commercial pectin in the "fingerprint" region suggest that the extract is an effective pectin. Analysis of spectra of the two pectins (EMI-P and CV-P) shows clearly that the heating type does not have a significant effect on the structural properties of the extracted pectin. All spectra were similar, showing characteristic bands at 3440  $\text{cm}^{-1}$  ( $\nu_{\text{OH}}$ ), 2930  $\text{cm}^{-1}$  ( $\nu_{\text{CH}}$ ), 1740  $\text{cm}^{-1}$  ( $\nu_{\text{C=O}}\text{COOMe}$ ), 1640  $\text{cm}^{-1}$  ( $\nu_{\text{as}}(\text{COO})$ ), 1435  $\text{cm}^{-1}$  ( $\nu_{\text{s}}(\text{COO})$ ), 1240  $\text{cm}^{-1}$  ( $\nu_{\text{s}}(\text{CH})$ ), 1145  $\text{cm}^{-1}$  ( $\nu_{\text{COC}}$ ) glycosidic bond, ring) and 1100  $\text{cm}^{-1}$  ( $\nu_{\text{C-C}}$ ).

## 4. Conclusion

Extraction using electromagnetic induction (EMI), as an emerging novel technology, was applied for the extraction of pectin from citrange (*Citrus sinensis* × *Poncirus trifoliata*) albedos. The properties of the extracted pectins were compared with those obtained by using CV heating. The time required for the extracting process was significantly reduced from 90 min for CV method to 30 min for EMI method. The comparison of physicochemical properties of pectin among different extraction methods indicated that EMI heating does not have a significant influence on the structural properties of pectin.

In conclusion, it should be noted that the results of this study represent a new approach which deserves to be continued in future studies.

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