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ORIGINAL PAPER

Effect of Degritting of Phenolic Extract from Sour Cherry Pomace on Encapsulation Efficiency—Production of Nano-suspension

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Abstract The objective of this study was to study the influence of purification of sour cherry pomace extract on particle size distribution of suspension and on encapsulation efficiency of powders. In addition, antioxidant activity, surface morphology, and color of powder and capsules were determined. Extraction of phenolic compounds was performed at 30 °C with shaking at 70 rpm for 24 h with 1:20 solid–solvent ratio. Ethanol–water (1:1) was used as the solvent. Filtered extract was concentrated in a rotary evaporator and freeze dried to produce extracted phenolic powder (EPP). Purified extracted phenolic powder (PEPP) was obtained by degritting at 10,000 rpm for 2 min and then by freeze drying for 48 h. Purification reduced Sauter mean diameter ($D_{[32]}$) of concentrated extract from 5.76 μm to 0.41 μm. In encapsulation, two types of coating materials were used. The first one contained 10 % maltodextrin (MD) and 90 % distilled water, while the second one contained 8 % MD, 2 % gum arabic (GA), and 90 % distilled water. Samples were homogenized using ultrasound (160 W, 50 % pulse) for 20 min. Microsuspensions containing EPP had $D_{[32]}$ of 1.65 and 1.61 μm when 10 % MD and 8 % MD-2 % GA aqueous solutions were used for coating, respectively. It was possible to obtain nano-suspensions when purification step was performed. Suspensions prepared with PEPP and 10 % MD and 8 % MD–2 % GA for coating had $D_{[32]}$ of 0.396 and 0.334 μm, respectively. As a result of purification, encapsulation efficiency of the capsules increased significantly from 86.07–88.45 % to 98.01–98.29 % ($P<0.001$).

Keywords Encapsulation · Nano-suspension · Purification · Sour cherry pomace · Ultrasonication

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Introduction

Fruits and vegetables are essential dietary sources. They undergo different processes at food factories in order to increase their shelf-life and accessibility to different geographical regions. As a result, a large variety of products are produced that may serve as alternatives to fresh fruits and vegetables. Juices are one type of these products. Pomace, which contains seeds, pulp, stems, and skin of the fruit, is generated as a byproduct of fruit juice production. Pomaces contain many natural antioxidants (Vattem and Shetty 2003; Ajila et al. 2011), including carotenoids, ascorbic acid, anthocyanins, flavanols, and flavonols (Garcia et al. 2009; Ruberto et al. 2007; Moure et al. 2001). Studies demonstrate that antioxidants from fruits and vegetables reduce the risk of cardiovascular diseases (Hu 2003; Scalbert et al. 2005) and certain types of cancer (Tamimi et al. 2005; Nkondjock et al. 2005).

The recent demand in nutraceutical and functional food production, cosmetics, and pharmaceutical industry is toward the replacement of synthetic antioxidants by the natural ones (Moure et al. 2001). The effectiveness of natural antioxidants extracted from pomace is dependent on storage stability, bioavailability, and bioactivity of phenolic content. Natural antioxidants are susceptible to spoilage during storage. In addition, direct usage of polyphenols is limited due to unpleasant taste of most of the phenolic compounds. The

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encapsulation of extracted antioxidants can prevent these problems.

Recently, microencapsulation is performed to store phenolic compounds extracted from fruits or vegetables in small capsules from which compounds can be released under specific conditions (Saenz et al. 2009; Bakowska-Barczak and Kolodziejczyk 2011). Packaged antioxidants are called core material while packaging materials are called coating material. Coating materials that are used in encapsulation can be made of sugars, gums, proteins, natural and modified polysaccharides, lipids, and synthetic polymers (Gibbs et al. 1999; Sanchez et al. 2011). Preparation of nano-suspensions and nanoencapsulation of phenolic compounds have not yet been demonstrated.

Nanoencapsulation has many outstanding advantages. Core material can be released under control depending on the pH and temperature of the medium and on the bioavailability of material. Nanoparticles can pass through the smallest capillary vessels because of their small size and can penetrate cells and tissue gap to arrive at target organs (Jung et al. 2000).

Prior to encapsulation of polyphenols extracted from pomace, the extract should be filtered in order to remove both organic and inorganic foreign particles of larger size. The purpose of filtration is to adjust and control particle size distribution of encapsulated dry powder and emulsion it is produced of. Pomace is rich in dietary fibers (Yi et al. 2009) which remain in the extract even after fine filtration. On the other hand, depending on the origin of the pomace, it may contain impurities, such as soil and mineral crystals. Nevertheless, after extraction and filtration processes, extract still contains tremendous amounts of suspended particles.

The main objective of this research is to investigate the possibility of preparation of the nano-suspension containing phenolic powder extracted from sour cherry pomace. It is also aimed to study the effect of presence of the foreign particles that remain in the concentrated extract after filtration on the particle size distribution of suspension and on encapsulation efficiency of freeze-dried capsules.

Materials and Methods

Materials

Sour cherry pomace was provided by Karmey Fruit Juice Factory (Karaman, Turkey). The samples studied were by-products of fruit juice manufacturing and were sun dried at the factory. Maltodextrin (MD) (DE=4–7), gum arabic (GA), Folin–Ciocalteu's phenol reagent, sodium carbonate, 1,1-diphenyl-2-picrylhydrazyl (DPPH), ethanol (absolute), methanol G CHROMASOLV®, gallic acid, and acetic acid (100 %) were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA).

Extraction of Phenolic Compounds

Stones, stems, and other foreign materials were removed from sour cherry pomace powder by screening. Then, sour cherry pomace powder (20 g) was weighed into a 500-mL glass flask and extracted with 400 mL ethanol/water (1:1, v/v). The extraction of phenolic compounds was performed in sealed flasks, which were placed into shaking water bath (GFL, GFL Gesellschaft für Labortechnik mbH, Burgwedel, Germany) at 30 °C and 70 rpm for 24 h. The extract was vacuum filtered. Then, the filtrate was concentrated by a rotary evaporator (Heidolph Laborota 4000 efficient; Heidolph Instruments GmbH & Co, Schwabach, Germany) at 40 °C.

Production of Phenolic Powder

The concentrate remaining after rotary evaporation was frozen at −20 °C in a deep freezer (D 8340 SM; Beko, Istanbul, Turkey) and then freeze dried (Christ Alpha 1–2 LD plus; Martin Christ Gefriertrocknungsanlagen GmbH, Osterode am Harz, Germany) at −52 °C and at 0.075 mbar for 48 h (Fig. 1). Dry samples were manually ground to obtain homogeneous extracted phenolic powder (EPP).

Purification of Extracted Phenolic Concentrate

The purification of extracted concentrate (P1) was performed as shown in Fig. 1 in SIGMA 2-16PK centrifuge (Sigma Laborzentrifugen GmbH, Osterode am Harz, Germany). Then 7.5 mL of concentrate was centrifuged at 5,000

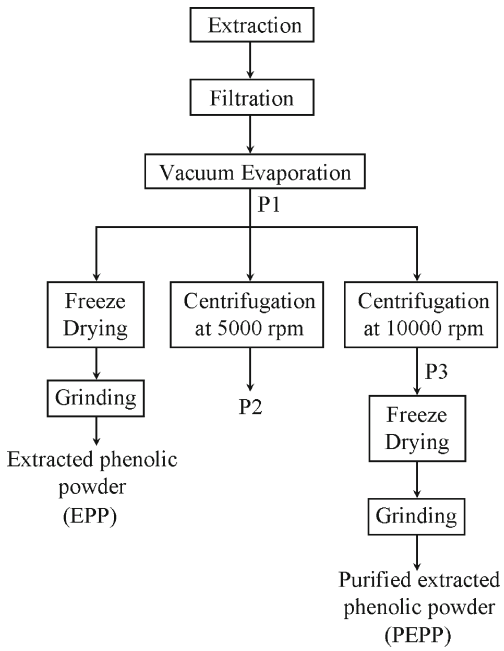

Fig. 1 Flow chart of the procedure to obtain the extracted phenolic powders

and 10,000 rpm angular velocities for 2 min to obtain P2 and P3 samples, respectively. Liquid part was carefully collected after centrifugation.

Purification at 10,000 rpm angular velocity for 2 min was selected to produce purified extracted phenolic powder (PEPP) by considering the results of particle size analysis. Clear concentrate was carefully collected after centrifugation.

Production of Purified Extracted Phenolic Powder

The PEPP powder was produced at the same conditions previously described in the production of phenolic powder part.

Preparation of Suspensions and Capsules

Maltodextrin (MD) was dissolved in distilled water 1 day before the preparation of the suspension and kept overnight in a shaking water bath. Gum arabic (GA) was dissolved in distilled water and mixed at 50 °C using a magnetic stirrer (MR 3001K; Heidolph Instruments GmbH & Co, Schwabach, Germany) 2 h prior to encapsulation. Additionally, to prepare the nano-suspension, GA solution was centrifuged at 10,000 rpm angular velocity for 2 min and filtered through a 0.45-μm filter (Gema Medical S. L., Barcelona, Spain). Total concentration of dissolved solid was 10 % (w/w). Two different coating solutions were prepared. The first solution was composed of 10 % MD and 90 % distilled water, and the second one was composed of 8 % MD, 2 % GA, and 90 % distilled water. All suspensions were prepared in two stages: (a) Pre-suspensions were obtained by weighing coating material solutions, adding the core material (EPP, PEPP) in the ratio of 1:20 (core-coating), and stirring for 5 min at 4,000 rpm using a high-speed blender (IKA Works Co, Rawang, Selangor, Malaysia). (b) These pre-suspensions were further homogenized using the ultrasonic probe (Sonic Ruptor 400; OMNI International, Kennesaw, GA, USA) with a diameter of 3.8 mm by applying 160 W with 50 % pulse for 20 min. During the homogenization process, samples were placed in water bath with cold water at 4 °C to prevent the overheating of the suspensions. Each experiment was duplicated.

Suspensions were frozen in the deep freeze and then freeze dried at −52 °C and at 0.075 mbar for 48 h. Dried samples were manually crushed and kept at −20 °C while excluding light for further analyses.

Particle Size Analysis of Suspension and Extracted Concentrate

Particle size distributions of P1, P2, and P3 concentrates and suspensions were determined by the laser light scattering method using Mastersizer 2000 (Malvern Instruments, Worcestershire, UK). The mean diameter of the particles was expressed as the Sauter mean diameter ($D_{[32]}$):

$$D_{[32]} = \frac{\Sigma n_i d_i^3}{\Sigma n_i d_i^2} \quad (1)$$

where n_i stands for the (number-based) frequency of occurrence of particles in size class i, and d_i for mean diameter of these particles.

The width or "span" of the particle size distributions was calculated with the following formula:

$$\text{Span} = \frac{[d(v,\ 90) - d(v,\ 10)]}{d(v,\ 50)} \quad (2)$$

where $d(v, 10)$, $d(v, 50)$, and $d(v, 90)$ are the diameters at 10 %, 50 %, and 90 % cumulative volume, respectively (Elversson et al. 2003). The instrument also calculates the specific surface area (m^2/g) of the dispersed particles.

Total Phenolic Content Analysis

The modified Folin–Ciocalteu method (Beretta et al. 2005) was used to determine the total phenolic content (TPC) of EPP and PEPP and capsules. One hundred milligrams of sample was dispersed in 1 mL ethanol, acetic acid, and water (50:8:42) (Saenz et al. 2009). This dispersion was agitated using a vortex (ZX3; VELP Scientifica, Usmate, MB, Italy) for 1 min and then filtered through a 0.45-μm filter. Gallic acid (0–100 mg/mL) was used as a standard. TPC was expressed as milligrams of gallic acid equivalent (GAE) per gram of dry weight.

Surface Phenolic Content and Encapsulation Efficiency Analysis

For the determination of surface phenolic content (SPC), 100 mg of microcapsules was dispersed in 1 mL of ethanol and methanol (1:1) mixture (Saenz et al. 2009). Dispersions were agitated for 1 min using vortex and then filtered through a 0.45-μm filter. SPC of dispersions was measured by the Folin–Ciocalteu (Beretta et al. 2005) method. SPC was expressed as milligrams of gallic acid equivalent (GAE) per gram of dry weight. Encapsulation efficiency (EE) was calculated from the following formula:

$$\text{EE}(\%) = \frac{\text{TPC} - \text{SPC}}{\text{TPC}} \times 100 \quad (3)$$

Antioxidant Activity Analysis

Total antioxidant activity (TAA) of phenolic powder and capsules was measured by (1,1-diphenyl-2-picrylhydrazyl) DPPH method (Yen and Duh 1994). Briefly, 100 mg of

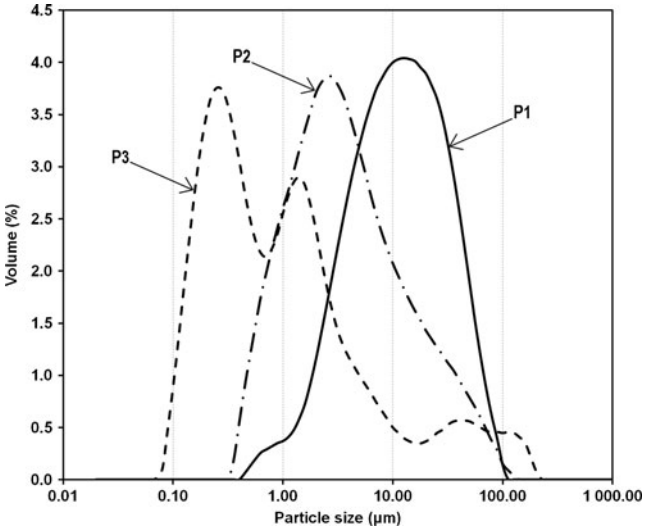

Fig. 2 Effect of centrifugation on particle size distribution of concentrated extracts: P1, P2, and P3

sample was weighed and dispersed in 1-mL ethanol, acetic acid, and water (50:8:42) mixture. Dispersion was agitated for 1 min using a vortex and then filtered using Millipore filter through a 0.45-μm filter. One hundred microliters of filtered samples were added to 25 ppm DPPH solution and left to stand in the dark for 1 h prior to being determined spectrophotometrically at 517 nm. DPPH concentration of sample was calculated using a calibration curve, taking dilution factor into consideration for samples. Antioxidant activity was calculated from the following formula:

$$\mathrm{DPPH} = \mathrm{DPPH}_{t=0} - \mathrm{DPPH}_{t=1\mathrm{h}} \quad (4)$$

where $\mathrm{DPPH}_{t=0}$ is initial DPPH concentration and $\mathrm{DPPH}_{t=1\ \mathrm{h}}$ is concentration of DPPH in the sample after 1 h.

Determination of Color of Powder and Capsule Samples

Surface color of powder and capsule samples was measured as reflected color in CIE (L^*, a^*, b^*) color space using a UV-2450 UV–Vis spectrophotometer (Shimadzu Co., Kyoto, Japan) using illuminant type C (2° standard observer). The color coordinates of L^* (darkness/whiteness), a^* (greenness/redness), and b^* (blueness/yellowness) were directly calculated as mean of three determinations performed for each sample. The instrument also calculated the difference in the color (ΔE^*) which can also be calculated from the following formula:

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (5)$$

where ΔL^*, Δa^*, and Δb^* are the differences between the color values of standard and sample. Barium sulfate ($BaSO_4$) was used as a standard.

Surface Morphology of Powder and Capsule Samples

The images of outer structure of the capsules and powders were obtained using scanning electron microscopy (SEM). The samples were coated with gold/palladium using Hummel VII sputter coating device (Anatech USA, Union City, CA, USA) and analyzed with JSM-6400 electron microscope (Jeol Ltd., Tokyo, Japan) operating at 20 kV. Micrographs were taken at 100× and 500× magnification.

Statistical Analysis

All experiments were replicated twice. Data was analyzed by two-way analysis of variance (ANOVA) ($P \leq 0.05$) using MINITAB software 15 version (Minitab Inc., State College, PA, USA). The independent variables considered were powder type (EPP and PEPP) and the composition of coating material (8 % MD–2 % GA and 10 % MD). The dependent variables were the encapsulation efficiency, SPC, $D_{[32]}$, span, SSA, TAA, L^*, a^*, b^*, and ΔE.

Results and Discussion

In order to compare the influence of the centrifugation on particle size distribution of extracted concentrate, three different samples were prepared (P1, P2, and P3) and analyzed (Fig. 2). Our results revealed that particle size distribution was significantly different for the sample which was centrifuged at 10,000 rpm (P3) than the sample centrifuged at 5,000 rpm (P2). As centrifugation is applied and as rotational speed is increased, particle size distribution curve

Table 1 Influence of angular velocity on purification of dispersion

Sample	Angular velocity (rpm)	Time (min)	$D_{[32]}$ (μm)	Span	Specific surface area (m^2/g)
P1	–	–	5.76±0.013a	3.27±0.007c	1.04±0.007c
P2	5,000	2	1.97±0.008b	6.83±0.017b	3.04±0.017b
P3	10,000	2	0.40±0.003c	19.69±0.043a	14.70±0.062a

Columns having different letters (a, b, and c) are significantly different ($P \leq 0.05$)

Table 2 Particle size analysis results of emulsions prepared with different coating materials and powder types

Powder type	Coating type		$D_{[32]}$ (μm)	Span	Specific surface area (m^2/g)
	MD (%)	GA (%)			
EPP	10	0	1.650±0.0720a	5.8±1.10b	3.66±0.160b
EPP	8	2	1.610±0.1260a	5.5±0.31b	3.75±0.285b
PEPP	10	0	0.396±0.0255b	35.9±13.40a	15.20±1.000a
PEPP	8	2	0.334±0.0160b	16.5±4.82a	17.70±0.630a

Columns having different letters (a and b) are significantly different ($P \leq 0.05$)

EPP extracted phenolic powder, *PEPP* purified extracted phenolic powder, *MD* maltodextrin, *GA* gum arabic

shifted to the left (lower diameters). This can be explained by Stokes' Law. Equation of Stokes' Law (Leung 2007) can be expressed as:

$$V_{so} = \frac{(\rho_S - \rho_L) g d^2}{18\mu} \quad (6)$$

where ρ_S and ρ_L are densities of solid and liquid, respectively, g is centrifugal acceleration, d is diameter of particle, μ is viscosity of liquid, and v_{so} is separation velocity, where the subscript "o" stands for separation of an individual particle with no interaction with other particle in an ideal dilute suspension.

Since P2 and P3 samples were prepared from the extracted concentrate P1, initially they had the same particle size distribution and diameter with that of P1. Densities and viscosities were also the same for P2 and P3 samples. The only parameter that changed was the centrifugal acceleration. Therefore, sample spun at higher angular velocity contained particles with smaller Sauter diameter ($D_{[32]}$) (Table 1). On the contrary, span of P3 sample was the highest and significantly different from that of P2 and P1. The reason for this is the larger and more uniform particle size distribution. By removing large particles from the dispersion, smaller particles which could not be detected in P1 and P2 samples were reported for P3 sample, thus particle size distribution curve shifted to the left (smaller size) (Fig. 2). The shift in particle size distribution caused significant change in cumulative volumes, which increased the span parameter. Since specific surface area is indirectly proportional with $D_{[32]}$ value, it was significantly different for all samples with the highest value reported for P3. Filtration was insufficient to remove particles with diameters in the range of 100 μm–1 μm from the extract. These particles might be soluble or insoluble and might be some inorganic pieces like dust and mineral crystals. Drying of pomace under the sun and on the ground may lead to the contamination of pomace with particles from the environment.

In order to compare the influence of purification of concentrate and different types of coating materials on the particle size distribution of the suspension, a two-by-two

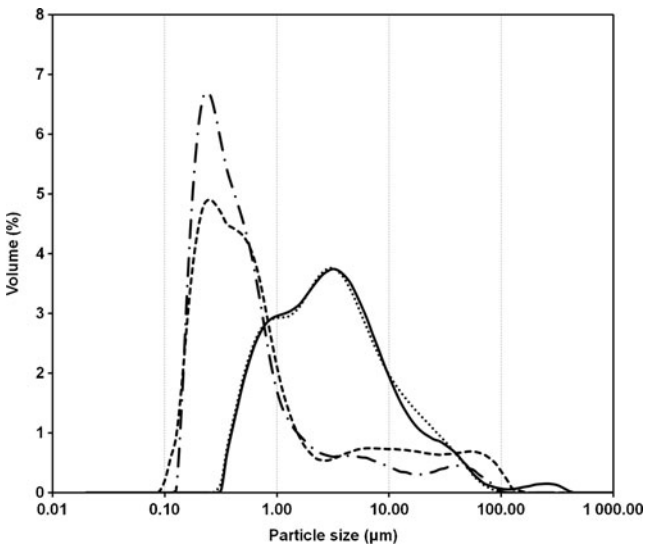

Fig. 3 Particle size distribution of micro-suspensions prepared with 10 % MD (*solid line*) and 8 % MD–2 % GA (*dotted line*), nano-suspensions prepared with 10 % MD (*dashed line*) and 8 % MD–2 % GA (*dash dotted line*)

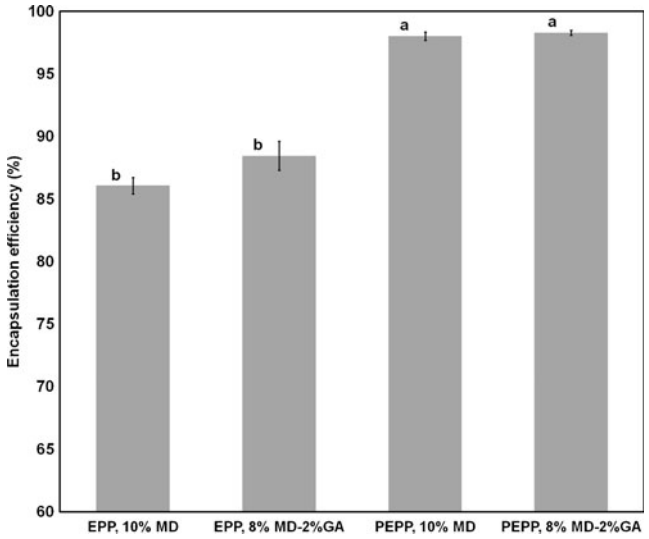

Fig. 4 Encapsulation efficiency of capsules prepared with different coating materials and powder types Bars with different letters (a, b) are significantly different ($p \leq 0.05$)

Table 3 Surface phenolic content and antioxidant activity data for capsules prepared from EPP and PEPP with different MD and GA concentrations

Powder type	Coating type		SPC (mg GAE/g dry weight)	DPPH (ppm DPPH/g dry weight)
	MD (%)	GA (%)		
EPP	10	0	4.24±0.020a	1.85±0.050a
EPP	8	2	3.52±0.355a	1.87±0.020a
PEPP	10	0	0.74±0.080b	2.01±0.005a
PEPP	8	2	0.64±0.015b	1.91±0.005a

Columns having different letters (a and b) are significantly different ($P \leq 0.05$)

EPP extracted phenolic powder, *PEPP* purified extracted phenolic powder, *MD* maltodextrin, *GA* gum arabic

full factorial design was planned with two different core materials: EPP and PEPP. Two types of coating materials, including 10 % MD and combination of 8 % MD and 2 % GA, were used. The results in Table 2 reveal a significant influence ($P<0.001$) of purification of extracted concentrate on $D_{[32]}$, span, and specific surface area values of suspensions. Suspensions prepared with PEPP had smaller particle diameters resulting from the small $D_{[32]}$ value of P3; most of the particles were in the nano range. Therefore, purification appeared to be a critical parameter in the preparation of nano-suspensions. The overall results showed that addition of GA to the coating material had no significant influence ($P>0.05$) on particle size distribution of the suspension (Fig. 3). Similar to extracted concentrate, purification significantly ($P<0.05$) changed the span of the suspensions. High span values showed that the suspension contains a very large range of particles of different diameters. It can be seen in Fig. 3 that most of the particles of the suspensions prepared with PEPP were in the nano range, and there was continuous and approximately equal percent volume range of large particles which had remained in the PEPP after centrifugation at 10,000 rpm for 2 min. On the other hand, particle size distribution appeared to be more compact for suspensions prepared with EPP. Jafari et al. (2007a) reported that homogenization in IKA blender and ultrasonication increased the span of sub-micron suspensions. In addition, after purification, total content of impurities decreased; therefore, energy density of ultrasonication of total solids in the suspension increased, leading to more disruption and formation of smaller particles. Gordon and Pilosof (2010) in their study reported formation of many small particles after 10-min sonication. The decrease in $D_{[32]}$ increased specific the surface area of the suspensions. Therefore, suspensions prepared with PEPP had significantly ($P<0.001$) higher specific surface areas when compared to suspensions prepared with EPP (Table 2).

The aim of purification was not only to decrease the particle size distribution of the suspension but also to study its effect on the encapsulation efficiency. The results in Fig. 4 show that purification had a significant influence on the encapsulation efficiency ($P<0.001$). This can be explained by the reduction of the particle size of suspension and concentrate, which causes formation of smaller particles with lower SPC. TPC of capsules were 30.43 mg GAE/g dry weight and 37.10 mg GAE/g dry weight for EPP and PEPP, respectively. Results of SPC are given in Table 3. There was a significant difference in SPC of capsules prepared from EPP and PEPP ($P<0.001$), while the type of coating material had no significant ($P>0.05$) effect on SPC. In the study performed by Jafari et al. (2007b), surface oil content decreased with decreasing particle size of the encapsulated powder. Soottitantawat et al. (2003) reported that there was greater loss of flavor from the larger feed emulsion droplets during spray drying of encapsulated D-limonene. It was also shown that surface oil content decreased for smaller emulsion droplets. Capsules prepared from nano-suspension can be ground to have smaller particle size when

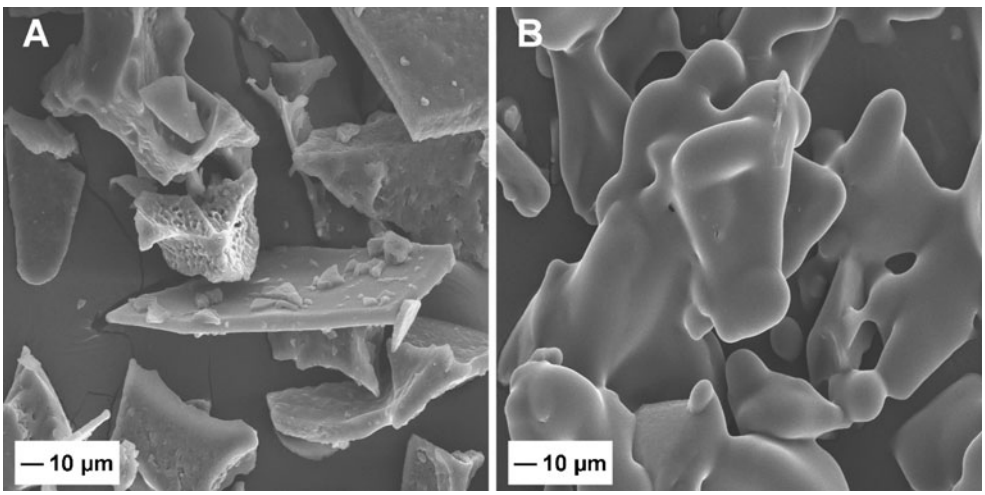

Fig. 5 Scanning electron microscope micrographs of phenolic powders EPP (**a**) and PEPP (**b**)

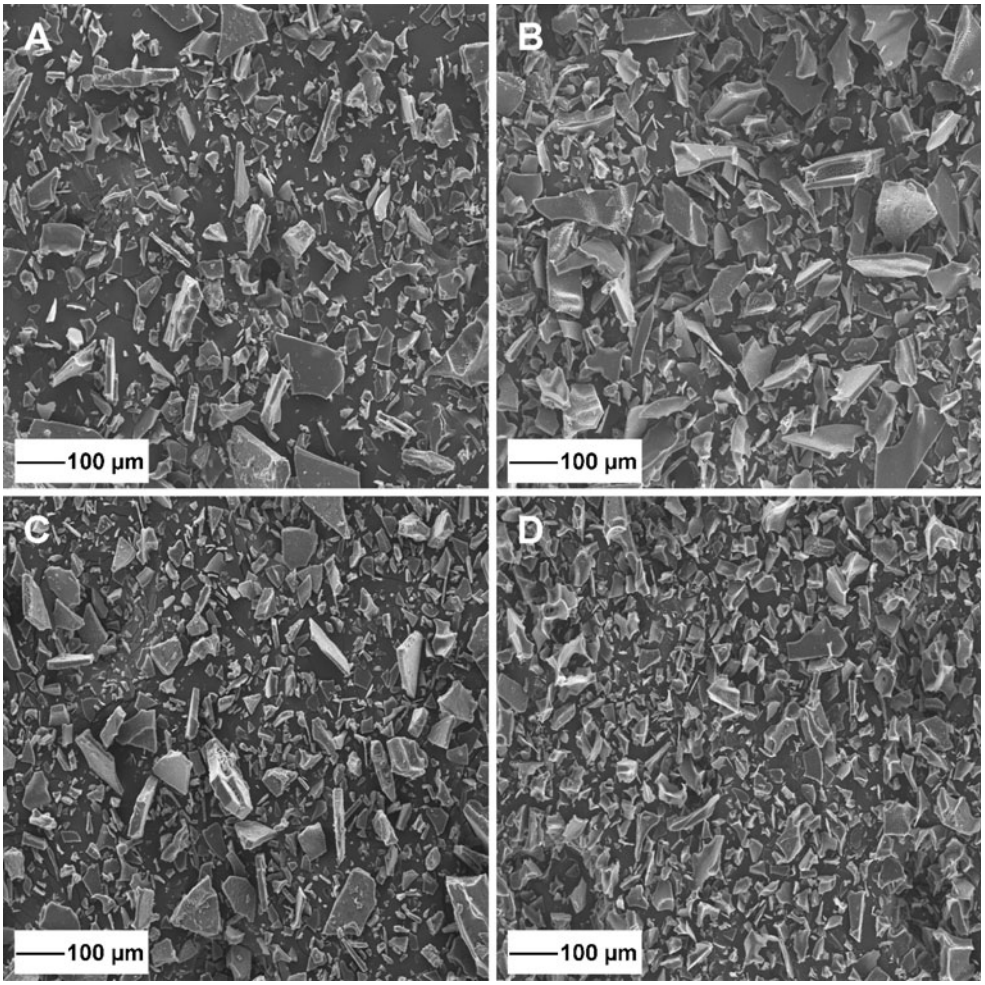

Fig. 6 Scanning electron microscopy pictures of phenolic powder capsules prepared with EPP and 10 % MD (**a**), PEPP and 10 % MD (**b**), EPP and 8 % MD–2 % GA (**c**), and PEPP and 8 % MD–2 % GA (**d**)

compared to capsules containing EPP. Consequently, the coating material type had no significant ($P>0.05$) influence on encapsulation efficiency.

Figure 5 shows the SEM pictures of the phenolic powders and capsules produced with different core and coating materials. It was seen that PEPP (Fig. 5b) particles had a smooth surface, while the surface of EPP (Fig. 5a) was wrinkled and particles had sharp edges. Surface of EPP was covered with small particles some of which may be foreign substances. As mentioned previously, purification

Table 4 Color measurements of powder and capsules

Powder type	Coating type		L^*	a^*	b^*	ΔE^*
	MD (%)	GA (%)				
EPP[a]	–	–	34.5±0.24	20.1±0.09	11.7±0.03	69.5±0.57
PEPP[a]	–	–	31.4±0.17	24.6±0.12	11.0±0.05	73.7±0.82
EPP[b]	10	0	50.1±0.35b[c]	17.4±0.05b	13.4±0.01a	54.5±0.34a
EPP[b]	8	2	50.4±0.19b	18.3±0.08b	14.0±0.04a	54.7±0.19a
PEPP[b]	10	0	56.0±1.54a	20.8±0.45a	11.0±0.10b	49.6±1.76b
PEPP[b]	8	2	56.2±1.08a	20.7±0.23a	10.8±0.18b	49.6±1.09b

Columns having different letters (a and b) are significantly different ($P\leq0.05$)

[a] Uncoated phenolic powder

[b] Encapsulated phenolic powder

[c] Statistical analysis was performed only for capsules, without including data of EPP and PEPP

resulted in the removal of most of the particles in 100 μm–1 μm diameter range; therefore, the micrograph of unpurified phenolic powder showed impurities. The capsules prepared with EPP and 10 % MD (Fig. 6a) and with EPP and 8 % MD–2 % GA (Fig. 6c) were similar in structure; on the other hand, capsules prepared with PEPP and with 10 % MD (Fig. 6b) were larger when compared to capsules prepared with PEPP and 8 % MD–2 % GA (Fig. 6d). Capsules with 10 % MD coating material produced with EPP and PEPP were similar, exhibiting more agglomeration for those produced with PEPP. Particle size of capsules with 8 % MD–2 % GA prepared with PEPP was smaller when compared to capsules prepared with EPP. This can be explained by smaller particle size distribution of the suspension it was produced of. Moreover, the most homogenous particle size distribution was observed for capsules with PEPP and 8 % MD–2 % GA.

Total antioxidant activity of the phenolic powders was found to be 7.09 and 6.80 ppm DPPH/g dry weight for EPP and PEPP, respectively. Purification process and coating material type were found to have no significant ($P>0.05$) effect on the total antioxidant activity of capsules (Table 3).

Color measurement (Table 4) of phenolic powders showed that purification increased lightness and redness of the powder. The remaining wet sediment's color was light brown (data not shown); therefore, purified powder was lighter and more reddish than EPP. Conversely, purification increased lightness of capsules significantly ($P=0.0013$), which can be explained by the low presence of the phenolic compounds on the surface of capsules prepared with PEPP as compared to capsules prepared with EPP. Formulation of coating material type had no significant effect on lightness, a^*, b^* values, and ΔE. Redness of capsules showed significant difference ($P<0.001$) with core material type and was higher for capsules prepared with PEPP, related to higher redness of uncoated PEPP.

Conclusion

This work demonstrated that degritting of the extracted phenolic concentrate was a critical parameter for preparation of nano-suspensions. Sauter mean diameter of purified concentrate was in nano range, but it was in the micron range for unpurified concentrate. Degritting decreased the Sauter mean diameter and increased specific surface area of dispersed particles significantly. Furthermore, degritting process increased the encapsulation efficiency of the capsules significantly. L^* and a^* values of capsules increased in the presence of purified phenolic powder. There was no significant effect of coating material type formulation on encapsulation efficiency, Sauter mean diameter, and color of the suspension. It was demonstrated that phenolic compounds from sour cherry pomace could be encapsulated in the production of functional food components. This study gave a novel approach in the production of nano-suspensions.

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