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Effect of the pearled in the isolation and the morphological, physicochemical and rheological characteristics of barley starch

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ABSTRACT

In diverse industries, the starch of different botanical sources is widely used due to its functionality. The objective was to evaluate thermal properties, rheological behavior, particle size distribution and structural characteristics of starch isolated from pearled and whole barley. Commercial corn starch was used for comparison. Whole barley starch (WBS) and pearled barley starch (PBS) had average gelatinization temperatures of 61.3 and 61.6 °C, and enthalpy values of 9.19 and 8.54 J/g, respectively. The stored samples for 7 days presented a phase transition temperatures of 49.9 and 51.8 °C, and enthalpy value of 1.9 and 1.7 J/g, for WBS and PBS, respectively. At the longest storage time (14 days) the temperature of the phase transition was similar and an increase was showed in the enthalpy value for WBS (2.3 J/g) and PBS (2.4 J/g). The viscoelastic behavior of pastes at 90 °C and gels at 25 °C were characterized by $G' > G''$ and no statistical difference was found between both starches. The granule size distribution of PBS and WBS showed a bimodal pattern. The pearled process of barley did not affect significantly some characteristics of its starch.

1. Introduction

Barley (*Hordeum vulgare* L.) is an ancient and important cereal grain crop. It is ranking in fifth place of production among all food crops in the world behind maize, wheat, rice and soy bean (Baik & Ullrich, 2008). In Mexico, barley production has been increases in the last years. At present, the fifth national cereal production place is occupied by barley grain, following maize, sorghum, wheat and bean, displacement to rice. In Mexico, from the annual production of barley, a 60% was employed in food industry, principally in malt which is destined to brewer industry, 34% as cattle food, 3% in rubbish, 2% for seeds and 1% for food applications (Fundación Guanajuato Produce) Actually, there is a tendency to diversify the applications of barley, for example, barley was employed in fuel alcohol production (Ingledew, Jones, Bhatty, & Rossnagel, 1995), in biodegradable films (Tejinder, 2003), as partial substituent of wheat flour (Ragaee & El Sayed, 2006) or as a high dietary fibre ingredients (Izydorczyk, Chornick, Pauelley, Edwards, & Dexter, 2008). The Mexican Minister of Agriculture is interesting to diversify the end-use of barley growing in this country such as starch isolation and modification (Fundación Produce Guanajuato).

Barley grain is typically pearled to remove the hull and bran before being consumed or further processed (e.g. starch isolation). Production of pot barley in the first stage of pearling, may remove 7–14% of the weight of the grain. Further abrasion results in the removal of seed coat (testa and pericarp), aleurone, subaleurone layers, and germ, leaving behind a central endosperm rich in carbohydrates (largely starch and β-glucans) and protein (hordeins and glutelins) (Bhatty, 1997). The final product of fine pearl may not constitute more than 60–70% of the grain. Starch is the main component of barley, during the pearled of the grain, some changes may be produced in the starch granules present in the periphery of the endosperm, and then physicochemical and functional characteristics of the starch might be modified. During the pearled of the barley grain it is possible to produce annealing as was reported in maize (Krueger, Walker, Knutson, & Inglett, 1987), but pearled of the barley grain before starch isolation can be used to produce a purified starch with novel applications. In the same sense, we think that is possible to eliminate the pearled step and isolate starch of the whole barley grain with high purity without significantly alterations of their physicochemical and functional properties. Elimination of the pearled step reduces the processing cost and

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consequently barley starch can be more competitive in the market. There are not studies reported of starch isolated from barley growing in Mexico and even more the effect of pearled on starch characteristics of this starch. In hull-less barley, Bhatty and Rossnagel (1998) found small differences in color, protein and total dietary fibre between Canada and Japan barley starches. If starch with physicochemical and rheological characteristics is produced from whole barley grain, so an economic process might be proposed to starch isolation.

In this work, starch of barley was isolated from pearled (PBS) and whole grain (WBS) seeds. Physicochemical, morphological and rheological characteristics of barley starches were evaluated and compared with commercial corn starch (CCS) sample.

2. Materials and methods

2.1. Samples and chemicals

Selected whole barley (*H. vulgare* L.) grains from commercial variety M-16 (“Esmeralda Zapotlan”) were cultivated in 2005 at Zapotlan of Juarez, Hidalgo, Mexico. The barley grains were selected about norm NMX-FF-043-SCFI-2003 and were washed with distilled water to eliminate dust and other adhering substances. Two lots were separated, one lot was conditioned with a humidity of 17% for 24 h to pearled (PBS) in a mill Dayton, model 4K638C Strong Scout, the other was maintained with the shell (WBS), and both were used for starch isolation. Commercial common corn starch (CCS) employed as comparison was gift of Arancia, Corn Products, S.A. de C.V. (Toluca, Mexico). All reagents were of ACS grade.

2.2. Isolation of barley and corn starches

Starches from PBS and WBS were extracted using a wet-milling procedure proposed by Adkins and Greenwood (1966) and modified by Paredes-Lopez, Schevenin, Hernández, and Cáarabez-Trejo (1989). In brief, the grains were soaked (16–24 h) in sodium acetate buffer 0.02 M containing 0.01 M mercury chloride (1:1 v/v) and then adjusted at pH 6.5 with sodium acetate buffer 2 M. The ratio of soaking solution/grains was 2:1 (v/w). The mixture was kept at room temperature and was stirred occasionally for 24 h. The solution was drained off, and the softened grains were washed thoroughly with distilled water. Afterwards the grains (150 g) were grind in a blender (Black and Decker, model BLM2350P, Mexico, D.F.) with 500 mL of water at the maximum speed for 1.5 min. The dispersion was sifting in a Testing Equipment, model RNU through sieves no. 40 (425 mm), 100 (150 mm), 200 (75 mm), 270 (53 mm) and 325 (45 mm). In each sieve the residue was washed with distilled water until no more starch was released. The final suspension was kept at room temperature for 24 h to settle of starch, and then water was decanted. The starch was re-suspended in a solution of 0.1 M aqueous NaCl–toluene (7:1) and then mixed at room temperature (15 h) and 50 rpm overnight. The suspension was centrifuged at 9000*g* for 15 min, and the supernatant of the toluene phase containing proteins and fat was discarded. The top grayish layer of the precipitate was carefully removed and the bottom white layer of starch was repeatedly washed with NaCl–toluene (7:1 v/v) solution. Thereafter, the isolated starch was dried at 40 °C for 24 h and stored at room temperature in a sealed container.

2.3. Chemical analysis

Moisture content was determined by weight loss of accurately weighed 3 g starch samples (in triplicate) after heating at 130 ± 3 °C for 1 h (AOAC, 1990, method 925.10). Nitrogen content (N) was determined using Dumas method from N × 6.25 and using 2 g of sample (AACC, 2001). Ash and lipids (AOAC, 1990), total starch (Goñi, Garcia-Alonso, & Saura-Calixto, 1997) and apparent amylose (Hoover & Ratnayake, 2002) were determined.

2.4. Thermal properties

Gelatinization parameters were measured by DSC using a Calorimeter (DSC TA Instruments USA, model 2010), equipped with a thermal analysis data station (Ta Instruments, Newcastle, DE) and following the procedure by Paredes-Lopez, Bello-Perez, and Lopez (1994). Starch (2 mg dwb) was weighed directly in an aluminum DSC pan (TA series 900796.901) of 20 μL capacity. Deionized water was added with the help of a Hamilton micro syringe to achieve a starch–water suspension containing 70% water. Pans were hermetically sealed and equilibrated for 1 h at room temperature to allow complete hydration of starch. The pan with the sample was placed in the calorimeter and heated at a rate of 10 °C/min from 20 to 120 °C. An empty pan was used as reference (Paredes-Lopez et al., 1994). Indium and empty aluminum pan were used as reference to calibrate the DSC. Peak temperature (T_{peak}), and enthalpy of gelatinization (ΔH) were calculated automatically. To evaluate retrogradation, gelatinized samples were stored at 4 °C by 7 and 14 days before rescanning, after, the samples were equilibrated at room temperature by 1 h. Temperature range and heating rate were 25–230 °C and 10 °C/min, respectively. An empty pan was used as reference for all measurements. The percentage of retrogradation was calculated:

$$\text{Retrogradation } (\%) = \frac{\Delta H_{\text{retrogradation}}}{\Delta H_{\text{gelatinization}}} \times 100$$

2.5. Pasting characteristics

Pasting properties of starches were measured on a Rapid Visco Analyzer (RVA-4), model 3D (Newport Scientific, Warriewood, Australia) using the RVA General Pasting Method (Newport Scientific Pty. Ltd., Warriewood, Australia). A starch sample of 4.0 g was weighed directly in the aluminum RVA sample canister, and distiller water (25.5 g) was added to a total constant sample weight of 29.5 g. The slurry was then manually homogenized using the plastic paddle to avoid lump formation before the RVA run. A programmed heating and cooling cycle was set form 74 min, where it was first held at 25 °C, heated to 90 °C, further held at 90 °C for 10 min, before cooling to 25 °C whiting and holding at 25 °C for 10 min, the speed heating. All measurements were replicated.

2.6. Viscoelastic properties

Starch dispersions with 5% (w/v) of total solids were prepared using distilled water. Their viscoelastic properties were measured under low amplitude oscillatory shear in a strain rheometer (TA Instruments Rheometer model AR 1000, New Castle, USA) using a parallel plates system (sandblasted plate) with a diameter of 60 mm, and a gap of 1000 μm. The parallel plates were covered with mineral oil to avoid water evaporation during the test. To determine the linear viscoelastic region (LVR), strain amplitude sweeps were done between 0.3% and 3% at 1 Hz and either a heating or cooling rate of 2.5 °C/min. Once the LVR was found, the machine was programmed for running time sweeps of a heating (25–90 °C)–cooking (90 °C, 10 min)–cooling (90–20 °C). Frequency sweeps (0.1–10 Hz) were run at a strain constant (0.6%), using the same heating procedure in both stage. The storage (G') and loss (G'') modulus were evaluated from each test.

2.7. Particle size distribution

The particle size distribution of starch granules was determined by laser diffraction analysis (Malvern Instruments Ltd. 2000, Worcestershire, UK) with a dispersion Unit (Hydro 2000 MU) at 25 °C. The instrument outputs a volume distribution as the fundamental measurement as well as median diameter $D[v, 0.5]$. Laser diffraction requires media of different refractive indices, in this study were used a 1.330 and 1.335 for water and starch, respectively.

2.8. Scanning electron microscopy

Scanning electron micrographs of PBS and WBS barley starches were obtained directly to mount on circular aluminum stubs with double-sided sticky tape. The fine powder of starch was coated with 12 nm gold in a electro-deposited (Denton, model Vacuum Desk II). Then examined and photographed in a scanning electron microscope (JEOL, model JSM-G-300, Tokyo, Japan) at an accelerating voltage of 20 kV, 18 mm. Analysis were for triplicate at 1000×.

2.9. Statistical analysis

Results are presented as means ± SEM (standard error of mean) of three separate determinations. A commercial software program (Sigma Stat ver. 2.03, Jandel Corporation, San Rafael, CA) was used to evaluate by one-way analysis of variance (ANOVA) to determine differences in mean values based on data collected from replications of each measurement. Statistically significant differences ($p < 0.05$) were evaluated using the Tukey multiple comparison procedure.

3. Results and discussion

3.1. Chemical composition

Table 1 shows the proximal composition of PBS and WBS. Ash, protein, total starch and amylose contents were not different in both samples. In general, the pearled process did not affect the minor components of starch as well as the total starch and amylose level. However, the lipid content was different ($p = 0.05$), because the WBS had higher amount of lipid (approximately up to 100%) than PBS. The difference in the lipid content might be due to during the pearled of the seed, some portion of the germ is separated decreasing the external lipids that can be retained in the starchy endosperm of the seed (Morrison, 1988). The high amount of total starch determined in the powder apart from the PBS and WBS is due to high efficiency of the isolation procedure. Lower value of total starch was obtained in starch isolated from normal maize seeds (89.7%) (Méndez-Montealvo, Trejo-Espino, Paredes-Lopez, & Bello-Perez, 2007), but the isolation procedure was different. The low amount of minor components increases the possible applications of barley starch because in some products high purity is required (for example in glucose and fructose syrup, low amount of protein present in the starch is desirable). The amylose content determined in both barley starches situated at this starch as normal, like to normal maize starch. Using a potentiometric titration, barley starch had an amylose content of 24.6% and maize starch of 24.3% (Chavez-Murillo, Wang, & Bello-Perez, 2008). Amylose content in normal maize starch was 20.4% (Méndez-Montealvo et al., 2007), and in other study white maize starch had 27% (Agama-Acevedo et al., 2005). The method used in amylose determination has influence in the value obtained. The amylose content affect the physicochemical and functional properties because starches with high amylose content produced firmer and more opaque gels, with greater retrogradation tendency and has better film-forming properties.

3.2. Thermal properties

The average gelatinization temperature (T_{peak}) of PBS and WBS was similar (Table 2) (0 days) and higher value (70.0 °C) was determined in commercial corn starch. WBS presented a slight higher enthalpy of gelatinization (0 days) than PBS, indicating a slight disorganization of double helices of amylopectin due to pearled process. Similar gelatinization temperature was assessed in native barley starch (60.3 °C), but higher enthalpy of gelatinization was determined (10.9 J/g) (Chavez-Murillo et al., 2008). This temperature is in agreement with these reported for small and large granule size (61.0 and 58.0 °C, respectively) isolated from normal barley starch, but higher enthalpy of gelatinization was determined (6.8 and 7.9 J/g, respectively) (Vasanthan & Bthatty, 1996). The enthalpy value is more sensible of the changes of the ordered double helices (Cooke & Gidley, 1992). It was postulated that gelatinization enthalpy value is affected by amylose/amylopectin ratio, quality and amount of crystallites (Ahmad, Williams, Doublier, Duran, & Buleon, 1999; Tester, 1997) and with the major amount of long chains in the amylopectin (Yuan, Thompson, & Boyer, 1993). Higher temperature and enthalpy of gelatinization were determined in normal maize starch, where additionally to the parameters above mentioned the granule size is playing an important role in this phase transition. In this study, amylose content was similar in both barley starches, that is in agreement with the gelatinization parameters obtained.

DSC data of retrograded WBS and PBS starch at 4 °C for 7 and 14 days are summarized in Table 2. In general, the temperature of peak associated to the phase transition (retrogradation) was similar at 7 and 14 days, indicating that reorganization of the starch chains in both barley starches was similar. No difference between barley starches and commercial corn starch was obtained, although a slight higher amylose value was determined in corn starch, but was not reflect in this characteristic. The retrogradation temperature was lower than obtained during starch gelatinization, this pattern is due to that small and/or imperfect crystals are formed during storage and minor temperature is necessary for disorganization (Bello-Perez, Ottenhof, Agama-Acevedo, & Farhat, 2005). This is in agreement with the enthalpy value, because lower value was calculated in the storage samples; however, the enthalpy value increased at longer storage time, but not difference was obtained between both barley starches. Commercial corn starch

Table 1
Chemical composition (%) of pearled barley starch (PBS), whole barley starch (WBS) and commercial corn starch (CCS) on a dry basis (except moisture).

Sample	Moisture	Ash	Lipids	Protein	Total starch	Amylose content
CCS	5.51 ± 0.07[a]	0.09 ± 0.01[a]	1.43 ± 0.06[a]	1.00 ± 0.05[a]	85[A]	33.4 ± 1.85[a]
PBS	7.56 ± 0.32[b]	0.41 ± 0.03[b]	0.88 ± 0.31[b]	0.86 ± 0.12[a]	97.87 ± 3.28[b]	27.26 ± 2.38[b]
WBS	10.97 ± 0.1[c]	0.39 ± 0.01[b]	1.70 ± 0.30[c]	0.90 ± 0.02[a]	97.03 ± 3.02[b]	28.42 ± 3.90[b]

Mean values from three repetitions ± SEM.
Different letters within column indicate significant differences at ($p < 0.05$).
[A] Provide by supplier.

Table 2
Thermal properties of pearled barley starch (PBS), whole barley starch (WBS) and commercial corn starch (CCS).

Sample	T_{peak} (°C)			ΔH (J/g)			Retrogradation (%)	
	0 days	7 days	14 days	0 days	7 days	14 days	7 days	14 days
WBS	61.3 ± 0.1[a]	49.9 ± 0.5[a]	50.5 ± 0.2[a]	9.2 ± 0.1[b]	1.9 ± 0.0[b]	2.3 ± 0.1[a]	20.7	25.2
PBS	61.6 ± 1.6[a]	51.8 ± 0.3[b]	50.3 ± 0.5[a]	8.5 ± 0.1[a]	1.7 ± 0.1[a]	2.4 ± 0.1[a]	20.0	28.0
CCS	70.0 ± 0.3[b]	51.8 ± 0.2[b]	50.5 ± 0.3[a]	10.3 ± 0.2[c]	3.0 ± 0.1[c]	4.1 ± 0.1[b]	29.0	40.0

Mean values for three repetitions ± SEM.
Different letters within column indicate significant differences at $p < 0.05$.
Sample effect is represented by small letters in each column.
T_{peak} = maximum temperature of gelatinization of 0 days and retrogradation for 7 and 14 days.
ΔH = enthalpy of gelatinization for 0 days and retrogradation for 7 and 14 days.

showed higher enthalpy of retrogradation than barley starches, amylose content of these cereal starches plays an important role in this parameter. The enthalpy value is more susceptible to the changes at molecular level during starch heating and storage. Lower retrogradation temperature (40.7 °C) was obtained in native barley starch stored for 7 days, but higher enthalpy value was calculated (2.5 J/g) (Chavez-Murillo et al., 2008) that those obtained at the same storage time in this study. The retrogradation percentage increased with storage time, at 7 days no difference was observed between barley starches, but at 14 days a slight increase in this parameter was assessed. The retrogradation percentage of barley starches was lower than that obtained in commercial corn starch (40% of retrogradation at 14 days) (Table 2). The low retrogradation tendency of barley starch was related with its higher amount of short chains (Chavez-Murillo et al., 2008) than those obtained in maize starch (Yuan et al., 1993), although cereal starches are characterized by the high amount of short chains, amylose level might be responsible of this difference in the retrogradation of barley and corn starches.

3.3. Pasting properties

The pasting viscosity profiles of PBS, WBS and CCS starches tested with a Rapid Visco Analyzer (RVA) are shown in Fig. 1. The pasting properties of starch are influenced by other components present in the starch suspension during heating as well as the interactions between starch molecules in the granule (Doublier, Paton, & Llamas, 1987; Hoover & Vasanthan, 1992; Wang & White, 1994). The pasting temperature of both barley starches was similar and when this parameter was compared with CCS, the former reached to the maximum viscosity at higher temperature (Chavez-Murillo et al., 2008; Hoover & Vasanthan, 1992; Wang & White, 1994). However, difference was showed in the peak viscosity, the pearled barley starch presented higher value of this parameter. This pattern might be due to slight change in the structure of starch components, where more OH^- groups are freedom to interaction with water molecule and higher swelling was presented in PBS. The peak viscosity reflects the ability of starch granules to swell freely before their physical breakdown (Singh, Singh, Kaur, Singh, & Singh, 2003). When starch is heated in the presence of water, the granules are swollen while some components, including amylose and external chains of amylopectin, diffuse out, resulting swollen and dispersed particles present in the continuous phase (Thebauding, Lefebvre, & Doublier, 1998). The peak viscosity of the barley starches was obtained at the end of the holding step, for this reason a slight decrease in the viscosity was detected, because immediately the cooling (re-association) step started. When the temperature cooled down the viscosity increased, which resulted from network formation between amylose and amylopectin while it retained an amount of water (Gimeno, Moraru, & Kokini, 2004; Mali et al., 2003) and gave the characteristic of a gel.

3.4. Viscoelastic properties

Fig. 2 shows the profiles of frequency sweep of starches at the second (90 °C) and third stage (25 °C) in heating–cooling process. In all starches, $G' > G''$ at 90 °C however, the dependence of G' with the frequency was higher ($G' \propto \omega^{0.13}$). Similar dependence was

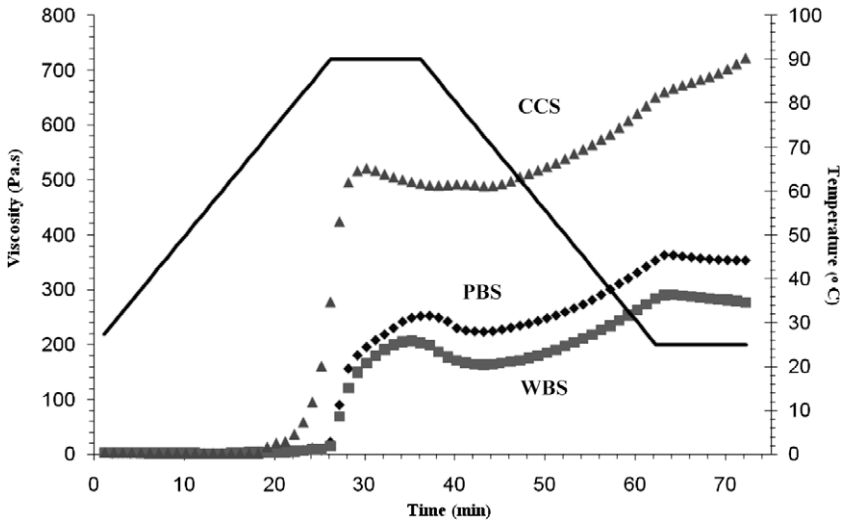

Fig. 1. Pasting properties by RVA of whole barley starch (WBS), pearled barley starch (PBS) and commercial corn starch (CCS).

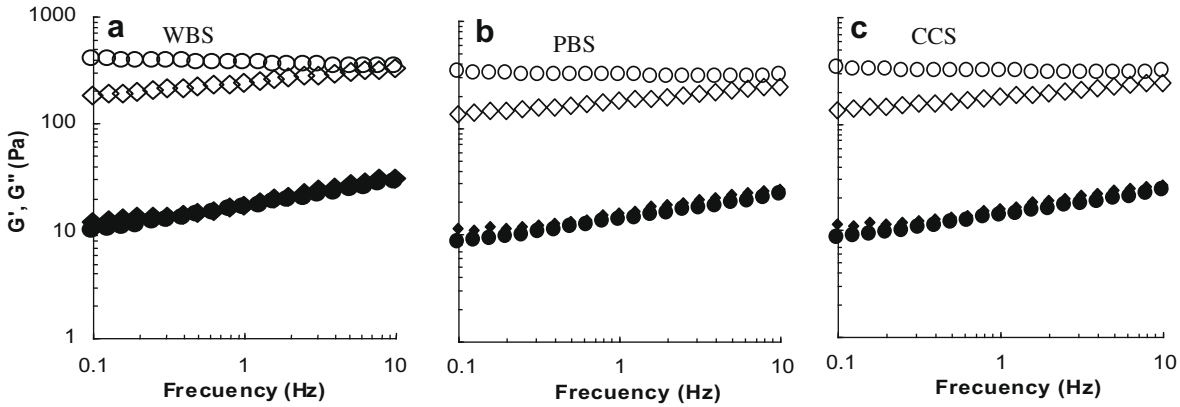

Fig. 2. Pastes at 90 °C (diamonds) and gels at 25 °C of (a) whole barley starch (WBS), (b) pearled barley starch (PBS) and (c) commercial corn starch (CCS). G' (empty symbols), G'' (filled symbols).

found in banana starch pastes at 60 °C (Nunez-Santiago, Bello-Pérez, & Tecante, 2004). According the rheological definition of gel (Ferry, 1980): both moduli, independent of frequency, G' greater than G'' and tan δ well below 1.0; at 90 °C, a starch paste is obtained due to the high dependence of G' with frequency and tan δ not well below 1 (data not shown). The amylose chains present in the continuous phase at 90 °C were in a disorder state (random coil). At this temperature, elastic moduli was higher for WBS and minor for CCS, while for PBS the behavior was intermediate. This pattern is mainly due to the swollen granules, because the amylose present in the continuous phase does not produce viscous solutions at such temperature.

When starch cools to ambient temperature the amylose in the continuous phase forms a three-dimensional network resulting in a gel (Miles, Morris, Orford, & Ring, 1985) where the minimum amylose concentration is about 1 (Clark, Gidley, Richardson, & Roos-Morphy, 1989). In this work, at 25 °C, a characteristic of a gel: low dependence of G' with frequency ($G' \propto \omega^{0.01}$), G' was significantly greater than G'', and tan δ was lower than 0.1, was observed (data not shown). At this temperature a three-dimensional amylose network in the continuous phase of the starch pastes was expected; however, the disperse phase (amylopectin swollen granules) have their contribution, so the rheological behavior is attributed to the amylose gel and to the starch granules embedded randomly in the amylose network (Carnali & Zhou, 1995). In frequency sweep of CCS, the modules were similar to those of barley starches, but a small difference was observed. This difference among starches in the variation of G' might be attributed to the difference in granule size, amylose/amylopectin ratio, and chain/length distribution of amylopectin (Singh & Kaur, 2004). However, the pearling process of barley grain could modify, to determine level, the above-mentioned characteristics. More studies in this sense are necessary.

3.5. Particle size distribution

Particle size analysis of the two starches is shown in Fig. 3. Studied starches presented a bimodal distribution, with a small peak between 2 and 4 μm, and the principal component shows an $D[v, 0.5]$ of 17.84 and 18.04 μm for PBS and WLS, respectively. Small (2–10 μm) and large granules (12–26 μm) have been isolated from pin-milled and air-classified fractions of waxy, normal and high-amylose barley (Vasanthan & Bthatty, 1996); however, large granules in barley starch are a small amount (~10–20%) of the total number of starch granules but is a high proportion (85–95%) of the total weigh of starch (Morrison, Scott, & Karkalas, 1986). Starch from another sources have similar behavior. In this context, in a modified waxy corn starch a bimodal size distribution was reported, a small peak was found with granule size of approximately 2–3 μm and a big peak with a granule size around 20 μm (Tecante & Doublier, 1999). Granule size distribution was tested in starches isolated from developmental corn lines using a microscopy technique; they reported granule size lower 5 μm and higher 17 μm, with a mean granule size for the 15 starches studied between 8.4 and 11.5 μm (Ji et al., 2003). In starches from other non-conventional botanical sources (*Curcuma longa* and *Curcuma zedoaria*) and using an image analysis, an average granule size of 20–25 and 20–30 μm was determined (Leonel, Sarmento, & Cereda, 2003).

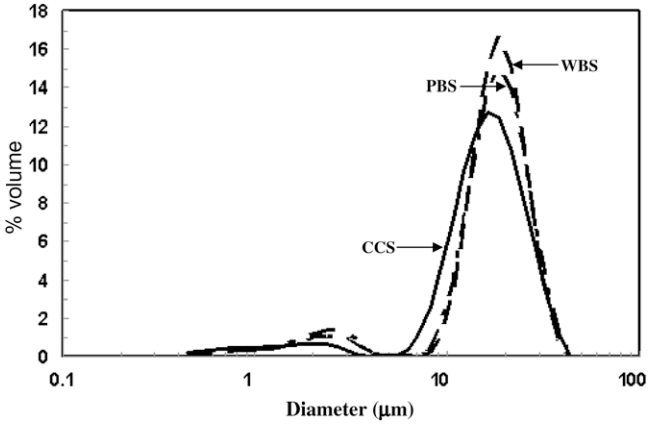

Fig. 3. Particle size distribution of whole barley starch (WBS), pearled barley starch (PBS) and commercial corn starch (CCS).

3.6. Morphological characteristics

The scanning electron micrographs of PBS and WBS starches are shown in Fig. 4. Difference in the shape, size and surface of both barley starch granules is not evident (Fig. 4a and b), with a round shape and smooth surface. Small and large granules are present in both cereal starches. The pearled process of the seed did not affect the morphological characteristics of starch granule. Other cereal starch as maize, presented a granule size ranged between 10 and 15 μm, with a higher heterogeneity showing round, oval and polygonal shapes (Espinosa-Solis, Jane, & Bello-Perez, 2009). Sizes and shapes of starch granules have impact in some physicochemical, functional and nutritional characteristics because larger granules develop high paste viscosity and small granules had higher digestibility.

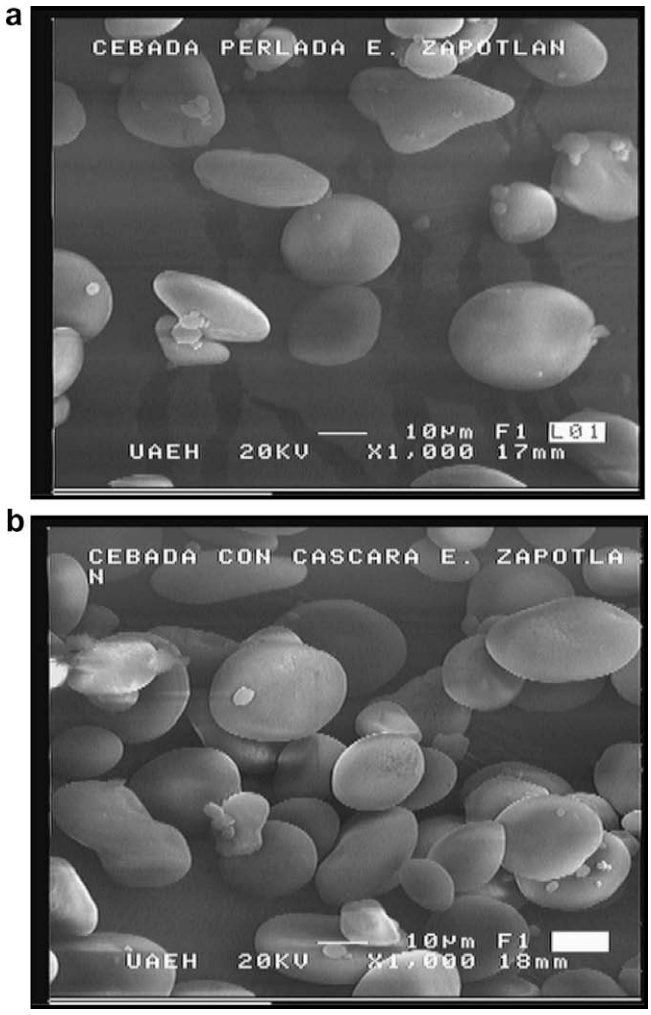

Fig. 4. Scanning electron microscopy of: (a) whole barley starch (WBS); (b) pearled barley starch (PBS).

4. Conclusions

Whole barley starch (WBS) had higher lipid level than pearled barley starch (PBS). In general, the pearled of barley did not affect the gelatinization and retrogradation parameters of the starch. Difference was showed in the peak viscosity, because the pearled barley starch presented higher value of this parameter. WBS and PBS presented differences in G' and G'', with $G' > G''$. Morphological characteristics and granule size distribution of both barley starches were similar. The pearled of the barley grain did not affect the characteristics of its starch, because the whole barley can be used to isolation of this polysaccharide.

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