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Extraction methods and some physical properties of mesquite (*Prosopis chilensis* (Mol) Stuntz) seed gum†

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Abstract: To evaluate the potential use of mesquite (*Prosopis chilensis* (Mol) Stuntz) seed gum, the behaviour of the gum was studied using two extraction methods (alkaline and acid), different pH values, two concentrations (0.2 and 0.4% w/v) and different temperatures. The capacity of the gum to stabilise food foams was also evaluated. The alkaline extraction yield (24.9%) was higher than the acid extraction yield (17.7%). Owing molecular to hydrolysis caused by the acid, acid extraction resulted in a lower protein content. Gum from acid extraction had a higher viscosity than that from alkaline extraction at all temperatures investigated (10, 20, 30, 40, 50 and 60 °C). There were no significant differences between the viscosities of mucilage dispersions at the different values of pH studied (3.0, 4.0 and 5.0). The addition of extracted mesquite gum (obtained by either method and at either concentration studied) to egg white foam provided a higher stability and decreased the liquid drainage and collapse of the foam.

Keywords: mesquite; *Prosopis chilensis*; gum; foam stability; mesquite seed gum; algarrobo seed gum

INTRODUCTION

Mesquite or 'algarrobo' (*Prosopis* spp) trees are leguminous plants trees that are widespread in arid and semi-arid zones of the world. Two different types of polysaccharide mucilage material have been identified in mesquite, namely a bark-exuded gum and a galactomannan fraction (storage polysaccharides) in the endosperm of the seed.[1,2] It has been reported that the endosperm of the mesquite seed accounts for about 30% of the seed by weight.[3]

Galactomannans are neutral polysaccharides composed of a linear mannan backbone bearing side chains of single galactose residues. They are normally extracted from the seed endosperm of Leguminosae, which is protected by the seed coat. They differ from each other in their mannose/galactose ratio, which may range from 1.6:1 to 4.5:1. Locust bean gum and guar gum are the most widely known galactomannans There are, however, other galactomannans from less well-known sources, eg tara gum, mesquite gum, and casia gum, all of which are now receiving more attention.[4,5] According to Figueiredo[6] and Sharma and Sony,[7] the mannose/galactose ratio in *Prosopis* species is between 2:1 and 4:1.

A major obstacle to the economic recovery of the seed gum of some species, in particular mesquite seed gum, is the toughness of the seed pod. The difficulty encountered in separating the seed from the surrounding pulp and the endosperm from the cotyledons is another obstacle to economic recovery.[3]

Usually, pods of leguminous trees are harvested when dry and then crushed or broken in a hammer mill. The material is then passed through a series of sieves that sort the broken pieces according to size. The seeds are further separated from pieces of pod of the same size by blowing air through the mixture.[3] Seeds are also separated manually from the pods.[4]

Endosperm is obtained by removing mechanically, physically or chemically the hull and cotyledons.[5] Azero and Andrade[4] reported gum extraction from *P juliflora* seeds in water, at room temperature overnight, removing the hull and germ by filtration. Gum was recovered from the filtrate by precipitation in ethanol, then dried at 45 °C and milled. In a chemical method, whole seeds were treated with acid at elevated temperatures to carbonise the hull, which was then removed by washing.[3] Escobar *et al*[8] treated seeds from *P chilensis* with sodium hydroxide

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at high temperature, separating the hull, endosperm and cotyledons manually.

Water-soluble/dispersible polysaccharides, termed hydrocolloids or gums, are known as viscosity builders and/or gelling agents in aqueous systems.[9] They create a structure that can be viewed as a continuum. First they build viscosity which, in a further step, may result in a gel. Whipping air into this structure creates a foam and, by desiccation of either of them (gel or foam), a film is formed.[10]

The mucilage or gum of the mesquite seed presents viscous properties with pseudoplastic behaviour halfway between guar gum and garrofin gum.[11] Vásquez *et al*[12] concluded that, at constant temperature, an increase in the concentration of mesquite dispersion leads to a higher viscosity. Yáñez[13] observed that the mucilage of mesquite has a thickening capacity which is directly proportional to the dispersion temperature and concentration.

Although they are not true emulsifiers, galactomannans may be considered as stabilisers, because they improve the long-term stability of food systems.[9]

Foams can be defined as systems of two phases consisting of gas bubbles dispersed in a continuous phase, trapped within a thin phase, liquid or solid.[14,15] There is a large variety of foams of very diverse consistencies, such as milk shakes, meringues, creams, ice creams, the foam of beer and even bread. Normally a uniform distribution of small bubbles imparts softness as well as an increase in the perception of aromas.[16] They can be obtained by whipping a large mass of air into an aqueous solution of protein. Foams are food products in which natural hydrocolloids may be used owing to their functional properties.[16] Hydrocolloids increase the viscosity of the continuous phase. They increase the viscosity and elasticity of the interphase layer that separates the bubbles, helping to prevent coalescence.[17] They form an elastic barrier between the gas bubbles, protecting them from collapse.[15]

In order to evaluate the possible use of mesquite seed gum as a food additive, it is necessary to know about its extraction method and its behaviour under different conditions. The objectives of this research were: to study two methods of wet extraction of mesquite (*P chilensis* (Mol) Stuntz) seed gum; to determine the effects of the pH and concentration of the gum obtained by both methods on the viscosity of dispersions at different temperatures; and to assess the capacity of dispersions of mesquite seed gum to stabilise food foams.

EXPERIMENTAL

Pods of mesquite were collected at the Experimental Station of the Facultad de Ciencias Agronómicas, Universidad de Chile (Rinconada, Maipú, Chile). The seeds were separated from the pods manually. Two different methods were used to extract mucilage from the seeds, one with 0.75% w/v sodium hydroxide at 80 °C for 20 min (alkaline extraction) and the other with 72% w/v sulphuric acid at 80 °C for 20 min (acid extraction). The wet gums obtained were dried at 37 °C for 16 h and then milled at 60 mesh.

Gum characterisation

Yield was calculated as the dry weight of the gum relative to the seed weight, expressed as a percentage. Moisture contents was determined by heating in a vacuum oven at 70 °C for 4 h.[18] Ash content was determined by incineration at 550 °C.[18] Protein content was determined by the micro-Kjeldhal method, using 6.25 as conversion factor.[18] Lipid content was determined by solvent extraction in a Soxhlet apparatus.[18] Na^+ and K^+ contents were determined by emission spectrophotometry, and Ca^{2+} content by atomic absorption spectrophotometry.

Colour parameters L^*, a^* and b^* were measured in a Minolta (Osaka, Japan) CR-200b tristimulus colorimeter. H^* and C^* values were calculated from the measured parameters.

Three replications (30 g of seed) were carried out for each analysis.

Viscosity of dispersions

Dispersions of mesquite seed mucilage at two concentrations (0.2 and 0.4% w/v) were prepared. Dry mucilage was hydrated at room temperature for 16 h with distilled water. The dispersions were mixed with a magnetic stirrer at 50 °C for 90 min and then, homogenised for 2 min using a Braun (Kronberg, Germany) Minipimer. The pH was adjusted to 3.0, 4.0 and 5.0 by adding 1 M citric acid. The viscosity of the dispersions was measured using a Brookfield (MA, USA) viscometer (RVT model with spindle No 1) at several temperatures (10, 20, 30, 40, 50 and 60 °C). Measurements were made in both recently prepared dispersions and dispersions stored for 24 h.

Viscosity data were analysed using a completely random design with factorial structure $2 \times 2 \times 3$ and four replications. To determine significant differences among factors, the Student–Newman–Kreus (SNK) test was used.

Foam stability

Meringue was prepared by whipping 25 g of egg white with sugar syrup of 65°Brix for 1 min at low speed and 1 min at high speed using an Oster (Boca Raton, FL, USA) 2602-51 blender. Two different concentrations of the gum (0.2 and 0.4% w/v) were added to individual mixtures, which were then whipped for another 3 min. The stability of the foams was measured through the syneresis (by collecting the drained liquid in a graduated probe) and the volume reduction at 0, 6, 24 and 48 h after meringue preparation. A completely random design was used with a factorial structure of $2 \times 2 + 1$ control (without mucilage) and four replications.

RESULTS AND DISCUSSION

Gum characterisation

The gum yield obtained by alkaline extraction was higher than that from acid treatment (Table 1), and

Table 1. Yields and chemical and physical characteristics (mean ± standard deviation) of mesquite seed gum obtained by sulphuric acid (72% w/v H_2SO_4) and sodium hydroxide (0.75% w/v NaOH) extraction

	Treatment	
Parameter	NaOH	H_2SO_4
Yield[a]	24.9	17.7
Moisture[b]	3.73 ± 1.56	4.22 ± 0.81
Protein[c]	5.16 ± 0.59	2.50 ± 0.19
Lipid[c]	0.43 ± 0.17	0.19 ± 0.04
Ash[c]	2.06 ± 0.22	2.02 ± 0.30
Cations[d]		
K^+	0.39 ± 0.02	0.52 ± 0.48
Ca^{2+}	0.10 ± 0.0	0.19 ± 0.01
Na^+	0.18 ± 0.01	0.15 ± 0.04
Colour		
*L**	63.20 ± 3.40	74.40 ± 2.95
*a**	0.22 ± 0.15	0.33 ± 0.18
*b**	22.87 ± 1.4	19.10 ± 4.4
*C**	22.87 ± 1.4	19.13 ± 4.4
*H**	90.07 ± 1.6	89.73 ± 4.7

[a] % dry gum weight relative to seed weight.
[b] % wet basis.
[c] g per 100 g DM.
[d] % dry weight.

higher than that reported by Cruz[19] for *P pallida* and *P juliflora* (22%). Gum yield is strongly dependent on the endosperm development in the seed, which varies with the seed size and growing conditions. The seeds used in this research showed some insect damage and some dehydration. When treated with sulphuric acid, the seed coat was destroyed by carbonisation.[3] This caused some loss of the gum into the extraction medium. On the other hand, sodium hydroxide softened the seed coat, allowing manual separation of the endosperm.

The values of moisture content observed (Table 1) were lower than the ones reported by Vásquez *et al*[12] for *P chilensis* gum (8%) and by Ward[20] for locust bean gum (12.8%) and guar gum (9.9%).

The ash contents of the gums were similar to those obtained by Escobar *et al*[8] (0.9–2.1 g per 100 g DM); however, the values are a little higher than those of commercial guar gum (1.5%) and locust bean gum.

In acid-extracted gum the lipid content was very low, whereas the level in alkali-extracted gum was similar to that reported by Vásquez *et al*[11] (0.4%).

Acid extraction resulted in a lower protein content owing to molecular hydrolysis caused by the acid. In alkaline extraction the value observed was lower than that reported by Vásquez *et al*[12] for *P chilensis* (6.9%), but similar to the protein contents found by Ward[20] in commercial guar gum and locust bean gum (3–6%).

The extracted gums had low concentrations of cations; however, their Na^+ content was a little higher than the values reported by Ward[20] for commercial gums (10 mg per 100 g)

The colour parameters indicated that the gums presented a similar colour, regardless of the extraction method used. The L^* value of acid-extracted gum was higher than that of alkali-extracted gum, resulting in a whitish gum.

Viscosity of dispersions

Effect of extraction method on viscosity

Fig 1 shows that, at all temperatures studied (10, 20, 30, 40, 50 and 60 °C) and at both times of measurement, gum from acid extraction had the higher viscosity value. At 10 °C the viscosity of the mucilage dispersion from recently prepared alkaline extraction represented about 55% of the viscosity of the mucilage dispersion from acid extraction. After 24 h it was 66%. During extraction with 0.75% w/v sodium hydroxide the mucilage may undergo changes in the structure of the polysaccharide, causing a lower viscosity. Goycoolea *et al*[21] indicated that, in galactomannans, alkaline conditions caused a reduction in viscosity. This was due to a reduction in the weight of the molecules and to the suppression of intermolecular association. Upon carrying out the extraction with 72% w/v sulphuric acid, the formation of hydrogen bonds occurred, increasing the dispersion viscosity. At 24 h after its preparation, having been cooled to 10 °C, the viscosity of the dispersion of alkali-extracted mucilage remained almost stable. In contrast, the viscosity of the acid-extracted dispersion showed a 16% decrease. As the initial viscosity of the dispersion is not recovered after cooling, it is probable that, during

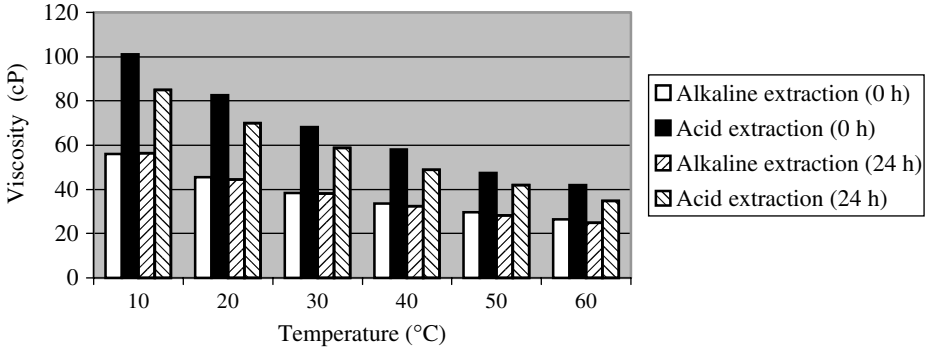

Figure 1. Viscosity of dispersions of mesquite mucilage extracted by two methods at different temperatures, in samples newly prepared and after 24 h.

heating, the molecules underwent some irreversible changes in their conformation.

Similarly as occurs in many other gums, the viscosity of the mucilage dispersion extracted by both methods diminished as the temperature increased. At 60 °C the viscosity was only 40% of that at 10 °C, both in dispersions newly prepared and after 24 h. Casas *et al*[22] reported that the apparent viscosity of guar gum dispersions decreased upon heating, this behaviour being completely reversible.

Effect of concentration on viscosity

The viscosity of dispersions of mesquite seed mucilage increased when the concentration was increased from 0.2 to 0.4% w/v at all temperatures studied, both in dispersions newly prepared and after 24 h (Fig 2). These results are in agreement with Vásquez *et al*,[11] who concluded that, at constant temperature, an increase in mucilage concentration leads to a higher viscosity, which may be due to a higher amount of solute in the dispersion. According to Casas *et al*,[22] in guar gum dispersions this effect was due to the aggregation of the gum in solution.

Viscosities of the 0.2% w/v mucilage dispersions were similar both at the beginning and after 24 h of the assay. On the other hand, viscosities of the newly prepared 0.4% w/v dispersions were higher than those obtained after 24 h. At the higher solute concentration, both higher temperatures and a longer time may cause the formation of irreversible structures in the hydrocolloid. On comparing the viscosity data of recently prepared dispersions against those obtained after 24 h at 10 °C, a 13% a decrease was observed.

In new samples, as the temperature was increased from 10 to 60 °C, the viscosity of mucilage dispersions diminished. A higher decrease of 59.4% was seen in the 0.4% w/v dispersions as against 47.5% in the 0.2% w/v dispersions. At 24 h after preparation the viscosity of the mucilage dispersions showed a decrease when the temperature was increased from 10 to 60 °C: 61.0% in the 0.4% w/v dispersions and 49.6% in the 0.2% w/v dispersions.

Effect of pH on viscosity

There were no significant differences ($p < 5\%$) between the viscosities of mucilage dispersions at the different values of pH studied. The same tendency was observed at each temperature. There were no changes either in the newly prepared dispersions (Fig 3) or in the dispersions after 24 h. This may indicate a non-ionic behaviour of the mucilage in the range of pH used in this research (3.0–5.0). Guar gum dispersions show a similar behaviour, because their non-ionic nature allows stability in a wide range of pH from 1.0 to 10.5.[23]

Since the effect of pH on viscosity is one of the most important factors to be considered in the selection of a gum for food application, the stability shown by the dispersions of mesquite mucilage at the pH values used in this research signifies a good possibility for its incorporation in a large variety of foods.

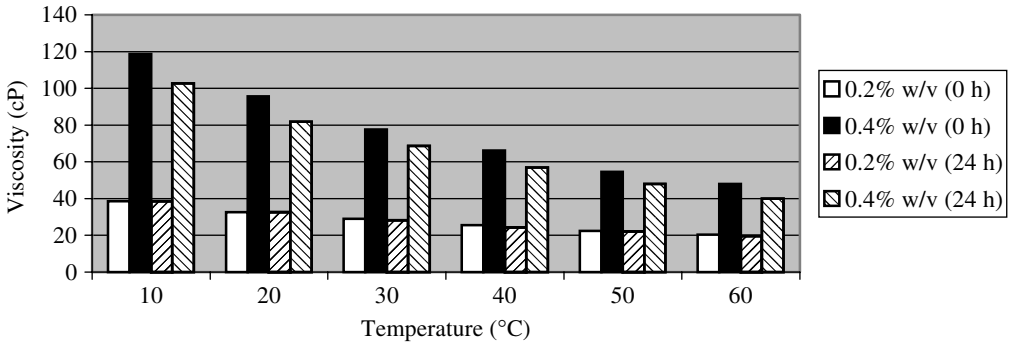

Figure 2. Viscosity of dispersions of mesquite mucilage of two concentrations at different temperatures, in samples newly prepared and after 24 h.

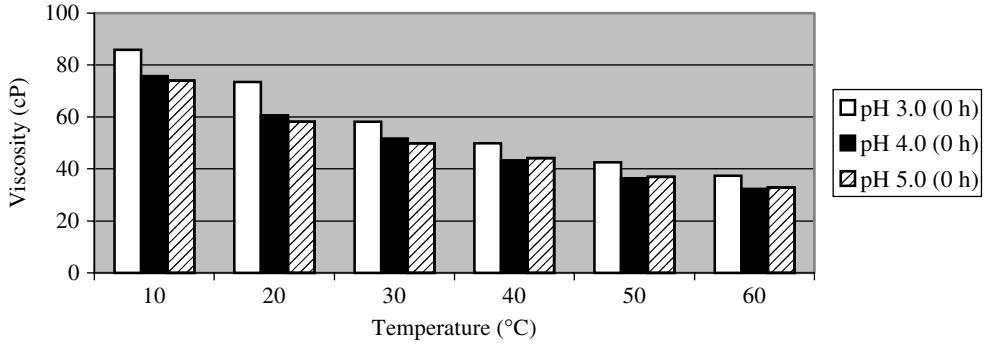

Figure 3. Viscosity of newly prepared dispersions of mesquite mucilage at three pH values and different temperatures.

Stability of foams

Foam stability, as determined by the drainage of liquid from the foam (syneresis) and by the collapse of the foam column,[24] depends on the mechanical properties of the protein lamella.[14] Egg white forms expanded and stiff foams with very small bubbles and a high liquid drainage rate at 50 min after preparation.[25]

Syneresis

The addition of extracted mesquite gum (obtained by either method and at either concentration studied) to egg foam (meringue) provided a higher stability and decreased the liquid drainage and collapse of the foam. Yáñez[13] also found a higher stability in an orange mousse-type dessert when algarrobo gum was added. The control showed a high amount of syneresis, which agrees with Ferreira *et al*,[26] who reported a drainage of 12% after 2 h in egg white foam. The highest syneresis among treatments with mesquite seed gum was observed after 48 h in foams supplemented with gum extracted by the alkaline method (27.8 ml at both concentrations). The lowest drainage was found in foams with 0.4% w/v acid-extracted gum, showing a significant difference of 27.5% from the control (Fig 4). Within each treatment there were no significant differences in foam syneresis at the different times of analysis.

Volume

At 6 h after preparation the foam volume did not show significant differences between treatments (Fig 5). However, at 24 and 48 h the foam supplemented with alkali-extracted gum showed a significant volume reduction. Again, within the various treatments, there were no significant differences in foam volume reduction at the different analysis times.

It was observed that, with the addition of gum from acid extraction to egg white foams, they maintained their volume for up to 48 h without significant differences among times of analysis. On the other hand, foams with an addition of alkali-extracted gum showed a reduction in volume at 24 h after preparation (77.9% with 0.2% w/v gum and 35.0% with 0.4% w/v gum). At 48 h a further collapse (61.3% with 0.4% w/v gum and 14.9% with 0.2% w/v gum) was observed. The higher volume reduction in foams with alkali-extracted gum addition could be caused by structural changes in the gum molecules that may affect its properties.[21]

As shown in Figs 4 and 5, the control foam had a large volume and the highest liquid drainage. At 6 h after preparation the growth of large bubbles at the expense of smaller ones, known as the Ostwald ripening effect,[27] was observed. The highest foam stability (the lowest syneresis and the highest volume) was found in foams with mesquite seed gum from acid extraction added. Although gums are not expected to have significant surface activity, some galactomannans have been shown to stabilise food systems via a combined reduction in surface tension, increase in viscosity and decrease in mobility.[9,28] Protein foams are important in many processes within the beverage and food industry, as they provide texture and consistency and aid appearance. Consequently, the

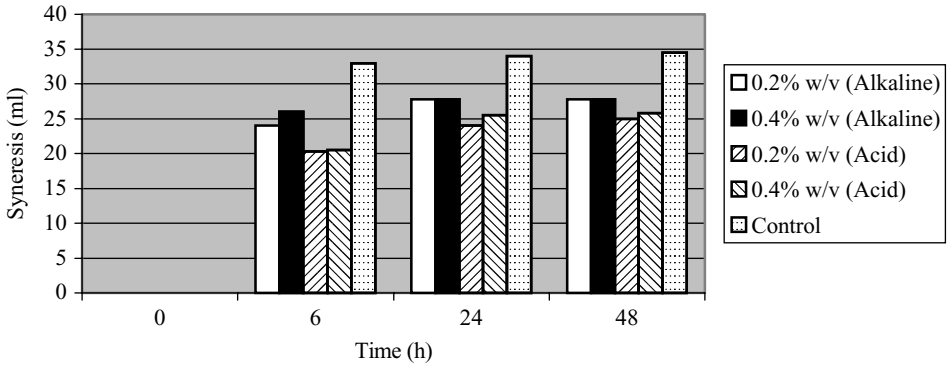

Figure 4. Changes in syneresis of foams with added dispersions of mesquite seed gum extracted by two methods and at two concentrations.

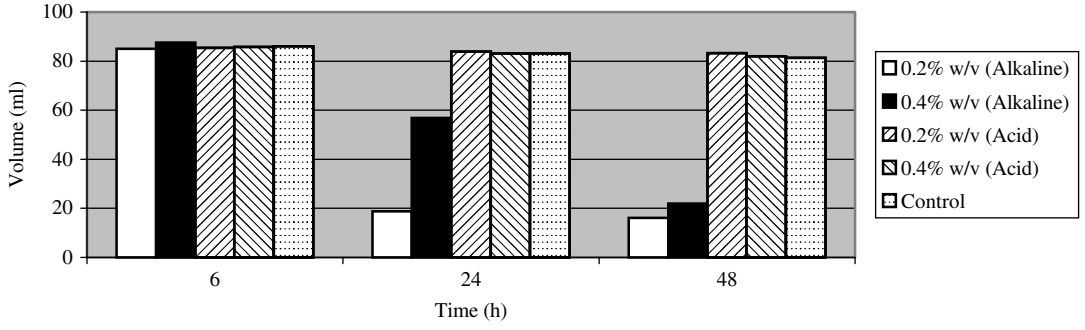

Figure 5. Changes in volume of foams with added dispersions of masquite seed gum extracted by two methods and at two concentrations.

improvement of their stability with hydrocolloids is a very interesting objective.[25]

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