

Extraction and characterization of mucilage in *Opuntia* spp.

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Abstract

The cactus pear (*Opuntia ficus indica*) mucilage is an interesting ingredient for the food industry because of its viscosity properties. We studied the conditions for the extraction and precipitation of the plants mucilage. Extraction conditions were: pad/water ratios (1:51:7), extraction temperature, (40 ± 2 and 16 ± 2 °C) and extraction time (4, 8 and 16 h). For the precipitation of the mucilage two types of alcohol (ethanol and isopropyl alcohol) and two water/alcohol ratios (1:3 and 1:4) were used.

No differences were found in any of the measured variables among the different extraction or precipitation methods.

The average mucilage yield after drying was 1.48% based on fresh weight (f.w.) and 19.4% based on dry weight (d.w.).

The dried mucilage had in average 5.6% moisture; 7.3% protein; 37.3% ash; 1.14% nitrogen; 9.86% calcium and 1.55% of potassium. The colour analysis showed a high L^* value and the chromatic co-ordinates were in the yellow-greenish spectrum.

The use of isopropyl alcohol is recommended in ratio 1:3, since its commercial value is lower in comparison with ethanol.

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1. Introduction

The genus *Opuntia* (v.n. “Nopal” Cactaceae) is characterized by the production of a hydrocolloid commonly known as mucilage (Fluxá, 1991), which forms molecular networks that are able to retain large amounts of water (Saag et al., 1975). Mucilages are complex polymeric substances of carbohydrate nature, with a highly branched structure (McGarvie and Parolis, 1981; Medina-Torres et al., 2000, 2003; Goycoolea and Cárdenas, 2004; Matsuhira et al., 2006), which contains varying proportions of L-arabinose, D-galactose, L-rhamnose and D-xylose, as well as galacturonic acid in different proportions. The mucilage structure is proposed as two distinctive water-soluble fractions. One is a pectin with gelling properties with Ca^{2+} , and the other is a mucilage without gelling properties (Goycoolea and Cárdenas, 2004). Majdoub et al. (2001) reported that in *Opuntia ficus indica* the water-soluble polysaccharide fraction with thickening properties represents less than 10% of the water-soluble material.

Nopal pads (cladodes) are succulent and shaped as a racket of about 60–70 cm in length with a thickness of 2–3 cm. The thickness depends on both the age of the plant and the water and nutrients received during growth (Sudzuki et al., 1993). The epidermis has two layers, one of green cells, the chlorenchyma and another internal layer, which is formed by a cylinder of white cells, known as parenchyma. Their main function is the storage of water (Pimienta, 1990; Granados and Castañeda, 1996). Within the tissues, in the chlorenchyma and parenchyma, there are mucilaginous cells that store mucilage; this material is commonly known as “nopal dribble” (Pimienta, 1990; Terrazas and Mauseth, 2002). These particular cells are more abundant in the parenchyma. This complex mucilage exhibits the osmotic property of retaining water strongly (Sudzuki et al., 1993).

Tissue studies have demonstrated that the mucilage is present only in the Golgi Apparatus, and the mucilage synthesis takes place probably in it and in the vesicles are derived from it (Trachtenberg and Mayer, 1981). These polysaccharides swell when dissolved in water, or in some cases, form colloidal and very viscous suspensions or jellied masses (Sáenz and Montoya, 1999).

In particular, the mucilage of *O. f. indica* is composed of arabinose, galactose, rhamnose, xylose and galacturonic acid (Trachtenberg and Mayer, 1981). There are other minerals present, such as Ca^{2+} and the K^{+} , carbohydrates and dietary fibre. The Ca^{2+} and the K^{+} are of great interest with regard to human nutrition (Sáenz and Montoya, 1999).

As a result of the potential use of the nopal in several products in the world market (such as fruit beverages, yoghurts, etc.), economic interest in the genus *Opuntia* has increased considerably. The area where it is cultivated has increased (Reynolds and Arias, 2001). The interest in the genus is due to the important role they play, in arid and semi-arid zones, in the success of the sustainable systems of agriculture (Barbera et al., 1999). The most suitable plants for cultivation are those as *Opuntia* genus that can withstand conditions of water shortage, high temperatures and poor soil and that are easily handled in the orchard, thus providing food for subsistence agriculture. The *Opuntia*, in particular *O. f. indica*, satisfies many of these requirements (Barbera et al., 1999).

A more efficient use of this plant would be favored by an increased use of the pads, from the pruning process, for the hydrocolloid (mucilage) extraction. This component could then be used as a thickening agent additive in the food, pharmaceutical and cosmetic industries.

Studies done by Sáenz et al. (1992) in cactus fruits peel and in pads (Sáenz and Sepúlveda, 1993) reported that the mucilage yield was 1.0% and 1.2% fresh weight (f.w.),

respectively. Different authors have used varying methods for the mucilage extraction that have influenced the obtained yield (Nobel et al., 1992; Sáenz et al., 1992; Cárdenas et al., 1997).

The objective of this work is to determine the most appropriate method for a water extraction of cactus pads mucilage, considering as variables the relationships between pad/water, the temperature/time conditions and the type of alcohol used for mucilage precipitation.

2. Materials and methods

Two trials were conducted, Trial 1 to determine the optimum extraction methods for the mucilage from the pads, followed by a second trial (Trial 2) to optimize the precipitation of the mucilage after extraction.

2.1. Extraction of the mucilage

For the extraction of the mucilage in the two trials, the nopal pads were crushed in a blender (Moulinex) with rotative knives type 320, homogenized with water in the ratio 1:5 and 1:7, and then filtered through a fine cloth and centrifuged in an IEC centrifuge model CS (3560 g). In order to reduce the amount of alcohol used in the precipitation, the mucilage solution was concentrated to a third of its volume in a Büchi evaporator model RE120.

2.1.1. Trial 1. Extraction method

We used a completely randomized design, with six treatments and three repetitions per treatment (Fig. 1). The variables considered were the relationship pad/water, time/temperature. The experimental unit consisted of 200 g of crushed pads from 2- to 3-year-old plants growing in a commercial plantation in central Chile. The harvest of the cladodes was carried out during May and June, with time intervals of 20 days. Each harvest (3) corresponded to a repetition. ANOVA and DUNCAN tests were used to detect the treatment differences.

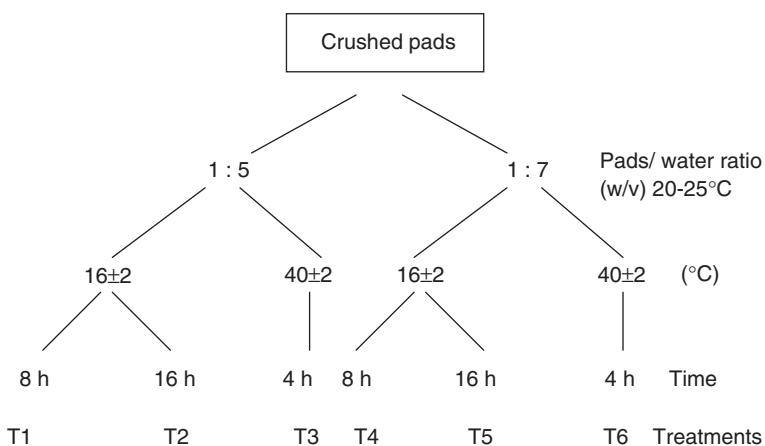


Fig. 1. Treatments applied in the mucilage extraction (Trial 1).

Studied variables are shown in Fig. 1, and were the following:

- The pad/water ratio was examined. The raw matter was crushed, homogenized with water in the relationships: 1:5 and 1:7 defined in preliminary trials.
- *Temperature*: Two temperatures for the extraction were examined, 16 ± 2 and 40 ± 2 °C.
- *Time*: for the extraction at 16 ± 2 °C, maceration times were 8 and 16 h, respectively. For the extraction at 40 ± 2 °C, maceration lasted 4 h.
- The mucilage was precipitated with ethanol and isopropyl alcohol and dried in a vacuum oven at 70 °C.

2.1.2. Trial 2. Method of precipitation

The experimental design was completely randomized with a 2×2 factorial structure, where the first factor corresponds to the type of alcohol (ethanol or isopropyl alcohol), and the second factor to the ratio aqueous extract: alcohol (1:3 or 1:4), with three repetitions per treatment (Fig. 2). The experimental unit of crushed pad consisted 200 g as in Trial 1. ANOVA and DUNCAN tests were used to detect the treatment differences.

Measured variables are shown in Fig. 2, and are the followings:

- Two type of alcohol were used for the precipitation: isopropyl alcohol and ethanol were tested in two proportions, 1:3 and 1:4 alcohol/water, using the best extraction method of the Trial 1 (1:7, 15–18 °C and 16 h).

After precipitation with ethanol and isopropyl alcohol, samples were dried in a vacuum oven at 70 °C.

2.2. Chemical and physical analysis

The following analyses were conducted in the mucilage obtained from the two trials:

Moisture: Moisture content was measured by drying samples at 73 °C in a vacuum oven (AOAC, 1984).

Protein: The nitrogen content was measured using the micro-Kjeldahl method (AOAC, 1984). The percentage of protein was obtained using the factor 6.25.

Ash: Determined by dry incineration in a Heraeus muffle at 550 °C for 8 h (AOAC, 1984).

Inorganic components: A photometric method was used to determine potassium and atomic absorption for calcium analysis (AOAC, 1984).

Colour parameters: The colour parameters (L^* , a^* , b^*) were determined using a Minolta CR-200b. The chroma (C^*) and the value (H^*) were calculated according to McGuire (1992).

Yield: It was determined on fresh and dried weight and expressed as mucilage percentage (%).

3. Results and discussion

3.1. Extraction optimization trials

The moisture content in the fresh cladodes was 91.9% f.w. (8.1% dry weight (d.w.)). This value is in agreement with the 88% and 91% (f.w.) previously found by Pimienta

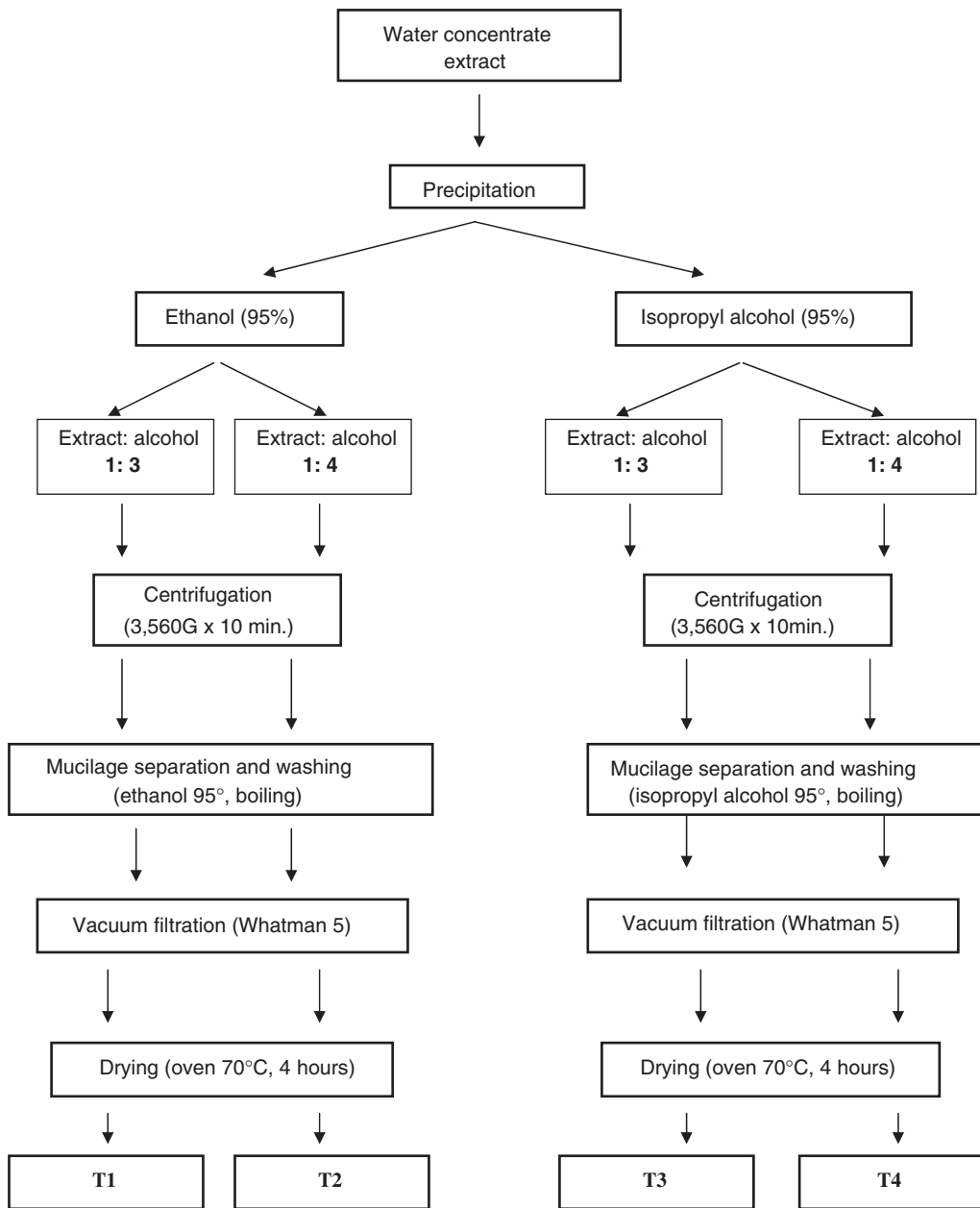


Fig. 2. Treatments applied for the mucilage extraction (Trial 2).

(1990). The moisture content value found is greater in young cladodes than in the older ones.

The extraction and purification with ethanol dissolves part of the chlorophyll present in the pads and produces a clear yellow mucilage powder ($L^* > 86$), similar to other commercial gums used in the food industry.

The mucilage yield obtained in each treatment was based on fresh and d.w. as shown in Table 1. The mucilage content, as f.w., was greater than that reported by Cárdenas et al. (1997) of 0.07% and slightly higher than that reported by Sáenz and Sepúlveda (1993) of 1.2%.

The mucilage consists of 17.9% of total d.w. of the cladodes, similar to that reported by Goldstein et al. (1991), of 9–19% (d.m.). The same authors point out that the mucilage pads content could vary depending on climatic conditions, such as cold and rain due to the ability of these polysaccharides to absorb water as a plant defence against stress conditions.

Saag et al. (1975), working with other varieties of *Opuntia* reported, after a water extraction and precipitation with ethanol, yields of 0.53% (f.w.) for *Opuntia monacantha* and of 0.48% (f.w.) for *Opuntia nopalea cochinillifera*. The same authors pointed out that the yields depended on the climatic conditions and the crop age.

According to the statistical design, no significant differences in yield between the treatments were detected.

The effect of the pads/water relationship on the mucilage yield showed a small tendency to increase when the amount of water used for the extraction was increased. The best yields obtained were with pad/water ratio 1:7. The highest value was reached in T6 (pad/water ratio 1:7, 40 ± 2 °C, and 4 h of extraction) and the lowest yield was in T1 (pad/water ratio 1:5, temperature 16 ± 2 °C, 8 h of extraction). Therefore, it could be suggested that when the amount of water is increased in the pad/water ratio (1:7), a greater mucilage yield can be obtained.

Similarly, when the temperature was increased from 16 ± 2 to 40 ± 2 °C, a small increase in the yield extraction took place. The same occurred when the time was increased from 8 to 16 h, although these increments were not statistically significant. However with respect to the temperature, this factor has a greater influence on the mucilage yield, as compared with the extraction time. The treatments in which the temperature was greater (namely T3 and T6) allowed a better mucilage extraction like that of 16 ± 2 °C, in spite of the short extraction time (4 h). These parameters are important and will need to be considered if the process is to be done at an industrial level, since any yield increase will affect the process costs.

Therefore, in future research the trial of greater amount of water and/or higher temperature for the extraction should be addressed, since this could probably lead to an increase in the mucilage yield.

Table 1
Mucilage yield and chemical composition (g/100 g f.w.) (Trial 1)

| Treatment | Yield (% fresh weight) | Yield (% dry weight) | Moisture | Protein | Ash | Nitrogen | Calcium | Potassium |
|-----------|------------------------|----------------------|--------------|--------------|---------------|---------------|----------------|---------------|
| T1 | 1.33 a* ± 0.1 | 16.50 a* ± 1.8 | 4.9 a* ± 0.6 | 7.9 a* ± 1.5 | 36.2 a* ± 2.3 | 1.26 a* ± 0.2 | 10.90 a* ± 0.7 | 1.63 a* ± 0.2 |
| T2 | 1.36 a ± 0.2 | 16.87 a ± 2.1 | 5.7 a ± 1.7 | 7.8 a ± 1.2 | 35.4 a ± 2.0 | 1.28 a ± 0.2 | 10.85 a ± 0.8 | 1.61 a ± 0.2 |
| T3 | 1.45 a ± 0.1 | 17.95 a ± 1.6 | 5.9 a ± 1.7 | 7.3 a ± 0.3 | 34.9 a ± 1.5 | 1.17 a ± 0.1 | 10.53 a ± 0.4 | 1.81 a ± 0.3 |
| T4 | 1.44 a ± 0.1 | 17.86 a ± 0.8 | 5.5 a ± 1.1 | 6.1 a ± 0.7 | 39.1 a ± 2.4 | 0.98 a ± 0.1 | 12.67 a ± 1.6 | 2.01 a ± 0.3 |
| T5 | 1.52 a ± 0.1 | 18.89 a ± 1.1 | 4.5 a ± 0.6 | 7.3 a ± 0.8 | 38.8 a ± 1.2 | 1.17 a ± 0.1 | 11.83 a ± 0.4 | 1.88 a ± 0.2 |
| T6 | 1.56 a ± 0.1 | 19.26 a ± 1.7 | 4.7 a ± 0.9 | 7.1 a ± 0.7 | 39.0 a ± 1.9 | 1.13 a ± 0.1 | 11.73 a ± 0.5 | 1.82 a ± 0.1 |

*Different letters indicate significant differences ($p \leq 0.05$).

3.2. Mucilage analysis

The mucilage moisture fluctuates between 4.5% and 5.9%, without significant differences between the treatments (Table 1). The average was 5.2%, which differed from that reported by Fluxá (1991) who determined a moisture level of 21.74%. These differences could be attributed to the conditions in which the analyses were done or the powder cladode hygroscopicity, since Fluxá (1991) dried at room temperature.

In general the protein content was similar in all the treatments, without differences between them. The average was 7.3%, the highest being 7.9% in T1, and the lowest, 6.1% in T4 (Table 1). This high protein content could be due to the analytical method used (micro-Kjeldahl), which determines not only the nitrogen from the proteins but the total nitrogen in the sample. Treatments using a smaller relationship of pads/water tended to show a higher protein content than those where a larger pad/water ratio was used, so the protein content in T1 and T2 was greater than in T4 and T5, and T3 presented a higher value than T6. There are no references for mucilage protein content. However, the references related to nopal flour (from entire cladodes) indicated a 4.4% protein content using a blend of pads of different age (Lecaros, 1997). López et al. (1977), cited by Pimienta (1990) reported a protein content of 3.7% in 3-year-old pads and 9.4% in nopalitos (young cladodes). Nobel (1983) and Flores and Bauer (1977), cited by Pimienta (1990), reported values from 4.29% of protein in pads of 8 months to 6.15% of protein in pads of 3 months.

The ash content in the mucilage was high in all the treatments and between 34.9% and 39.1%, without significant differences between them. The average was 37.2%, very different to that obtained by Fluxá (1991) in mucilage extracted from cactus pear fruit peel, where 12% was determined. In mucilage extracted from 2- to 3-year-old *O. f. indica* pads from our Faculty Campus, the ash content was 23.73% (Sepúlveda et al., 2002). Malainnine et al. (2003) in *O. f. indica* cladodes from Morocco, reported an ash content of 19.6%.

The ash content and its chemical composition vary in both the same and different *Opuntia* species. This is influenced by the chemical soil composition and by the complex phenomenon used by the plants to absorb their nutrients (Villarreal et al., 1963). Also, it is important to mention that the chemical composition of the ash varies in accordance with the season of the year (Pimienta, 1990). In the present study, the treatments in which the relationship pads/water was greater, the ash content tended to be higher as compared with those where the relationship was smaller (Table 1).

The nitrogen, calcium and potassium content are shown in Table 1. The nitrogen content was 1.17%. McGarvie and Parolis (1981) reported nitrogen contents of 0.87% and 1.1% in two mucilage samples, similar to those determined in this research. No significant differences between the treatments were observed. However, in the treatments where the mucilage was obtained using a smaller ratio pad/water, the tendency was to obtain greater nitrogen content, as compared to those where the amount of water was greater. So, in T1 and T2 a higher value than in T4 and T5 was obtained. The same occurred in T6 with respect to T3 (Table 1).

The calcium content was high in all the treatments, between 10.53% and 12.67%. No significant differences between them were observed. There are no references about calcium content in the mucilage. The calcium content in the cladodes has been reported to fluctuate between 5% and 9.5% (Pimienta, 1990). In nopal flour, values of 3.43% were determined

by Lecaros (1997). Such results were lower than the ones observed in this study with an average of 11.42% in the mucilage.

The calcium content increases with the cladodes age. For example, this value is three times higher in cladodes of 1-year-old than in 7-month old cladodes of (Nobel, 1983; Gibson and Nobel, 1986, cited by Pimienta, 1990). In this research, where pads of 2–3 year old were used, the higher content could be attributed to the age of the pads used.

According to Trachtenberg and Mayer (1981) the mucilage appears as a calcium salt in the mucilage cells. Ca^{2+} has a significant effect on the water holding capacity and other biophysical properties of the mucilage from *Opuntia* (Trachtenberg and Mayer, 1982). Calcium oxalate is the main form of calcium in the succulent tissue of *O. f. indica*, as well as in other cactaceae. The physiologic paper of the calcium oxalate deposits is not clear, but they seem to play an important role in the defence mechanism of the plant (Franceschi and Horner, 1980, cited by Pimienta, 1990). According to Pimienta (1990), a plant with a deficit in calcium could reabsorb these calcium oxalate deposits. Therefore, another possible explanation of the high amount of calcium determined could be that, in the harvested pads, there was a deficiency of calcium and the plant reabsorbed the external calcium oxalate deposits.

The values of the calcium content in the treatments, where the amount of water used for the mucilage extraction was higher, tended to increase compared with those where the amount of water was lower (Table 1).

The potassium content fluctuated between 1.61% and 2.01% without significant differences between treatments. The average of potassium was 1.8%, slightly greater than the value reported by Nobel (1983) of 1% in cladodes of 6 months maturity, but this value corresponded to the composition of the whole pads and not of the mucilage. Fluxá (1991) found values of 3.20% of potassium in mucilage from the fruit peel and Lecaros (1997) determined 2.05% in nopal flour. This last value does not differ considerably from the value observed in this study.

To complement this study, another analyses on the extracted mucilage were done, determining 0.71% of ether extract and 0.69% of crude fibre. There are not any references concerning mucilage, fibre or ether extract. References about cladodes are 1.3% for ether extract in 3-year-old pads (López et al., 1977 cited by Pimienta, 1990), and 1.48% of ethereal extract in pads 6 months old (Nobel, 1983; Flores and Bauer, 1997 cited by Pimienta, 1990).

Regarding crude fibre, Lecaros (1997) determined 6.76% crude fibre in cladode flour. In the mucilage, the low percentage of crude fibre content (0.69%) was expected because the mucilage is only a small portion of the cladode flour.

3.3. Mucilage colour

Table 2, shows the colour parameter values. The mucilage presented a high L^* value, superior to 86 and a chromaticity in the yellow-greenish spectrum. In all the treatments, the a^* value turned out to be negative and the b^* value positive. According to the statistical analysis, significant differences between the treatments do not exist.

3.4. Mucilage precipitation trials

3.4.1. Mucilage yield

The moisture content of the cladodes was 92.8%, a value slightly greater, though very similar, to that reported by Pimienta (1990), who pointed out a water content of 88–91%, where the highest percentages corresponded to younger cladodes.

Table 2
Color parameters of different mucilage treatment (Trial 1)

| T* | L* | a* | b* | H* | C* |
|----|---------------|---------------|--------------|----------------|--------------|
| T1 | 87.8 a* ± 1.0 | -1.8 a* ± 0.4 | 7.0 a* ± 1.8 | 104.7 a* ± 1.7 | 7.2 a* ± 1.8 |
| T2 | 88.1 a ± 0.8 | -0.9 a ± 1.3 | 7.1 a ± 1.1 | 96.2 a ± 10.4 | 7.3 a ± 1.1 |
| T3 | 87.2 a ± 0.6 | -1.7 a ± 0.4 | 6.6 a ± 0.4 | 104.0 a ± 2.4 | 6.6 a ± 0.4 |
| T4 | 88.9 a ± 1.8 | -1.3 a ± 0.4 | 7.1 a ± 1.9 | 99.3 a ± 0.4 | 7.2 a ± 2.0 |
| T5 | 87.9 a ± 0.6 | -1.1 a ± 0.4 | 8.0 a ± 1.9 | 97.6 a ± 3.3 | 8.1 a ± 1.9 |
| T6 | 86.6 a ± 0.4 | -1.6 a ± 0.4 | 7.0 a ± 1.1 | 103.0 a ± 1.4 | 7.1 a ± 1.1 |

T = treatments.

*Different letters indicate significant differences ($p \leq 0.05$).

L* = lightness; a* = red (+) or green (-) direction; b* = yellow (+) or blue (-) direction.

C* = chroma and H* = hue angle.

The mucilage yield expressed with respect to f.w. (1.5%), was higher than the 0.07% obtained by Cárdenas et al. (1997). Based on d.w., the yield obtained was 20.8%, slightly higher than the value reported by Goldstein et al. (1991), who pointed out that the content of mucilage in relation to the dry matter from the cladodes, ranged between 9% and 19%. However, the climatic conditions at the time of the pads collection (winter, cold and rain), may justify this high value, since the same authors indicate that such values could increase under favourable hydrated conditions, especially in the cells of the parenchyma where the water was stored.

No significant differences in yield were observed between the alcohol type and the alcohol/water ratio used.

3.5. Mucilage analysis

The mucilage moisture content was between 5.6% and 6.2% (Table 3). The average was 5.9%, similar to the 5.2% obtained in the first trial.

On the other hand, the protein content (Table 3) was very similar among the treatments and fluctuated from 6.7% to 7.5%, with no statistical difference between them. The average was 7.2%, very similar to the value 7.6% obtained in Trial 1. Lecaros (1997) reported 4.4% for 2–3-year-old flour cladodes and Pimienta (1990) reported up to 6.15% in 3-month old cladodes. All the values are relatively high compared with references. This is possibly due to the method used in this study (micro-Kjeldahl), which determined the total nitrogen content of the sample not the nitrogen solely from protein.

The ash content present in the mucilage ranged between 36.7% and 38.1%. The average went from 37.3%, very similar to the 39.3% reported in Trial 1, and greater than the 12% obtained by Fluxá (1991) in the peel. The reasons that may explain this large difference could be the influence of several factors in the mucilage composition (Pimienta, 1990), such as the soil, the species, as well as the complex phenomena related to plant nutrition (Villarreal et al., 1963).

The percentages of nitrogen, fell in a range from 1.07% to 1.2%, with no statistical differences. The average content was 1.2%, similar to the 0.87% and 1.1% determined in *O. f. indica* by McGarvie and Parolis (1981), in accordance with those reported in Trial 1. Comparing the nitrogen content in the treatments T1 and T3 (ratio extract/alcohol 1:3)

Table 3
Mucilage yield and chemical composition (g/100 g f.w.) (Trial 2)

| Treatment | Yield fresh weight basis (%) | Yield dry weight basis (%) | Moisture | Protein | Ash | Nitrogen** | Calcium** | Potassium** |
|---|------------------------------|----------------------------|------------|------------|-------------|------------|-----------|-------------|
| T1 (ethanol 95°, ratio extract:alcohol = 1:3) | 1.51 a*±0.1 | 20.90 a±3.2 | 6.0 a*±0.1 | 7.5 a*±0.1 | 36.8 a*±1.0 | 1.02 | 8.3 | 1.15 |
| T2 (ethanol 95°, ratio aqueous extract:alcohol = 1:4) | 1.58 a±0.0 | 21.90 a±3.4 | 6.0 a±0.4 | 7.4 a±0.1 | 37.6 a±3.5 | 1.18 | 8.7 | 1.47 |
| T3 (isopropyl alcohol, ratio aqueous extract:alcohol = 1:3) | 1.36 a±0.1 | 18.80 a±4.2 | 6.2 a±0.1 | 6.7 a±0.3 | 38.1 a±2.5 | 1.07 | 8.2 | 1.15 |
| T4 (isopropyl alcohol ratio aqueous extract:alcohol = 1:4) | 1.58 a±0.1 | 21.90 a±3.9 | 5.6 a±0.2 | 7.3 a±0.2 | 36.7 a±2.0 | 1.17 | 8.0 | 1.47 |

*Different letters indicate significant differences ($p \leq 0.05$).

**Compound sample.

(Table 3), the content was slightly higher in the mucilage precipitated with ethanol as compared to the isopropyl alcohol. But it seems that this characteristic is lost when the volumes of alcohol used increased, since in the treatments T2 and T4 (ratio 1:4), the values tend to be similar (Table 3).

The calcium content was similar among the different treatments, varying from 8.0% to 8.7%, with an average of 8.3%, a value higher than that reported by Pimienta (1990), which fluctuated between 5% and 9.5%, but which was lower than the value obtained in Trial 1.

The potassium content was 1.2%, inferior to the 1.8% obtained in Trial 1 but nearer to the 1% content reported by Nobel (1983), who worked with cladodes 6 months old.

3.6. Mucilage colour

No significant differences among treatments were found for mucilage colour. Table 4 shows the colour parameters. L^* value was higher in all the treatments and reflects a high clarity in the colour of the mucilage. The chromaticity is located in the yellow-greenish spectrum; the same tendency was observed in Trial 1.

4. Conclusions

- Mucilage yield from *O. f. indica* pads was not affected by the ratio of pad/water used during the extraction protocol, nor by the temperature, processing time or type of alcohol used in the precipitation.
- The chemical composition of the mucilage extracted by different methods did not present significant differences. Consequently, the use of isopropyl alcohol is recommended in ratio 1:3, since its commercial value is lower in comparison with ethanol. In a large-scale system, this would imply a cost reduction in the extraction process.

Table 4
Color parameters of different mucilage treatment (Trial 2)

| T* | L* | a* | b* | H* | C* |
|----|---------------|---------------|---------------|---------------|---------------|
| T1 | 76.3 a* ± 1.6 | -0.4 a* ± 0.4 | 10.2 a* ± 1.0 | 10.3 a* ± 1.0 | 91.1 a* ± 2.1 |
| T2 | 79.7a ± 1.5 | 0.4 a ± 0.3 | 10.4 a ± 0.5 | 10.5 a ± 0.5 | 87.8 a ± 1.9 |
| T3 | 79.7 a ± 1.2 | -0.2 a ± 0.1 | 11.6 a ± 0.4 | 11.6 a ± 0.4 | 91.0 a ± 0.5 |
| T4 | 79.8 a ± 0.8 | -0.2 a ± 0.3 | 11.5 a ± 0.4 | 11.5 a ± 0.4 | 91.2 a ± 1.4 |

*Different letters indicate significant differences ($p \leq 0.05$).

L* = lightness; a* = red (+) or green (-) direction; b* = yellow (+) or blue (-) direction.

C* = chroma and H* = hue angle.

- The colour and purity of the nopal mucilage was not affected by the extraction conditions studied.

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