Chemical, biochemical, and fatty acids composition of seeds of *Opuntia boldinghii* Britton *et* Rose[£]

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Received 17 November 2008, Accepted 31 January 2009

Abstract

Opuntia boldinghii Britton and Rose, is a Cactaceae distributed in Venezuelan semiarid and coastal regions. In this research, the proximate composition showed: moisture 7.66%; ethereal extract 5.53 g/100g; protein (N x 6.25) 2.89 g/100g; total ash 2.53 g/100g; crude fiber 16.26 g/100g. Minerals determined were: calcium 0.59 mg/100g; phosphorus 24.93 mg/100g; potassium 2.80 mg/100g; iron 1.34 mg/100g. Total carotenoids value was 0.92 mg/100 and vitamin C concentration was 4.15 mg ascorbic acid/100g. Caloric value was calculated at 349.07 Kcal. Antinutritional factors present were: total tannins 0.33%; condensed tannins 0.08% of leucocyanidin equivalent; trypsin inhibitors units 25.26 mg pure inhibited trypsin/g and non-detected saponins. Fatty acids profile showed: linoleic 67.20%; oleic 18.00%; palmitic 10.40%; stearic 3.00%; palmitoleic 0.50%. *In vitro* protein digestibility was 28.15%. In conclusion, *O. boldinghii* seeds are an important source of natural fiber and, given its high linoleic acid content, its oils can be used as a nutraceutic agent.

Key words: antinutritional factors, bromatological analysis, cactus seeds, fatty acids, minerals, *Opuntia boldinghii*.

Introduction

Cacti are an important resource in semiarid zones. In these regions, fruits and stems are consumed directly as food or as forage, and are used for making marmalade, drinks and syrup. On the other hand, cacti fruits are sources of natural coloring substances (Dominguez-Lopez, 1985; Saenz *et al*., 1998; Ruiz-Feria *et al*., 1998; Sepúlveda *et al*., 2000; Viloria-Matos and Moreno-Alvarez, 2001; Moreno-Alvarez *et al*.,2003). The Cactaceae family is a botanical group of the new world and Mexico is the country with the largest center of diversity of this family (Ortega-Niebla *et al*., 2001). Its importance lies in the fact that there is evidence of it being a pre-Hispanic food and its current potential in the food and pharmaceutical industries (Ruiz-Feria *et al*., 1998; Moreno-Alvarez *et al*., 2003). In Venezuela, cacti have little commercial utility even though they show great food potential and its agricultural requirements are scanty. The Cactaceae family is represented by columnar species with rounded and creeper-like forms constituting food for bats (Soriano *et al*., 1991; Sosa and Soriano, 1996), birds (Fleming and Sosa, 1994), and humans (Dominguez-Lopez, 1985).

The *Opuntia* genus is a member of Cactaceae family and in Venezuela is represented by the following species: *O. bisetosa* Pittier; *O. boldinghii* Britton and Rose; *O. caracasana* Salm-Dyck; *O. caribaea* Britton and Rose; *O. crassa* Haw (excluded because it is considered to be an ecotype of *O. caracasana* Salm-Dyck); *O. curassavica* (L.) Miller; *O. depauperata* Britton and Rose; *O. schumannii* Weber and *O. elatior* Miller (Trujillo and Ponce, 1988). The species *O. lilae* has been added to the list, with three new species remaining to be described. This would bring the species to a total of twelve (Baltasar Trujillo, personal communication of 31/05/2004), and distributed as natural elements of semiarid ecosystems. *O. boldinghii* Britton and Rose is a cactus plant originating in semiarid regions, especially along the Venezuelan coastline (Ponce, 1989).

Studies of *O. boldinghii* fruits have shown the presence of betalain-type pigments (betacyanins and betaxanthins) (Viloria-Matos *et al*., 2002). Proximate analyses have also been performed both on fruits and on cladodes (Moreno-Alvarez *et al*., 2006). There is, however, no information on the chemical antinutritional composition of the fatty acids profile of seeds to allow this scantily-exploited species to be put to appropriate use.

Materials and methods

Sample collection and preparation

Opuntia boldinghii Britton and Rose fruits were collected in the sector "La Sabana", along the national highway to Urama village (at approximately two kilometers from the Simón Rodriguez University), in Carabobo State (Bolivarian Republic of Venezuela). Fruit samples were taken from ten different plants pursuant to the criteria set forth by Viloria-Matos and Moreno-Álvarez (2001) for fruits of the same species. The samples were transported in thermally insulated containers at a temperature of 7±1 ºC. Fruits were washed and thorns were removed. Later, the pulp was separated using an Eastern Electric®, Model JX5000 unit and the seeds were obtained. The seeds were grounded in a VEM, Model TGL-3324 unit and subsequently dried by forced convection in a Felisa®, Model FE-294AD stove (temperature 45±1 ºC for 72 hours).

Proximate seed analysis

Moisture content, protein, ethereal extract, ash, and crude fibre were analyzed according to AOAC (1990) methods.

Mineral, total carotenoids and vitamin C contents

Minerals constituents (Ca, P, K and Fe) were determined according to AOAC (1990) methods: Ca, K and Fe using an atomic absorption spectrophotometer (PERKIN ELMER®, Model 3100), and phosphorus (P) content was determined by the phosphomolybdate method. Total carotenoids were evaluated following the methodology indicated by Moreno-Álvarez et al. (1999). Vitamin C content was determined by application of the 2.6 dichloroindophenol volumetric method (AOAC, 1990).

Caloric content

Caloric content was calculated by application of the model established by Bognár and Piekarski (2000).

Antinutritional factor analysis

Total tannins content was analyzed by application of the procedure established by Arogba (2000). Condensed-tannins evaluation (Leucocyanidin equivalent %) was performed by the procedure described by Porter et al. (1986). Trypsin inhibitors were determined according to the methodology indicated by Hamerstrand and Black (1981). The presence of saponins was determined by application of the methodology described by Albornoz (1980).

***In vitro* digestibility**

In vitro digestibility of protein was evaluated by application of the methodology described by Tilley and Terry (1963).

Fatty acids composition of seed oil

The composition of fatty acids was determined through gas chromatography using a HEWLETT-PACKARD, Model 5730 gas chromatograph with a flame ionization detector, glass column (with an external diameter of 10mm, internal diameter of 2mm, and length of 1.82 m), 10% GP-SP 23.30 fill, and Chromosorb 100/120 WAW support, detector temperature at 250 ºC, programmed temperature of 160 ºC for two min and 180 ºC for sixteen min at a temperature gradient of 4 ºC/min. Fatty acid patterns were used for the respective comparison.

Results and discussion

The proximate composition of the seeds is shown in Table 1. Ether extract (5.53%), protein (2.89%), ash (2.53%), and raw fiber (16.26%) content are similar to findings of Domínguez-López (1995) for *Opuntia ficus indica* seeds. However, Lamghari *et al*. (1998) and Sawaya *et al.* (1983) reported the following values for the same species: ethereal extract 6.77-17.20%; protein 11.80-16.60% and ashes 5.90-3.00%, which were higher than the values reported in this study. Nevertheless, the values, show differences with respect to the species: *O. heliabravoana*; *O. xoconostle;* and *O. elatior* (Moreno-Alvarez *et al*., 2007; Prieto-García, 2006).

The nutritional composition of *O. boldinghii* seeds is shown in Table 2. Calcium (0.59 mg/100g), phosphorus (24.93 mg/100g), iron (1.34 mg/100g), and potassium (2.80 mg/100g) contents are similar to those reported by Domínguez-López (1995) for *O. ficus indica* seeds, but different from those reported by Prieto-García *et al*. (2006) for *O. heliabravoana* and *O. xoconostle*. Total carotenoids value (0.92 mg/100g) is higher that the value reported by Moreno-Álvarez *et al*. (2003) for the pulp of the same species. Vitamin C content (4.15 mg/100g) is lower than the content reported for *O. boldinguii* pulp and cladodes (Moreno-Alvarez *et al*., 2006). Energy (349.07 Kcal) is similar to that indicated by Moreno-Álvarez *et al*. (2007) for *O. eliator* seeds.

Table 1. Chemical composition *O. boldinghii* (mean, g/100g ± SD).

Moisture	Ether extract	Protein	Ash	Crude fibre
7.66±0.06	5.53±0.16	2.89±0.15	2.53±0.16	16.26±0.76

n=3 samples, per triplicates

Table 2. Nutritional composition of *O. boldinghii* seeds (mean ± SD).

Parameter	Value
Calcium (mg/100g)	0.585±0.004
Phosphorus (mg/100g)	24.93±0.03
Potasium (mg/100g)	2.80±0.01
Iron (mg/100g)	1.341±0.010
Total Carotenoids (mg/100g)	0.918±0.010
Vitamin C (mg/100g)	4.15±0.08
Energy (Kcal)	349.07±0.23

n=3 samples, per triplicates.

Table 3 contains the results of the evaluation of some antinutritional factors. Total tannins content (0.33%) is lower than that reported by Caramori *et al*. (2004) for total tannins in *Hymenaea courbaril* (0.39%), but similar to the findings of León *et al*. (1993) in certain leguminous plants (*Vigna unguiculata* and *Cajanus cajan*). The percentage of condensed tannins (0.08% of Leucocyanidin equivalent) is lower than the percentage reported by González–Gómez et al. (2006) for mango and certain leguminous plants. The chemical structure of condensed tannins allows them to join to the polysaccharides, mineral, proteins, and enzymes involved in digesting the aforementioned compounds (Otero and Hidalgo, 2004). If tannins occur in high concentrations, they can have a negative influence on the processing within the intestinal tract. In the case of *O. boldinghii* seeds, condensed tannins levels are low and could increase intestinal absorption of protein (Gonzalez-Gómez et al., 2006).

Trypsin inhibitor concentrations of 25.26 mg pure trypsin inhibition/g sample (TIU) were found. This is an acceptable value but is below the lowest value of the range reported by Ortega-Nieblas et al. (2001) who determined values of 54-66 mg pure trypsin inhibition/g of sample for Sonora desert cactus, and below the value reported for soy seeds (82 mg trypsin/g of sample). Saponins were not detected, and this result is similar to that obtained by Ortega-Nieblas et al. (2001) for certain columnar-cacti species (*Stenocereus gummosus*, *Pacchycereus pecten-aboriginum, and Paclycereus pringlei*). The *in vitro* digestibility value (28.15%) found was comparatively lower than the established Standards for casein (91.0%), certain columnar-cacti species (77-84%) (Ortega-Nieblas *et al*., 2001), and *O. ficus indica* (77 %) (Sawaya *et al*., 1983).

Table 3. Antinutritional components of seeds (media ± SD).

Total Tannins (%)	Condensed Tannins *	TIU**(Trypsin inhibition UNITS)	Saponins
0.33±0.01	0.08±0.01	25.26±0.01	ND

n=3 samples, per duplicates
* Leucocyanidina equivalent (%)
**mg pure tripsin inhibited/g
ND = not detected.

The composition of fatty acids in the lipid fraction of oil is shown in Table 4. Linoleic acid (67.2%) was the acid with greatest concentration followed by oleic acid (18.0%). Among the saturated acids, palmitic acid (10.4 %) was most prevalent. Similar values for linoleic acid (70.3 and 74.8%), oleic acid (16.8 and 12.8%), and palmitic acid (9.32 and 7.21 %) were published by Monia et al. (2005) for *O. ficus indica* and *O. stricta*, respectively. In comparison to the composition of conventional edible vegetable oils, cactus-seed oil surpasses the linoleic acid content of soy oils (*Glicyne max*) (49.7%), corn oils (*Zea mays*) (47.7%), sesame oils (*Sesamun indicum*) (44.5%), sunflower oils (*Helianthus annus*) (49.7%), and cotton oils (*Gossypium hirsutum*) (50.0%) (Astiasarán and Candela, 2000). For these reasons they can be included in the group of low-palmitic-acid and high-linoleic-acid content oils, an aspect that allows us to recommend the oil under study as a possible nutraceutic agent (Piga, 2004). It has previously been reported that linoleic acid is likewise present at higher concentrations in other genera of the Cactaceae family, i.e. 50-53 % (Ortega-Nieblas, 2001). This research showed an even higher percentage (67.2%).

Table 4. Fatty acids composition of *O. boldinghii.*

Fatty acid	Percentage of fatty acids to total fatty acids
Palmitic (C 16: 0)	10.4±0.1
Palmitoleic (C 16: 1)	0.5±0.1
Stearic (C 18: 0)	3.0±0.1
Oleic (C 18: 1)	18.0±0.1
Linoleic (C 18: 2)	67.2±0.1
Linolenic (C 18: 3)	0.3±0.1
Arachidic (C 20: 0)	0.3±0.1
Gadoleic (C 20: 1)	0.4±0.1

n = 2 samples, per duplicates.

Conclusions

This study show that *Opuntia boldinghii* seeds are a viable alternative for use in the Venezuelan food industry because they are a source of fiber and can also be used as flour in the formulation of processed foods. The higher linoleic-acid proportion of this oil allows it to be used as a nutraceutic agent.

Acknnowledgement

The authors thank the FONACIT-UNESR Pem 2001002271 Project for their financing of this paper.

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