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Characterization of two prickly pear species flowers growing in Tunisia at four flowering stages

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ABSTRACT

Opuntia flowers belonging to two species of prickly pear were evaluated at four flowering stages: vegetative, initial flowering, full flowering and post-flowering stage, for possible use as a potential source in the food enrichment. Chemical composition including moisture, ash, protein, fat, soluble sugars, total fibers, mineral amounts and fatty acid profiles of *Opuntia ficus-indica* and *Opuntia stricta* flowers were investigated. Functional properties (swelling capacity (SWC), water holding capacity (WHC), water solubility index (WSI) and oil holding capacity (OHC)) were also studied. Results showed that during the maturation of flowers, there is a decrease in protein contents whereas fat contents increase, for both species. High minerals amounts were noticed in *Opuntia* flowers and they can be considered as an excellent source of minerals. The fatty acids profiles were dominated by the palmitic acid (38–59%). The techno-functional properties (SWC, WSI, WHC and OHC) were found to be important and they can be modulated according to the temperatures. Owing to its chemical profile and functional properties, *Opuntia* flowers could be used as an ingredient to improve different physical and nutritional properties of foods.

1. Introduction

About 1500 species of cactus, belonging to the *Opuntia* genus are native to Mexico and widespread throughout Central and South America, Australia, South Africa, and the whole Mediterranean area (Hegwood, 1990). *Opuntia ficus-indica* and *Opuntia stricta* derived from *Cactaceae* family, and their fruits are the cactus pears. This plant grows wild in arid and semi-arid regions, where the production of more succulent food plants is severely limited. Many uses of different parts of *Opuntia* are reported (Hoffmann, 1980). The cladodes are consumed as fresh vegetables or added to casseroles (Hamdi, 1997; Saenz, 2000). In addition, they have been investigated as a possible treatment for gastritis, hyperglycemia, arteriosclerosis, diabetes, and prostatic hypertrophy (Frati-Munari, Jimenez, & Ariza, 1990; Hegwood, 1990; Palevitch, Earon, & Levin, 1993). Studies showed also the potential textural properties of cactus cladodes for the food industry (Ayadi, Abdelmaksoud, Ennouri, & Attia, 2009; Sepúlveda, Saenz, Aliaga, & Aceituno, 2007). The fruits are used for the manufacture of food products such as juices (Espinosa, Borrocal, Jara, Zorilla, & Medina, 1973), alcoholic beverages (Bustos, 1981), jams (Sawaya, Khatchadourian, & Almuhammad, 1983), and natural liquid sweeteners (Saenz, Arriagana, Fizsman, & Calvo, 1996). Moreover, nutritional, biological value and rheological characteristics of seed oil were studied (Ennouri, Bourret, Mondolot, & Attia, 2005; Ennouri et al., 2007).

Opuntia flowers have been traditionally used for medical purposes for a long time. The dried flowers of prickly pear are usually sold on the popular Tunisian markets, and are traditionally used as an infusion to treat kidney stones. To our knowledge, no data were reported concerning both the nutritional aspect of these flowers and their application in food products.

The nutritional and pharmacological benefits of the different parts of the prickly pear, in addition to its increasing importance at the industrial level, have motivated our investigation about the chemical contents of the flowers which are less known. Previous study of De Léo, De Abreu, Pawlowska, Cioni, and Braca (2010) describes the chemical content of *O. ficus-indica* flowers methanol extract. Also, a recent study shows the antiulcerogenic activities of *Opuntia inermis* flowers (Alimi, Hfaiedh, Bouoni, Sakly, & Ben Rhouma, 2011). In addition, the hexane extract and antibacterial

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Table 1
Proximate analysis of *Opuntia ficus-indica* and *Opuntia stricta* flowers during four flowering stages.

Species	Flowering stage	Moisture[a]	Ash[b]	Soluble sugars[b]	Total fiber[b]	Protein[b]	Fat[b]	Carbohydrates[b]	Energy[c]
Opuntia ficus- indica	(A)	81.5 ± 0.4^{ax}	1.6 ± 0.0^{ax}	0.5 ± 0.0^{ax}	54.1 ± 5.2^{ax}	16.7 ± 0.78^{ax}	1.8 ± 0.24^{ax}	26 ± 4.8^{ax}	185.1 ± 21.9^{ax}
	(B)	83.8 ± 0.4^{bx}	1.4 ± 0.3^{ax}	1.4 ± 0.2^{bx}	50.4 ± 4.6^{ax}	15.4 ± 0.7^{bx}	3.79 ± 0.19^{bx}	29.0 ± 4.0^{ax}	212.9 ± 17.6^{abx}
	(C)	84.6 ± 0.2^{cx}	1.5 ± 0.1^{ax}	9.3 ± 0.7^{cx}	41.4 ± 2.4^{bx}	13.1 ± 0.9^{cx}	2.27 ± 0.19^{ax}	41.7 ± 3.1^{bx}	240.8 ± 10.9^{bx}
	(D)	20.3 ± 0.1^{dx}	9.0 ± 0.8^{bx}	5.9 ± 0.5^{dx}	45.7 ± 2.6^{abx}	5.7 ± 0.35^{dx}	3.8 ± 0.85^{bx}	35.9 ± 2.1^{bx}	206.3 ± 3.9^{ax}
Opuntia stricta	(A)	83.6 ± 0.3^{ay}	1.5 ± 0.0^{ax}	4.0 ± 0.6^{ay}	53.5 ± 4.9^{abx}	13.5 ± 0.84^{ay}	1.5 ± 0.43^{ax}	30.4 ± 5.9^{abx}	184.7 ± 21.1^{abx}
	(B)	85.9 ± 0.3^{by}	1.5 ± 0.1^{ax}	3.9 ± 0.3^{ay}	49.5 ± 4.5^{ax}	9.01 ± 0.95^{by}	2.16 ± 0.24^{by}	37.8 ± 4.7^{by}	205.6 ± 16.4^{bx}
	(C)	88.3 ± 0.2^{cy}	1.2 ± 0.1^{by}	14.9 ± 0.4^{by}	54.1 ± 5.0^{aby}	10.1 ± 0.13^{cy}	1.2 ± 0.32^{ay}	33.5 ± 5.1^{aby}	182.8 ± 22.1^{aby}
	(D)	24.3 ± 0.3^{dy}	6.3 ± 0.4^{cy}	1.4 ± 0.7^{cy}	58.8 ± 1.8^{aby}	5.6 ± 0.82^{dy}	3.4 ± 0.27^{cx}	26.1 ± 2.1^{ay}	157.9 ± 6.0^{ay}

(A) Vegetative, (B) initial flowering, (C) full flowering and (D) post-flowering stage.
Values are expressed as mean ± standard deviation, $n = 3$.
Means followed by the same letter in the same column are not significantly different at $P > 0.05$, Duncan test.
a, b, c, d: are used to compare stages for the same species.
x,y: are used to compare the same stage for the two species.
[a] results are expressed in g per 100 g of fresh weight.
[b] results are expressed in g per 100 g of dry weight.
[c] energy is expressed in kcal per 100 g of dry weight.

activity of *O. ficus-indica* and *O. stricta* were investigated based on our previous contribution (Ammar, Ennouri, Khemakhem, Yangui, & Attia, 2012).

The aims of the present study were firstly to characterize the flowers belonging to two *Opuntia* species at four flowering stages regarding proximate composition, minerals, dietary fibers and fatty acids in order to explore the nutritional properties during different developmental stages. Secondly, some functional properties (such as water holding capacity, swelling capacity and oil holding capacity) were investigated because of their importance in relation to the functionality and nutritional quality in food applications. The results may contribute to improve the value of these flowers and may also provide an advanced knowledge about their uses in the food products.

2. Materials and methods

2.1. Origin of the flowers

O. ficus-indica and *O. stricta* flowers were collected from wild populations located in the region of Sfax, Tunisia (latitude 34°46′29″N, longitude 10°39′73″E; elevation: 41 m), where the climate is semi arid and is characterized by a mean rainfall of 200 mm/year. Samples were gathered during vegetative (A), initial flowering (B), full flowering (C) and post-flowering (D) stages during the period extending from May to June, 2010. The degree of flower maturity was determined on the basis of flower size, opening and coloring. In vegetative stage (bud developing), we have green closed petal flowers. In initial flowering stage, flowers are yellowish to orange; stamens are grouped together around the style in the beginning and become separated in the full flowering stage. The flower is in full when its color is bright yellow, it exhibits larger shape than that of the other flowering stages and starts nectar production. In the post-flowering stage, the flower becomes closed and dry (flower senescing).

Opuntia flowers are of variable size from 3 up to 10 cm long according to the progression of flowering. Floral development from bud to anthesis requires between 20 and 40 days. Harvesting of *O. ficus-indica* for vegetative and initial flowering stage is taking place in the period ranging from 20 to 25 May. The flowers at full flowering stage were harvested in the beginning of June. For *O. stricta* the harvesting period starts in the middle of June for the first three stages. For the post-flowering stage, flowers for both species, were collected in the last week of June.

2.2. Processing of flowers for analysis

Whole flowers were collected in one batch in the same sampling area at every developmental stage. Samples were classified and separated according to species and flowering stage. Each collected group was processed separately. The plant authenticity and the selection of the flowering stages were evaluated in the Alimentary Analysis Laboratory of the National Engineering School of Sfax, Tunisia.

Flowers were processed immediately after their harvest. The flowers samples were selected, cut into small pieces, and the initial moisture content was analyzed as shown in the Table 1. Then the flowers were stored at −20 °C until analysis.

Table 2
Mineral content of *Opuntia ficus-indica* and *Opuntia stricta* flowers during four flowering stages (mg/100 g of dry weight basis).

Species	Flowering stage	Ca	Fe	K	Mg	Na	Zn
Opuntia ficus indica	(A)	394.0 ± 15.6^{ax}	4.2 ± 0.7^{ax}	2238.6 ± 46.1^{ax}	397.3 ± 10.6^{ax}	76.7 ± 4.6^{ax}	3.5 ± 0.9^{ax}
	(B)	400.4 ± 10.2^{bx}	9.5 ± 0.3^{bx}	2386.4 ± 38.1^{bx}	329.8 ± 21.7^{bx}	83.5 ± 3.9^{ax}	3.8 ± 0.2^{abx}
	(C)	770.1 ± 32.6^{cx}	9.5 ± 2.1^{bx}	2278.7 ± 16.4^{ax}	429.4 ± 10.2^{cx}	137.2 ± 4.3^{bx}	3.6 ± 0.8^{abx}
	(D)	651.9 ± 21.8^{dx}	12.4 ± 1.1^{cx}	1255.9 ± 61.5^{cx}	280.7 ± 73.1^{bx}	117.9 ± 5.7^{cx}	2.4 ± 0.9^{acx}
Opuntia stricta	(A)	777.8 ± 61.2^{ay}	3.7 ± 0.1^{ax}	2028.3 ± 86.3^{ay}	400.7 ± 26.5^{axy}	75.8 ± 10.7^{ax}	2.5 ± 0.4^{ay}
	(B)	834.9 ± 43.4^{bx}	12.8 ± 2.6^{by}	1995.8 ± 50.1^{acy}	513.5 ± 33.3^{by}	134.4 ± 8.7^{by}	3.4 ± 0.6^{bx}
	(C)	718.1 ± 51.1^{cy}	14.1 ± 0.8^{by}	2077.2 ± 10.4^{ady}	465.9 ± 7.8^{cy}	95.1 ± 1.3^{cy}	2.9 ± 0.4^{abx}
	(D)	854.9 ± 73.8^{by}	13.8 ± 0.6^{bx}	1459.9 ± 45.5^{by}	464.2 ± 11.3^{cy}	139.7 ± 11.1^{by}	1.5 ± 0.2^{cy}

(A) Vegetative, (B) initial flowering, (C) full flowering and (D) post-flowering stage.
Values are expressed as mean ± standard deviation, $n = 3$.
Means followed by the same letter in the same column are not significantly different at $P > 0.05$, Duncan test.
a, b, c, d: are used to compare stages for the same species.
x,y: are used to compare the same stage for two species.