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EVALUATION OF THE PHYTOCHEMICAL COMPOSITION AND THE ANTIOXIDANT ACTIVITY OF CACTUS PEAR FLOWERS AND FRUIT DERIVATIVES

BOUSBIA Nabil[1*], MAZARI Azzedine[2], LAMOUDI Lynda[3], AKRETCHE-KELFAT Soraya[1], CHIBANE Naffisa[1] and DIF Mohamed Elamine[1]

1. Université des Sciences et Technologies Houari BOUMEDIENE (USTHB) – Faculté de Génie Mécanique et Génie des Procédés – Laboratoire des sciences de génie des procédés industriels – Algérie
2. Institut National de la Recherche Agronomique d'Algérie (INRAA) – Station de Mahdi Boualem Baraki – Division de Recherche Technologie Agroalimentaire – Algérie
3. Université des Sciences et Technologies Houari BOUMEDIENE (USTHB) – Faculté de Génie Mécanique et Génie des Procédés – Laboratoire de recherche de phénomène de transfert – Algérie

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Abstract

Description of the subject: Evaluate the phytochemicals and antioxidant activity of the peels, flowers and seeds of *Opuntia ficus-indica* L.
Objective : Valorization of bioactive compounds of cactus pear from Sidi Fredj (Souk-Ahras, Algeria).
Methods : Various organic extracts of the three parts of the plant have been the subject to determine the content of total polyphenols, flavonoids and betalains as well as a study of their antioxidant activities by DPPH test, FRAP and by phosphomolybdenum test (TAC).
Results : Quantitative analysis of phenolic compounds showed that flower extracts have the highest content of phenolic compounds and flavonoids. In addition, the peels have a high content of betalains. As for the evaluation of antioxidant activity, the flowers and seeds showed considerable DPPH free radical scavenging power. On the other hand, the peel extracts revealed an important total antioxidant capacity and a consequent ferric iron reducing power.
Conclusion : *Opuntia ficus-indica* peels, flowers and seeds are rich in antioxidants and hold high antioxidant activity.
Keywords : *Opuntia ficus-indica* L.; Betalains; Phenolic compounds; Antioxidant activity; Sidi Fredj (Souk-Ahras, Algeria).

ÉVALUATION DE LA COMPOSITION PHYTOCHIMIQUE ET DE L'ACTIVITÉ ANTIOXYDANTE DES FLEURS ET DÉRIVÉS DE FRUITS DU FIGUIER DE BARABARIE

Résumé

Description du sujet : Evaluer les composés phytochimiques et l'activité antioxydante des pelures, fleurs et graines de l'*Opuntia ficus-indica* L.
Objectifs : Valorisation des composés bioactifs la figue de barabarie de Sidi Fredj (Souk-Ahras, Algérie).
Méthodes : Divers extraits organiques des trois parties de la plante ont fait l'objet pour déterminer la teneur en polyphénols totaux, des flavonoïdes et bétalaïnes ainsi qu'une étude de leurs activités antioxydantes par test DPPH, FRAP et par le phosphomolybdate (CAT).
Résultats : L'analyse quantitative des composés phénoliques a montré que les extraits des fleurs possèdent la plus haute teneur en composés phénoliques et en flavonoïdes. De plus, les pelures présentent une teneur élevée en bétalaïnes. Quant à l'évaluation de l'activité antioxydante, les fleurs et les graines ont montré un pouvoir de piégeage des radicaux libres DPPH considérable. D'autre part, les extraits de pelures ont révélé une capacité antioxydante totale importante et un pouvoir réducteur du fer ferrique conséquent.
Conclusion : les pelures, fleurs et graines d'Opuntia ficus-indica sont riches en antioxydants et détiennent une forte activité antioxydante.
Mots clés: *Opuntia ficus-indica* L.; Bétalaïnes; Composés phenolics ; Activité antioxydante ; Sidi Fredj (Souk-Ahras, Algérie).

* Auteur correspondant: BOUSBIA Nabil, E-mail: nbousbia@usthb.dz

INTRODUCTION

The interest in cactus pears dates back thousands of years. In addition, this plant has aroused the curiosity of many researchers since the last decade, wanting to unravel its mysteries and discover its potential. Its capacity to evolve in dry and hot climates makes its exploitation particularly interesting. Especially since arid zones cover 40% of the world's land surface and are home to more than two billion people [1].

In addition, more and more studies are nowadays looking for natural ingredients and healthy foods which go beyond nutritional values and which are beneficial for health. The cactus pear seems to fulfill all the characteristics necessary to be considered a healthy food with multiple virtues. Indeed, it conceals many powers and interesting properties both in the medical, food, cosmetic and energy fields. It helps prevent human health from certain degenerative diseases such as cancer, diabetes, hypercholesterolemia, atherosclerosis and gastric diseases [2].

Moreover, it is a fast-growing plant with potential utility in the production of biogas and biofuels but also in the fight against desertification and soil rehabilitation [3]. The cultivation of this plant therefore seems to be a promising avenue for the future.

The oxidative stress induces damage to the genes of each cell of human body continuously [4, 6]. These lesions must be constantly repaired so that they do not set up as permanent mutations [7, 8]. The antioxidant activity of the cactus pear is reported to be twice that of pear, apple, tomato, bananas and white grapes and similar to that of pink grapefruit, red grape and orange [9].

The objective of the present study was to assess qualitatively and quantitatively the presence of bioactive phytochemicals in the derivatives of this fruit, which constitute peels, flowers and seeds. These by-products represent the major part of the fruit with 60% of the total weight [10] and are very little exploited and often considered as waste on an industrial scale.

It would therefore be interesting to estimate the potential of bioactive phytochemicals and to analyze their antioxidant activity in order to point out the importance held by these derivatives and to push the reflection towards a valuation of their future use.

MATERIAL & METHODS

1. Description of plant material

Orange fleshed cactus fruits were collected at full maturity, in non-irrigated thornless orchards of [*Opuntia ficus-indica* (L.) mill] in Sidi-Fredj, Souk-Ahras region (Algeria) at an altitude of 747 m, 36°10'23.2 "N latitude and 8°12'17.8" E longitude. The average annual temperature of this zone is close to 15°C, with a pronounced amplitude which can drop to -7°C between December and March (very cold winters) and above 35°C in summer (hot summer). As for the rainfall, it is 221 mm on average [11].

The peels were manually separated from the pulp using a knife. The seeds were separated from the pulp, previously homogenized in a laboratory blender, by sieving using a sieve fitted with a 2 mm mesh. The seeds were washed, then dried at room temperature. The peels were put in plastic food bags and stored at -20°C. The dried flowers were collected from the local market (supplied by an economic operator “Ilefbio”) and were stored at room temperature in airtight containers.

2. Preparation of sample extracts

The peels were thawed and dried in an oven at 45°C, recording the weight of a control sample every hour in order to follow the evolution of the drying process until stabilization of its weight. In order to proceed with the extraction, the samples of peels, seeds and flowers were crushed using a laboratory blender (Waring, USA) into a fine powder. Two grams of sample were macerated in aqueous methanol (80:20, v / v) and allowed to stir at room temperature for 24 hours. The mixture was filtered in order to recover the extract. A second maceration of the residue was carried out under the same conditions for 48 hours. The two extracts were then combined and evaporated using a rotary evaporator (Butchi Rotavapor R-3 model, Germany).The concentrates collected following evaporation were dissolved with ethanol and stored at -20°C until analysis.

3. Phytochemical Analysis

3.1. Determination of total polyphenols content

Phenolic quantification of extracts from peels, flowers and seeds was based on the method of the Folin-Ciocalteu reagent described by Singleton and Rossi [12], using gallic acid as a reference compound.

One mL of sample extract (0.5 mg /mL) was put in a tube and mixed with 0.5 mL of Folin-Ciocalteu reagent and 6 mL of distilled water. The mixture was stirred using a vortex. Then, 1.5 mL of 20 % sodium carbonate (Na_2CO_3) and 1.9 mL of distilled water were added. After a second shaking, the tubes were incubated for 2 hours at room temperature. A blank was prepared with all reagents except the sample. The absorbance was read at 760 nm using a spectrophotometer (Selecta UV, Spain). The quantification of the polyphenols was obtained referring to a standard curve of gallic acid. The results were expressed in mg gallic acid equivalent per 100 g of dry weight (mg GAE /100 g DW). The analysis was repeated three times for each sample.

3.2. Determination of flavonoids content

The flavonoid content of methanolic extracts of peels, seeds and flowers was determined by the method using quercetin as reference molecule according to the protocol reported by Abdel-Hameed [13], with slight modifications. Briefly, one milliliter of sample extract (2mg/mL) was mixed with one milliliter of 2 % aluminum trichloride ($AlCl_3$) reagent and one drop of acetic acid. The mixture was made up to 5 mL with distilled water. After stirring, the incubation took place 40 minutes at room temperature. The blank was prepared following the same procedure without adding the sample. Then, the absorbance was determined at 415 nm. The calibration curve was carried out with quercetin under the same conditions as samples extracts. The results obtained were expressed in milligram quercetin equivalent per 100 grams sample dry weight (mg QE /100 g DW). All determinations were performed in triplicate.

3.3. Determination of betalains content in the peels

The betalains content of the peels was determined by a spectrophotometric method. Ten grams of peels was mixed with 50 mL of distilled water and then stirred for 15 minutes. The aqueous extract was centrifuged at 1660 × g (Sigma centrifuge, Germany) for 10 minutes. The supernatant was subsequently filtered through a 0.45 µm nylon filter [14]. An aliquot (0.5 mL) was collected and appropriately diluted with distilled water. The quantification of the betalains was obtained by reading the spectrophotometric absorbance at 538 nm for the red pigments (betacyanins) and at 480 nm for the yellow pigments (the betaxanthins).

The content of betaxanthins and betalains was calculated as described by Stintzing et *al*. [15], according to the following formula: $\boldsymbol{BC(mg/L) = \frac{A \times DF \times MW \times 1000}{\varepsilon \times L}}$, Where: $\boldsymbol{A}$: Absorbance value , $\boldsymbol{DF}$: Dilution factor, $\boldsymbol{L}$: Cuve thickness in cm (L = 1 cm), $\boldsymbol{MW}$: Molecular weight (308 g/mol for betaxanthins and 550 g /mol for betacyanins), $\boldsymbol{\varepsilon}$: Molar extinction coefficient of betalains (48,000 $L.mol^{-1}$ for betaxanthins and 60,000 $L.mol^{-1}$ for betacyanins).

The results were expressed in mg/g of peels dry weight. The total betalains fraction was obtained by combining the betaxanthins and the betacyanins contents.

4. Evaluation of the antioxidant activity

4.1. DPPH Free radical scavenging activity

The DPPH free radical scavenging assay of *OFI* flowers and fruit derivatives extracts was performed according to the method described by Mazari et *al*. [11]. Briefly, a series of different sample concentrations (2 mL each) was added two mL of 0.1 mM DPPH methanolic solution. The blank was prepared by mixing two mL of methanol with two mL of the methanolic solution of DPPH. The mixtures were incubated for 30 minutes in the dark. Then, the absorbance was determined spectrophotometrically at 517 nm. The experiment was carried-out three times for each sample extract.

DPPH radical scavenging activity was calculated according to the following equation: $\boldsymbol{DPPH\ radical\ scaenging\ activity}\ (\%) = \frac{Ac - As}{Ac} \times \mathbf{100}$, Where: $\boldsymbol{Ac}$: is the absorbance of the control (blank), $\boldsymbol{As}$**:** is the absorbance of the sample.

The free radical scavenging activities of the different concentrations of *OFI* extracts permitted to plot the radical scavenging curves and thus letting to determine the IC_{50} value representing the concentration of the extract capable of scavenging 50% of the DPPH radicals.

4.2. Total antioxidant capacity (phosphomolybdenum test)

Total antioxidant capacity (TAC) was determined using the phosphomolybdenum method as described by Prieto et *al*. [16]. A 0.4 mL intake of the appropriately diluted sample extract was mixed in a test tube with 4 mL of the reagent (0.6 M sulfuric acid, 28 mM phosphate buffer, and 4 mM ammonium molybdate).

The tubes were then incubated at a temperature of 95°C in a water bath for 90 minutes. After cooling, the absorbance was read at 695 nm. Ascorbic acid was taken as the reference compound and was tested under the same operating conditions. Three tests were carried out for each experiment. The total antioxidant capacity was expressed in milligrams of ascorbic acid equivalent per gram of dry weight (mg AAE /g DW).

4.3. Ferric reducing antioxidant power

The reducing power was determined according to a procedure based on the method of Oyaizu [17]. Different concentrations of each sample extract (2 mL) were mixed in test tubes with 2 mL of phosphate buffer (0.2 M, pH 6.6) and 2 mL of a 1% solution of potassium ferricyanide ($K_3Fe(CN)_6$). The mixture was incubated at 50°C in a water bath for 20 min. To terminate the reaction, 2 mL of 10% trichloroacetic acid was added. The test tubes were centrifuged at 3900 rpm for 10 min. After that, 2 mL of the supernatant was recovered in a separate test tube and added 2 mL of methanol and 0.5 mL of 0.1 % solution of iron chloride. Then, the absorbance was read at 700 nm. The test was repeated three times for each experiment.

5. Statistical analysis

All the statistics were performed using the XLSTAT software for Windows.

Mean values obtained for the variables studied in the different groups were compared by one-way ANOVA, assuming that there were significant differences among them when the statistical comparison gives $p < 0.05$. To correctly assess the correlation between the contents of phytochemicals and the antioxidant activity estimated by the parameters SC_{50} and EC_{50}, the constants K (SC_{50}) and K (EC_{50}), which are the inverted fraction of SC_{50} and EC_{50}, were calculated and used in the correlation study.

RESULTS

1. Phytochemical composition of cactus pear flowers and fruit derivatives

1.1. Total polyphenols content

The Table 1 illustrates the average content of total polyphenols in the organs of *Opuntia ficus-indica*. Flowers show a very high content with the value of 737.76 mg GAE /100g DW. A lower content was observed for the samples of peels and seeds with the respective values 136.90 and 115.74 mg GAE /100 g DW. These results demonstrate the abundance of phenolic compounds in the cactus flowers compared to peels and seeds. They include a value six times greater than in the seeds.

Table 1 : Phytochemical content and antioxidant activity of cactus pear derivatives.

	Flowers	Peels	Seeds
Polyphenols (mg GAE /100 g DW)	737.76 ± 28.85^a	136.90 ± 53.77^b	115.74 ± 2.62^b
Flavonoids (mg QE /100 g DW)	75.05 ± 3.94^a	7.53 ± 0.06^b	3.99 ± 0.31^b
Betacyanins (mg /g DW)	n.d.	4.18 ± 0.23	n.d.
Betaxanthins (mg /g DW)	n.d.	6.76 ± 0.08	n.d.
Total betalains (mg /g DW)	n.d.	10.94 ± 0.19	n.d.
DPPH SC_{50} (mg /mL)	0.37 ± 0.004^a	3.34 ± 0.006^b	0.35 ± 0.09^a
FRAP EC_{50} (mg /mL)	1.46 ± 0.07^a	15.29 ± 0.12^c	1.65 ± 0.08^b
Total antioxidant capacity (mg AAE /g DW)	12.89 ± 1.67^b	19.36 ± 0.52^a	6.44 ± 0.83^c

In each row different letters mean significant differences and constitution of homogeneous group ($p<0.05$). n.d. : not determined

1.2. Flavonoids content

In the light of the obtained results and compared to the derivatives of the fruit, the flowers had the highest content of flavonoids with a value of 75.05 mg QE /100g DW. This content is significantly higher than the flavonoid content of the peels and seeds with respective values of 7.53 and 3.99 mg QE /100 g DW.

1.3. Betalains content

The analyzed peel extract contained more betaxanthins than betacyanins with the respective contents of 6.76 and 4.18 mg /g DW. The total betalains content was 10.94 mg/g DW. The predominance of betaxanthins is at the origin of the yellow-orange color of the peel.

2. Antioxidant activity of cactus pear flowers and fruit derivatives

2.1. DPPH Free radical scavenging activity

The DPPH test was used to evaluate the radicals scavenging activity of methanolic extracts of seeds, peels and flowers of *Opuntia ficus-indica* against DPPH free radicals. This capacity was estimated by the SC_{50} parameter representing the concentration of the extract capable of scavenging 50 % of the DPPH free radicals.

The results obtained show that the flowers and the seeds exhibit the greatest free radical scavenging activity with very close SC_{50}, namely, 0.37 and 0.35 mg /mL, respectively.

2.2. Total antioxidant capacity

The determination of the total antioxidant capacity by the phosphomolybdate test revealed a highest capacity for cactus pear peels with a value of 19.36 mg AAE/g DW, and a relatively high capacity in the flowers with 12.89 mg AAE /g DW. In addition, the seeds showed the lowest antioxidant capacity with 6.44 mg AAE /g DW.

2.3. Ferric reducing antioxidant power

The reducing power of ferric iron (FRAP) is a revealing indicator of the antioxidant potential. The reducing capacities of extracts from the peels, seeds and flowers of *Opuntia ficus-indica* were expressed in mg /mL in terms of the median effective concentration EC_{50}. The results obtained (Table 1) testify to a high reducing power of ferric iron by the extracts of flowers and seeds with the respective values of 1.46 and 1.65 mg /mL. This capacity is ten times greater than the reducing capacity of the extract of the peels, which displays an EC_{50} of 15.29 mg /mL.

DISCUSSION

1. Phytochemical composition of cactus pear flowers and fruit derivatives

1.1. Total polyphenols content

Toure et *al.* [18], carried out a study on samples of fruits and cladodes of *Opuntia ficus-indica* in the region of Tamara (Morocco). They recorded a value of 73.12 mg GAE /100 g DW for seeds. This result is lower than that of the present study. Similarly, the results mentioned by Chougui et *al.* [19], on *OFI* seeds, testify of a much lower total polyphenol content with values between 48 mg GAE/100 g DW for the red variety and 89 mg GAE/100 g DW for the orange variety. Elsewhere, Benattia and Arrar [20], noted a total polyphenol content of 144.50 mg GAE/100g DW on seeds from the region of Tlemcen (Algeria). In addition, Berrabah et *al.* [21], observed a value close to that of the present study with 752 mg GAE/100 DW in the flowers of the cactus pear from Ain Defla (Algeria). They also noted a higher content with 883 mg GAE/100g DW on samples of flowers from Tiaret (Algeria).

The *OFI* flowers are thus characterized by a very high polyphenol content, which is clearly higher than the polyphenol content of the whole fruit. Indeed, [14] mentioned the value 218.8 mg GAE/100g DW on extracts of red-skinned cactus pears cultivated in Murcia, Spain. Moreover, De Wit et *al.* [22], reported in their study an amount of total phenols of 231.1 mg GAE /100 g DW.

Phenolic compounds are secondary metabolic products widely distributed in plants. They have biological and pharmacological properties that may offer protection against chronic disease. They exhibit an important antioxidant effect because they are able to neutralize the effects of oxidizing free radicals and reactive oxygen [18]. The variation in the content of phenolic compounds depends on several factors, in particular, the type of variety, the geographical origin, the degree of maturity, the storage conditions and the extraction and analytical protocols [23].

1.2. Flavonoids content

Chougui et *al.* [19], observed in their study on *Opuntia* seeds from the region of Bejaia (Algeria) a lesser quantity of flavonoids (2.6 mg QE/100 g DW). As for the peels, Kuti [24], recorded a slightly higher flavonoid content (6.95 mg QE/100 g DW) than the data of the present study in samples of green-fleshed peels from Texas. Furthermore, Berrabah et *al.* [21] in their investigations on the flavonoids content on flowers samples from Algeria they reported values close to the present study. In fact, they recorded a value of 80 mg QE/100 g DW on methanolic extracts of cactus pear flowers from the Tizi-Ouzou region and 96 mg QE/100 g DW in the sample from Msila region. Flavonoids are phenolic pigments that are the source of the color of some fruits and flowers. They have an important field of action and have many medicinal properties. Particularly active in maintaining good circulation, these antioxidants also have anti-inflammatory and antiviral properties and protective effects on the liver [25].

They are recognized according to Ross et *al.* [26], to play multiple roles in the reactions of higher plants against stressors of different origins, ranging from defense against pathogens and predators to protection of leaves against UV radiation. Flavonoids are very present in the leaves, seeds, bark and flowers of plants, abundant in vegetables and present in foods of plant origin (fruits, cereals, legumes, nuts, etc.) and drinks [27, 28]. This presence is largely influenced by genetic factors and environmental conditions [28]. As in fruits and vegetables, the type of flavonoids and their content vary among cultivars [29, 30].

1.3. Betalains content

The betalains content found was significantly higher than that noted by Cano et *al.* [31]. They reported the values 4.54 and 2.90 mg/100g FW for the Spanish varieties *Sanguinos* (red) and *Verdal* (orange), respectively. Furthermore, our results are higher than those of Valero-Galván et *al.* [32], whom analyzed red-colored peels of *Opuntia ficus-indica* from Mexico and registered the values 1.16 mg /g for betacyanins and 0.08 mg /g for betaxanthins. The betalains, red, yellow and purple pigments that are constituents of the cactus pear characterizes the color of the fruit. Cota-sánchez [33], demonstrated that these pigments have antioxidant properties and their concentration is responsible for the differences and intensity of color types. Cactus pears peels are a promising alternative source for naturally occurring dyes destined for the food processing industry.

2. Antioxidant activity of cactus pear flowers and fruit derivatives

2.1. DPPH Free radical scavenging activity

A significantly lower activity was noted for the peels with an SC_{50} of 3.34 mg /mL. This low activity is probably due to the rather long storage period of the peels. Regarding flowers, the result obtained is slightly weaker than the result found by Ammar et *al.* [34], with an SC_{50} value of 0.24 mg /mL on ethanolic extracts of flowers from the region of Sfax, Tunisia. Alimi et *al*. [35], also conducted a study on the antioxidant activity of *Opuntia* flowers in in Gafsa (Tunisia). They recorded an SC_{50} value of 0.147 mg /mL. Moreover, Melgar et *al.* [36], noted SC_{50} in the peels of two cultivars of cactus pears from Sicily (Italy) with a value of 4.6 mg/mL for the cultivar *Opuntia ficus-indica* var. *gialla* and 4.1 mg /mL for the cultivar *Opuntia ficus-indica* var. *sanguigna*. On the other hand, Toure et *al.* [18], noted an SC_{50} value of 0.185 mg /mL in their research carried out on extracts of seeds of cactus pears originating from Temara (Morocco). This demonstrates that the North African cactus pears display a relatively greater antioxidant activity than those of the European continent.

2.2. Total antioxidant capacity

The results noted during our analyzes on the peels are clearly superior to those found by Aparicio-Fernández et *al.* [37]. Indeed, the latter recorded a value of 8.79 mg EAA /g for the antioxidant capacity of peels from the Mexican cultivar *Opuntia ficus-indica* San Martin from a San Sebastian producer. Abdel Fattah et *al.* [38], noted a lower total antioxidant capacity (3.04 mg AAE /g) on cactus pear seeds from Cairo (Egypt), representing half of the value recorded in the current study.

2.3. Ferric reducing antioxidant power

A study carried out by El Mannoubi [39], on peels extract from a local market in Tunis highlighted an EC_{50} of 12.61 mg /mL, which is close to that of the present study. Berrabah et *al.* [21], reported in their work an EC_{50} of 5.4 mg /mL on methanolic extracts of flowers of the cactus pear from Mascara region (Algeria). This result is about three and a half times weaker than that recorded in the present study. According to the results of the applied biological activity tests, the cactus pear derivatives as flowers, seeds and peels have a significant antioxidant power. These results clearly show that the antioxidant activity is correlated with the presence of bioactive compounds such as polyphenols, flavonoids and betalains (Table 2).

Table 2 : Pearson (n) matrix correlation of phytochemical composition and antioxidant activity parameters of *Opuntia ficus-indica* derivatives.

Variables	Polyphenols	Flavonoids	Betacyanins	Betaxanthins	Total Betalains	*K* (SC_{50})	*K* (EC_{50})	TAC
Polyphenols	**1**							
Flavonoids	**0,99**	**1**						
Betacyanins	-0,47	-0,46	**1**					
Betaxanthins	-0,47	-0,46	**0,99**	**1**				
Total Betalains	-0,47	-0,46	**0,99**	**1,00**	**1**			
K (SC_{50})	0,41	0,40	**-0,99**	**-0,99**	**-0,99**	**1**		
K (EC_{50})	0,57	0,56	**-0,98**	**-0,99**	**-0,99**	**0,98**	**1**	
TAC	0,02	0,03	**0,85**	**0,85**	**0,85**	**-0,88**	**-0,79**	**1**

Bold values are different from 0 at a significance level alpha = 0.05. TAC : Total Antioxidant Capacity.

3.3. Principal Component Analysis (PCA)

The biplot makes it possible for studied parameters to be correlated with the phytochemical contents. The aim is to identify tissues types that are most associated with a particular antioxidant. In the current PCA biplotting of phytochemical components and antioxidant properties of cactus pear organs, factors 1 (77.40 %) and 2 (22.14 %) explained (99.54 %) of the variation (Fig. 1).

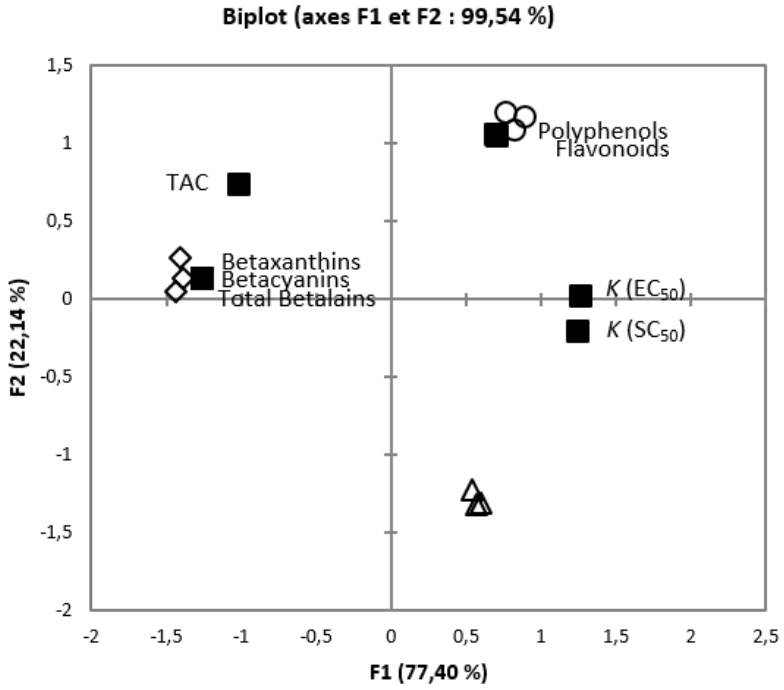

Figure 1 : Score and loading biplot of principal component analysis applied to the data set of phytochemical content and antioxidant activities of *Cactus* pear derivatives.
Data were presented as filled squares, while the cactus pear derivatives were presented with empty symbols: Flowers (circles), Seeds (triangles) and peels (diamond).

Betalains and total antioxidant capacity (TAC) variables were bundled together with the peels. A significant correlation (r = 0.85) was observed between betalains and TAC (Table 2). This means that betalains is the main antioxidant that strengthened the TAC. Flowers extract is closely associated to the contents of polyphenols and flavonoids and was clustered together with the radical scavenging activity and reducing power constants, which implies that polyphenols and flavonoids were the key antioxidants that enhanced the activities of these two parameters. Among the studied tissues, seeds were the less rich in the analyzed phytochemicals and exhibited the weakest total antioxidant capacity strength; however; still this organ displayed the same scavenging activity against DPPH radicals and almost the same reducing power as flowers extract. This may be due to other phytochemical antioxidants, like carotenoids and ascorbic acid that are present in the seeds and that would have contributed in a synergistic way to the antioxidant activity of their extract [40].

CONCLUSION

Most of the Algerian territory is based on arid lands characterized by a dry and hot climate. This medium is conducive to the cultivation of *Opuntia ficus-indica*, a plant with multiple virtues and great potential that unfortunately is still much underexploited in the country.

Curious to carry out its exploitation, we opted for a valuation of its by-products that are often set aside on an industrial scale. The bioactive compounds of *Opuntia ficus-indica* derivatives, peels, seeds and flowers were quantified, and then evaluated their antioxidant activity.

Among the studied tissues, flowers are the organ richest in polyphenols and flavonoids. The seeds showed an antiradical activity and a reducing power quite similar to that of the flowers. The peels were endowed with the greater total antioxidant capacity than flowers and seeds, which is probably due to the fact that they are provided in particular with betalains and other antioxidants.

Overall, the whole tissues of the products derived from cactus pear are quite rich in antioxidant molecules and present interesting antioxidant activities for human health and well-being. It is therefore essential to valorize them in the food industry as nutrient compounds or as a food supplement.

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