Morphological and physicochemical diversity of prickly pears in Bejaia-Algeria

Nadia Chougui, Mustapha Bachir-bey, Abderezak Tamendjari

Laboratory of Applied Biochemistry, Department of Food Sciences, Faculty of Natural and Life Sciences, University of Bejaia, Algeria.

Abstract: Prickly pear (Opuntia ssp.) is native to America and now naturalized in other countries due to its adaptability. In Algeria, it grows mainly on the Mediterranean coast and its production is still traditional. Little information is available on the locally plants (types of species and varieties, production, chemical composition...). To overcome this lack of knowledge, we investigated, in this study, the populations that develop in some areas of Bejaia (north-east of Algeria).

Twenty one populations were harvested from different localities and 15 criteria were investigated. The first data showed a diversity of prickly pear in Bejaia. The populations can be differentiated by their morphological characteristics and chemical composition. The spiny and orange prickly pear is the most predominated population. Among the populations studied, AM.IC2, AK.B3 (orange) and OZ.IA (red) seem to have the best chemical properties.

In addition, the analysis of the 21 populations on the basis of 15 criteria by the Principal Component Analysis and the Hierarchical Clustering technique has highlighted three main groups which are themselves divided into sub-groups. These data showed the presence of several varieties and probably of a second Opuntia specie. However, it would be more judicious to support these hypotheses by analyzing more criteria.

Keywords: Prickly pear, Morphological characters, Physico-chemical properties, Antioxidants, Principal Component and Hierarchical Clustering analyses.

1. Introduction

Opuntia ssp., commonly known as prickly pear, is native to semi-arid regions of Latin America. Its culture has spread around other continents with the rhythm of civilizations. It is actually cultivated in various parts of the world due to its ability to adapt to different environmental conditions (Chopra et al., 1960; Nobel and Bobich, 2002; Mulas and Mulas, 2004). The plant parts (fruit, flower and skin) are traditionally used as feed and for medicinal and cosmetic purposes and for the production of natural dye (Stintzing and Carle, 2005).

Efforts have been made to improve its production and uses in many countries such as America (Mexico, Argentina), Europe (Italy and Spain) and Africa (South Africa, Morocco and Tunisia). In addition, scientists expect that in the future, declining water resources and global desertification may even increase the importance of *Opuntia* spp. as an effective system of food production, including fruit and vegetable parts (Stintzing and Carle, 2005).

In Algeria, prickly pear grows in different regions, mainly located on the Mediterranean coast. Its development is spontaneous, and its production stills traditional. Very little information is available on the locally plants (types of varieties, production, chemical composition...). Indeed, except the exhaustive reference on the flora of Algeria described by Quezel and Santa (1962-1963) in their book "The New Flora of Algeria and southern regions" and the work of Ait Youssef (2006) who realized a plant collection developing in Algeria and their traditional uses, there is no study devoted to the species or varieties of prickly pears that could adapt to the soil and climate of the country.

Various studies have reported that the physicochemical composition of fruits varies with the variety and the environment (Robinson, 1974; Gibson and Nobel 1986; Irizar- Garza and Peña-Valdivia, 2000; Nobel, 2001). This composition has a major importance since it provides indications for plant selection.

This work aimed to determine the types of populations of prickly pears that exist in some areas of Bejaia and to collect information on the quantitative and qualitative characteristics of each population.

2. Material and methods

2.1. Sampling

Twenty one populations of prickly pears were harvested from several localities of Bejaia situated at 260 Km from Algiers (Aokas-Tizi, Sidi Aich, Chemini-Takrietz, Seddouk, Berbacha-Khellile, Berbacha-Berri, Samoun-Tagherbit, Ouzellaguen-Ighzer Amokrane, Akbou-Biziou, Amizour-Ighil n'Chiha and Tazeboujt) during the month of August 2008 and September (Figure 1).

The geographical coordinates (latitude, longitude and altitude) were recorded for each sample of *Opuntia* population (Table 1). Altitudinal distribution areas are 36 m (Tazeboujt) to 767 m (Barbacha–Khelil).

Bejaia is characterized by a dry period from June to September with an average temperature of 21.8°C to 25.5°C and precipitation of 75.5 mm, the humid period extends from September to May with an average temperature of 11.3°C to 19.8°C and precipitation of 680.0 mm (Merdas, 2007). The climate of this region is Mediterranean. The soils are poorly drained and generally composed of fertile soils and stones.

Random samples of 210 ripe fruits were collected from the different localities corresponding to 10 fruits of each population. The samples were packaged, labeled and transported to the laboratory to perform the measurements.

2.2. Sample preparation

The fruits were treated within 24 hours after harvest. The fruits were brushed and rinsed thoroughly with water to remove impurities and glochids. They were then dried at room temperature and peeled. The edible portion of each fruit was ground and filtered through a sieve to separate the seeds from the juicy pulp. The juicy pulps obtained were stored at -20°C until analysis.

2.3. Analysis

2.3.1. Determination of morphological characteristics

The sizes (length and width) of each fruit were measured using a caliper. The weights of each whole fruit and that of its compartments (skin, edible portion, juicy pulp and seeds) were obtained using a precision balance (Statorius AG Gottingen, Germany).

2.3.2. Determination of physicochemical parameters

The fruits contain different compounds of which concentrations vary according to the fruit. Measurements of pH, moisture, brix, and the acidity were performed on the 21 samples collected. These measurements were determined by the AOAC methods (AOAC, 1980).

2.3.3. Determination of total phenolic compounds

The total phenolic compounds of the prickly pear populations were extracted using aqueous ethanol (70 %, v/v). Ten grams of juicy pulp of each sample were added to 50 ml of aqueous ethanol. The mixture was then stirred for 2 h and then filtered. The filtrate obtained was concentrated by evaporation at 40°C using a rotary evaporator (Muchi Rotavapor R-200, Germany). The extract was reconstituted in pure methanol and stored at -20°C.

The Folin-Ciocalteu method of Velioglu et al. (1998) was adopted to determine the content of total phenolic compounds in the extracts of the prickly pear juicy pulps; 1.5 ml of Folin-Ciocalteu, diluted 10 times, were mixed with 250 ml of extract. After 5 min, 1.5 ml of sodium carbonate (6 %) were added, followed by 1 h incubation in the dark. The absorbance was measured at 760 nm against a blank.

The concentration of total phenolic compounds of the extracts is expressed as mg gallic acid equivalent per 100 g fresh weight.

2.3.4. Determination of betalaines

Betalains of the juicy pulp of each sample were extracted according to the method reported by Maataoui et al. (2006) using aqueous methanol 80 % (v/v). The mix was centrifuged at 4000 rpm/min for 20 min. The supernatant obtained contained the total betalains. The betalains content (BC) was calculated as described by Stintzing et al. (2003): BC [mg/L] = $(A*DF*MW*1000/\xi*l)]$ where A is the absorption value, DF is the dilution factor, and l is the path length (1 cm) of the cuvette.

Betalains are composed of two main pigments: betacyanin and betaxanthin. Their content was determined taking into account the following properties: the molecular weight (MW) and molar extinction coefficient (ξ) of betayanin (MW = 550 g/mol; ξ= 60 000 L/mol.cm; λ= 538 nm) and indicaxanthin (MW= 308 g/mol; ξ= 48 000 L/mol.cm; λ=480 nm).

3. Statistical Analysis

Morphological characteristics data represent the average of ten trials, whereas, physicochemical parameters and antioxidant levels were of three tests.

The variance (ANOVA) with a factor $p \leq 0.05$ was applied using the software STATISTICA 5.5 Fr. Correlation analysis was performed using the coefficient Pearson correlation. In addition, the Hierarchical Clustering (HCA) and Principal Component Analyses (PCA) were performed for multivariate data classification by v2013.4.03 XLSTAT software.

4. Results and discussion

The overall results are given in table 2.

4.1. Physicochemical properties

The statistical analysis of the characteristics of the harvested fruits has highlighted significant differences for all parameters (color, shape, weights of the fruits and their compartments, width and length of the fruits, pH, brix, moisture, acidity and pigments and phenolic levels of the juicy pulp of each population) $p \leq 0.05$.

4.1.1. Spines, color and shape

The prickly pears can be distinguished according to the presence or absence of spines, color and shape. Among the samples collected, there were spiny and spineless populations with fruit shapes of ovoid and elongated ranging in color from green to red (Table 2).

According to the ration obtained, the spiny populations are more dominant with 57 % (Table 3). Spiny populations have been shown to be more resistant to weather and other environmental factors. Indeed, the presence of spines ensures multiple functions such as capturing the dew, protection of the skin against the heat of the sun, drying wind or cold and protection against animals (Nobel et Hartsock, 1983). Regarding the shape, the ovoid shape is most common at around 62 % compared to the elongated shape. The orange population is the one that predominates (86 %) in the different localities of Bejaia.

This analysis allowed to distinguish two groups according to the presence or the absence of spines, two groups according to the shape and four groups according to color.

4.1.2. Morphological description

Descriptive statistics of the morphological factors for the 21 samples, including minimum, maximum, mean, standard deviation and variance are summarized in Table 2.

According to the results obtained on morphological characteristics (width, length and weight**)**, significant differences were noticed between the population samples. The length and the width of the fruits varied from 6.46 to 9.33 cm and 3.92 to 5.80 cm, respectively. The longest fruit was AM.IC2 followed by TAK1, TAK3, SEM, OZIA, TAK2 and SED2, while, the smallest ones were represented by AKB2, BAK, AOT2, TAZ2, SIA. The largest fruits are represented mainly by AMI.C2, AOT1, TAZ1, SIA and SEM, while, the narrowest ones are OZ.IA AKB2, AKB1, SED3 and AKB3.

The weight of harvested fruits varied considerably. An interval of 63.94 to 127.92 g was recorded. The weight can explain up to 45 % of the total variance.

Furthermore, the fruit consists of different compartments: the skin and the edible portion composed of juicy pulp sprinkled with seeds. The edible portion was the most important part of the whole fruit; its average weight was 48.19 g. However, it varied, considerably between samples from 25.97 (BA.B) to 69.86 g (TAZ1) with a mean of 88.93 g.

The juicy pulp weight is also variable; values were distributed in the interval ranging from 26.6 g (SED3) to 72.33 g (AM.IC2) with a mean of 41 g.

The weight of the skin was close to that of the edible portion; it was averaging 37.67 g; the lowest weight was recorded for AK.B2 (23.63 g) and the highest for AM.IC2 (55.52 g) with the mean of 37.76 g.

The seeds are the weakest part of the fruit with an average weight of 2.96 g. Variations among the samples studied are significant but remain low. The highest weight obtained was 3.92 g (SI.A) and the lowest 1.84 g (AO.T3).

The weight of the edible portion of the fruit is the second factor that contributes to the variation with around 20 % followed closely by the juicy pulp weight with 17.30 % and then by the skin weight with 10.33 %. However, the seed weight was very weak less than 0.1 %.

Relationships between weights of the fruits and those of their compartments were observed (Table 3). Indeed, the weight of fruit increased with the increase of those the different compartments; positive and significant coefficient correlation superior to 0.7 were found. In addition, the fruit sizes and particularly the width showed also relationship (r up to 0.8) with the fruit and its compartments weights.

However no relationship between fruit length and width, the coefficient correlation was 0.364.

4.1.3. Physicochemical properties

The physicochemical properties of the harvested fruits are important in determining the quality and nutritional quality of fruit processing. The results are summarized in Table 2. Significant but weak differences at $p \leq 0.05$ were found.

The fruit populations are characterized by high moisture levels (84.44 - 93.49 %), which explains their juiciness. All samples presented a low acidity (0.03-0.07 %) and high pH (6.21-6.62) which is typical to prickly pears. They are sweet due to their Brix (sugar content) averaging 13 % with 15 % as the highest value and 11.5 % as the lowest one. These two properties are similar to other common fruits contrarily to pH and acidity values. The high pH, low acidity and high sugar content make this fruit an environment conducive to the growth of microorganisms.

4.1.4. Total phenolic compouds and betalains content

The quantification of the total phenolic compounds (TPC) and betalains was performed on the ethanol extract and fresh juicy pulp respectively. Betalains are pigments that are not found in other common fruits; we distinguish two pigments bétaxanthines and betacyanins responsible of yellow-orange and red-purple colors respectively. Both pigments are separately determined. The role of these pigments is not limited only to provide the coloring but recently they are considered also as antioxidants.

Table 2 includes data on TPC and betalains contents of the different populations of the prickly pears harvested.

The average of the TPC content was 51.70 mg/100g MF; it varies considerably between samples, ranging from 41.92 mg/100g (AM.IC2) to 66.6 mg/100g (AK.B 3).

Betalains are present in all fruits and in variable contents. They varied from 0.73 mg in SIA (green variety) to 8.97 mg/100g in OZ.IA (red variety). Betaxanthins are more abundant than betacyanins. The highest levels were recorded in AK.B1 (7.63 mg/100g) and OZ.IA (2.93 mg/100 g). Betacyanins are responsible of the red color of OZ.IA, the unique sample found in Bejaia. The lower levels are found in SIA fruit (green fruit) with values 0.39 mg and 0.40 mg, respectively.

Fruit color is important economically. Indeed, cultivar production varies from one country to another, depending on the color, for example yellow cultivar is the most abundant in Italy; it constitutes 90% of prickly pear production (Guirrieri et al., 2000). In Algeria, it is the orange variety that is most consumed.

Moreover, phenolic compounds can explain 8.16 % of the total variance. Whereas, betalains showed no effect on the variation observed among the populations collected.

4.2. Hierarchical Clustering analysis (HCA) and Principal Component Analysis (PCA)

In order to visualize the relationship structure within the 21 populations of *Opuntia* on the basis of 15 variables (morphological and physico-chemical properties), the HCA and PCA were performed.

The HCA method provides a dendrogram which is a decision tree where each branch corresponds to a class (Hartigan, 1979; Kaufman, 1990; Husson, 2010). The dendrogram obtained according to Ward's method using Euclidean distances is illustrated by Figure 2. Figure 2 showed a clear separation of samples into groups and subgroups. It suggests the existence of three major groups (G1, G2 and G3) which are themselves subdivided into smaller subgroups. The distances within these subgroups are short, indicating that they are very close allied with common properties. However, the dissimilarities between groups were more important particularly between G3 and the two other groups (G1 and G2).

Concerning the PCA analysis, the variables and individuals were projected on the factorial plane F1-F2. These principal components can explain about 57.1% of the total variance (Figure 3a). The circle of correlations shows the proximity of the variables inside the circle. The closer a variable is to the circle of correlations, the better we can reconstruct this variable from the first two components (and the more important it is to interpret these components); the closer to the center of the plot a variable is, the less important it is for the first two components (Abdi and Williams, 2010). The variables: the weight and width of the fruits and their compartments are closer to the axis 2 which explains that these variables contribute highly to the axis 1 with around 80 %, while variables: acidity, length and betalaines content have higher correlations with the axis 2, and to which they contribute with around 60 % (Figure 3b).

The percentage of contribution of the morphological and physico-chemical factors as well as the coordinates of each variable are given in table S1.

The HCA results concord with those obtained by the PCA; populations were distributed in three major groups:

- G1 is composed of a single sample: AM IC2 which is morphologically distinguished from the other fruits. Indeed, it has particularly higher weight (whole fruit and compartments) and higher width;

-G2 is composed of 12 samples (TAZ1, TAK1, AO.T1, TAK2, TAK3, TAZ2, SED1, SED2, BA.K, SEM, SI.A and AM.IC1) which have average morphological and physico-chemical properties. SIA is particularly away from the group. It is distinguished by a low content in betalaines;

- G3 consists of 8 samples (AO.T2, AO.T3, AK.B1, AK.B2, AK.B3, SED3, OZ.IA and BA.B) which are characterized mainly by higher levels of phenolic compounds and betalains, especially for three populations (OZ.IA, AK.B1 and AK.B3) and medium weight and sizes. In addition OZ.IA is particularly away from the group and it is closer to the axis 2. It correlates highly with betalaines.

From all the results, it appears that the 21 populations varied according to morphological and physico-chemical composition characters. This implies that the variation within populations is not due only to differences in environmental factors (soil type, precipitation rate...) as it has already been reported for *Opuntia* spp. (Buxbaum, 1958).

The effects of spine, shape, color and even the locality origin are not sufficient to explain these variations since each group is formed of populations with these different criteria. Concerning the location origin, it seems that the differences between locations, where samples harvesting were done, are not significantly enough to influence the appearance or the chemical composition of the fruits.

The *Opuntia* classification represents a big challenge for taxonomists. Indeed, in some classifications, *Opuntia* represents a large range of plants with different form stems (trees, shrubs...) and in others; these plants can be reclassified in ten or more genera (Hunt and Taylor, 1990).

In addition, there are significant variations between samples harvested which is in contrast to the belief of the existence of a single local variety "*O. ficus indica*". This is probably related to the high level of phenotypic plasticity, interspecific hybridization and polyploidy (Scheinvar, 1999; Wallace and Gibson, 2002). Indeed, according to Benson (1982), these factors have played a key role in the evolution of the diversity of cactus and also contributed to the confusion in their nomenclature.

Moreover, given the cluster model obtained and dissimilarities between G3 and the other groups, another hypothesis could be suggested on the possible existence of a second species in Bejaia. To support this hypothesis, other descriptions are necessary to be investigated; the most used is the description of the genetic material of plants. However, this practice is long and expensive, and the results do not necessarily improve the accuracy of the descriptions or their usefulness.

Similar studies have been undertaken on *Opuntia* ssp. and showed that other criteria may be considered and may even be sufficient to describe the variability between populations, as concluded Mondragón-Jacobo (2002) in his study in which he analyzed 34 traits including qualitative and quantitative aspects, and found that 20 of them were relevant to discriminate samples of central Mexico.

A field study and further analysis of other factors in addition to those already investigated as the presence of spines, the cladode sizes (length and width), the number and morphology of seeds and the number of areolas on the fruit and the cladode were considered important to study the *Opuntia* ssp. (Stuppy, 2002; Peña- Valdivia et al., 2008). This would allow a better characterization of cactus and the distinction between wild plants and domesticated plants.

5. Conclusion

Following these results, it appears that Bejaia presents a diversity of varieties differentiated by shape, color and by the chemical composition. According to the selection criteria, the spiny and spineless prickly pears grow in different localities of Bejaia with the dominance of the first population. Four varieties were clearly identified by color: green, yellow, orange and red; the orange fruit is more abundant contrarily to other varieties.

The analysis of variance of the 15 criteria separately revealed differences among the 21 samples of which some were deemed superior to others. Regarding the weight of the fruit and their compartments, the brix, pigments and phenolic compounds contents, AM.IC2, AK.B3 and OZ.IA showed up.

However, this analysis is simple and does not get a good view of the data. The ACP and CAH are better tools for multivariate analysis. They helped to highlight the similarities and dissimilarities among the 21 samples. According to the criteria studied and particularly morphological criteria, three groups were distinguished, which are themselves divided into sub-groups. One of the groups is particularly stood out (G3), which leads to believe in the existence of several varieties and possibly even a second *Opuntia* specie. However, it would be wiser to support these hypotheses by analyzing other criteria.

Moreover, these varieties deserve a place in a variety trial of prickly pears to select superior populations for fresh consumption, industrial transformation or development programs for different regions of the country.

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Table 1: Geographical distribution of prickly studied.

Provenance	Vernacular names	Latitude E	Longitude N	Elevation (m)	Code	Topography	Harvest date
Akbou- Biziou	Akermous	36°29	4°36	174	AK.B 1	Flat area	10/08/08
	Akermous				AK.B 2		10/08/08
	Akermous				AK.B 3		10/08/08
Amizour-Ighil n'Chiha	Akermous	36°38	4°55	247	AM.IC1		26/08/08
	Akermous				AM.IC2		26/08/08
	Taroumith	36°37	5°15	212	AO.T 1		15/08/08

Aokas- Tizi	Tinslemt				AO.T 2	Low slope	15/08/08
	Akermous				AO.T 3		15/08/08
Barbacha -Khelil -Berri	Akermous	36°34	4,58	767	BA.K		22/08/08
	Akermous	36°36	4,54	321	BA.B		22/08/08
Ouzellaguen-Ighzer Amokrane	Akermous	36°32	4,36	436	OZ.IA		03/09/08
Seddouk	Akermous	36,32	4°41	350	SED 1		04/08/08
	Akermous				SED 2		04/08/08
	Akermous				SED 3		04/08/08
Semaoun-Tagherbit	Taspegnolith	36°36	4°50	452	SEM		01/08/08
Sidi Aich	Akermous	36°32	4°41	95	SI.A	Flat area	15/08/08
Chemini-Takerietz	Awthem	36°34	4°39	116	TAK 1		10/08/08
	Elmenchi				TAK 2		10/08/08
	Akermous				TAK 3		10/08/08
Tazeboujt	Takermousth	36°45	5°04	26	TAZ 1	Low slope	15/08/08
	Takermousth				TAZ 2		15/08/08

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Table 2: Morphological and physico-chemical properties of the 21 populations of *Opuntia* collected at Bejaia

Sample	Spi.	Col.	For.	Lenght	Wide	Fruit	Edible part	Peel	Juicy pulp	Seeds	H°	pH	Acidity	Brix	PC	Bc	Bx	BT
AK.B 1	P	O	El	7.41±0.47	4.41±0.20	68.71±7.85	41.39±4.86	27.09±3.60	31.86±4.64	2.62±0.35	88.57±0.17	6.49±0.01	0.058±0.000	13.35±0.00	48.84±4.41	0.62±0.11	7.63±0.20	7.80±0.13
AK.B 2	A	O	Ov	6.46±0.30	4.30±0.18	63.94±6.99	40.12±5.67	23.63±4.76	28.69±5.58	2.59±0.48	93.49±2.02	6.25±0.00	0.053±0.004	14.50±0.00	65.44±2.93	0.55±0.11	3.53±0.16	4.08±0.26
AK.B 3	A	O	Ov	7.06±0.61	4.55±0.13	76.28±8.38	42.65±5.55	33.37±3.72	31.62±5.67	2.42±0.41	87.62±0.12	6.30±0.01	0.047±0.004	15.00±0.00	66.60±2.58	0.90±0.11	6.79±0.64	7.69±0.76
AM.IC1	A	O	Ov	6.96± 0.32	5.12±0.19	84.30±9.04	31.08±4.72	37.42±3.22	46.68±6.17	3.37±0.68	88.50±0.19	6.22±0.04	0.055±0.004	12.50±0.00	46.52±0.89	0.33±0.02	4.18±0.01	4.51±0.02
AM.IC2	P	O	El	9.33±0.08	5.80±0.08	127.92±4.89	56.97±2.70	55.52±2.71	72.33±3.10	3.53±0.18	89.74±0.26	6.40±0.01	0.075±0.010	11.50±0.00	41.92±0.69	0.60±0.09	5.20±0.02	5.80±0.11
AO.T 1	A	O	Ov	6.98±0.67	5.42±0.58	108.54±32.09	61.21±16.15	46.48±17.17	46.42±12.38	3.25±0.99	87.54±1.15	6.23±0.02	0.056±0.004	14.53±0.06	43.38±1.99	0.35±0.06	4.17±0.32	4.53±0.39
AO.T 2	P	O	Ov	6.66±0.49	4.69±0.23	78.93±10.30	42.66±5.86	35.72±5.90	32.75±4.45	2.09±0.73	87.54±0.05	6.43±0.00	0.032±0.000	13.53±0.03	42.24±5.55	0.33±0.04	4.39±0.17	5.19±0.38
AO.T 3	P	O	El	7.43±0.67	4.56±0.36	74.72±17.29	36.90±9.99	37.15±8.62	27.20±8.69	1.84±0.80	87.93±0.80	6.43±0.03	0.038±0.000	12.50±0.00	46.50±2.20	0.49±0.09	4.89±0.07	4.73±0.21
BA.K	P	O	Ov	6.53±0.45	4.87±0.35	86.63±11.97	53.13±8.23	34.08±7.61	41.89±7.93	3.10±0.46	87.05±1.23	6.40±0.01	0.045±0.000	12.43±0.06	46.81±1.70	0.40±0.01	5.56±0.39	5.39±0.14
BA.B	A	O	Ov	6.69±0.57	4.65±0.29	65.98±10.87	25.97±5.76	29.70±4.90	35.69±7.04	2.39±0.45	87.28±0.10	6.55±0.01	0.043±0.004	14.50±0.00	45.03±3.01	0.40±0.17	5.56±0.23	5.96±0.37
OZ.IA	P	R	El	7.58±0.45	4.73±0.33	77.08±12.95	48.12±9.90	28.35±4.33	38.02±7.48	2.78±0.71	89.58±0.03	6.22±0.03	0.073±0.009	12.50±0.00	49.31±0.64	2.93±0.17	6.10±0.23	8.97±0.40
SED 1	P	O	Ov	6.91±0.35	4.90±0.20	85.64±9.42	53.95±6.36	31.33±3.35	39.82±5.89	3.34±0.46	86.97±0.16	6.54±0.02	0.057±0.006	14.00±0.00	49.02±0.44	0.31±0.04	3.83±0.24	4.14±0.29
SED 2	P	O	El	7.55±0.43	4.94±0.24	94.48±9.01	50.58±6.16	43.47±3.40	37.56±5.82	3.09±0.48	89.26±0.05	6.41±0.15	0.038±0.013	14.17±0.29	59.26±5.41	0.37±0.05	4.02±0.43	4.39±0.37
SED 3	P	J	El	6.69±0.30	4.46±0.23	64.50±7.87	37.67±5.17	26.43±3.11	26.65±4.90	2.88±0.81	89.62±0.08	6.44±0.01	0.045±0.00	12.00±0.00	62.08±4.76	0.30±0.01	3.44±0.08	3.74±0.07
SMA	P	O	Ov	7.69±0.44	5.22±0.40	95.82±16.36	40.18±7.89	41.41±7.98	53.85±10.49	3.02±0.48	85.70±0.73	6.21±0.02	0.042±0.000	14.57±0.06	47.23±1.90	0.40±0.02	5.37±0.39	5.77±0.39
SI.A	A	V	Ov	6.68±0.33	5.29±0.24	106.31±14.76	57.49±8.89	48.13±7.67	40.96±6.88	3.92±0.73	87.50±0.09	6.55±0.09	0.042±0.005	14.33±0.021	48.92±0.32	0.39±0.13	0.41±0.05	0.72±0.15
TAK 1	A	O	Ov	8.38±0.57	5.05±0.37	107.37±12.45	65.40±8.20	40.40±5.56	49.76±8.15	3.84±0.53	87.21±6.37	6.47±0.01	0.036±0.004	13.00±0.00	54.17±6.62	0.37±0.06	3.45±0.04	3.81±0.10
TAK 2	P	O	El	7.58±0.43	4.75±0.27	91.25±14.69	53.60±11.08	36.73±5.52	40.83±10.12	2.85±0.50	88.89±0.05	6.62±0.01	0.049±0.004	12.50±0.00	61.68±6.11	0.32±0.02	4.25±0.04	4.56±0.06
TAK 3	A	O	El	7.81±0.46	4.92±0.28	96.10±12.17	54.94±9.65	40.18±4.88	40.17±8.89	2.85±0.89	88.96±0.05	6.25±0.07	0.047±0.004	12.50±0.00	56.87±4.30	0.26±0.05	3.86±0.82	4.11±0.14
TAZ 1	P	O	Ov	7.15±0.16	5.41±0.22	114.04±12.12	69.86±8.27	43.76±5.07	56.23±7.64	3.61±0.30	87.76±0.05	6.48±0.01	0.049±0.004	14.50±0.00	52.30±0.75	0.38±0.04	5.60±0.51	5.98±0.55
TAZ 2	A	O	Ov	6.70±0.61	5.07±0.32	99.00±16.06	48.06±7.83	50.64±12.01	33.85±4.81	2.84±0.50	84.44±4.98	6.51±0.02	0.041±0.004	14.00±0.00	51.48±0.67	0.45±0.08	5.02±1.04	5.47±0.17
Mean±SD				7,25±0,69	4,87±0,44	88,93±17,62	48,19±11,18	37,67±8,47	40,61±10,96	2,96±0,54	88,15±1,79	6,40±0,13	0,05±0,01	13,35±1,03	51,70±7,53	0,54±0,57	4,59±1,46	5,11±1,71
Interv.				6,46 - 9,33	3,92- 5,80	63,94-127,92	25,97- 69,86	23,63- 55,52	26,64- 72,33	1,84-3,92	84,44- 93,49	6,21- 6,62	0,032- 0,075	11,5- 15	41,92- 66,60	0,26- 2,93	0,41- 7,63	0,79- 8,97
Var. %				0,07	0,03	44,70	17,98	10,33	17,30	0,04	0,46	0,00	0,00	0,15	8,16	0,05	0,31	0,42

Spi: spin; Col: colour, For: form P: Presence. A: Absence; O: Orange; R: Red; J: Yellow; V: Green; v: Ovoid; El: Elongated; Width and length (cm); Weigth fruit and compartment (g); PC : phenolic compounds (mg EAG/100g); Bet : betacyanins ; Bx : betaxanthins and T. Bet : total betalains (mg/100g); H°: humidity (%). Acidity (%) Brix (%); Interv: interval; Var: variance.

Table 3: Proportion of spines, form and colour characteristics of the 21 populations of *Opuntia* collected at Bejaia

Characteristic	Nombre /21 samples	Proportion (%)
Spines :		
- Presence	12	57.14
- Absence	09	42.86
Frome :		
- Ovoid	13	61.90
- Elongated	08	38.10
Colour :		
- Green	01	4.76
- Yellow	01	4.76
- Orange	18	85.71
- Red	01	4.76

Table 4: Correlation coefficients between the weight and size of fruits and those of the various compartments.

Variables	Width (cm)	Fruit (g)	Eadible portion (g)	Skin (g)	Juicy pulp (g)	seeds (g)
Length (cm)	0.364	0.563**	0.356	0.448*	0.665***	0.286
Width (cm)		0.879***	0.515*	0.865***	0.795***	0.658***
Fruit W (g)			0.782***	0.905***	0.837***	0.721***

*. **. ***: Significant at P values ≤ 0.05. P ≤ 0.01 and P ≤ 0.001 respectively.

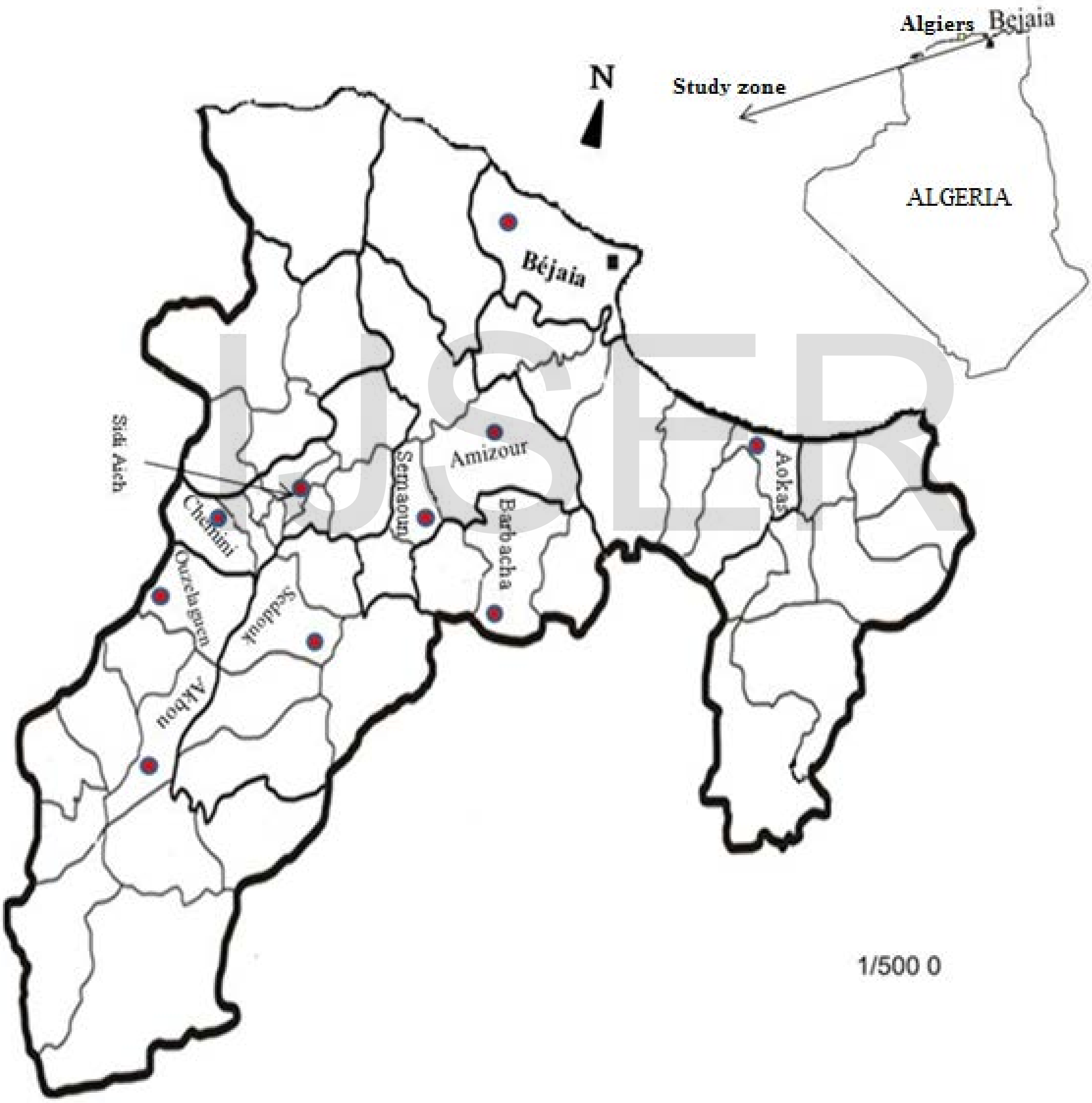

Figure 1: Locations of samples collected (Berthoalain.com)

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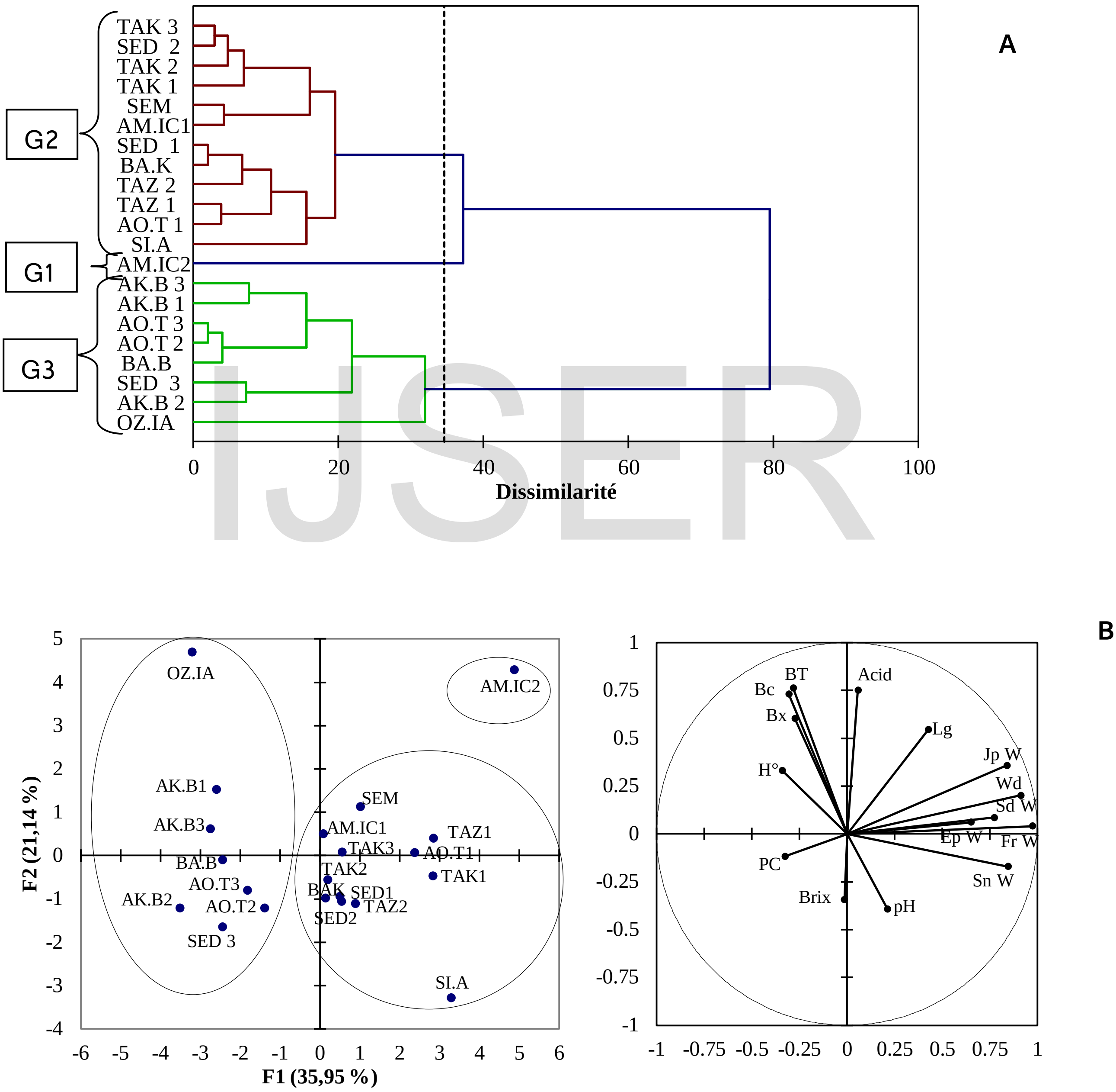

Figure 2: Hierarchical clustering analysis (HCA) dendrogram (A) and principal component analysis (PCA) score plot (B) of 21 populations of *Opuntia* by according to15 factors (morphological and physico-chemical factors).

(W: weight; Lg: length; Wd : width; Sd W: seeds weight ; Jp W:juicy pulp weight; Ep W: edible portion weight Fr W: fruit weight ;Sn W: skin weight; PC: phenolic compound ; Bet: betacyanins ; Bx : betaxanthins ; BT : Total betalains H ° : humidity).

Supplementary table:

Table S1: PCA *Opuntia* Characteristics Factor scores, contributions of the observations to the components

	Coordinates of the variables		**Contribution of variables (%)**	
	F1	F1	F2	F2
Length (cm)	0,481	4,293	12,558	0,631
Width (cm)	0,933	16,142	0,025	-0,028
Fruit weigth (g)	0,963	17,184	0,887	0,168
Edible portion weigth (g)	0,723	9,690	0,009	0,017
Skin weigth (g)	0,875	14,185	0,067	0,046
Juicy pulp weigth (g)	0,814	12,302	7,280	0,481
Seed weigth (g)	0,787	11,490	0,001	-0,007
Brix (%)	0,005	0,000	5,953	-0,435
Acidity (%)	0,039	0,028	18,867	0,774
pH	0,289	1,545	6,323	-0,448
Humidity (%)	-0,329	2,010	0,795	0,159
PC (mg EAG/100g)	-0,367	2,494	2,025	-0,253
Bc (mg/L)	-0,366	2,482	13,811	0,662
Bx (mg/L)	-0,383	2,716	13,317	0,650
BT (mg/L)	-0,431	3,438	18,082	0,757