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Assessment of some agro-technological parameters of cactus pear fruit (*Opuntia ficus-indica* Mill.) in Morocco cultivars

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Cactaceae had always attracted attention by their strange shapes and important adaptability supporting extreme conditions. For this reasons, Fruit traits were measured on 13 cultivars growing in different locations in Morocco. Results show significant differences between the cultivars. The source of this variation was probably genetic without excluding the geographic effects. The Tamri, Berkan, Ait Baha cultivars showed small fruit dimensions and weight. In contrast, Sidi-Ifni M, Nador, Mohammedia and Ben Guerir were greater than 100 g by fruit. Sidi-Ifni M, Hoceima, Mohammedia and Nador, although larger, contained few seeds, about 200 seeds per fruit; while Tamri, Ait Baha, Safi, Meknes and Tafraout contained over than 230 seeds per fruit. High levels of juice about 62 ml/100 g pulp were obtained with Sidi-Ifni M, Nador, Mohammedia and Ben Guerir cultivars. Total sugars of the 13 cultivars were quite similar and pH was low in Tamri and close to neutrality in the rest of cultivars. Therefore, oil extracted from *Opuntia ficus-indica* seeds constituted 13.6% of the whole seed. Thin-layer chromatography in conjunction with gas-liquid chromatography-mass spectrometry revealed a relatively high degree of unsaturation, 83.32% and 16% for saturated fatty acid, with a linoleic acid content of 63.66% followed by oleic 18.34%, palmitic 12.84% and stearic acid 2.81%. Based on these results, *O. ficus-indica* seed oil appears to be a good potential source of edible oil for human and (or) animal consumption. Our investigation describes that Tamri and Tafraout cultivars are not really a commercial viable fruit due to low total soluble solids value and highest seeds number per fruit. Against Mohammedia, Sidi Ifni M and Nador cultivars proved to have the highest fruit weight, very good total soluble solids value and low number of seeds, these cultivars can therefore be planted for both fruit production and for harvesting of cladodes for animal feed.

Key words: *Opuntia ficus-indica*, cultivars, fruit juice, acidity, total soluble solids, seeds.

INTRODUCTION

Opuntia is the largest genus of Cactaceae with more than 360 species. In the Mediterranean basin, some *Opuntia* species (mainly *Opuntia ficus-indica* Mill.) were introduced five centuries ago from the areas of origin (Casas et al., 2002), progressively invading natural habitats in Spain (Vila et al., 2003), South Africa (Moran and Zimmermann, 1991) and Australia (Johnson, 1982).

The successful introduction of *Opuntia* in these areas has been attributed to its Crassulacean acid metabolism (CAM). The CAM plants take up CO_2 primarily at night,

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leading to high water-use efficiency and high drought resistance, which are important features for arid regions with limited rainfall (Nobel, 1988). In south of Morocco which is the most arid region, larger part of the area is an absolute desert with almost no vegetation and one can easily travel for large area without coming across a single plant. The xerophytes vegetation is dominant and characterizes a type of natural plant life. The eco-geography and climatic factors play a significant role in determining the type of vegetation. Natural populations of cactus *Opuntia,* are widely distributed in arid and sub-arid areas in Morocco; it plays a great role in the biodiversity of the forest's ecosystem (Msanda et al., 2005). The plants have a marked capacity to withstand prolonged drought periods without collapsing and are considered as an important potential source of food and feed in many desert areas of the world (Brutsch, 1979). *Opuntia* includes different fruit forms, usually consumed fresh but due to the short season, efforts are being expanded to prolong their availability beyond season by cold storage (Berger et al, 1978). The tender green cladodes are used as vegetables and also as stock feed (Crosta and Vecchio, 1979; Hoffman, 1979).

The potential supply of lipid from fruits by products may be enormous and should to be investigated. Future edible oil supplies may depend on the discovery and development of similar types of plants (Kamel, 2000). Seeds of certain *Opuntia* species such as *Opuntia streotacantha* and *O. ficus-indica* were reported to contain good quality edible oil (Paradez, 1973) (Sawaya and Khan, 1982). However, information on the nutritional value of the seeds is lacking. The preservation and sustainable management of genetic resources of this millennium species is proved necessary for maintaining the biodiversity of its ecosystem. Morphological variation, fruits and seeds among the natural populations of species are useful in selection program for genetic improvement (Bahadur, 1995). The morphological variability signifies the adaptation of the species to the environment and it may be genetically determined or environmentally induced (Chiveu et al., 2009). Limited work has been done on *O. ficus-indica* in Morocco, with absolutely no research on its genetic variability basis on agro-morpho-metric fruits and seeds.

However, the variation has practical implications because conservation programs collect seed from provenances where genotype presents good quality of traits. Agro-morphological study was an essential component for the assessment of diversity and classification until the 1970s. At present, agro-morphological study is still considered and has been deployed as an initial step for cultivar identification and diversity assessment (Huh et al. 2008). According to Pimienta and Muñoz-Urias (1999), selection of cactus pears has been directed towards large and attractive fruits. In addition, fruit size and areole density were among the significant traits useful to separate wild from domesticated cactus pear (Mondragón Jacobo, 2002).

The usual approach in plant germplasm description is to include as many morphological traits as possible. Presence of spines and fruits dimensions, length and width, as well as number of areoles allowed the characterization of cactus pear. Cladode dimensions as well as fruit size were found to be significant to study a collection of cactus pear (Peña-Valdivia et al., 2008). Some other traits useful in the separation of cactus pear accessions are fruit dimensions and total sugar content (Valdéz-Cepeda et al., 2003) (Gutiérrez-Acosta et al., 2000). In the present study, we have evaluated fruit quality of different cultivars that occur in Morocco and determined which cultivar had fruit of a higher quality.

MATERIALS AND METHODS

Plant materials

Cultivars were collected from thirteen locations of *O. ficus-indica* in Morocco; it covers an area from Northeast of Morocco to southwest. Geographic data base (latitude, longitude, and altitude) were recorded for each cultivar using a global positioning system (Table 1). The altitudinal distribution ranges from 36 m in Tamri to 1215 m in Tafraout. Climate of this region is arid and sub-arid Mediterranean type. Rainfall is scarce and very variable (100 to 500 mm in annual average), taking place mainly during the cold period, while summer season is dry. Still there are differences between the sites in mean annual rainfall and mean annual temperature (Table 1). The locations represent different soil conditions and a variety of climatic conditions. They correspond to different eco-geographical situations. Matured fruit was carried out randomly from each selected cultivar. The samples were packed, labeled and brought to the laboratory for measurement and data collection. Random samples of 780 mature fruits were collected from all locations corresponding to 60 fruits for each cultivar.

Traits studied

When 30 to 60% of all the fruit on the plant reached optimal ripeness, the samples for laboratory analysis were picked. Fruits with similar peel colour break were selected randomly from different plants for each cultivar and analysed for their quality. (Fruit weight (g), pulp weight (g) fruit diameter (cm), fruit length (cm), total soluble solids (TSS, °Brix), seeds per pulp, yield of juice, pH fruit, total seeds number and oil content). Fruit mass was obtained by weighing each fruit individually. The peel was sliced longitudinally while both ends were removed. After removal of the pulp, the peel was sliced lengthwise. Both sides of the peel were measured (mm) and the peel mass (g). The pulp mass (g) was weighed to determine the edible amount in the fruit. The pulp mass of each individual fruit was divided by its specific fruit mass in order to obtain a relative value. A total soluble solid (TSS) in percentage Brix was measured with a refractometer to determine sugar content of the fruit. A spatula was used to liquidize a small area in the middle of the fruit. One drop of this liquid was placed on the lens of the refractometer to determine the TSS. The method for quantitative trait data collection is given in Table 2.

Extraction of total lipids (TL)

Freshly and intact prickly pear fruits *O. ficus-indica* were carefully selected according to the degree of ripeness measured by fruit

Table 1. Geographic distribution of *Opuntia ficus-indica* cultivars.

Cultivars	Vernacular names	Code	Latitude W	Longitude N	Altitude (m)
Ait Baha	Achefri	AB	30°10’	9°14’	222
Tafraout	Achefri	TA	29°53’	9°00’	1215
Sidi-Ifni M	Moussa	SM	29°20’	10°08’	66
Sidi-Ifni A	Aissa	SA	29°20’	10°08’	65
Tamri	Achefri	TR	30°40’	9°52'	36
Ben Guerir	Aknari	BG	32°30’	7°53’	434
Chaoun	Zaaboul	CH	35°08’	5°16’	555
Hoceima	Delahia	HO	30°57’	4°17’	1100
Nador	Hndiya	NA	35°15’	3°40’	70
Berkane	Hndiya	BR	34°51’	2°36’	200
Meknès	Hndiya	MK	33°47’	5°29’	700
Mohammedia	Hndiya	MH	33°41’	7°19’	64
Safi	Aknari	SF	32°40’	9°04’	56

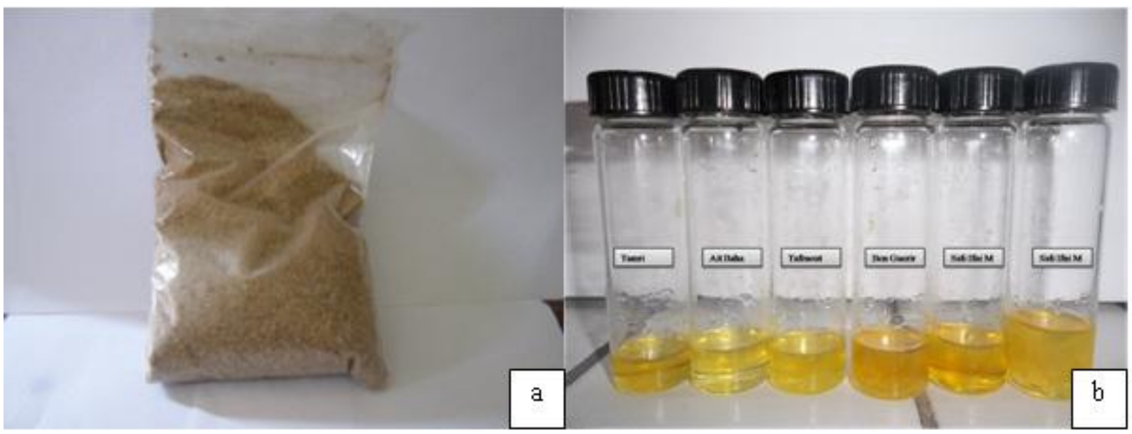

Figure 1. Oil extraction of cactus seeds from different areas of Morocco: (a) powder of cactus seeds used for extraction. (b) oil after extraction.

color (red to purple), the pH value of the pulp (pH 6.05) and the total titratable acidity (0.39%). Fruits were brushed under distilled water, air-dried and hand-peeled. Seeds were isolated by pressing the whole edible pulp and rinsing the residue with distilled water. 40 g of each provenance to a constant weight (Figure 1a), placed in a stove oven maintained at 105°C until dried to constant weight using desiccators and analytical balance. A lipid was isolated using a hexane extraction procedure (Yang and Kallio, 2001). About 200 ml of hexane was poured into the round bottom flask and was inserted in the centre of the extractor. The apparatus was heated at 60 to 70% and allowed for 8 h of continuous extraction and the oil is extracted with a continuous reflux of hexane. After extraction, the extract was then filtered through a filtering system, containing the layers of cotton and anhydrous sodium sulfate, previously washed with n-hexane. The collected solvent was removed using a rotavapor apparatus at 70°C. The extract was collected in a flask. The oil obtained finally weighed again every day until weight stability. Finally oil extracted was placed in an incubator fan and then stored at -4°C for fatty acid analyses. Oil content as a percentage was calculated for each sample and the volume of oil extracted was carried out by weighing the density of the oil (Figure 1b) (Butera et al., 2002).

Fatty acid identification

Fatty acids profile was determined quantitatively using gas chromatography (GC). The FAMEs compositions were analyzed using oil sample with the same characteristics as the oil analysis. The FAMEs were identified by comparison with the fatty acid methyl ester peaks and retention time of the standard with the sample peaks. Peak integration was performed using typical chromatogram of peak, area of different fatty acid was used as a reference of chromatography software. The quantity of FAMEs in the sample was calculated according to the formula giving by Were et al., (2006).

Data collection and statistical analysis

In assessing fruit quality traits of cactus pear cultivars a fully randomized experimental design with random sampling of all data points was carried out. During the course of the study, data for fruit quality traits were collected for each cultivar, and entered into the Statistica v 10. The results were analysed by linear variance analysis (ANOVA) and Duncan’s Test. All values were considered

Table 2. Fruit characteristics of the cactus pear (*Opuntia* spp.) cultivars from 13 morocco provenances.

Provenance cultivars	Fruit weight (g)	Pulp weight (g)	Fruit diameter (cm)	Fruit length (cm)	Total soluble solids (°Brix)	Total seeds number/pulp	Seeds/ pulp (g)	Juice (ml 100 g pulp -1)	Fruit pH
Ait Baha	84.47[cd]	51.43[c]	3.71[b]	6.94[e]	19.43[abc]	229.50[he]	0.12[de]	52.87[f]	5.28[f]
Tafraout	87.66[cd]	47.98[c]	3.69[b]	7.27[d]	18.65[bcd]	230.87[e]	0.13[cde]	62.87[b]	6.28[b]
Sidi-Ifni M	108.55[a]	58.74[b]	4.57[a]	7.94[a]	19.36[abc]	203.14[h]	0.23[a]	62.84[b]	6.28[b]
Sidi-Ifni A	81.5[cd]	50.57[c]	3.22[c]	7.34[cd]	19.65[abc]	213.14[g]	0.13[cde]	62.86[b]	6.28[b]
Tamri	86.03[cd]	48.25[c]	3.16[c]	7.65[abc]	17.13[e]	298.23[a]	0.16[bc]	46.87[g]	4.68[g]
Ben Guerir	103.06[a]	63.44[a]	3.45[bc]	7.33[cd]	19.81[a]	275.42[b]	0.14[cde]	56.87[e]	5.68[e]
Chaoun	84.12[cd]	51.2[c]	3.7[b]	6.94[e]	19.56[abc]	218.62[f]	0.13[cde]	60.87[c]	6.08[c]
Hoceima	88.64[c]	48.24[c]	3.77[b]	7.29[d]	18.56[cd]	178.62[i]	0.17[b]	60.84[c]	6.08[c]
Nador	107.55[a]	58.45[b]	4.51[a]	7.90[a]	19.3[abc]	200.36[h]	0.23[a]	60.87[c]	6.08[c]
Berkane	80.62[d]	50.55[c]	3.22[c]	7.33[cd]	19.75[ab]	219.13[f]	0.13[cde]	60.13[d]	6.01[d]
Meknès	86.91[cd]	48.35[c]	3.17[c]	7.65[abc]	17.03[e]	254.04[d]	0.11[ef]	62.73[b]	6.27[b]
Mohammedia	106.91[a]	63.15[a]	3.78[b]	7.53[bcd]	19.55[abc]	176.69[i]	0.24[a]	63.88[a]	6.38[a]
Safi	97.4[b]	52.08[c]	4.39[a]	7.73[ab]	18.13[d]	262.84[c]	0.15[c]	63.84[a]	6.38[a]
Mean	92.58	53.27	3.72	7.45	18.92	227.74	0.17	59.87	5.99

significantly different when p≤ 0.05.

RESULTS AND DISCUSSION

The cultivars of *Opuntia ficus indica* exhibited considerable variation for morphological characters. The variation in the current study might not have been due exclusively to differences in environmental factors as huge variation among the cultivars within a district have been reported for *Opuntia ssp* (Buxbaum, 1958). The existence of significant variation among cultivars from different locations was in contrast to previous assumptions of a single variety "local *Opuntia ficus indica*"; this is probably related to the high level of phenotypic plasticity, polyploidy and interspecific hybridization (Wallace et al., 2002) (Scheinvar, 1999).

The comparison of fruit quality for 13 cultivars grown in Morocco is ranked in decreasing order of fruit character (Table 2). As judged by the ranking for all fruits characters, the highest and lowest value of cultivars traits were significantly different in all provenances. Slightly more than half of the provenances had virtually same fruits characters.

Fruit size and weight

Significant difference (p<0.05) was detected between cultivars (Table 2). A tendency for the cultivars to have a fruit weight greater than 100 g in Sidi-Ifni M, Nador (107.55 g), Mohammedia (106.91 g) and Ben Guerir (103.06 g) compared to the rest of provenances. Fruits diameter had a low variability between cultivars tested (Table 2). Cultivars that had the widest equatorial diameter were Sidi Ifni M (4.57 cm), Nador (4.51 cm) and Safi (4.39 cm). Cultivars that had the lowest diameter were mainly Tamri (3.16 cm), Meknès (3.17 cm), Bekran and Sidi Ifni A (3.22 cm). Cactus pear fruit weight is affected by the number of seeds (Barbera et al., 1994), cladode load (Inglese et al., 1995), water availability (Barbera, 1984) and ripening time (Barbera et al., 1994).

There was a high variability of fruit length within cultivars tested. Cultivars that had the highest fruit length were Sidi Ifni M (7.94 cm), Nador (7.90 cm), and Safi (7.73 cm). Cultivars with the lowest length were Ait Baha and Chaoun (6.94 cm), Tafraout (7.27 cm) and Hoceima (7.29 cm).

Fruit characteristics size and weight depended on the cultivar of the plant. They play an important role in consumer selection of food. Indeed, fruit mass or size are very important since consumers associate it with better value for money (de Wit et al., 2010). Karababa et al. (2004) and Bekir (2004) suggested that size and weight of cactus pear fruit are influenced by locality, season and environment. While Felker et al. (2002) reported that fruit size was not determined by environmental or edaphic factors, but genetic factors. The current results support the effect of variety on fruit size.

Pulp weight

Cactus pear fruits are of the berry type with a juicy pulp that contains many hard-coated seeds (Barbera et al. 1992). The weight of pulp should not be lower than 55 to 60 g in fruits destined for export markets (Inglese et al. 1995). Cultivars with the highest weight of pulp content were Ben Guerir (63.44 g), Mohammedia (63.15 g) and Sidi Ifni M (58.74 g). Tafraout, Hoceima, and Tamri produced fruit with the lowest weight pulp at 47.98 g, 48.24 g and 48.25 g respectively (Table 2). The range of percentage pulp content within all varieties tested (47.98 to 63.44 g) is higher than that previously reported (30 to 60 g) for South African cactus pear varieties (Wessels, 1988).

Total soluble solids content

TSS measured as °Brix, is an indication of sugar content. Sugar content is an important criterion of fruit quality for consumers since they prefer sweet fruits (Inglese et al., 1995). In general, as fruits ripen, levels of soluble solids in the cell vacuoles increase as acidity decreases. Ben Guerir (19.81 °Brix), Berkan (19.75 °Brix)~~,~~ Sidi Ifni A (19.65 °Brix) and Sidi-Ifni M (19.36 °Brix) were found to have high TSS content (Table 2). Meknès (17.03 °Brix), Tamri (17.13 °Brix) and Safi (18.13 °Brix) had the lowest recorded TSS content. The mean TSS content for the cultivars tested was 18.91 °Brix. In addition, statistical analysis showed the absence of significant differences ($p<0.05$) among these values and these were in agreement with the results published (Stintzing et al., 2003). Indeed, total soluble solids is highly influenced by crop management and environment since cactus pear fruit grown in dry areas are sweeter than those grown in humid areas (Mondragón-Jacobo and Pérez-González, 2001) or being irrigated (Inglese et al., 1995). In fact, the fruit of *Opuntia* was considered a very sweet fruit and this was due to the presence of reducing sugars in the pulp, especially glucose and fructose (Stintzing et al., 2003).

Seed per fruit

In general, several cultivars of provenances had a significantly highest number of seeds. The cultivars with the highest (298.23) and lowest (176.69) amount of seeds per fruit were Tamri and Mohammedia respectively. Sidi-Ifni M, Sidi Ifni A, Chaoun, Berkan, Hoceima, Mohammedia and Nador cultivars shared the position of least seeds per fruit.

While most investigators have reported the percentage of seeds per pulp is more meaningful as only the pulp is eaten and also because the percentage of pulp to whole fruit has significant variation among provenances cultivars (Felker et al. 2002). When the cultivars are compared on the basis of seeds per pulp, the significant advantage of the cultivars of Mohammedia (0.24 seeds/g pulp), Nador (0.23 seeds/g pulp), Sidi Infi M (0.23 seeds/g pulp) and Hoceima (0.17 seeds/g pulp), which also have a low percent pulp to total fruit weight, becomes non-existent. However, fruit growth potential and percent core are determined by effective pollination, hence seed content. Late fruits are heavier and more seeded than summer fruits. As Pimienta and Engleman (1985) have suggested that the pulp develops from the seeds, completely seedless varieties may be theoretically impossible. Caplan, (1995) has stated that the presence of seeds in cactus pears is the major deterrent to first time consumers and that a research priority should be directed to developing varieties with fewer, smaller and softer seeds. Nevertheless, late fruits have less seeds per unit core weight than summer fruits. Since seed unit dry weight does not change with ripening time, it is likely that more favorable environmental conditions during fruit growth result in a greater core development (Lawes et al. 1987).

pH and juice fruit

Different studies were done in order to reduce the pH value of the juice (Espinosa et al.). In this study, pH values are nearly similar in the most provenances, and a surprising decrease in pH in Ait Baha (5.28), Tamri (4.68) and Ben Guerir (5.68) cultivars. Moreover, a significant difference was observed in juice yield per gram of pulp with a Mohammedia fruit having the greatest yield of 63.88 ml of juice 100 g/pulp. Ait Baha and Tamri cultivar appears to the average consumer to be less juicy (52.87 ml, 46.87 ml of juice 100 g/pulp respectively) than the rest of cultivars, with respect to yield of juice of pulp it is nearly identical. These values are in agreement with those reported by (Felker et al. 2002) that report a juice yields ranging from 53.6 to 69.8 ml 100 g/l of pulp. However, the striking difference between cultivars on yield of juice was due to difference in pulp firmness (Felker et al. 2002).

As cactus fruits have a short post harvest shelf life, it would be useful to develop juice and other products from cactus fruits that could be used throughout the year. A recent economic analysis of fresh fruit production for export, for the domestic market and for juice production found that even if 100% of the cactus pear production were used to produce juice, at the same price as lemons, the internal rate of return for cactus pear production for juice would be 20% (Felker and Guevara 2001).

Oil content

Thin-layer chromatography of the oil in conjunction with GC-MS showed that the degree of unsaturation was over 83% and just 16% for saturated fatty acid. Linoleic acid was found to be the dominant fatty acid 63.68%, followed by oleic 18.35%, palmitic 12.85% and stearic acid 2.82% (Table 3). The amount of linoleic acid in *O. ficus-indica* oil was higher than that in majority of commonly consumed oils such as corn, soybean and cottonseed and close to that of safflower oil (Swern, 1982). In general, the higher level of unsaturation and particularly high level of linoleic acid in conjunction with the absence of linolenic acid, which affect adversely the stability of the oil indicated that *O. ficus-indica* seeds might be an excellent potential source of oil. Since *O. ficus-indica* seeds were found to constitute only about 12 to 15% of the whole fruit and the yield of the oil from the seeds was about 13.6%. The use of seeds for their oil content may not be economically viable, although oil seems to be a largest source of an excellent vegetable oil. However, such an operation might become feasible if it was a part of an integrated project whereby the fruit pulp could be utilized for the production of various food products along with the utilization of the seeds for edible oil and the resulting meal as a potential source for animal feed.

In the present study, the oil contents of the *Opuntia* seeds revealed a variation among the different localities, ranging from 2.71% Sidi Ifni A to 6.41% Ben Guerir (Figure 2). Seed oil contents found in this study were generally equal to the oil yields found in reports on *Opuntia* seed oil content, which were within the range of 40 g to 100 g (Charrouf and Guillaume, 1999; Huyghebaert, 1974; Nerd et al., 1994). These results are in agreement with those of Coskuner, (2003) who reported an oil content of 6.91%. Moreover, Salvo et al. (2002) reported that oil content from Italian cultivar was about 9.14% and Ramadan and Mörsel, (2003) also reported that oil content from German cactus was about 9.9%. These differences may be related to geographic or genetic conditions since the oil content of crops varies with the crop cultivars, soil and climatic conditions of an area (Breene et al. 1988).

The main constituent of all the oils is the fatty acids which may include saturated fatty acids (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA)(Mehmood et al. 2008). The evaluation of the total fatty acids (TFA) content in *O. ficus-indica* shows the variation between provenances studied. Fatty acid profiles of the seed samples revealed a large variation for most of the fatty acids examined. The predominant fatty acids found were oleic, linoleic, palmitic and stearic acid. Large variation was found in saturated fatty acids (palmitic and stearic) and unsaturated fatty acids (oleic, linoleic) percentages among localities. Oleic acid was highest 18.59% in Tafraout. Linoleic acid was 64.24% in Ait Baha and Safi. Less variation was found in palmitoleic and stearic acids between provenances. These results are in agreement with those of Sawaya and Khan (1982). Furthermore, the evaluation of the unsaturation degree of these fatty acids with oil content and altitude shows that is difficult to establish the relation between altitudinal gradient with oil contents and fatty acids. This suggests a large variation in fatty acid associated with other factors. Hence, this variation in *Opuntia* oil for this samples analyzed was mainly associated with differences in environmental condition of this ecotypes, which varied considerably (Nobel 1983; 2003). On the other hand, the lower inheritance of TFA shows that the FA contribution from environmental factor. All factors which can be also affected by the biohydrogenation or conversions of the polyunsaturated fatty acids (PUFA) promote a large variability in fatty content. The differences detected in the fatty acids explained by all factors and the relationship between fatty acid and these factors have been widely documented in literature. So, a large geographic and climatic difference that influences crop production in the fatty acid composition is reported.

Correlation and cluster classification

There was a significant positive correlation between the fruit weight and pulp weight and seeds number value, indicating that where fruit are heavy the seeds number are low on the fruit. There was also an inverse relationship between juice and seeds number. This was clearly demonstrated in the case of Mohammedia, which had the lowest number seeds but the highest yield of juice (Table 4).

The dendrogram indicated that based on fruit quality traits, planted cultivars did not all cluster into one group of closely related cultivars (Figure 3). Therefore, the risk of genetic homogeneity within moroccan cultivars is low. From the findings of this study it is evident that no single cultivar outperformed all others for all the fruit quality traits evaluated. The cluster showed three groups of *Opuntia* cultivars: (i) Group I is clearly differentiated from the two other groups, it included four cultivars with the highest pulp weight and low number of seeds in fruits. (ii) Group II included mostly cultivars from north and one from south. (iii)Group III included five cultivars of *Opuntia*, which possess fruits of a smaller size with high number of seeds in fruits. Sidi Ifni is found in both groups II and III probably due to exchange and dispersion by humans. Like Sidi Ifni M and Sidi Ifni A, they are under the same environmental conditions, but they are different in some fruit characteristics.

Conclusion

In this study, morpho-metric traits were used for

Table 3. Fatty acid composition in *Opuntia ficus-indica* seeds from thirteen provenances studied.

Parameter	Saturated fatty acid composition (%)					Unsaturated fatty acid composition (%)				
	Myristic	**Palmitic**	**Heptadecanoic**	**Arachidic**	**Stearic**	**Oleic**	**Linoleic**	**Linolenic**	**Eicosenoic**	**Palmitoleic**
Cultivars	**C14.0**	**C16.0**	**C17.0**	**C20.0**	**C18.0**	**C18.1**	**C18.2**	**C18.3**	**C20.1**	**C16.1**
Ait Baha	0.12±0.03	12.90±0.08	0.06±0.00	0.22±0.07	2.78±0.08	17.93±0.69	64.24±0.93	0.31±0.02	0.2±0.06	0.78±0.04
Tafraout	0.13±0.03	12.87±0.06	0.06±0.02	0.26±0.07	2.86±0.04	18.59±0.30	63.55±0.24	0.3±0.04	0.18±0.00	0.82±0.00
Sidi-Ifni M	0.14±0.00	12.83±0.01	0.05±0.00	0.17±0.00	2.82±0.01	18.36±0.01	63.53±0.01	0.31±0.01	0.17±0.01	0.81±0.00
Sidi-Ifni A	0.14±0.01	12.87±0.03	0.05±0.00	0.2±0.03	2.84±0.02	18.27±0.14	63.78±0.03	0.33±0.03	0.15±0.01	0.82±0.01
Tamri	0.14±0.01	12.77±0.20	0.07±0.01	0.19±0.00	2.73±0.01	18.41±0.08	63.3±0.11	0.29±0.01	0.16±0.01	0.77±0.08
Ben Guerir	0.19±0.06	12.82±0.04	0.07±0.01	0.18±0.01	2.85±0.01	18.51±0.18	63.55±0.29	0.32±0.02	0.17±0.02	0.84±0.05
Chaoun	0.14±0	12.83±0.00	0.05±0.00	0.17±0.00	2.82±0.01	18.36±0.00	63.53±0.00	0.31±0.00	0.17±0.00	0.81±0.00
Hoceima	0.14±0	12.84±0.01	0.05±0.00	0.17±0.00	2.84±0.02	18.36±0.00	63.66±0.18	0.31±0.00	0.16±0.01	0.81±0.00
Nador	0.14±0.03	12.87±3.04	0.05±0.01	0.20±0.00	2.83±0.65	18.36±4.23	63.75±14.97	0.33±0.09	0.15±0.03	0.82±0.20
Berkane	0.19±0.06	12.82±0.03	0.07±0.00	0.18±0.00	2.85±0.01	18.36±0.18	63.55±0.28	0.32±0.02	0.17±0.02	0.84±0.04
Meknès	0.17±0.03	12.82±0.00	0.07±0.00	0.19±0.01	2.84±0.01	18.36±0.09	63.63±0.11	0.32±0.00	0.17±0.00	0.83±0.01
Mohammedia	0.12±0.00	12.88±3.06	0.05±0.00	0.27±0.09	2.87±0.69	18.36±4.51	63.47±14.83	0.28±0.04	0.17±0.04	0.82±0.18
Safi	0.12±0.03	12.90±0.07	0.06±0.00	0.22±0.07	2.78±0.08	18.36±0.69	64.24±0.93	0.31±0.02	0.2±0.05	0.78±0.04

Table 4. Linear correlation matrix of the cactus pear (*Opuntia* spp.) cultivars based fruit characteristics.

Parameter	Fruit weight (g)	Pulp weight (g)	Fruit diameter (cm)	Fruit length (cm)	Total soluble solids (°Brix)	Total seeds number/pulp	Seeds/ pulp (g)	Juice (ml 100 g pulp -1)	Fruit pH
Fruit weight									
Pulp weight	0.84***								
Fruit diameter	0.71**	0.41^{ns}							
Fruit length	0.64*	0.30^{ns}	0.46^{ns}						
Total soluble solids	0.20^{ns}	0.54^{ns}	0.20^{ns}	-0.34^{ns}					
Total seeds number	-0.21^{ns}	-0.20^{ns}	-0.36^{ns}	0.06^{ns}	-0.52^{ns}	-0.38^{ns}			
Seeds/g Pulp	0.83***	0.70**	0.73**	0.50^{ns}	0.40^{ns}	0.20^{ns}	-0.69**		
Juice (Ml 100 g Pulp -1)	0.26^{ns}	0.17^{ns}	0.37^{ns}	0.19^{ns}	0.25^{ns}	0.26^{ns}	-0.57*	0.47^{ns}	
Fruit pH	-0.00^{ns}	-0.08^{ns}	0.25^{ns}	-0.18^{ns}	0.19^{ns}	0.05^{ns}	-0.47^{ns}	0.18^{ns}	0.66*

Characterization of genetic diversity among cultivars of *O. ficus-indica* in Morocco.Then, all the morpho-metric traits were correlated to the fruit in order to establish any relationship which might exist between them. The information obtained would be used for germplasm conservation, management and selection for domestication and improved cultivars regeneration. We have observed significant

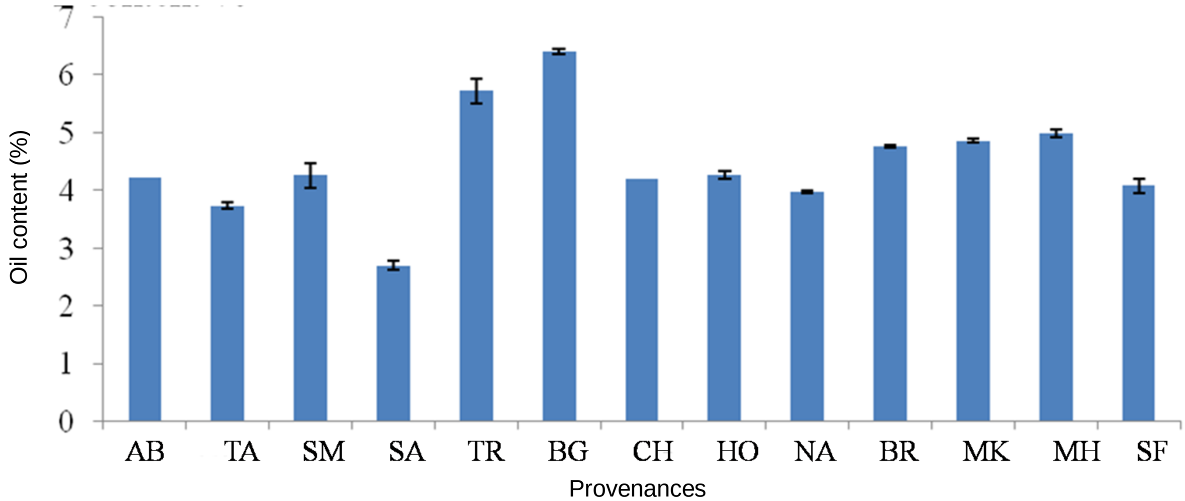

Figure 2. Oil contents of the *Opuntia ficus-indica* seeds.

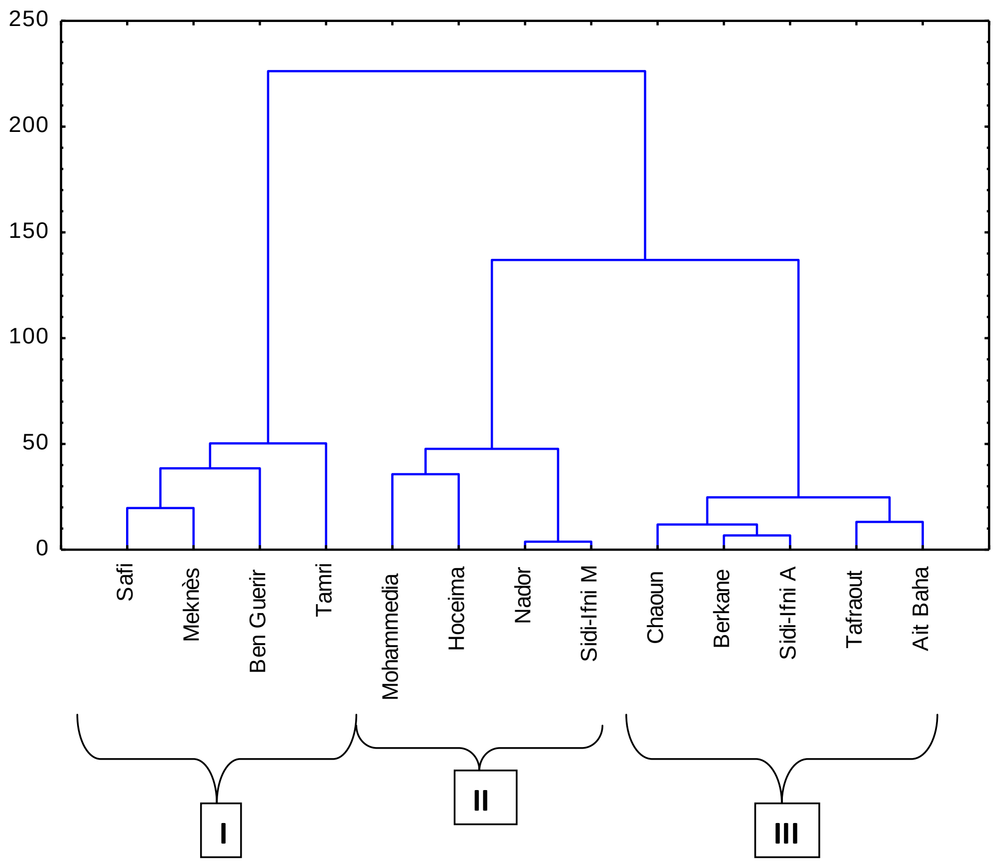

Figure 3. Dendrogram constructed from morphological traits and fruit quality.

variations in provenances cultivars; therefore, it was very difficult to characterize provenances according to their geographic origin.

Varieties that are recommended for fruit production are Mohammedia, Nador and Sidi-Ifni M, which scored above average in most fruit characteristics. All these cultivars meet the minimum fruit production criteria. They have great earning potential, because of its early bearing tendencies. Hociema can also compete with this early market. It is difficult to decide which fruit is most attractive, because this is a very subjective preference. It depends on personal taste, what the market is familiar with and how the fruit is going to be consumed, say, in a salad, as edible fruit or as a processed product, like jam. Emphasis should be given to cultivars that have a competitive fruit weight, a fair pulp weight and pulp content, for example Sidi Ifni M. Some of these cultivars may also perform differently in other areas, indicating why variety trials in different climatic areas are essential before variety recommendations can be made.

Cultivars in Tamri and Tafraout appear not to have a commercial viable fruit due to low sugar, and highest seeds number per pulp. Against, Mohammedia Sidi Ifni M and Nador cultivars proved to have the highest fruit weight, very good TSS value and low number of seeds, these cultivars can therefore be tested in the comparative plantation for both fruit production and for harvesting of cladodes for animal feed.

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