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RESEARCH ARTICLE

Comparative analysis of some biochemical parameters of argan pulp morphotypes (*Argania spinosa* (L) Skeels) during maturity and according to the continentality in Essaouira region (Morocco)

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Abstract *Argania spinosa* (L.) Skeels is an endemic forest tree for Morocco. The phytochemical compounds evaluation of four different morphotypes of their fruit pulps was investigated. The total content of sugar, protein and phenolic compounds were monitored during three different stages of maturation in the semi-continental (Mejji) and littoral regions (R'zwa). Total sugars, proteins, phenolics increased up to the ripe stage of all argan fruit morphotypes in the two regions. Spherical shape had higher sugar and protein content than other morphotypes. A significant difference ($p < 0.05$), was demonstrated by Pearson's test, between the different morphotypes at three stages studied for all the phytochemicals compounds. Likewise, ANOVA test established that the variation of this compounds was influenced by the stage of maturation and/or region of development and/or their interaction according to fruit shape. Results from this study revealed that the increase of these parameters level take place for the most part during the last stages of maturity which synchronize with fruit softening. Furthermore, our results showed information about the richness of argan fruit pulp in carbohydrates compounds and secondary metabolites as the possibility of their contribution in nutritive forage value especially at ripe stage.

Keywords *Argania spinosa* (L) · Fruit pulp · Phytochemical compounds · Maturation stage · Morphotype

Introduction

Argan (*Argania spinosa* (L)) is a popular forest tree crop, endemic and emblematic in the Sideroxyleae tribe, the lonely representative species of the tropical of Sapotaceae in Morocco; thus the tree is of monotypic genus (Swenson and Anderberg 2005). It occupies an area of around 320,000 square miles (Charrouf and Guillaume 2009), whereas the tree density and surface area decreases by an average of 600 ha/year (Moroccan minister of agriculture statistics). This relic species is known as a great reservoir of the proliferation and dissemination of *Ceratitis capitata* which actively migrates from the argan tree and invades continuously bordering agricultural areas (Alaoui et al. 2010).

Argania spinosa is more adapted essentially to the macaronesien ecoregion (Benabid 2000, 2012), in the arid and semi-arid regions. According to Emberger (1939) and Boudy (1950), argan tree develops in the isotherm altitudinal limit (m = 3.8 °C) and supports a high temperature of order of 50 °C. In these areas, argan tree has a great ecological role, it allow to fight against hydric and wind erosion and to arrest desert encroachment due to their deep root (Benzyane and Khatouri 1991). As well as it has an interesting socio-economical role, due to the exploitation of each part of tree [wood (M'hirit 1989), leaves, fruits

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(Fellat-Zarrouck et al. 1987)] and unsaturated comestible oil from its kernels (Chimi et al. 1994). The argan oil is also widely used in the preparation of the cosmetic products (Luis et al. 2005). Therefore, it represents a source of income and food for the autochthonus population (Benchakroun 1990) and it is classified World Heritage of Humanity by the United Nations since 1998, because of its contribution to the preservation of the ozone.

The cytology of these plants is poorly known relatively few molecular studies (Majourhat et al. 2007). However, the identification and characterization of variability was traditionally established according to the both types of markers: morphological (Bani-Aameur 2004; Chernane et al. 2000) and biochemical (Chernane et al. 2000; El Mousadik and Petit 1996) markers. It was found that the great phenologycal diversity seen in argan fruit is the result of genetic and pedoclimatic conditions (Falconer 1981). Bani-Aameur et al. (1999) distinguished mainly six fruit shapes (narrowly ellipsoid, ellipsoid pointed, ellipsoid, obovate, high-spheroid and spheroid) in southwest Morocco. Subsequently, several authors identified four very different fruit shapes in several localities in the argan forest in Morocco (Metro 1952; Sandret 1957; Morton and Voss 1987; Maalah 1992).

During our work in the region of Essaouira on the center west of Morocco, we identified ten different forms. Each tree produces one type of shape. We chose four most representative forms in this study (fusiform, oval apiculate, spherical and globular shapes). The first work which refers to the analysis of argan fruit pulps, was done with the aim of evaluating its fodder value (Battino 1929; Sandret 1957). It contains between 20 and 50 % of moisture, carbohydrates (18.5 %), cellulose (12.9 %) and proteins (5.9 %) (Fellat-Zarrouck et al. 1987). The same authors reported that fat content of argan fruit pulp is 6 % which consist of glyceride (33.3 %), latex (63.4 %) and insaponifiable part (3.3 %). In studies about pulp of fruit volatiles, the resorcinol has been identified as majority compound (73.5 %) (Charrouf and Guillaume 2005). Moreover, El Monfalouti et al. (2012) found a high amount of total polyphenols in the pulp (75.78 mg of gallic acid equivalent/g dry weight) and six compounds were detected (Isoquercitrin, hyperoside, rutin and quercitrin). In a previous qualitative study, sixteen phenolic compounds were identified in argan fruit pulp, mainly flavonoid glycosides and flavonoid aglycons (Charrouf et al. 2007).

Unfortunately, not all these studies took in account the morphotypical variability and the maturity stage of the argan fruit. Therefore, the objective of this research was to follow the phytochemicals compositional changes during argan fruit maturation by analyzing some phytochemical compounds in the pulp of four morphotypes from semi-continental and littoral regions in order to provide additional information about the evolution of the contribution in nutritive forage value of each form.

Materials and methods

Plant material

Argan (*Argania spinosa*) fruits were harvested from littoral (R'zwa) and semi-continental (Mejji) regions in Essaouira (Morocco).

R'zwa, located 15 km in the south of Essaouira at 150 m above the sea level (31°24′23.5″N and 009°45′11.0″W) and the mean annual precipitation is 378.7 mm. According to the card of bioclimatic stages defined by Emberger (1955), this region is located in the littoral climate (15 °C < m < 25 °C); the soil is essentially sandy.
Mejji, situated 138 km in the South West of Marrakesh at 292 m above the sea level (31°32′54.0″N and 009°22′50.2″W) and the mean annual precipitation is 198.7 mm. Depending on this Emberger's card, this area is located in the semi-continental climate (25 °C < m < 35 °C); the geologic nature of the ground is a limestone of the Cretaceous Cenomanien.

Argan fruits were collected in the mid of June 2011 according to maturation stage (Table 1): green, ripening and ripe stages and belonging to fusiform, oval apiculate, spherical and globular morphotypes. After harvesting, fruits were washed with tap water and stored at −20 °C. The pulp of fruit is used for the measurement and three replicates were carried out, three fruits were used for each replicate for each morphotype of fruit.

Chemicals

All the chemicals reagents used for biochemical and enzyme analysis were of the analytical grade (Sigma-Aldrich).

Total sugar content

Total sugar content was determined by the phenol–sulphuric acid method (Dubois et al. 1956). 100 mg of the samples were extracted in 4 ml of 80 % ethanol and centrifuged (5000 rev/min for 10 min). The supernatant was recovered while the pellet was taken up with 2 ml of 80 % ethanol. The 50 µl of pulp extracts were treated with 1 ml of phenol 5 % and after stirring, 5 ml of concentrated sulfuric acid was added to the mixture, then, it was incubated at 90 °C for 6 min. Total sugar concentrations were determined according to the standard curve method of glucose at 485 nm and expressed as mg/g FW (FW = fresh weight) of fruit.

Table 1 Variation in the color of the skin and pulp of argan (*Argania spinosa* (L.) Skeels) fruit during maturity stages

Maturity	State of fruit maturity
Green	Unripe, skin green-greenish, pulp white, the fruit is hard
Ripening	Unripe, skin entirely yellow, pulp light brown, the fruit is hard
Ripe	Ripe, skin completely yellow, pulp brown and fully soft

Protein extraction

Extraction of the protein from the fresh argan fruits pulp was carried out using the method of Zouiten (2002) and El Hassni (2005).

A 200 mg of pulp was ground in the cold (4 °C) in 1.5 ml of Tris-maleate buffer (0.1 M; PH 6.5) containing Triton X-100 (0.1 g/l), the ground material is vortexed and then centrifuged at 4000 rpm for 10 min. This procedure was repeated 3 times, and the recovered supernatants were collected and it was used as an extract for protein analyses.

Protein determination

Total protein content was determined according to the method of Bradford (1976), using bovine serum albumin as a standard. The 50 µl of the protein extract is added to 1.5 ml of Bradford reagent, after stirring, the mixture was incubated at 30° for 30 min. The absorbance of the samples was evaluated by graphic interpolation on a calibration curve at 595 nm.

Extraction and determination of total phenolic compounds

250 mg fresh pulp sample was grinded three times with 1.5 ml of 80 % methanol at 4 °C. The homogenate was centrifuged at 4000 rpm for 10 min and supernatants were collected and then constitute the hydroalcoholic extract (Zouiten 2002; El Hassni 2005).

To determine total phenolics, 10 µl of hydroalcoholic extract was mixed with 2 ml of distilled water and 250 µl of Folin-Ciocalteu's reagent. After stirring for 3 min, 500 µl of sodium carbonate (20 %) were added; the tubes are then shaken well and incubated at 40 °C for 30 min. The optical density was determined at 760 nm. The levels were expressed as mg equivalent of catechin per g of FW (mg of CE/g FW).

Statistical analysis

Each treatment was carried out in triplicate. The data obtained were statistically analyzed using the statistical package IBM SPSS Statistics (v.20). Analysis of variance (ANOVA), multivariate and Tukey's multiple range tests were applied, in order to evaluate the influence of morphotype and maturation stages on chemical composition of argan fruits pulp in two regions, followed by Duncan's test at $p < 0.05$ to determine significant differences between means. Correlation analysis was performed employing Pearson's test.

Results and discussion

During maturity, argan fruit shows a multitude modification in color, dimension and texture signifying that compositional changes are going on. Figures 1, 2, 3 and Tables 2 and 3 present the values of the representative parameters of development for the four argan morphotypes explored.

Sugar content

The results obtained from total sugar content assay (Fig. 1) display a significant differences ($p < 0.05$) between morphotypes exist in semi-continental and littoral region according to maturation stages.

For the four morphotypes, a significant increase during the maturity of argan fruits from green to ripe stage exist for the total sugar content (29.97 ± 15.46–353.33 ± 54.67 mg/g FW) in semi-continental region and from 57.37 ± 0.85 to 299.92 ± 22.78 mg/g FW in littoral region.

During all maturation stages in two regions, spherical form was only morphotype that had the highest values content of total sugar from 85.50 ± 8.81 to 353.33 ± 54.67 mg/g FW and from 90.76 ± 2.36 to 299.92 ± 22.78 mg/g FW in semi-continental and littoral region, respectively.

However, a significant difference found only at ripening and ripe stages between globular and oval apiculate forms (from 57.39 ± 0.85 to 123.40 ± 13.19 mg/g FW and from 61.64 ± 5.75 to 207.79 ± 7.67 mg/g FW, respectively) in littoral region. In general, the ripe stage for all morphotypes studied was characterized by the greatest total sugar content values. These results agreed with those reported by Youmbi et al. (2010) for *Cytherea spondias* Sonn fruits. There have been numerous studies attributed to increasing levels of total sugar at advanced stages of fruit maturity. Aydin and Kadioglu (2001) observed that glucose level of medlar fruits (*Mespilus germanica* L.) continuously

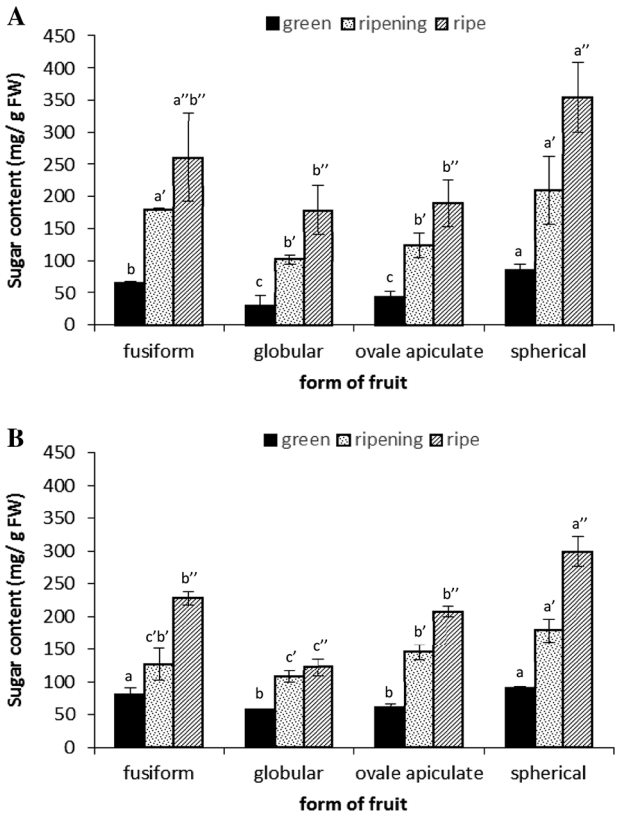

Fig. 1 Evolution of sugar content (mg/g FW) in four forms of argan fruits pulp during green, ripening and ripe maturation stages in semi-continental (**a**) and littoral (**b**) regions. Data followed by *different letters* in the same maturation stage are significantly different at 0.05 probability level by Duncan's test (n = 3)

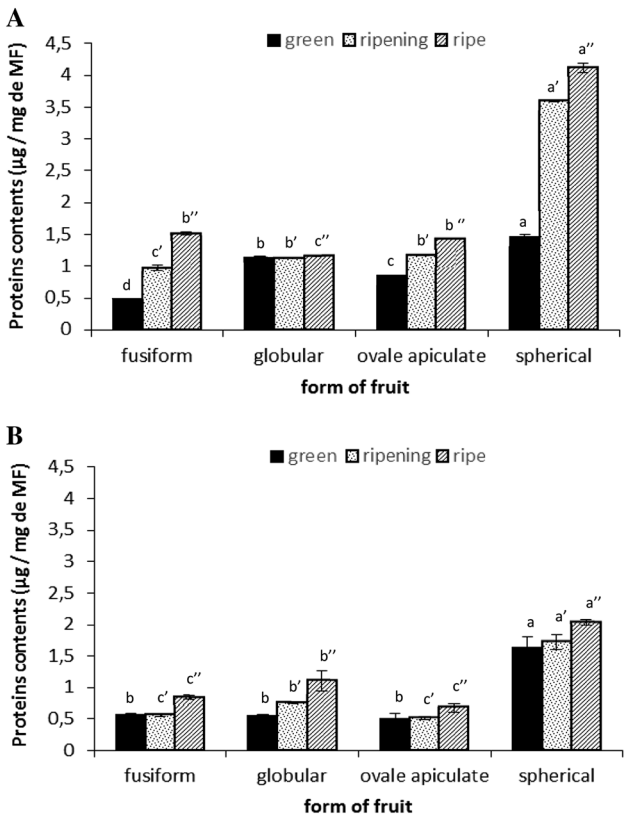

Fig. 2 Evolution of protein contents (µg/mg FW) in four forms of argan fruits pulp during green, ripening and ripe maturation stages in semi-continental (**a**) and littoral (**b**) regions. Data followed by *different letters* in the same maturation stage are significantly different at 0.05 probability level by Duncan's test (n = 3)

increases with maturation. The same result was observed by El Arem et al. (2011) who concluded that total sugars increased up to the full ripe stage from Basser, Rutab to Tmar stages of all date types studied (Alig, Degla, Deglet Nour, Gosbi and Horra). In addition, Kadioglu and Yavru (1998) found that the soluble sugar level progressively augmented from early development to the finale of the maturation stages of cherry laurel.

The increase in this molecular metabolism content can be explained by the generation of sugar by photosynthesis and carbon metabolism, especially the sucrose cleaving enzymes in source and sink tissues to control growth and development (Roitsch and Gonzalez 2004). The main notable result found in the tomato apical meristem showed that may genes are spatially regulated that encode carbon metabolic proteins such SUS, AGPase, and Snf1-related kinases (SnRK) and play a role as markers for beginning leaf development (Pien et al. 2001). These findings prove a role for sugar metabolism and signaling in timing of fixed developmental programs during the growth of the plant. In addition, genetic analyses showed wide relations between sugar and plant hormone signaling such abscisic acid (Arroyo et al. 2003; Cheng et al. 2002; Price et al. 2003) and ethylene (Price et al. 2004). Additionally, sugars also participate in the transcriptional regulation of other hormone signaling components.

It can be concluded that the significant difference between four morphotypes in two regions studied can be due to the environmental and genetic factors effect that could have an impact on the sugar content by altering of the enzymes implicated in synthesis and breakdown process. On the other hand, the build-up of sugar concentration from green to ripe stages clearly indicate that the pulp of argan fruit at ripe stage is an excellent source of readily available carbohydrates for cattle raising in these regions.

Protein content

Changes during fruit maturation in fresh weight of total proteins expressed as µg/mg FW in the semi-continental and littoral region are shown in Fig. 2.

Total proteins of all morphotypic argan fruit increased significantly ($p < 0.05$) and gradually from green to ripe stage. The total protein varied from 0.48 ± 0.01 to

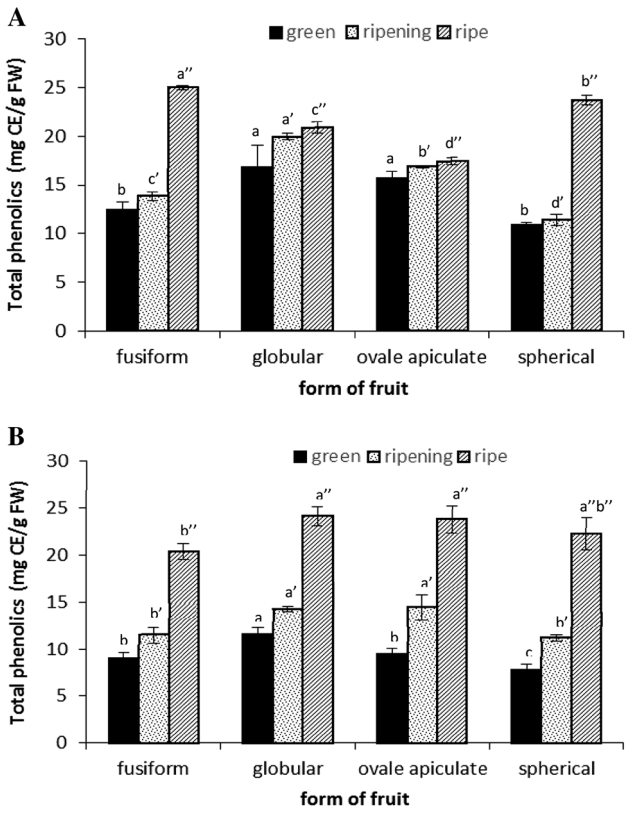

Fig. 3 Evolution of total phenolic (mg CE/g FW) in four forms of argan fruits pulp during green, ripening and ripe maturation stages in semi-continental (**a**) and littoral (**b**) regions. Data followed by *different letters* in the same maturation stage are significantly different at 0.05 probability level by Duncan's test (n = 3)

4.12 ± 0.08 μg/mg FW in semi-continental region and from 0.50 ± 0.09 to 2.03 ± 0.04 μg/mg FW in littoral region.

Spherical morphotype have the highest values at green, ripening and ripe stages (1.45 ± 0.44; 3.59 ± 0.01 and 4.12 ± 0.08 μg/mg FW, respectively) in the semi-continental region, and (1.62 ± 0.17; 1.72 ± 0.12 and 2.03 ± 0.04 μg/mg FW, respectively) in the littoral region. While the lowest protein contents were found in fusiform morphotype (0.48 ± 0.01; 0.97 ± 0.04 and 1.52 ± 0.02 μg/mg FW) in semi continental region, and oval apiculate morphotype (0.50 ± 0.09; 0.51 ± 0.02 and 0.68 ± 0.06 μg/mg FW) in littoral region, during the three maturation stages.

Our results revealed a similar tendency to those found in many fruits likes Tunisia date varieties, in which total proteins increased significantly during Besser, Rutab and Tmar maturation stages (El Arem et al. 2011). Clemente and Correia (2006) also reported that protein concentration in uvaia (*Pseudomyrcianthes pyriformis* (Camb.) Kaus) pulp is continuously enhanced with maturity stages.

Other work published by Bashir and Abu-Goukh (2003) showed that total protein increased progressively to the complete ripe stage in pulp of white and pink guava but suddenly decreased at the over-ripe stage, the same result found in the pulp of three mango cultivars by Abu-Goukh and Abu-Sarra (1993).

The intervention of some enzymes which have a significant role in the softening of the fruit such as cellulose

Table 2 ANOVA results for the effect of region and maturation stages on biochemical compounds in four morphotypic of argan fruit pulp

Morphotype	Source of variation	Phenolic compound	Total sugar	Total protein
Fusiform	Maturation (M)	***	***	***
	Region (R)	***	ns	***
	R × M	*	ns	***
Globular	Maturation (M)	***	ns	***
	Region (R)	***	***	***
	R × M	***	**	***
Oval apiculate	Maturation (M)	***	***	***
	Region (R)	ns	*	***
	R × M	***	ns	***
Spherical	Maturation (M)	***	***	***
	Region (R)	***	ns	***
	R × M	*	ns	***

ns Not significant

* Statistical significance at $p \leq 0.05$

** Statistical significance at $p \leq 0.01$

*** Statistical significance at $p \leq 0.001$

Table 3 Pearson's correlations coefficients among traits observed in four morphotypical argan fruit pulp

Morphotype	Analytical parameters	Phenolic compound	Total sugar	Total protein	Maturation degree
Fusiform	Phenolic compound	–	0.809**	0.858**	0.877**
	Total sugar	0.809**	–	0.803**	0.873**
	Total protein	0.858**	0.803**	–	0.752**
Globular	Phenolic compound	–	0.507*	0.805**	0.788**
	Total sugar	0.507*	–	ns	0.880**
	Total protein	0.805**	ns	–	0.499*
Oval apiculate	Phenolic compound	–	0.702**	ns	0.765**
	Total sugar	0.702**	–	ns	0.956**
	Total protein	ns	ns	–	ns
Spherical	Phenolic compound	–	0.883**	0.528*	0.907**
	Total sugar	0.883**	–	0.692**	0.946**
	Total protein	0.528*	0.692**	–	0.604**

ns Not significant

* Statistical significance at $p \leq 0.05$

** Statistical significance at $p \leq 0.01$

and polygalacturonase could explain the augmentation of protein concentration during maturation (El Arem et al. 2011) and the enzymes needed for the maturity process are proteins contained in ripening fruits as supported by Frenkel, Klein and Dilley (1968). Many studies demonstrated that a number of fruits such cherimoya, pineapple, cherry, Japanese pear or pepper accumulate chitinases and thaumatin-like during their maturity (Barre et al. 2000; Fils-Lycaon et al. 1996; Gońi et al. 2009; Kim et al. 2002; Sassa and Hirano 1998; Taira et al. 2005). They might be implicated in plant development processes (Kasprzewska 2003) and in fruit maturation (Peumans et al. 2000; Choudhury et al. 2009).

Secondly, values clearly showed a difference between same morphotype from the two regions for the same stage of maturity (1.12; 1.13 and 1.17 µg/mg FW in semi-continental region and 0.55; 0.75 and 1.10 µg/mg FW in littoral region, for green, ripening and ripe stage, respectively) for globular form for example. These results were similar to those found by Tlili et al. (2014) for *Rhus tripartitum* fruits collected at different maturity stages from two Tunisian regions.

Other authors established that protein content of plants could vary with soil, climatic conditions, and cultivars origin (El Arem et al. 2011; Tlili et al. 2011). Importantly, several genes that encode metabolic proteins involved in sugar signal generation undergo transcriptional feedback regulation by their own products (Rolland et al. 2006).

It can be stated that pulp of argan fruits have an important nutritional value that could be used as a raw material source in the food of cattle due to potential source of proteins and sugars contents especially at ripe stage.

Total phenolic compounds

The evolution of total phenolic content during argan fruits maturation in the two regions is reported in Fig. 3.

A gradual increase was found, there were marked significant ($p < 0.05$) difference in the phenolic content at different stages of maturity according to the four morphotypes of fruits analyzed.

In the semi-continental region, as can be deduced, globular morphotype contained the highest phenolic compounds at green and ripening stages (16.84 ± 2.21 and 20 ± 0.30 mg/g FW, respectively). While fusiform and spherical morphotypes had a highest amount of phenolic concentration at ripe stage (25.03 ± 0.23; 23.71 ± 0.52 mg/g FW, respectively), but at the green and ripening stages, spherical morphotype had the lowest phenolic content (10.88 ± 0.24–11.43 ± 0.56 mg/g FW, respectively).

In the littoral region, globular form characterized by a high level of total phenolic content at green stage (11.58 ± 0.69 mg/g FW), and a considerable content at ripening and ripe stage for globular and oval apiculate morphotypes (14.23 ± 0.23–24.10 ± 1.03 and 14.37 ± 1.33–23.76 ± 1.44 mg/g FW, respectively).

Summarizing, this steeply accumulation in total phenolic content during maturation is in good agreement with those reported by Vela et al. (2002) for Algeria loquat variety (*Eribotrya japonica*). They found that total phenolics accumulated gradually along the maturity stages and their concentration arrived to fivefold during the last month of fruit development.

Mainland and Tucker (2000) also reported that the anthocyanin and total phenolic content of five blueberry

cultivars increased with progressing maturity. These results are in contrast with numerous researches, which indicated that these phenolic compounds were generally more abundant in the beginning of maturation. Their concentration tend to decrease with maturity in apricot (Dragovic-Uzelac et al. 2007), in the medlar fruit (Ayaz et al. 2008; Rop et al. 2011) and in 15 peach cultivars (Lee et al. 1990).

To explain the evolution of phenolic content in the fruit, the pathway of phenolics synthesis must be investigated. It is known that the key enzyme of the phenylpropanoid pathway is phenylalanine ammonia lyase (PAL) which catalyze the initial and obligated phase in the biosynthesis of phenols compounds (Lancaster et al. 2000) by deamination of L-phenylalanine to form trans-cinnamic acid with the release of NH_3 and this deamination initiate the main phenylpropanoid pathway. Therefore, the rise in phenol level might be consequence of PAL induction by maturation process, which act through increased transcription of PAL mRNA. Moreover, the biotic and abiotic stresses, which characterized as activators also enhance PAL activity in the same manner (Saltveit 2010).

In general, the control of the production of plant phenolics implicates a matrix of potentially imbrication regulatory signals. These cover developmental signals, such as the production of anthocyanins during fruit and flower development, and environmental signals for protection against abiotic and biotic stresses (Cheynier et al. 2013).

Influence of environmental factors on phytochemical compounds and their morphotypic correlations

During maturity stages, changeability has been detected between argan fruit morphotypes for all phytochemical compounds studied. For this point, a multivariate test was exploited to found the source of this changeability. Table 2 shows factors affecting fruit biochemical compounds in four morphotypic argan fruit.

ANOVA results showed that maturation stage influenced significantly all biochemical compounds in argan fruits, except on total sugar for globular form. Concerning region effect, it does not have a significant effect on total sugar for spherical and fusiform morphotypes and on phenolic compounds for oval apiculate form. However, the region had a significant effect on total protein for all morphotypes studied.

A significant interaction between region and maturation stage was found on biochemical compounds, except on the total sugar in fusiform, oval apiculate and in spherical forms.

It was observed that total protein content, was mainly influenced significantly ($p < 0.001$) by maturation stage, region and their interaction (RxM) for all morphotypes considered, followed by phenolic compounds. Whereas, total sugar content was influenced differently by these source of variation according to the kind of morphotypic argan fruit.

Table 3 shows Pearson's correlation coefficients between phytochemical components and degree of maturation in four morphotypic argan fruit.

The maturation degree was positively and highly ($p \leq 0.01$) correlated with all phytochemical compounds, except for total protein of oval apiculate. Similarly, significant positive correlation values among phenolic compounds, total sugar and total protein for all morphotypic fruits, except between phenolic compounds and total protein for oval apiculate shape.

On the other hand, a significant relationship was observed between total sugar and phenolic compounds for all morphotypical fruits. In contrast, there was a difference in existence of correlation between total sugar and other phytochemical compounds according to the fruit's morphotype and the same observation was found for total protein.

Summarizing, the statistical analysis showed the significant effect by different manner, of the maturity stage, region or/and the interaction between them on some or all phytochemical compounds according to the morphotypical fruit. This difference may be explained by the difference in the influence of environmental conditions over the growing season on some biochemical compounds than other compounds, in agreement with multitude research (Brooks et al. 1993; Bureau et al. 2009). A study released by Serrano et al. (2005) reported that the location, year or climate had a significant effect on the some phenolic content as anthocyanin and flavonoid in sweet cherry. Furthermore, Tomás-Barberán et al. (2001) showed that temperature had a significant effect on anthocyanin production in apples or plums. Similarly, i Forcada et al. (2013) reported that the chemical composition of sugar and phenolic compounds and other biochemical compounds of peach and nectarines are significantly affected by rootstocks, climate, harvest conditions and scion genotype.

The positive correlation between total sugar and total phenolic that was found in our study, was also reported by Abidi et al. (2011) for nectarine fruit and by Pirie and Mullins (1977) for berries; that could be explained by the effect of sugars in the control of phenolic biosynthesis. As DeJong (1999) who found that, the appropriate content of sugars in or near the fruit is important for phenolic compounds production during fruit development.

Indeed, the difference in phytochemical compounds analyzed in the argan fruits pulp might be a result of maturation processes and a fruit's morphotypes, which could be related to genotypic factor, as well as an adaptation to the environmental changes in relationship with geographical position.

Conclusion

In this study, the pulp of argan fruit displayed, there was profound changes in texture, and color during maturation stages. There were also significant differences in the levels of sugar, protein and phenolic contents of argan fruit between maturity stages during fruit maturation for each morphotypical forms according to the region of development.

In generally, the pulp of argan fruits was very rich in sugar and proteins at ripe stage, especially for spherical morphotype in the semi-continental and littoral region. The phenolic contents became important with the maturation for four morphotypes grown in these regions.

It can be deduced that fruit maturity, region and morphotypes differences through maturation, cause considerable influences in the changes of these phytochemical compounds in the pulp of argan fruit. Although this experimentation could not measure some other compounds probably present in the fruit, the composition of the pulp at ripe stage improves the nutritive value for cattle in these regions especially the spherical shape.

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