Morphological, nutritional and chemical description of "Vatikiotiko", an onion local landrace from Greece

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ABSTRACT

"Vatikiotiko" is an onion local landrace from Greece with special quality features, such as strong and pungent taste and storability. In this study, we tried for the first time to describe this landrace and record its morphological traits and nutritional value in comparison with commercially cultivated genotypes ("Creamgold", "Red Cross F1" and "Sivan F1"). Nutritional value of "Vatikiotiko" was higher than commercial genotypes, whereas total sugars, fructose and glucose content were lower in "Vatikiotiko" and "Creamgold" onions. Fatty acids composed mostly from polyunsaturated fatty acids (linoleic and α-linolenic acid), whereas for "Vatikiotiko" saturated and monounsaturated fatty acids were detected in equal amounts (29.79 and 30.60%, respectively). "Vatikiotiko" and "Creamgold" had low antioxidant activity (DPPH radical scavenging activity), especially when comparing with "Sivan F1" and "Red Cross F1", whereas no flavonoids were detected in "Vatikiotiko". The overview of "Vatikiotiko" landrace supported its special character regarding its nutritional value (sugar content, mineral composition and fatty acids profile) and the necessity to revalorize and protect its traditional culture. The potential of introducing it as Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) product has also been discussed.

Chemical compounds studied in this article: Oxalic acid (PubChem CID 971); Malic acid (PubChem CID 525); Citric acid (PubChem CID 311); Fumaric acid (PubChem CID 21418); Palmitic acid (PubChem CID 985); alpha-tocopherol (PubChem CID 2116); Linoleic acid (PubChem CID 3931); alpha-linolenic acid (PubChem CID 5280934); Fructose (PubChem CID 3426); Sucrose (PubChem CID 5988)

Keywords: Alliaceae*; Allium cepa* L.; antioxidant activity; flavonoids; landrace; onion

1. Introduction

The modernization and intensification of agriculture throughout the last decades along with the reduction of rural population have resulted in vast biodiversity loss, since farmers grow pure lines and hybrids and tend to abandon traditional landraces and cultivars (Negri, Maxted & Vetaläinen, 2009). However, the increased consumer concern for healthy and safe foods has resulted in an ever-growing demand for food products with specific and unique characteristics, closely linked with specific cultivation and production methods, place of origin and composition (Siracusa, Avola, Patane, Riggi & Ruberto, 2013). In addition, there is a need for preserving genetic resources in order to conserve both local landraces and crop-related culture (Negri et al, 2009; Veteläinen, Negri & Maxted, 2009) within the framework of EU directives for agrobiodiversity (Commission Directive 2008/62/EG of 20 June 2008).

Onion is a vegetable crop of major importance for many countries in the world, with significant beneficial effect on human diet (Lanzotti, 2006). In Greece, it is particularly important since it is cultivated in 7.000 ha with a total production of 249.600 tn and average yield of 39.31 tn ha^{-1} (FAO, 2012), whereas specific regions in the south and middle part of Greece are mostly cultivated with onions. "Vatikiotiko" is a local landrace of a short-day onion that is cultivated only in the region of Vatika of the Lakonia prefecture where winters are mild and allow for very early production of dry bulbs at the end of spring. The cultivation is carried out according to traditional cultivation practices that originate from the late medieval ages and transferred from generation to generation, whereas the total cultivated area is about 20 ha with a total production of 700 tn.

The importance of this landrace comes from the fact that it is the first onion product that comes out in the Greek market in the spring, a period where storage onions from the summer harvest have been either out of stock or of very poor quality. Another important aspect of this product is its cultural importance for this region, since its survives through the centuries, and its special taste and flavor due to the microclimatic conditions of the region, which render this product of high quality and with great potential for exporting in foreign markets as a "Made in Greece" product, either as a Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) product (EC Regulation, 2006). In addition, its high dry matter content makes it ideal for long term storage. So far, the small scale production barely covers the market needs, however in case of more intensive and higher total production the potential for long storage should be very useful.

The aim of the present study was to report the chemical composition of "Vatikiotiko" landrace in comparison with three well established onion cultivars and hybrids marketed in Greece ("Red Cross F1", "Sivan F1" and "Creamgold"), with special interest in nutritional value, mineral composition, content in organic acids, sugars and tocopherols, fatty acids composition and antioxidant properties. In addition, since there is no literature regarding "Vatikiotiko" landrace, we tried to describe for the first time the morphology and quality of dry bulbs in comparison with the commercial cultivars and hybrids.

2. Materials and Methods

2.1 Plant material and experimental sites

Samples of onions (30 kg of dry onion bulbs) were collected within the first fortnight of June 2014 (10-15th of June), from farmers directly after curing for 2 weeks and

when ready for marketing. Harvesting for all onions was applied at the stage of 50% fallen tops, except for the case of "Creamgold" onion where no details were available. "Vatikiotiko" and "Sivan F1" onions were collected from Lakonia prefecture (latitude 36° 31′ 42″, longitude 23° 02′ 51″, 10 meters above the sea level) on June 10-12, 2014. "Red Cross F1" onions were collected from the region of Thebes (latitude 38° 19′ 39″, longitude 23° 19′ 04″, 120 m above sea level) on June 12-14, 2014 and "Creamgold" onions were bought from a retail supermarket, in net bags of 1 Kg and 50-70 mm diameter grading on June 15, 2014. "Vatikiotiko", "Sivan F1" and "Red Cross" were short day onions, whereas "Creamgold" was a long-day onion.

2.2 Morphological and quality features

After collection, samples from each onion were divided in three batch samples for further analyses. Prior to chemical composition analyses a description of morphological and quality features of bulbs for each genotype was conducted. The recorded features were bulb shape and diameter, fresh and dry weight, number of scales, color of tunic and flesh, thickness of tunic and total soluble solids (°Brix) of edible flesh. Bulb shape was recorded according to International Plant Genetic Resources Institute descriptors for *Allium* spp. (IPGRI, 2001).

Each bulb was bisected equatorially and the number of scales and tunic thickness were measured. TSS content was measured with hand-held refractometer TR53000C (T.R. Turoni SRL, Italy) on juice taken from the edible scales (Carl Zeiss Jena, Germany). Bulb firmness was recorded with a flat bottom probe (d=9 mm and 9 mm width) using digital fruit firmness tester TR53205 (T.R. Turoni, SRL, Italy) and applied to the equatorial axis at three different points. Color measurements were carried out with the implementation of Chroma Meter CR-400 (Konica Minolta Inc.,

Tokyo, Japan) using the CIELAB co-ordinate system (L, a, b), whereas for Chroma values (C^*) which according to McGuire (1992) describes color saturation and hue angle (h^*) which describes color shadiness (0° = red-purple, 90° = yellow, 180° = bluish-green and 270° = blue), were determined according the following formulas:

$$C^* = \sqrt{a^{*2} + b^{*2}},$$

$$h^* = 180 + \left(\frac{\left(arctan\frac{b^*}{a^*}\right)}{6.2832}\right) * 360, when\ a^* < 0 \text{ and}$$

$$h^* = \left(\frac{\left(arctan\frac{b^*}{a^*}\right)}{6.2832}\right) * 360, when\ a^* > 0.$$

Titratable acidity was calculated as g malic acid/100 mL of juice, after titration with 0.1 N NaOH to an endpoint of pH 8.2. Three samples per genotype were analyzed and their mean value was used for statistical analysis.

2.3 Nutritional and chemical composition

For chemical composition sampling, onion bulbs were bisected equatorially in order to obtain a section of about 1 cm height and 10 g of fresh weight and after removing the outer skin the flesh was cut in small pieces. Samples were taken from 15 bulbs (150 g of fresh weight in total) from each genotype and all the samples were pulled in one and stored at deep freezing conditions (-80°C) and freeze dried prior to analysis. The freeze dried samples were powdered with pestle and mortar and divided in three samples for further analysis.

The samples were analysed for proteins, fat, carbohydrates and ash using the AOAC (1995) procedures. The crude protein content (N×6.25) of the samples was estimated by the macro-Kjeldahl method; the crude fat was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus; the ash content was determined by incineration at 600±15°C. Total carbohydrates were

calculated by difference. Energy was calculated according to the following equation: Energy (kcal) = 4 × (g protein) + 4 × (g carbohydrate) + 9 × (g fat).

For the mineral composition samples of dry bulbs tissues were dried in a forced-air oven at 72°C to constant weight, ground to powder, subjected to dry ashing and extracted with 1 N HCl to determine the mineral. Ca, Mg, Fe, Mn, Zn, and Cu content were determined by atomic absorption spectrophotometry (Perkin Elmer 1100B, Waltham, MA) and Na and K content by flame photometry (Sherwood Model 410, Cambridge, UK).

Organic acids were determined following a procedure previously described by the authors (Pereira, Barros, Carvalho & Ferreira, 2013). The analysis was performed using a Shimadzu 20A series UFLC (Shimadzu Coperation, Kyoto, Japan). Separation was achieved on a SphereClone (Phenomenex, Torrance, CA, USA) reverse phase C_{18} column (5 μm, 250 mm × 4.6 mm i.d) thermostatted at 35 ºC. The elution was performed with sulphuric acid 3.6 mM using a flow rate of 0.8 mL/min. Detection was carried out in a DAD, using 215 nm and 245 nm (for ascorbic acid) as preferred wavelengths. The organic acids found were quantified by comparison of the area of their peaks recorded at 215 or 245 nm with calibration curves obtained from commercial standards of each compound.

Free sugars were determined by high performance liquid chromatography coupled to a refraction index detector (HPLC-RI), after an extraction procedure previously described (Guimarães et al., 2013). The equipment consisted of an integrated system with a pump (Knauer, Smartline system 1000, Berlin, Germany), degasser system (Smartline manager 5000), auto-sampler (AS-2057 Jasco, Easton, MD, USA) and an RI detector (Knauer Smartline 2300, Berlin, Germany). Data were analysed using Clarity 2.4 Software (DataApex, Podohradska, Czech Republic). Sugars identification

was made by comparing the relative retention times of sample peaks with standards and quantification was based on the RI signal response of each standard, using the internal standard (IS, melezitose) method and by using calibration curves obtained from the commercial standards of each compound.

Fatty acids were determined after a transesterification procedure as described previously by the authors (Guimarães et al., 2013). The fatty acids profile was analyzed with a DANI 1000 gas chromatographer (GC) equipped with a split/splitless injector and a flame ionization detector (FID). Fatty acid identification was made by comparing the relative retention times of FAME peaks from samples with standards. The results were recorded and processed using Clarity 4.0.1.7 Software (DataApex, Podohradska, Czech Republic).

Tocopherols were determined following a procedure previously described by the authors (Guimarães et al., 2013). Analysis was performed by HPLC (equipment described above), and a fluorescence detector (FP-2020; Jasco) programmed for excitation at 290 nm and emission at 330 nm. The compounds were identified by chromatographic comparisons with authentic standards. Quantification was based on the fluorescence signal response of each standard, using the IS (tocol) method and by using calibration curves obtained from commercial standards of each compound.

2.4 Antioxidant activity and bioactive compounds

Antioxidant activity and bioactive compounds were assessed according to methods previously reported by Roriz et al. (2014). Methanolic/water (80:20, *v/v*) extracts were obtained from the lyophilized material. Each sample (1 g) was extracted twice by stirring (25 ºC at 150 rpm) with 30 mL of methanol/water (80:20, *v/v*) for 1 h and subsequently filtered through a Whatman No. 4 paper. The combined methanol/water

extracts were evaporated at 40 ºC (rotary evaporator Büchi R-210, Flawil, Switzerland) to remove the methanol and further frozen and lyophilized. The extracts were redissolved in methanol/water (80:20, *v/v*) at a final concentration of 50 mg/mL and further diluted to different concentrations to be submitted to the distinct *in vitro* assays.

DPPH radical-scavenging activity was evaluated by using an ELX800 microplate reader (Bio-Tek Instruments, Inc; Winooski, VT, USA), and calculated as a percentage of DPPH discolouration using the formula: $[(A_{DPPH}-A_S)/A_{DPPH}] \times 100$, where A_S is the absorbance of the solution containing the sample at 515 nm, and A_{DPPH} is the absorbance of the DPPH solution. Reducing power was evaluated by the capacity to convert Fe^{3+} to Fe^{2+}, measuring the absorbance at 690 nm in the microplate reader mentioned above. Inhibition of β-carotene bleaching was evaluated though the β-carotene/linoleate assay; the neutralization of linoleate free radicals avoids β-carotene bleaching, which is measured by the formula: β-carotene absorbance after 2h of assay/initial absorbance) × 100. Lipid peroxidation inhibition in porcine (*Sus scrofa*) brain homogenates was evaluated by the decreasing in thiobarbituric acid reactive substances (TBARS); the colour intensity of the malondialdehyde-thiobarbituric acid (MDA-TBA) was measured by its absorbance at 532 nm; the inhibition ratio (%) was calculated using the following formula: [(A - B)/A] × 100%, where A and B were the absorbance of the control and the sample solution, respectively (Guimarães et al., 2013). The results were expressed in EC_{50} values (sample concentration providing 50% of antioxidant activity or 0.5 of absorbance in the reducing power assay) for antioxidant activity and Trolox was used as a positive control.

Total phenolics were estimated by Folin-Ciocalteu colorimetric assay according to procedures previously described (Barros, Oliveira, Carvalho & Ferreira, 2010) and the results were expressed as mg of gallic acid equivalents (GAE) per g of sample. Total flavonoids were determined by a colorimetric assay using aluminum trichloride, following procedures previously reported (Barros et al., 2010); the results were expressed as mg of (+)-catechin equivalents (CE) per g of sample.

2.5 Statistical analysis

The data from morphological traits and mineral composition were subjected to statistical analysis using the STATGRAPHICS Plus 5.1 logistic package. Differences between treatment means were compared at $P<0.05$ with ANOVA in order to find the statistically significant differences. Colour measurements means were compared by the Least Significant Difference test (LSD) at $P<0.05$. For nutritional and chemical composition, three samples were analysed for each one of the onion genotypes, whereas all of the assays were carried out in triplicate. The results were expressed as mean values and standard deviation (SD). The chemical composition and antioxidant activity were analysed using one-way analysis of variance followed by Tukey's HSD test with $\alpha= 0.05$ using the SAS v. 9.1.3 statistical program.

3. Results and discussion

3.1 Evaluation of morphological traits

The evaluation of morphological traits of dry bulbs showed that for "Vatikiotiko" onion the typical shape is shape number 9 (high top) (**Appendix A**) with slight deviations, which were less than 10% of the examined bulbs (IPGRI, 2001). For "Sivan F1" the typical shape was between the shape number 3 and 9 (rhomboid and

high top) (82% of the bulbs) with the rest having a flat globe shape (number 2). For "Red Cross F1" the shape ranged within the shapes 3, 6 and 9 (90% of bulbs), whereas for "Creamgold" onion the 85% of bulbs had the globe shape (number 5) and the rest 15% of the bulbs a shape between 2 and 5 (flat globe and globe) or 2 and 6 (globe and broad elliptic).

Significant differences were also observed in most of the other morphological traits, such as bulb fresh and dry weight, bulb diameter, firmness and tunic thickness and tunic and flesh color (**Tables 1** and **2**). However, since the samples were from different genotypes and grown under different conditions these results had to be expected and are in accordance with reports where different cultivars, accessions or selections of the same cultivar had differences in morphological traits (Riggi, Avola, Siracusa & Ruberto, 2013; Simó, Pascual, Cañizares & Casañas, 2014). The higher dry matter content and the larger firmness and tunic thickness of "Vatikiotiko" onion also indicate a genotype that is ideal for long storage, however further studies need to be conducted in order to confirm this argument (**Table 1**).

3.2 Nutritional and chemical evaluation

Nutritional value of the studied onion genotypes is presented in **Table 1**, where significant differences can be observed in favor of "Vatikiotiko" onion. These results differ from the reported nutritional value for raw onion (USDA, 2008). In addition, pH values of onion juice were low for all genotypes (5.50 - 5.77), whereas titratable acidity ranged from 0.027 to 0.038 g of citric acid per 100 g of bulb fresh weight. These differences could be mostly due to the lower water content of "Vatikiotiko" as well as to different growing conditions in comparison to other genotypes (Ariyama et al., 2006). Therefore, considering the use of onion as spice, food flavoring or raw in

salads and the relatively small daily consumption, the higher nutritional value of "Vatikiotiko" onion could be more beneficial for human health, since the consumption of 100 g of raw onion could provide with 52-62% more protein, 42-45% more carbohydrates and 43-46% more energy comparing to the other genotypes.

Mineral composition of onion bulbs differed significantly with "Vatikiotiko" onion having higher content in Na, Ca, Mg, Mn, Fe than the other genotypes except for the case of Phosphorus, where no significant differences were detected (**Table 3**). The mineral content of onions in our study was higher than that suggested by USDA (USDA, 2008) for raw onions for most of the nutrients and especially for Ca, Mg and Fe.

The differences in nutritional value and mineral composition between the studied genotypes and the already reported composition for raw onions (USDA, 2008) could be partly due to the effect of genotype and mainly due to cultivation practices and environmental factors (Ariyama, Nishida, Noda, Kadokura & Yasui, 2006; Riggi et al., 2013; Pérez-Gregorio, García-Falcón, Simal-Gándara, Rodrigues & Almeida, 2014). The fact that the samples derived from different regions where farmers apply different farming methods (e.g. "Vatikiotiko" onion which is transplanted as seedling, whereas for "Sivan F1" and "Red Cross F1" direct sowing is applied) and usually grow under different climate and soil conditions could explain these differences.

Total organic acids content and individual acids content was significantly higher in "Vatikiotiko" onion in comparison with the other genotypes, except for the case of ascorbic acid where "Creamgold" onion had the highest content (**Table 4**). These results could be attributed partly to low water content of "Vatikiotiko" bulbs. However the fact that during its cultivation are applied traditional practices with low agrochemical inputs (fertilizers) may explain these results.According to Pérez-

Gregorio et al. (2014) the use of high amounts of synthetic fertilizers can increase plant growth and development, and consequently plant resources are consumed for growth instead of secondary metabolites production, such as organic acids. In our study the main acids that contribute mostly to edible flesh acidity are malic (121.04 - 240.21 mg 100 g^{-1} fresh weight) and citric (125.56 - 221.63 mg 100 g^{-1} fresh weight) acids. Similar results have been reported by Caruso et al. (2014) but with lower content for both acids. In contrast, Galdón, Rodríguez, Rodríguez & Romero (2008) reported that glutamic acid was the prevalent organic acid (325 ± 133 mg 100 g^{-1}) followed by citric (48.5 ± 24.1 mg 100 g^{-1}) and malic (43.6 ± 10.4 mg 100 g^{-1}) acids, however they also reported significant differences between the different onion cultivars that could explain the contradictory results.

The ascorbic acid content fluctuated between the genotypes, ranging from 1.97 ("Red Cross F1") to 4.09 mg ("Creamgold") 100 g^{-1} fresh weight, which falls within the published range for vitamin C content in onion bulbs (Caruso et al., 2014). Gorinstein et al. (2009) reported that red onion had a higher content in ascorbic acid than white and yellow onion, however in our study that was not the case which could be attributed mostly to genetic and environmental factors (climate conditions and cultivation season), as well as to the fact that only edible part of the bulbs were studied. The importance of ascorbic acid in human diet originates from its function as vitamin C, as well as from its antioxidant activity (García-Herrera et al., 2014). Ascorbic acid is the most abundant vitamin in onion bulbs, followed by vitamin B, however onion is not considered an important source of ascorbic acid in human diet due to the small average daily consumption with overall contribution to daily requirements in human diet amounting up to 7% (USDA, 2008).

Significant differences in sugars content were also observed among the studied onion samples. “Vatikiotiko” raw dry bulbs had the highest °Brix mean value compared to the other genotypes, mostly because of the lower water content, whereas total sugars content was higher for “Sivan F1” (**Tables 1** and **4**). Fructose, glucose, sucrose and trehalose were detected in all the samples with differences between the various genotypes. The results for “Red Cross F1” and “Sivan F1” hybrids are in agreement with those of Caruso et al. (2014) who also reported that the main sugars in onion dry bulbs and welsh onions were also fructose and glucose. However, from our study it is indicated that sugars composition depends on the genotype, as has also been reported by Vågen & Slimestad (2008), with “Vatikiotiko” having a lower content of monosaccharides comparing to the other genotypes.

The sugars composition of onions plays an important role as it determines their intended use, since onions with high dry matter content (>15%) and low levels of reducing sugars are mostly suitable for long storage (Randle & Lancaster, 2002). “Vatikiotiko” onion seems to match this profile due to its high dry matter content (16%) and sugars composition (2.48% of total sugars) (**Table 4**), and in case of a production increase it could be recommended for long storage. Onion flavor is also depended on TSS and sugars composition, with reducing sugars playing an important role for onion sweetness (Malor, Balcells, Mallor & Sales 2011).

Onion is not considered a significant source for fatty acids in human diet considering both its low content and the small amounts of average daily consumption. However, twenty one individual fatty acids (FA) were detected in the raw bulb onions of the present study (**Table 5**). Saturated fatty acids (SFA) provide a large portion of total FA, ranging from 28.04% (“Creamgold”) to 35.94% (“Red Cross F1”), with palmitic acid (PA, C16:0) being the most abundant (18.14 to 20.71%), followed by C18:0 and

C22:0 (2.55 to 7.70% and 1.43 to 2.27%, respectively). Monounsaturated fatty acids (MUFA) were present at various amounts depending on genotype, ranging from 15.57 ("Creamgold") to 30.60% ("Vatikiotiko") of total FA, with oleic acid (OA, C18:1n9) being the most important (14.60 to 29.40%). Polyunsaturated fatty acids (PUFA) were the most important ones providing the largest amount of total fatty acids for all the studied genotypes, ranging from 39.60 ("Vatikiotiko") to 56.38% ("Creamgold"), with linoleic acid (LA, C18:2n6) being the most abundant (36.34 to 50.85%) followed by alpha linolenic acid (ALA, C18:3n3) (3.13 to 5.20%). PUFA/SFA ratio showed great variation among the genotypes and ranged from 1.19 ("Sivan F1") to 2.01 ("Creamgold").

Tocopherols and tocotrienols compose vitamin E in plant tissues, the amount of which can be affected by many factors including genotype, stage of maturity, growing and climate conditions, harvest time and even post-harvest conditions (Chun, Lee, Ye, Exler & Eitenmiller 2006). Onion bulbs do not contain significant amounts of lipophilic bioactive compounds such as tocopherols. According to the literature only traces of tocopherols have been detected in onions (Rabinowitch & Brewster, 1989; USDA, 2008), whereas Chun et al. (2006) reported amounts of 0.04 mg 100 g^{-1} edible weight. In our study we found that tocopherols consist only from α-tocopherol and the amounts detected were similar to those previously reported ranging from 14.42 ("Sivan F1") to 38.44 ("Red Cross F1") μg 100 g^{-1} fresh weight (**Table 5**).

3.3 Antioxidant activity

Regarding antioxidant properties of the studied onions, "Sivan F1" had higher antioxidant potential comparing to the other genotypes. The evaluation of the phenolics content showed significant variation (**Table 6**), with "Sivan F1" having a

significantly higher content (25.96 mg GAE g^{-1} extract) comparing to the other genotypes. Chun, Kim, Smith, Schroeder, Han & Lee (2005) reported a phenolic content of 24.27 mg GAE 100 g^{-1} which is considerably lower than the results from our study, whereas Sharma, Assefa, Kim, Ko, Lee & Park (2014) reported values of 5 mg GAE g^{-1}. The contradictory results could be explained by the differences in genotype, growing conditions and environment as already has been reported by Pérez-Gregorio et al. (2014).

DPPH radical-scavenging activity, reducing power, β-carotene bleaching inhibition and TBARS inhibition assays showed similar trends with "Sivan F1" genotype having the highest antioxidant potential (**Table 6**). However, it must be taken under consideration that different antioxidant assays may result in different results regarding antioxidant activity (Ou, Huang, Hampsch-Woodill, Flanagan & Deemer 2002).

Onion is an important source of flavonoids in human diet, with two subgroups of these compounds being present in great amount, namely anthocyanins which are responsible for the red to purple color of the skin, and flavonols which are responsible for the yellow to brown color (Griffiths, Trueman, Crowther, Thomas & Smith 2002). More than 25 different flavonols have been detected in onion, with quercetin derivatives being the most important regardless of cultivar (Slimestad, Fossen & Vågen 2007). In our study, significant differences were observed in total flavonoids content between the tested genotypes. More specifically, "Sivan F1" had the highest content in flavonoids, whereas in "Vatikiotiko" onion no flavonoids were detected (**Table 6**). Since these plant secondary metabolites are responsible for the yellow color of plant tissues, it could be expected that "Creamgold" genotype should have the highest content, however its skin color is light yellow comparing to "Sivan F1" which has a dark red to yellow color. In addition, the fact that the non-edible parts of bulbs

(tunic and outer scales) are richer in flavonoids than the inner and edible scales (Pérez-Gregorio et al., 2014), the color differences of the bulb flesh could partly explain the differences of the tested genotypes in flavonoid content, since “Sivan F1” has light creamy color, “Red Cross F1” light creamy blueish, “Creamgold” light yellow to green and “Vatikiotiko” light creamy to red. Therefore, flavonoids content seems to be affected by multiple factors other than simply skin or flesh color.

Galmarini, Goldman & Havey (2001) reported that onions are a good source of flavonoids such as quercetin, dietary fibers and fructans, which have a beneficiary effect on human health. Olson, Gustavsson & Vågen (2010) have reported a wide range of flavonoids content, with sweet onions (low pyruvate content and high sucrose and fructose content) having double to triple the amount comparing to red onions, whereas Yang, Meyers, Van der Heide & Liu (2004) have reported even larger differences among onion genotypes that come up to 11-fold differences. Therefore, the fact that “Sivan F1” had the highest fructose and sucrose content could explain its highest content in flavonoids from red onions such as “Red Cross F1” and “Vatikiotiko”.

Pérez-Gregorio et al. (2014) also reported significant differences in the flavonoids content of three red and two white traditional cultivars of onions, with red onion cultivars having higher flavonoids content than white onions, a result that is in contrast with the results of our study where dark red onions “Red Cross F1” and “Vatikiotiko” had lower flavonoids content than red to yellow (“Sivan F1”) and yellow onions (“Creamgold”).

However, Crozier, Lean, McDonald & Black (1997) reported similar results with these from our study, therefore it could be suggested that flavonoids content is a quality trait which apart from skin color is affected by various factors such as

genotype, growing conditions, bulb size or bulb part (Perez-Gregorio et al., 2014) and day length sensitivity (Sharma et al., 2014). In addition, harvest time and post-harvest handling can affect chemical composition of bulbs. Mogren, Olsson & Gertsson (2007) has reported that lifting time of onions can affect flavonoids content, with late lifting (80% fallen leaves) resulting in up to 45% more quercetin comparing to early lifting (50% fallen leaves). Curing process is also important, where quercetin content increased significantly during field curing comparing to curing under shade (Mogren, Olsson & Gertsson, 2006).

Red onions of our study ("Red Cross F1" and "Vatikiotiko") showed lower antioxidant activity than red-yellow ("Sivan F1") and yellow ("Creamgold") genotypes according to their DPPH radical-scavenging activity (**Table 6**). Cheng, Chen, Jin, Wang, Shi & Liu (2013) reported similar results for red and yellow varieties, whereas Morales-Soto et al. (2014) reported significant differences in antioxidant activity between four white and four red onion varieties according to harvest date, with onions harvested earlier having higher antioxidant activity. In our study, all onions were collected after 50% of tops have fallen, except for the case of "Creamgold" onion where no details were available. Therefore, it could be suggested that growing conditions could be of major importance regarding the antioxidant activity of onion and harvesting date could be a useful means to increase antioxidant activity and nutritional value of onion.

4. Conclusions

The growing demand of market for food products of high quality and specified origin and cultivation methods, allows the farmers to turn to traditional cultivars and local landraces that are suitable for less intensive cultivation techniques and adapted to

specific climate conditions. Furthermore, the conservation of the culture that is attached with specific products and regions will further increase the added value of these products. In this context, "Vatikiotiko" onion is a very promising vegetable crop with special character and properties, since its very rich in minerals, carbohydrates, proteins and organic acids, and should be capitalized as either a Protected Designation of Origin (PDO) or a Protected Geographical Indication (PGI) product. In addition, the fact that its nutritional value is very high renders it beneficial for human health and worth for further exploiting.

5. Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version.

6. References

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