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Yield and Quality Parameters of two Radicchio (*Cichorium intubys* L.) Cultivars as Affected by Growth Season

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Summary

Last decade radicchio become more popular vegetable, as a result, of the increasing demand of fresh-cut vegetables where radicchio contribute to the more attractive appearance. This study evaluate the growth season (normal and late transplanting, 31/7 and 12/9 respectively) of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') on their quality parameters (yield and chemical composition) as well as the storage potential of heads from one harvest. Cultivar had no significant effect on the yield or quality parameters of radicchio. On the contrary, yield as well as percentage of marketable heads significantly affected by growth season with drastic decrease for the late growth period. However, heads from the late growth period had higher content of SSC, nitrates, phenolics and antioxidant activity. The storage of radicchio heads at 0 °C resulted in significant decrease on their visual quality after 7 days however after 21 days of storage heads were over the limit of marketability.

Key words. antioxidants – head compact – nitrates – storage

Introduction

Recently new or less known crops are attracting growers interesting in order to achieve better income. One promising crop is radicchio (*Cichorium intubys* L.) because it is colourful and attribute to the colour variety of fresh-cut mixed salads, for which there is an increasing demand by the consumers. Radicchio is a head of deep dark red leaves with bright white ribs as well as characterized by a discreet bitterness. Main problems for satisfactory yields of quality product are the low percentage of plants with marketable compact heads and bolting of plants (Suhonen 1991; Rangarajan and Ingall 2001). There are several types of radicchio as the most widespread 'Chioggia', a variety with very compact head, 'Treviso' a variety with long, conical, compactly arranged leaves and 'Verona' another no very compact heading type.

The traditional cultivated area of radicchio is Northern Italy, therefore it is known as "Italian chicory", with expansion last years in middle Europe and North America (Bertolini et al. 2003; Poli et al. 2002). Radicchio is used in Greece mainly by the fresh-cut industry but because of the limited cultivated areas, every year import of raw product is required. The postharvest life of radicchio is limited and it can be stored for 16 to 21 days under the optimum conditions of 0 °C and 95 % relative humidity (Suslow and Cantwell 1999).

The suitable cultivation period of radicchio is limited because of the requirements of temperature and daylength. Low temperatures reduce plant growth and reduced the number of long-days that is necessary for flower induction while long days (> 13 h) induced bolting of plants (Gianquinto 1997; Pimpini and Gianquinto 1988; Rangarajan and Ingall 2001). Therefore, the spring crop is not suitable because of the high percentage of bolting plants (Gianquinto 1997).

It is well known, that the vegetable consumption is correlated with many human diseases reduction because of their antioxidants compounds content such as vitamins and phenolics (He et al. 2007; Saura-Calixto and Goni 2006). Information about radicchio antioxidant properties is limited and restricted either on anti- and pro-oxidant activity of water soluble compounds (Papetti et al. 2002) or on antioxidant activity during storage (Koukounaras and Siomos 2010).

The present work was undertaken in order to study the growth period of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') on head quality parameters and their chemical composition as well as the storage potential of heads from one harvest.

Materials and Methods

Two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') were cultivated in the experimental farm of Aristotle University of Thessaloniki, Central Macedonia, Greece, under usual production practices. Plants were transplanted at a density of 6.06 plants m^{-2} on 31 July ("normal" growth period) and 12 September ("late" growth period) while harvest of heads was done after 97 days and after 152 days respectively. During the growing season, daily mean temperature was recorded (Table 1).

Immediately after harvest, radicchio transferred to the laboratory, within 10 min where each head was weighted and evaluated subjectively for the head compact and scored using a scale from 5 (totally compact) to 1 (open). From the above heads only these with weight over 100 g were considered as marketable and used for further analysis.

Two radicchio heads of each cultivar consider as a replication for compositional analysis. Heads of each replication were macerated in a blender. Soluble solids content (SSC) was measured in the blended material using an Atago PR-1 hand-held refractometer (Atago Co Ltd, Tokyo, Japan). Nitrate content was determined according to Cataldo et al. (1975). Ascorbic acid was extracted in 1 % oxalic acid and measured by using Reflectoquant ascorbic acid test strips in an RQflex reflectometer (Merck, Darmstadt, Germany). Total soluble phenols were determined according to Scalbert et al. (1989) and expressed as mg gallic acid equivalents (GAE) g^{-1} FW and antioxidant capacity according to Brand-Williams et al. (1995), expressed as mg ascorbic acid equivalents (AEAC) $100g^{-1}$ FW.

For the study of storage potential of radicchio, heads from the first harvest ("normal" growth period) were placed into 0 °C with > 95 % relative humidity. The 7th, 14th and 21st day of storage 6 heads (3 replications consisting of two heads each) of both cultivars were evaluated for optical quality and weight loss determination. The overall visual quality of radicchio heads were evaluated subjectively using a scale from 9 (excellent) to 1 (unacceptable). At the 3rd, 7th, 14th, 17th and 21st day of storage respiration of radicchio heads was determined. Air samples were taken after closing the heads in 5 L glass jars for 1.5 h and CO_2 concentration was measured according to Saltveit and Strike (1989) by injecting the gas samples into a stream of N_2 carrier gas flowing through a CO_2/O_2 analyser (model Combo 280, David Bishop Instruments, UK).

Data were analysed by analysis of variance (ANOVA) using a completely randomized design with three replications and the means were compared by the Duncan's multiple range test at the 0.05 level with MSTAT version 4.00/EM (Michigan State University). For heads mean weight and their compact score means are presented ± S.E.

Table 1. Monthly temperature during the experimental period and the average monthly temperature of last 30 years.

Month	Experiment period (°C)	30 years average (°C)
August	28.1	26.2
September	21.6	21.9
October	17.6	16.3
November	13.1	11.1
December	9.2	6.9
January	6.8	5.3
February	6.4	6.8
March	10.3	9.8

Results and Discussion

The FW of harvested heads was affected by growth period for both cultivars, with signification decrease of head weight for the late growth period about 56 and 43 % for 'Chioggia' and 'Verona' respectively (Table 2). Among cultivars, significantly higher head weight was observed for

Table 2. Heads weight and marketable heads weight as well as the compact of heads of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') grown either at "normal" growth period (transplanting 31/7) or "late" growth period (transplanting 12/9).

Cultivar	Growth period	Heads weight (g)	Compact of heads (5–1)	Marketable heads weight (g)	Compact of marketable heads (5–1)
'Chioggia'	Normal	185.5 ± 13.5	4.19 ± 0.14	208.0 ± 12.5	4.39 ± 0.14
	Late	82.1 ± 16.1	4.45 ± 0.09	131.4 ± 14.7	4.60 ± 0.10
'Verona'	Normal	157.2 ± 13.0	4.43 ± 0.10	192.9 ± 11.5	4.41 ± 0.11
	Late	77.5 ± 11.6	4.31 ± 0.12	129.0 ± 12.9	4.00 ± 0.21

'Chioggia' only for normal growth period. On the other hand, the parameter that greatly affected by growth season was the percentage of marketable head. For both cultivars the data showed a significant sharp decrease for the late growth period more or less to 50 % of the normal growth period (Fig. 1). Similarly to the results of heads weight the weight of marketable heads was affected by growth period about 37 and 33 % for 'Chioggia' and "Verona" respectively (Table 2). The above results confirm previous reports (Gianquinto 1997; Pimpini and Gianquinto 1988; Rangarajan and Ingall 2001) about the special requirements of this crop. During the normal growth period the mean temperature was 22.3 °C while for the late growth period was 11.4 °C. Therefore, the cultivation of radicchio is suggested in areas with high temperatures in the growth stage of the plants to achieve satisfactory growth rate.

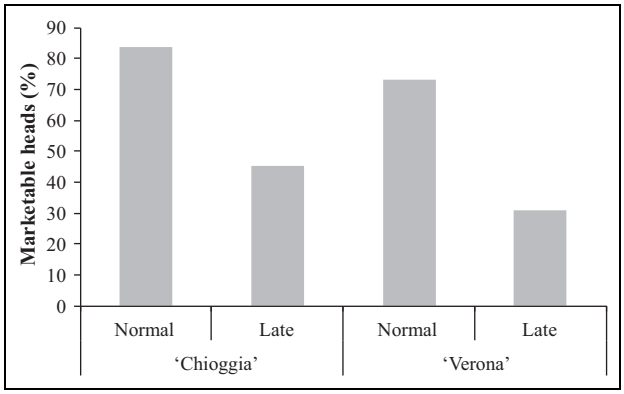


Fig. 1. Percentage (%) of marketable heads of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') grown either at "normal" growth period (transplanting 31/7) or "late" growth period (transplanting 12/9).

Compact of heads was very good (score > 4) with no difference among the 2 growth periods for 'Verona' while heads of 'Chioggia' were more compact at the late growth period (Table 2). The compact of heads is critical since the appearance of a product is the most important criterion by consumers (Ares et al. 2008).

An analysis of variance was performed in order to evaluate the contribution of cultivar, growth period as well as their interaction in chemical composition of radicchio. The results show that only the growth period significantly affected all the measured parameters of radicchio (SSC, nitrates, total phenols and DPPH) while ascorbic acid was not affected by both factors (Table 3). Means comparison clearly show that for both radicchio cultivars growth during late period produce heads with higher levels of SSC, total phenols, DPPH as well as nitrates (Table 3).

The higher nitrates on late growth period cultivated radicchio heads were expected because is well know that nitrate accumulation is light dependent (Blom-Zandstra 1989) and during winter period we had low light conditions. However, the nitrate content in both cultivars and both growing periods was much lower than the maximum permissible level of 2500 to 4500 mg kg^{-1} fresh product specified for spinach and lettuce by the EC Regulation (European Commission 2005).

No significant effect of cultivar or growth period on ascorbic acid content was recorded. Probably this observation is due to the very low concentration of radicchio heads (average of 7.08 mg $100g^{-1}$ FW) as had been determined by Biesiada and Kolota (2010) as an average of different nitrogen fertilization levels of radicchio transplanting the first week of August (7.53 mg $100g^{-1}$ FW). Moreover, the contribution of ascorbic acid to the total antioxidant activity was not significant.

On the contrary, for radicchio the antioxidant activity increased linearly with total soluble phenols content [DPPH = 0.0325 + (0.00276 * Phenols); R = 0.984, P < 0.001, Microstat]. Papetti et al. (2002) reported that radicchio contained several water-soluble components with

Table 3. Mean comparison and analysis of variance for soluble solids content (SSC; %), nitrates (mg kg^{-1} FW), ascorbic acid (mg 100 g^{-1} FW), total phenols (mg gallic acid equivalents g^{-1} FW), and antioxidant potential (mg ascorbic acid equivalents antioxidant capacity 100 g^{-1} FW) of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') grown either at "normal" growth period (transplanting 31/7) or "late" growth period (transplanting 12/9).

Growth period	SSC	Nitrates	Ascorbic	Phenols	DPPH
Normal	6.25 ± 0.11	8.78 ± 1.18	8.39 ± 1.43	0.14 ± 0.01	39.92 ± 3.56
Late	7.55 ± 0.24	17.16 ± 2.18	5.77 ± 0.39	0.36 ± 0.04	118.87 ± 12.01
Source of variance					
Cultivar (A)					
Growth period (B)	***	*		***	***
A × B					

*, **, *** Significant effect at the 0.05, 0.01 and 0.001 level, respectively

Table 4. Mean comparison and analysis of variance for overall visual quality (OVQ) in a scale from 9 to 1 and weight loss (%) of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') stored for 3 weeks at 0 °C.

Growth period	OVQ	Weight loss
0 weeks	9.00 ± 0.00	0.00 ± 0.00
1 week	6.75 ± 0.34	3.09 ± 0.45
2 weeks	5.92 ± 0.24	3.79 ± 0.75
3 weeks	5.50 ± 0.32	5.94 ± 1.25
Source of variance		
Cultivar (A)		
Storage period (B)	***	***
A × B		

*, **, *** Significant effect at the 0.05, 0.01 and 0.001 level, respectively

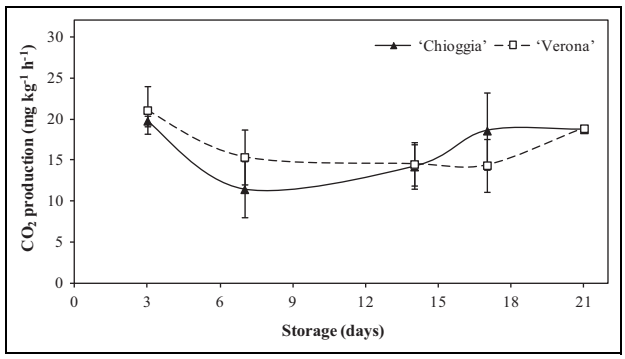


Fig. 2. Respiration of heads of two radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') during storage at 0 °C.

strongly antioxidant activity. In the literature there are no data about seasonal variation of antioxidants of radicchio, however for other vegetables the results are conflicting. In particularly, antioxidant activity of greenhouse tomatoes and white asparagus spears significantly varied during growth season (Toor et al. 2006; Papoulias et al. 2009) while no clear seasonal variation reported for cherry tomatoes (Raffo et al. 2006).

Finally the results of postharvest experiment show that even after 7 days storage visual quality of heads significantly decreased and further reduction was observed after 3 weeks of storage without differences among the two cultivars (Table 4). However, even after 21 days of storage the visual quality of the radicchio heads was over the limit of marketability. At the same time the weight loss was exceeded the 6 %. It is known that radicchio heads stored in Italy at −1 °C for 1–2 months (Bertolini et al. 1998). The results of respiration confirm that there were no differences between the two cultivars (Fig. 2). It is well known, that deterioration rate of fruits and vegetables are correlated with their respiration rate (Watada et al. 1996).

Conclusions

In summary, there are several practical implications of these results relevant to radicchio crop. First, the growth period of radicchio should be very carefully selected, since the percentage of marketable heads is drastically decreased by growth at late growth period. The two tested radicchio cultivars ('Rosso di Chioggia' and 'Rosso di Verona') could be both cultivated with a potential storage life of 21 days at low temperature. Moreover, with suitable treatment for both cultivars such as late growth season cultivation, we could improve their antioxidant properties and provide the consumer and industry with radicchio heads of higher nutritional value.

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