African Journal of Agricultural Research Vol. 6(3), pp. 538-544, 4 February, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.828
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Influence of organic and conventional production systems on the quality of tomatoes during storage

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Accepted 16 December, 2010

Consumers generally believe that organically grown tomatoes taste better and have higher nutritional value than their conventionally grown counterparts. The study was conducted to compare quality properties of tomato cultivars grown using organic and conventional production systems during storage at 13°C for 35 days. Results indicated that fruits grown using organic production system retained their firmness better during storage than their conventionally grown counterparts. However, conventionally grown fruit showed significantly higher red coloration. Other quality parameters examined in the study for organically produced fruit were either lower or similar to those in conventionally grown fruit. Microbial fertilization and plant activator significantly increased total soluble and reducing sugar contents. Thus, no definite conclusion can be reached with respect to the superior quality of organically grown fruit compared to their conventionally grown counterparts. The influence of growing system appears to be cultivar and growth condition dependent.

Key words: Microbial fertilization, plant activator, quality, tomato, storage, organic, conventional.

INTRODUCTION

Tomatoes are grown using both conventional and organic fertilizers. Recently there is an increasing demand in organically-grown products due in part to the common belief among consumers that organic products are healthier than conventional products (Ekelund and Tjärnemo, 2004) although research results remain inconclusive (Bourne and Prescott, 2002; Zhao et al., 2007).

Organically and conventionally grown tomatoes have been compared with respect to yield, and nutritional quality. However, inconsistent differences between organically and conventionally grown products were reported (Brandt and Molgaard, 2001). In a study reporting the effects of different types of fertilizers on the antioxidant components of tomato, Toor et al. (2006) indicated that the mean plant shoot biomass was significantly higher in plants grown with mineral nutrients, but in organically grown tomatoes total phenolics and ascorbic acid content were significantly higher. Moreover, the authors found no significant differences between mineral and organically grown plants for yield, dry matter content or soluble solids. However, it was reported that the juice of organically grown tomatoes showed significantly higher soluble solids and titratable acidity, but lower red coloration, ascorbic acid and total phenolics as compared to the juice of conventionally grown fruit (Barrett et al., 2007). The comparison of organically and conventionally grown strawberries for the phenolic contents revealed no conclusive results (Häkkinen and Törrönen, 2000). The authors determined significantly higher levels of total phenolics in organically grown fruit of only one cultivar but no significant differences in those of the other two cultivars evaluated in the study as compared to the conventionally grown fruit. In contrast, higher levels of total phenolics were obtained in organically-grown marrionberries and apples than their conventionally-grown counterparts (Asami et al., 2003; Weibel et al., 2000). Additionally, the conventionally produced tomato was shown to have significantly stronger flavor than the organically produced tomato (Zhao et al., 2007). On the other hand, organically grown

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crops were shown to contain higher mineral and vitamin content (Worthington, 1998), higher antioxidant content (Woese et al., 1997; Asami et al., 2003; Chassy et al., 2006), and better flavor (Weibel et al., 2000; Reganold et al., 2001) than crops produced using conventional production systems. Therefore it is necessary that further research comparing organically and conventionally grown fruit is required to reach a conclusive result.

Although there is an extensive research comparing the quality characteristics of organically and conventionally grown fruit, the research regarding the behavior of organically and conventionally grown fruit during storage is rather limited. Therefore, the objective of the present study was to determine and evaluate the changes in quality properties of tomatoes obtained via organic and conventional production systems during storage.

MATERIALS AND METHODS

The seedlings of two commercial tomato cultivars (Yeni Talya and Zorro) used in the study were obtained from a commercial supplier (Fiser Fidecilik, Antalya, Turkey). The study was conducted in the Research Farm of Faculty of Agriculture, Suleyman Demirel University, Isparta, Turkey in 2007 and 2008 crop seasons. The experiment was set up as a completely randomized design with 4 replications and each replication contained 20 plants. Seedlings were transplanted to the field on May 15 with 100 x 40 cm row spacing and regular cultural practices (weed and disease control, irrigation etc.) were applied uniformly throughout the experimental area. A commercial microbial fertilizer (Bionem), a plant activator (Crop-Set) and their combination along with one conventional fertilizer treatment and the organic (no fertilizers applied) treatment were employed in the study. Bionem [Alternatif Toros Tarım, Antalya, Turkey and contained >10^8 cfu/ml *Pseudomonas fluorescens*, melas (5 ml/l), corn oil (3 ml/l), oregano oil (1 ml/l) and sesame oil (1 ml/l)] and Crop-Set [Improcrop and contained 893.8 g/l *Lactobacillus acidophilus*, plant extract 147.15 g/l, 27.25 g/l manganese sulfate, 16.35 g/l ferrous sulfate and 5.45 g/l cupric sulfate] were applied to the plants twice during the experimental period. 200 ml of Bionem solution (1 l Bionem in 400 l of water) was applied twice to each plant as a drench to plant root area. For Crop-Set, 60 ml/da of the fertilizer was sprayed to both plants and the soil of the experimental area. For the conventionally grown plants, 50 kg/da composite fertilizer (15N:15P:15K) was applied to the experimental area prior to planting. Additionally, 20 kg potassium nitrate, 20 kg ammonium nitrate, 10 kg calcium nitrate and 10 kg micronutrients were applied to the conventionally grown plants via drip irrigation during the vegetation period per decare.

Sufficient amount of fruit from each treatment were harvested at green maturity stage and immediately transported to the laboratory. The fruit were surface sterilized using chlorinated water (200 µl/l) and then stored at 13°C for over a month. 20 fruit from each treatment were removed from storage every 5 days and their firmness, total soluble solids content, colour L, a, b values, and total and reducing sugars contents were determined. Additionally, weight loss was determined by regularly measuring (every 5 days) the weight of 10 marked fruit using a digital balance.

Firmness was determined for 20 fruit from each sample utilizing a pocket penetrometer (Model 0603, Eijkelkamp Agrisearch Equipment, Giesbeck, Netherlands) with a 0.6 mm probe. Measurements were taken from the opposite cheeks of each fruit (skin removed). The maximum force (N) required to reach the bioyield point was recorded.

For the determination of total soluble solids, three samples prepared from 20 fruit of each treatment were utilized. A piece of mesocarp tissue (1 g) from each of the 20 fruit was pureed. Total soluble solids were measured using a hand-held digital refractometer (Model WYT-1, Quanzhou Zhoungyou Optical Instrument Co. Ltd. China). Results were expressed as % Brix.

The colour L, a, and b values were measured on 20 fruit at two different locations in the equatorial zone using a Minolta CR-300 colorimeter. The results were expressed as L, C and H values.

Determination of total soluble and reducing sugar contents

For the extraction of total soluble and reducing sugars, 5 g of mesocarp tissue from 20 fruit of each treatment was homogenized in liquid nitrogen using a mortar and a pestle and then 20 ml of 95% ethanol were added to the each sample. The homogenates were incubated in a boiling water bath for 10 min and cooled to room temperature. The extracts were centrifuged at 8000 rpm for 15 min and the supernatants were passed through GF/C filter paper (Whatman). The residues were re-extracted with 20 ml of 80% ethanol, stirred for 30 min with a magnetic stirrer, and boiled for 10 min. After centrifugation, the supernatants were combined and adjusted to a final volume of 100 ml with 80% ethanol. Total soluble sugars were determined using 0.5 ml of the extracts as described in Dubois et al. (1956) and reducing sugar content was determined as described by Karakurt et al. (2009). Aqueous solutions of 40, 80, 120, 160 and 200 µg/ml glucose were used as standard.

Statistical analysis

Data were analyzed using Costat statistical program according to a completely randomized design (Costat, 2007) and the means were separated with Duncan's multiple range test at the 5% level of significance.

RESULTS AND DISCUSSION

Significant changes were observed during 35 days of storage in conventionally and organically grown tomatoes. The weight loss ranged from 4.46 to 7.41% after 35 days of storage (Table 1). While conventionally grown Yeni Talya showed the highest weight loss (7.41%), the lowest weight loss (4.46%) was observed in organically grown Zorro. There was an increase in weight loss in both organic and conventional fruit during storage in the two cultivars evaluated. The changes in soluble solids contents of both cultivars were minimal in response to treatments (Table 2). Soluble solids contents of conventionally and organically grown fruit and Bionem applied organically grown fruit of both cultivars did not change significantly during 30 days of storage. However, in Crop-Set applied fruit, soluble solids increased significantly during first 5 days of storage and then decreased towards the end of storage. Soluble solids are important contributors to flavor (Thybo et al., 2006; Dorais, 2007; Taiwo et al., 2007; Bender et al., 2008). In contrast to our findings, a higher level of total soluble solids in organically produced tomatoes was reported by Pieper and Barrett (2008) and Barrett et al. (2007). This

Table 1. Weight loss (%) of tomatoes during storage.

Cultivar	Treatment	Storage time (Days)							
		0	5	10	15	20	25	30	35
Yeni Talya	Bionem	0	1.41	1.41	2.82	4.23	4.23	5.63	5.63
	Crop-Set	0	0.94	0.94	1.89	3.77	3.77	4.72	5.66
	Bionem+Crop-Set	0	1.15	2.30	2.30	3.45	4.60	4.60	-
	Conventional	0	1.85	1.85	3.70	3.70	5.56	5.56	7.41
	Organic	0	1.11	2.22	3.33	4.44	5.56	5.56	6.67
Zorro	Bionem	0	1.23	1.23	2.47	3.70	3.70	4.94	-
	Crop-Set	0	1.09	2.17	2.17	3.26	3.26	4.35	-
	Bionem+Crop-Set	0	1.03	2.06	3.09	4.12	4.12	5.15	6.19
	Conventional	0	1.02	1.02	2.04	3.06	3.06	3.06	5.10
	Organic	0	0.89	1.79	2.68	3.57	3.57	3.57	4.46

Table 2. Brix values (%) of tomatoes during storage.

Cultivar	Treatment	Storage time (Days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	4.00	4.00	4.17	3.83	4.33	4.17	3.83
	Crop-Set	4.17 bc*	4.50 a	4.50 a	4.00 c	4.33 ab	4.00 c	4.00 c
	Bionem+Crop-Set	4.00	4.00	4.17	3.83	4.00	4.00	3.83
	Conventional	4.50	4.50	4.33	4.50	4.17	4.17	4.33
	Organic	4.00	4.00	4.00	4.17	3.67	4.17	4.00
Zorro	Bionem	4.33	4.17	4.33	4.00	4.33	4.17	4.17
	Crop-Set	4.33 ab*	4.50 a	4.50 a	4.17 ab	4.00 b	4.00 b	4.17 ab
	Bionem+Crop-Set	4.33	4.17	4.17	4.50	4.00	4.17	4.00
	Conventional	4.50	4.33	4.33	4.50	4.33	4.17	3.83
	Organic	4.33	4.00	4.33	4.17	4.17	4.00	4.17

*: significant at 5 % level.

effect could result from cultivar differences, variations in physiological maturity at harvest, or the increased vegetative growth characteristics of conventional crops (Thybo et al., 2006; Dorais, 2007; Taiwo et al., 2007; Pieper and Barrett, 2008).

Firmness decreased markedly during storage in both cultivars (Table 3). This decrease was more prominent in conventionally produced fruit. After 30 days of storage, the firmness values of organically and conventionally grown fruit declined from 5.36 to 3.85 N respectively. Overall fruit from plants treated with Bionem and Crop-Set retained their firmness better than those from conventionally grown plants. The significantly higher firmness retention in organically grown fruit results at least partially from the higher firmness values of these fruits at the beginning of storage. The higher firmness at the beginning of storage could be due to the possibility that organically grown fruit were less mature as compared to conventionally grown fruit. It was reported that organically produced tomatoes planted and harvested at the same time as conventionally produced tomatoes were less ripe than conventionally grown tomatoes (Zhao et al., 2007).

Significant changes were also observed in colour composition of tomatoes during storage and in response to growing system (Table 4a). Table 4a shows the colour L (brightness) values of tomatoes. L value demonstrated significant reduction during storage suggesting the loss of brightness in all treatments in both cultivars. A comparable level of decline in L value was also observed in both conventionally and organically produced fruit. Application of Bionem and Crop-Set did not significantly affect the trend of changes in brightness. In agreement with our findings Pieper and Barrett (2008) and Barrett et al. (2007) observed no significant difference in L value between conventionally and organically grown tomatoes. Significant changes were also observed in colour chroma (C*) value of all treatments (Table 4b). C* value

Table 3. Firmness values (N) of tomatoes during storage.

Cultivar	Treatment	Storage time (Days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	15.51 a*	14.77 b	13.03 c	8.96 d	6.31 e	5.50 f	4.84 g
	Crop-Set	13.84 a*	10.73 b	9.33 c	8.91 c	6.25 d	4.78 e	4.05 e
	Bionem+Crop-Set	12.86 a*	10.14 b	10.00 b	7.63 c	7.18 c	4.53 d	4.17 d
	Conventional	11.24 a*	11.15 a	8.82 b	6.62 c	4.66 d	4.50 d	3.85 d
	Organic	12.32 a*	12.12 a	10.61 b	8.60 c	5.93 d	4.90 e	4.84 e
Zorro	Bionem	12.94 a*	12.45 a	9.14 b	6.95 c	5.00 d	4.58 d	4.01 d
	Crop-Set	13.35 a*	13.19 a	11.98 b	9.29 c	6.62 d	5.64 e	4.32 f
	Bionem+Crop-Set	14.11 a*	13.72 a	11.07 b	8.55 c	7.18 d	6.54 d	4.50 e
	Conventional	11.93 a*	11.87 a	9.58 b	7.56 c	5.82 d	4.67 e	3.86 f
	Organic	14.28 a*	14.33 a	13.72 a	11.01 b	7.01 c	6.47 c	5.36 d

*: significant at 5 % level.

Table 4a. Colour L* values of tomatoes during storage.

Cultivar	Treatment	Storage time (Days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	65.26 a*	65.01 a	63.86 ab	59.63 b	50.51 c	45.19 d	43.25 d
	Crop-Set	66.50 a*	64.22 a	64.76 a	53.85 b	44.57 c	42.39 c	41.73 c
	Bionem+Crop-Set	65.08 a*	65.70 a	62.00 b	49.63 c	43.44 d	42.49 d	42.51 d
	Conventional	63.41 a*	64.33 a	64.12 a	58.07 b	45.98 c	43.32 c	43.02 c
	Organic	68.21 a*	64.73 b	63.31 b	51.27 c	43.51 d	43.63 d	42.67 d
Zorro	Bionem	67.85 a*	64.87 b	59.41 c	49.13 d	44.60 e	42.76 e	42.64 e
	Crop-Set	65.25 a*	64.60 a	63.40 a	54.45 b	45.10 c	44.07 c	43.35 c
	Bionem+Crop-Set	65.02 a*	65.32 a	63.69 a	52.69 b	46.36 c	43.73 d	42.22 d
	Conventional	62.65 a*	63.69 a	59.81 b	54.09 c	45.94 d	44.58 d	41.55 e
	Organic	64.73 a*	63.15 ab	60.76 ab	59.57 b	47.85 c	45.32 cd	43.12 d

*: significant at 5 % level.

Table 4b. Colour C* values of tomatoes during storage.

Cultivar	Treatment	Storage time (Days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	33.13 b*	28.06 c	27.33 c	34.32 b	34.11 b	38.83 a	38.78 a
	Crop-Set	35.37 c*	29.94 d	25.77 e	26.20 e	40.47 a	40.74 a	37.63 b
	Bionem+Crop-Set	32.09 c*	28.28 d	27.21 d	35.87 b	39.88 a	40.12 a	40.02 a
	Conventional	32.76 c*	30.75 cd	27.91 d	29.05 d	38.18 b	41.33 a	41.85 a
	Organic	28.81 c*	27.70 c	25.87 c	33.70 b	39.07 a	38.66 a	37.66 a
Zorro	Bionem	33.30 c*	29.36 d	28.72 d	36.10 b	40.11 a	40.10 a	40.79 a
	Crop-Set	30.74 b*	30.09 b	28.66 b	31.36 b	40.67 a	39.55 a	38.34 a
	Bionem+Crop-Set	29.78 cd*	31.29 cd	28.03 d	33.66 bc	37.44 ab	38.29 a	38.67 a
	Conventional	34.34 b*	32.95 b	30.99 b	34.83 b	39.96 a	40.16 a	39.82 a
	Organic	33.01 bc*	31.71 bc	31.21 cd	27.86 d	35.33 b	39.33 a	39.56 a

*: significant at 5 % level.

Table 4c. Colour H* values of tomatoes during storage.

Cultivar	Treatment	Storage time (days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	-68.28 c*	-72.12 d	-76.92 e	47.32 a	44.76 a	37.83 b	34.76 b
	Crop-Set	-74.93 d*	-72.55 d	-78.82 e	65.65 a	36.33 b	34.38 bc	31.34 c
	Bionem+Crop-Set	-73.88 b*	-77.27 b	36.12 a	43.62 a	37.54 a	35.14 a	32.75 a
	Conventional	-66.79 d*	-69.41 d	-74.41 e	67.72 a	43.39 b	38.40 c	35.91 c
	Organic	-75.39 d*	-74.43 d	-73.79 d	45.67 a	37.94 b	31.48 c	29.60 c
Zorro	Bionem	-64.66 d*	-76.53 e	72.50 a	43.56 b	38.76 c	34.71 c	35.01 c
	Crop-Set	-74.50 d*	-73.60 d	-77.54 d	57.04 a	40.26 b	36.98 bc	33.24 c
	Bionem+Crop-Set	-72.20 d*	-73.84 d	-77.97 e	48.38 a	37.44 b	33.38 c	32.65 c
	Conventional	-69.40 d*	-73.46 e	-77.59 f	56.81 a	42.60 b	37.79 c	35.84 c
	Organic	-70.03 d*	-74.57 de	-77.67 e	68.69 a	43.91 b	37.08 bc	33.78 c

*: significant at 5 % level.

Table 5. Total soluble sugar (mg/g) content of tomatoes during storage.

Cultivar	Treatment	Storage time (days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	18.60 d*	25.46 c	29.78 b	36.41 a	34.62 a	37.95 a	36.71 a
	Crop-Set	19.40 d*	21.59 d	23.41 d	35.84 c	33.79 c	42.72 b	46.94 a
	Bionem+Crop-Set	22.09 d*	27.03 c	33.03 b	35.75 ab	35.73 ab	38.76 a	38.47 a
	Conventional	18.10 e*	25.90 d	27.69 d	31.28 c	35.00 b	37.44 b	46.29 a
	Organic	24.85 d*	24.38 d	26.17 d	35.40 bc	34.85 c	38.86 b	43.16 a
Zorro	Bionem	22.28 e*	26.35 c	26.32 e	31.87 d	37.14 c	42.37 b	49.89 a
	Crop-Set	22.42 f*	21.84 f	27.67 e	30.54 d	37.40 c	42.63 b	48.99 a
	Bionem+Crop-Set	21.36 e*	27.26 d	30.74 c	34.52 b	34.69 b	39.59 a	41.61 a
	Conventional	18.07 e*	25.98 d	31.97 c	36.34 b	35.77 bc	41.68 a	41.08 a
	Organic	22.14 de*	20.42 e	23.67 d	33.54 bc	31.52 c	36.18 b	45.74 a

*: significant at 5 % level.

increased in both conventionally and organically produced fruits, but, this increase was more prominent in conventionally produced Yeni Talya fruit. The increase in C* value suggests an increase in the intensity of red coloration possibly resulting from an increase in lycopene content (Caris-Veyrat et al., 2004). The effect of production system on C* value was cultivar dependent. In Yeni Talya, the C* value of conventionally produced fruit was significantly higher than that of organically produced fruit. However, organically and conventionally produced fruit of Zorro showed comparable levels of C* value during 30 days of storage. Bionem application also significantly enhanced red colour development which could possibly result from increased availability of mineral nutrients (Dorais, 2007). In contrast to our results, significantly higher levels of lycopenes were obtained from organically grown tomatoes (Pieper and Barrett, 2008; Barrett et al., 2007; Caris-Veyrat et al., 2004). This could also be due to cultivar differences employed in reported studies. Likewise, significant variations were also observed in colour hue (H*) value (Table 4c). In all treatments of both cultivars, H* value decreased during storage suggesting a significant proportional decrease in yellowness and an increase in redness. The reduction in H* value was higher in organically-produced fruit. A decrease in yellowness and an increase in redness during ripening of tomato fruit were also reported by Kaur et al. (2006).

Sugars and acids played an important role in determining the taste of fruits and vegetables including tomatoes (Granges, 2002). Total and reducing sugar contents of tomatoes were affected by growing system, cultivar and storage (Tables 5 and 6). Total soluble and reducing sugars increased significantly during 30 days

Table 6. Reducing sugar (mg/g) content of tomatoes during storage.

Cultivar	Treatment	Storage time (days)						
		0	5	10	15	20	25	30
Yeni Talya	Bionem	8.21 f*	11.09 e	13.70 d	14.79 c	19.17 b	25.56 a	25.23 a
	Crop-Set	9.84 g*	12.18 f	13.52 e	14.90 d	19.22 c	25.29b	26.18 a
	Bionem+Crop-Set	8.27 f*	12.69 e	15.38 c	14.65 d	21.60 b	25.71 a	25.35 a
	Conventional	7.77 f*	11.94 e	14.47 d	15.03 c	18.72 b	24.22 a	24.03 a
	Organic	8.22 e*	10.52 d	13.04 c	12.82 c	17.53 b	25.98 a	25.51 a
Zorro	Bionem	9.93 e*	13.91 d	14.80 c	13.60 d	20.85 b	25.97 a	25.63 a
	Crop-Set	9.41 e*	11.87 d	14.59 c	14.44 c	20.58 b	24.44 a	24.18 a
	Bionem+Crop-Set	8.30 f*	12.82 e	14.36 d	14.41 d	19.29 c	26.42 b	27.07 a
	Conventional	8.07 e*	10.86 d	12.92 c	13.10 c	17.27 b	24.64 a	25.18 a
	Organic	8.34 e*	11.81 d	13.17 c	12.83 c	18.17 b	25.49 a	25.10 a

*: significant at 5 % level.

of storage period. Both total and reducing sugar content of Bionem treated fruit were significantly higher in Yeni Tayla cultivar. Bionem and a combination of Bionem and Crop-Set applications significantly increased total and reducing sugar content of tomatoes in Zorro cultivar. Bionem increases the colonization of beneficial bacteria and thus enhancing plant root development and the uptake of microelements and other nutrients. Moreover, it causes the production of antibiotics and growth regulators such as indol acetic acid (Bionem User Manual, Alternatif Toros Tarım, Antalya, Turkey). Crop-Set improves soil microbial population, increases soil organic matter and provides manganese sulfate, ferrous and cupric sulfate and lactobacillus fermentation products (Crop-Set User Manual, ARES Organik Tarım Ürünleri, İzmir, Turkey).

Collectively, it appears that no clear conclusion can be reached regarding the superior quality of organically grown fruit compared to their conventionally grown counterparts. However organic production system seems to improve firmness of tomatoes. Other quality parameters examined in the study for organically produced fruit were either lower or similar to those in conventionally grown fruit. Therefore, tomato quality appears to depend on cultivar, growing system and microbial fertilization (Granges, 2002; Heeb et al., 2005; Dorais, 2007; Pieper and Barrett, 2008). It can also be proposed that conventional tomatoes reach full maturity more quickly and are in a more advanced maturity stage at the time of harvest than organic tomatoes, and this difference has a significant impact on the quality and shelf life of organic and conventional products.

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