Research Article/Araştırma Makalesi

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MEDITERRANEAN AGRICULTURAL SCIENCES
(2020) 33(1): 9-14
DOI: 10.29136/mediterranean.620859

Determination of nutritional values and postharvest performance in different types of tomatoes stored under shelf-life conditions

Raf ömrü koşullarında muhafaza edilen farklı domates tiplerinin derim sonrası performansları ve besin değerlerinin belirlenmesi

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ARTICLE INFO

Received 16 September 2019
Received in revised form 29 February 2020
Accepted 02 March 2020

***Keywords*:**

Tomato
Solanum lycopersicum
Antioxidants
Nutritional quality
Shelf-life

ABSTRACT

In this study, beefsteak (cv. 'Tybif'), heirloom (cv. 'Yuksel Koy') and cluster types (cv. 'Merkur') of tomato were harvested at breaker stage of maturity and stored at 20ºC temperature and 60±5% relative humidity for comparing their ethylene production, respiration rate, postharvest performance and nutritional characteristics. Analysis for weight loss, antioxidant activity, carotenoid, flavonoid, total phenolics, ascorbic acid contents, ethylene production, respiration rates and amount of unmarketable fruits were determined during 21 days of storage. Weight loss, ethylene production, respiration rate, carotenoid content and amount of unmarketable fruits exhibited increase whereas flavonoid and ascorbic acid content showed decrease with extending storage duration. Maximum antioxidant activity, carotenoid, total phenolics and ascorbic acid contents and minimum weight loss, ethylene production and respiration rate were noted in beefsteak type of tomatoes. Based on results obtained it can be concluded that beefsteak type of tomatoes can be successfully stored with maximal nutritional quality for 21 days of storage as compared to heirloom and cluster types of tomatoes.

MAKALE BİLGİSİ

Alınış tarihi 16 Eylül 2019
Düzeltilme tarihi 29 Şubat 2020
Kabul tarihi 02 Mart 2020

***Anahtar Kelimeler*:**

Domates
Solanum lycopersicum
Antioksidan
Besin içeriği
Raf ömrü

ÖZ

Bu çalışmada beef (cv. 'Tybif'), köy (cv. 'Yüksel Köy') ve salkım tipi (cv. 'Merkür') domatesler çakır (dönüm) olum aşamasında derilmiş ve derim sonrası performansları, etilen üretimi, solunum hızı ve fitokimyasal özelliklerini karşılaştırmak amacıyla 20ºC sıcaklık ve %60±5 oransal nemde muhafaza edilmiştir. Çalışmada, 21 gün süren muhafaza süresince ağırlık kaybı, antioksidan aktivitesi, karotenoid, flavonoid, toplam fenolik maddeler, askorbik asit içerikleri, etilen üretimi, solunum hızı ve pazarlanamaz ürün miktarları belirlenmiştir. Muhafaza süresince ağırlık kaybı, etilen üretimi, solunum hızı, karotenoid ve pazarlanamaz ürün miktarları artış buna karşın flavonoid ve askorbik asit miktarları ise azalış göstermiştir. Maksimum antioksidan aktivite, karotenoid, toplam fenolik madde, askorbik asit içeriği ile en düşük ağırlık kaybı, etilen üretimi ve solunum hızı beef tipi domateslerden elde edilmiştir. Araştırma sonuçlara göre, raf ömrü koşullarında muhafaza edilen beef tipi domatesler, köy ve salkım tipi domateslere göre daha yüksek besin içeriğine sahip olmuştur.

1. Introduction

Tomato (*Solanum lycopersicum)* is the most produced and consumed vegetable in the world and Turkey. The global production of tomato is 177 million tons in which China is the major producer with 56.4 million tons whereas Turkey is ranked 4th with 12.6 million tons (FAO 2016). Tomato being an integral part of human diet is an important source of health promoting substances like antioxidants, carotenoids, flavonoids, phenols and ascorbic acid. Consumption of tomato fruit decrease the risk of cancer, chronic, osteoporosis and cardiovascular diseases (Rao et al. 1998; Giovannucci et al. 2002; Frusciante et al. 2007; Borguini and Torres 2009; Bhowmik et al. 2012). Frequent ingestion of small quantity of tomato may enhance the protection of cell from DNA damage produced by oxidant species (Riso et al. 2004). Food enriched with ß-carotenes and vitamin C minimize the chances of illness in human beings (Pandey et al. 1995).

Tomato fruit is classified as climacteric fruit with short postharvest life due to its perishability at room temperature and its ripening is mainly relied on the action of ethylene (Alexander and Grierson 2002). According to Anza et al. (2006), the nutritional composition of tomato is affected by the types, cultivars, ecological conditions, cultural practices, stage of maturity at harvest and storage conditions. Similarly, ascorbic acid content is affected by the cultivars. Viskelis et al. (2015) reported that ascorbic acid varies among the 8 tomato cultivars and they reported that 'Vilina' cultivar had the highest (15.9 mg 100 g^{-1}) and 'Viltis' cultivar had the lowest ascorbic acid content (7.8 mg 100 g^{-1}). In another study, George et al. (2004) reported that lycopene, ascorbic acid, phenolic contents and antioxidant activity varied among 12 genotypes. In the experiment, cherry cultivars '818' and 'DT-2' had higher level of antioxidants. It is important to determine carotenoid, lycopene, ascorbic acid, phenolic content and antioxidant activity based on which breeding programs can be designed to increase their amount. Therefore, this study was conducted to compute the nutritional amount in beefsteak, heirloom and cluster type of tomatoes during shelf-life conditions.

2. Materials and methods

2.1. Materials

In this study, beefsteak (cv. 'Tybif'), heirloom (cv. 'Yuksel Koy') and cluster (cv. 'Merkur') types of tomatoes harvested at the 'breaker stage' were used. The fruits were grown in a commercial greenhouse at Aksu, Antalya region (36°59'57.3" N 30°51'20.4" E). Harvested fruits were immediately transported to the postharvest physiology laboratory, Akdeniz University, Antalya, Turkey. Fruits with any kind of defects were discarded from the experiment. Different types of tomatoes were stored at 20°C temperature and 60+5% relative humidity for comparing their postharvest performance and nutritional values. The physicochemical analysis was performed on 0, 4, 7, 11, 14, 18 and 21 days of storage.

2.2. Methods

Individually labeled tomatoes were weighed with a digital balance having sensitivity of 0.01 g for determination of weight losses during storage. The fruits were weighed again at different intervals and weight losses were calculated as percent loss of initial weight (Jan and Rab 2012).

The antioxidant activity of tomatoes was analyzed by using 2.2-diphenyl-1-picrylhydrazyl (DPPH*) method described by Benvenuti et al. (2004). The percent inhibition values corresponding to each sample volume were calculated according to the equation (1).

$$\% \text{ inhibition} = \frac{A_{DPPH} - A_{Extract}}{A_{DPPH}} \times 100 \quad (1)$$

A_{DPPH}: The absorbance value of the DPPH* control sample
$A_{Extract}$: The absorbance value of the test sample

The EC_{50} value of the sample was calculated using the equation. One of the most important parameters for antioxidant activity determination by DPPH method is EC_{50} (efficient/effective concentration) value. The EC_{50} value is expressed as the concentration of the antioxidant substance which inhibits 50% of the DPPH radical present in the fruit samples. As the EC_{50} value decreases, the antioxidant activity increases (Cemeroglu 2010). The EC_{50} value was expressed in g fresh weight (fw) EC_{50}.

The total carotenoid content was determined according to Witham et al. (1971). The total carotenoid contents were calculated by using the equation (2) and reported as g kg^{-1} fw.

Chlorophyll a (g kg^{-1})= [12.7 (D663) – 2.69 (D645)] x V/1000 x W

Chlorophyll b (g kg^{-1})= [22.9 (D645) – 4.68 (D663)] x V/1000 x W

Carotenoids (g kg^{-1})= [4.69 (D440) – (chlorophyll a + chlorophyll b) x 0.286] x V/1000 x W (2)

V= Extract volume

W= Sample quantity

D= Absorbance value at wavelength

The total flavonoid contents of tomatoes were analyzed by following the method described by Karadeniz et al. (2005) and expressed as g kg^{-1}.

The total phenolic contents of extracts were analyzed according to the Folin-Ciocalteu method described by Spanos and Wrolstad (1990) and expressed as g of gallic acid equivalent (GAE) per kg of fluid extract. The calibration curve equation of GAE was y= 0.009x + 0.0561 and the coefficient of determination was R^2= 0.9996.

The total ascorbic acid contents of extracts were analyzed as described by Cemeroglu (2010). The calibration curve equation of ascorbic acid was y= 0.0123x + 0.0134 and the coefficient of determination was R^2= 0.9557. The contents of total ascorbic acid were calculated using the equation (3).

Ascorbic acid (g kg^{-1}) = $A_2 – A_1/a$ x DF (3)

A_1: The absorbance value of the extract sample

A_2: The absorbance value of the control sample

DF: Dilution factor

a: The slope of the ascorbic acid standard curve

Ethylene production and respiration rate were conducted at 3 days intervals at 20ºC with gas chromatography (GC) (Thermo Electron S.p.A., Strada Rivoltana, Milan, Italy). The sample was taken through gas tight syringe and injected to the GC for determination of ethylene and CO_2 production.

Fungal and physiological deterioration occurred in different types of tomato were noted and considered as unmarketable fruits (Jan and Rab 2012). Equation (4) is used for determination of amount of unmarketable fruits.

Unmarketable fruits (%)= Number of deteriorated fruits/ Total number of fruits x 100 (4)

The experiment was designed according to the Completely Randomized Experimental Design (RCD) with three replications and each replication contained ten fruit. Means calculated were subjected to Duncan's multiple range test to know the significant differences. The mean values obtained were analyzed in SAS program.

3. Results

3.1. Weight loss

Tomatoes are highly sensitive to rapid water loss which leads to rise in weight losses and affects the quality of fruit. Extension in storage duration resulted increase in weight losses possibly due to water loss. At the end 21 days of storage, maximum weight loss (9.52%) was noted in cluster type whereas minimum weight loss (6.03%) was recorded in beefsteak type of tomatoes (Table 1).

3.2. Antioxidant activity

The health benefits of tomatoes are due the presence of antioxidants. They are rich source of antioxidants which protects human body from the damages caused by free radicals. Extension in storage duration resulted in the increase of antioxidant activity except beefsteak type of tomatoes (Table 1). At the end of storage, maximum antioxidant activity 0.44 g fw EC_{50} was noted in beefsteak type of tomatoes whereas minimum antioxidant activity 0.65 g fw EC_{50} was found in heirloom type of tomatoes. However, there were no statistical differences between beefsteak and cluster types of tomato.

3.3. Carotenoid content

Lycopene is the major carotenoid present in tomato which decreases the risk of breast and prostate cancer in human body. Consumption of carotenoid can improve visual strength. Prolonging storage duration had caused increase in the content of carotenoids. At the end of storage, the highest carotenoid content (0.0349 g kg^{-1}) was noted in beefsteak type whereas the lowest carotenoid content (0.0145 g kg^{-1}) was recorded in heirloom type of tomatoes (Table 1).

3.4. Flavonoid content

Flavonoids are different group of phenolic secondary metabolites that acts as powerful antioxidants. Its high intake can decrease the risk of cardiovascular disease, cancer and other diseases related to age. The flavonoid content showed decrease with increase in storage. At the end of storage, maximum amount of flavonoid content (0.0277 g kg^{-1}**)** was recorded in heirloom type while minimum flavonoid content (0.0126 g kg^{-1}) was found in cluster type of tomatoes (Table 1). However, there were no statistical differences between beefsteak and cluster types of tomato.

Table 1. Comparison of nutritional attributes in different types of tomatoes stored under shelf-life conditions at 20°C temperature and 60±5% relative humidity.

Parameters	Tomato types	Storage duration (days)						
		0	4	7	11	14	18	21
Weight loss (%)	Beefsteak	-	1.40k	2.50j	3.51i	3.99hi	5.15f	6.03de*
	Heirloom	-	1.45k	2.60j	3.60i	4.67fg	6.12de	6.56cd
	Cluster	-	2.54j	4.31gh	5.75e	7.03c	8.79b	9.52a
$LSD_{5\%}$ St. Dur.*: 0.3145		St. Dur. × Tomato types: 0.5448		Tomato types: 0.2224				
Antioxidant activity (g FW EC_{50})	Beefsteak	0.22g	0.39e.g	0.20g	0.38e.g	0.33e.g	0.44de	0.44de
	Heirloom	1.21a	0.91b	0.91b	0.76bc	0.51de	0.51de	0.65cd
	Cluster	1.19a	1.28a	0.46de	0.43ef	0.23fg	0.45de	0.48de
$LSD_{5\%}$ St. Dur.: 0.1052		St. Dur. × Tomato types: 0.1822		Tomato types: 0.0689				
Carotenoid content (g kg^{-1})	Beefsteak	0.0035b	0.0066b	0.0075b	0.0078b	0.0082b	0.0136b	0.0349a
	Heirloom	0.0043b	0.0046b	0.0050b	0.0053b	0.0074b	0.0097b	0.0145b
	Cluster	0.0007b	0.0062b	0.0074b	0.0091b	0.0118b	0.0138b	0.0203ab
$LSD_{5\%}$ St. Dur.: 0.0107		St. Dur. × Tomato types: 0.0185		Tomato types: 0.007				
Flavonoid content (g kg^{-1})	Beefsteak	0.1827a	0.1154bc	0.0806b.e	0.0594c.f	0.0449d.f	0.0422d.f	0.0131f
	Heirloom	0.1345ab	0.1078bc	0.0624c.f	0.0431d.f	0.0422d.f	0.0387d.f	0.0277ef
	Cluster	0.0947b.d	0.0603c.f	0.0414d.f	0.0283ef	0.0282ef	0.0180ef	0.0126f
$LSD_{5\%}$ St. Dur.: 0.031		St. Dur. × Tomato types: 0.0537		Tomato types: 0.0203				
Total phenolics content (g kg^{-1} GAE)	Beefsteak	0.0283a	0.0276ab	0.0274ab	0.0217b.d	0.0210c.e	0.0203c.f	0.0164dh
	Heirloom	0.0273ab	0.0241a.c	0.0239a.c	0.0239a.c	0.0239a.c	0.0154e.h	0.0143gh
	Cluster	0.0116h	0.0115h	0.0169d.h	0.0200c.g	0.0209c.e	0.0147f.h	0.0143gh
$LSD_{5\%}$ St. Dur.: 0.003		St. Dur. × Tomato types: 0.0052		Tomato types: 0.002				
Ascorbic acid (g kg^{-1})	Beefsteak	0.2317d	0.1938ef	0.2501b	0.2594a	0.1719hi	0.1661ij	0.1627j
	Heirloom	0.2431bc	0.1970e	0.1929ef	0.1787gh	0.1857fg	0.1677ij	0.1594j
	Cluster	0.2498b	0.2366cd	0.1864fg	0.1974e	0.1820g	0.1069k	0.0995k
$LSD_{5\%}$ St. Dur.: 0.0045		St. Dur. × Tomato types: 0.0079		Tomato types: 0.003				
Unmarketable fruits (%)	Beefsteak	0f	0f	0f	0f	0f	0f	3.50bc
	Heirloom	0f	0f	0f	0f	3.18c	3.82b	5.25a
	Cluster	0f	0f	0f	0f	1.85e	2.35d	2.50d
$LSD_{5\%}$ St. Dur.: 0.2469		St. Dur. × Tomato types: 0.4277		Tomato types: 0.1617				

*: Means showed with different letters are statistically significant at ($p \leq 0.05$) according to Duncan's multiple range test.
Abbreviations**:** LSD= least significant difference, St. Dur.= Storage duration, St. Dur. × Tomato types; Storage duration × Tomato types.

3.5. Total phenolics content

Phenolic compounds are natural antioxidants which occur in all parts of the plant. They serve as antibiotics and pesticide. Extension in storage duration had caused decline in the total phenolic contents except cluster type which had shown zigzag behavior. At the end of storage, the highest total phenolic content (0.0164 g kg^{-1} GAE) was recorded in beefsteak type whereas the lowest total phenolics content (0.0143 g kg^{-1} GAE) was noted in both cluster and heirloom type of tomatoes (Table 1).

3.6. Ascorbic acid content

Higher vitamin C content can enhance the postharvest life of fruit. Ascorbic acid known as vitamin C act as dietary antioxidant as humans are not able to synthesize vitamin C therefore foods with rich vitamin C contents are of great interest. Tomatoes are important source of vitamin C. The effect of oxidative stress can be minimized through intake of ascorbic acid. There was considerable decrease in content of ascorbic acid with extension in storage. At the end of storage, the highest ascorbic acid content (0.1627 g kg^{-1}) was recorded in beefsteak type whereas the lowest ascorbic acid content (0.0995 g kg^{-1}) was noted in cluster type of tomatoes (Table 1). However, there were no statistical differences between beefsteak and heirloom types of tomato.

3.7. Ethylene production

Tomatoes are climacteric fruit which shows burst in ethylene production. Ethylene acts as a primary regulator of ripening in tomato fruit and therefore plays active role in changing color, texture, flavor and aroma of the fruit. Maximum ethylene productions in heirloom and cluster types were attained on 14th day of storage at 20ºC whereas beefsteak type of tomatoes had maximal ethylene production on 7th day of storage (Fig. 1). Cluster type tomatoes had the highest ethylene production (3.68 µl C_2H_4 kg^{-1} h^{-1}) followed by heirloom (2.54 µl C_2H_4 kg^{-1} h^{-1}) and beefsteak type of tomatoes (2.52 µl C_2H_4 kg^{-1} h^{-1}).

3.8. Respiration rate

Tomato fruit continues to respire after harvesting as the fruit is not in contact with plant anymore therefore it will have to use its own energy for internal process which is set by respiration. Proper control of respiration rate is obligatory for keeping quality of tomato fruit. Heirloom and cluster types tomatoes had peak climacteric rise on 11th day while beefsteak type of tomatoes had maximal CO_2 production on 14th day of storage (Fig. 2). Maximum CO_2 production was recorded in cluster type (3.66 ml CO_2 kg^{-1} h^{-1}) followed by heirloom (2.74 ml CO_2 kg^{-1} h^{-1}) and beefsteak type of tomatoes (2.01 ml CO_2 kg^{-1} h^{-1}).

3.9. Amount of unmarketable fruits

Tomatoes having physiological or fungal deterioration are considered unmarketable. Fruit with higher respiration rate deteriorates rapidly. The amount of unmarketable fruits exhibited increase with extension in storage duration. At the end of storage, the highest amount of unmarketable fruits (5.25%) were recorded in heirloom type whereas the lowest amount of unmarketable fruits (2.50%) were calculated in cluster type of tomatoes (Table 1).

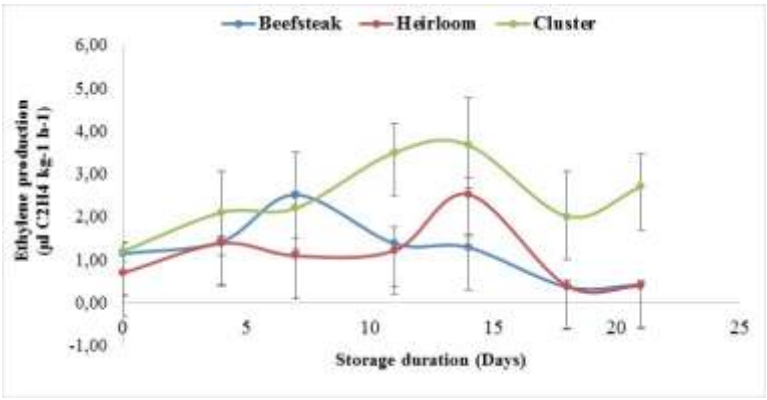

Figure 1. Ethylene production of different types of tomato at 20ºC.

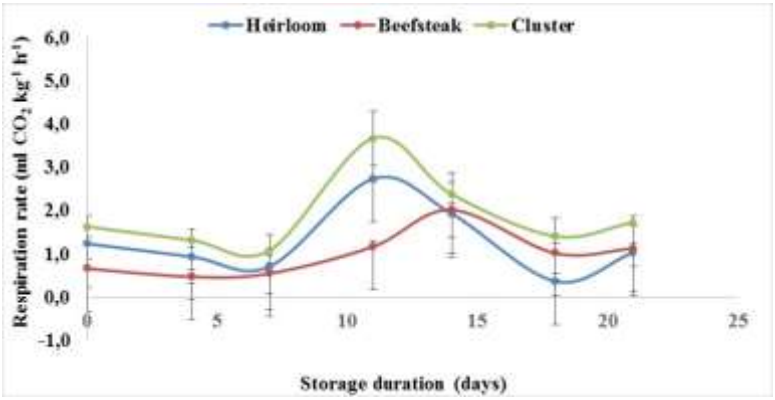

Figure 2. Respiration rates of different types of tomato at 20ºC.

4. Discussion

The weight losses increased as the ripening proceeds as mentioned by Sammi and Masud (2007). According to Javanmardi et al. (2006) tomato storage at higher temperature resulted in higher transpiration rates due to which weight losses are accelerated which agreed with the results obtained in this study.

Our results agreed with Tilahun et al. (2017) who reported significant differences in scavenging activity of DPPH radical under different ripening conditions of tomato. Furthermore, they showed that antioxidant activity was more at the red stage of tomato which may be due to increase in the lycopene content. This was in confirmation with our outcomes regarding heirloom and cluster types however contradict with the result of beefsteak type of tomatoes where zigzag behavior was observed. George et al. (2004) mentioned that antioxidant activity changes considerably depending on the genotypes as noticed in our experiment.

Increase in carotenoid content during this experiment can be because of advancement in ripening that change color of tomato from green to red with conversion of chloroplast to chromoplast, degradation of chlorophyll and accumulation of carotenoid occurs as explained by Alexander and Greirson (2002).

In our study, different types of tomatoes had significant effect on flavonoid content which agreed with Riadh et al. (2016) who mentioned that different cultivars of tomato significantly affected flavonoid content. Decrease in flavonoid contents with extending storage duration during this study was supported by the findings of Howard et al. (2000) who reported the decrease of flavonoid content during maturation of peppers. The losses in flavonoid content during our study may be because of metabolic transformation to secondary phenolic compounds Barz and Hoesel (1979).

Riadh et al. (2016) and George et al. (2004) mentioned the significant effect of total phenolic contents between the different cultivars of tomato as obtained in our study. Declining trend shown by total phenolic content with extending storage duration in our study can be because of the higher respiration rate that caused degradation of phenolic compounds Day (2001).

In our study different types of tomatoes had significantly affected the ascorbic acid content which was supported by the findings of Riadh et al. (2016) who revealed the significant effects among cultivars which confirmed our results. Decrease in ascorbic acid content during our study may be because of oxidation caused by oxidizing enzymes as reported by Tudor-Rado et al. (2016) in tomato.

Eum et al. (2009) reported rise and then decline in the ethylene production which agreed with our study. Lelievre et al. (1997) reported that the sudden rise in ethylene production pre-ripening climacteric fruits regulate alterations in physiological characteristics.

The climacteric nature of tomato allows sharp rise in production of respiration rate (Sammi and Masud 2007). Rise in metabolic activity of the fruit occur during the transition to the growth of the fruits can be the possible reason of this increase in the respiration rate during our study as reported by Karacali (1990).

In this study the amount of unmarketable fruits displayed increase with storage. The possible reason can be the rise in ethylene production and respiration rates which are the key elements that stimulate decay of fruits and vegetables (Gonzalez-Aguilar et al. 2010).

In conclusion, in the present study beefsteak, heirloom and cluster type of tomatoes stored under shelf life conditions exhibited increase in weight loss, carotenoid content, ethylene production, respiration rate and amount of unmarketable fruits whereas decrease in flavonoid and ascorbic acid contents. The amount of antioxidant activity, carotenoid, flavonoid, total phenolic and ascorbic acid contents noted in this study furthermore application of proper storage techniques that reduces weight losses, ethylene production, respiration rates and amount of unmarketable fruits can be used to improve the nutritional characteristics of these types of tomatoes. It can be concluded that beefsteak type of tomatoes had superior nutritional quality when compared with heirloom and cluster type of tomatoes.

Acknowledgements

The financial support for this study was provided by Scientific and Technological Unit Akdeniz University.

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