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Comparison of pesticide-free and conventional production systems on postharvest quality and nutritional parameters of peppers in different storage conditions

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ABSTRACT

The peppers were grown using either pesticide-free or conventional production systems and stored at 8 °C in one of four storage methods, i.e. regular atmosphere (control), cling film (CF), modified atmosphere packaging (MAP) or a proprietary controlled atmosphere (CA) storage system (Palliflex™, PL) of 2 kPa O_2 + 3 kPa CO_2. Internal atmospheres created by the MAP were periodically assessed during storage, and O_2 and CO_2 levels in both pesticide-free and conventionally-grown peppers were suitably maintained within recommended limits, 3–5 kPa O_2 + 2–8 kPa CO_2. Weight loss of peppers stored in PL was lower (<4% at 45 d) than for other treatments in both production systems. After 45 d of storage, peppers stored in PL and control had higher total soluble solids content compared with the CF and MAP treatments in the conventional production system. Titratable acidity and total phenolics content first increased then decreased in all treatments. The contents of ascorbic acid in both pesticide-free and conventionally-grown peppers declined, and β-carotene content increased progressively with storage time. In terms of the production systems, the lowest weight loss and total soluble solids contents were in the pesticide-free production system. Furthermore, the pesticide-free production system had higher titratable acidity, total phenolics and ascorbic acid contents, compared with the conventional production system. The lowest decay incidence was in the conventional production system. In conclusion, the pesticide-free production system could be an alternative production system for pepper growing and PL storage could be used to maintain postharvest quality attributes of peppers up to 45 d both in pesticide-free and conventionally-grown peppers.

1. Introduction

Red bell pepper (*Capsicum annuum* L.) is one of the most popular health-promoting vegetables traded on the global market (AgMRC, 2011). Pepper is a good source of numerous antioxidant compounds as well.

Pesticide residues in fruits and vegetables are of concern to consumers because such commodities are often eaten fresh and unprocessed. These concerns have raised the profile of organic fruits and vegetables consumption all over the world. Agricultural production systems are generally classified as organic, integrated or conventional. In conventional production system, farms utilize high-yield crop cultivars, chemical fertilizers, and pesticides (Marín et al., 2008). On the contrary, in the organic production system, synthetic pesticides and chemicals widely used in conventional farming system are banned (Hallmann and Rembiałkowska, 2012). For that reason, organic produce is considered by consumers as safer than conventionally-grown produce. However, the yield and product quality can be lower in an organic production system compared with a conventional production system. So, in the late 1990s, agronomists developed a new production system that falls between conventional and organic farming. This system, referred to as pesticide-free production, is designed largely for field crop production in which the crop is grown without the use of chemical pest control methods (Magnusson and Cranfield, 2005). Many research groups have studied nutritional and quality parameters in peppers produced in organic and conventional growing systems (Pérez-López et al., 2007; Marín et al., 2008; Hallmann and Rembiałkowska, 2012). However, the effect of pesticide-free and conventional production systems on postharvest quality attributes of peppers have not been studied.

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Modified atmosphere packaging (MAP) and controlled atmosphere (CA) storage are used to prolonged storage duration and shelf-life of different fruits and vegetables (Sandhya, 2010). Generally, cling film wrapping (Risse and Miller, 1986), MAP (Lownds et al., 1994) and CA storage (Polderdijk et al., 1993) are effective in pepper to decrease weight loss because of their water vapour permeability. Research on pepper storage show that MAP prolong and maintains the postharvest quality of peppers (Meir et al., 1995; Raffo et al., 2007; Manolopoulou et al., 2010). To date, commercial adoption of CA storage in pepper has been limited due to lack of economically-acceptable CA technology. A new CA storage system, Palliflex™ (Van Amerongen CA Technology), makes it possible to set desired O_2 and CO_2 levels in individual pallets. In this system, O_2 and CO_2 can be automatically injected or removed, based on operator set points programmed into the controller. This system is suitable for different fruits and vegetables in the same storage room and in special containers, because it can provide different atmospheric compositions for individual pallets. It extends the marketing period of fresh produces during storage, transportation, and distribution by maintaining fruit quality, nutritional and market value (Dogan and Erkan, 2014). In addition, the Palliflex™ storage system retards the degradation of bioactive compounds in medlar fruits (Selcuk and Erkan, 2015).

The aims of this study were to (1) evaluate the influence of pesticide-free and conventional production systems on postharvest fruit characters, (2) investigate the effects of different storage conditions on physiological properties, quality attributes and storage ability of kapia-type sweet red peppers.

2. Materials and methods

2.1. Experimental site and design

In this research, the effects of pesticide-free and conventional production systems on postharvest fruit quality of peppers grown in protected cultivation were investigated. For this purpose, peppers were grown in two different production systems namely conventional and pesticide-free. Fruit used in this experiment were grown in a greenhouse (≈0.2 ha) located on the campus of Akdeniz University (36° 53′ N; 30° 39′ E, altitude 39 m), Antalya, Turkey. The soil type of the greenhouse was sandy-loam, and the soil characteristics were as follows: pH: 7.9, lime: 15.9%, salinity: 0.072 dS m^{-1}, electric conductivity (EC): 2.5 mmhos cm^{-1}, organic matter: 1.44%. After soil disinfection with solar energy 6 weeks before planting, the greenhouse was arranged as per layout of the experiment, by dividing it into two separate compartments for pesticide-free and conventional production systems, with clear polycarbonate sheet (thickness: 12 mm, 100% Virgin Bayer Material, UV layer: one side UV protective layer) in order to prevent potential interference between the two production systems. Pesticide-free and conventionally-grown seedlings of three weeks old Urartu' peppers from a local company (Fitar Seedling Inc., Antalya, Turkey) were transplanted into the greenhouse in single rows in mid-September. The distance between plants within each row was 0.5 m and between two rows was 1 m.

2.2. Crop management, pest and disease control

After transplanting, the plants were watered using drip irrigation and all other cultural practices (e.g. mulching, pruning) were applied uniformly in both pesticide-free and conventional production systems compartments of the greenhouse during the growing period.

A heating system was installed in the greenhouse to maintain optimum growing temperatures at around 15 °C. Within the pesticide-free production system evaluated in this study, only microbial-based products/materials were used to control pests and diseases. All the microbial products/materials used in the study were provided by Bioglobal Corporation (Antalya, Turkey). With the exception of macro-nutrients (nitrogen, phosphorus and potassium), no synthetic chemical inputs, such as fertilizers and pesticides, were used throughout the study. To further identify the effectiveness of the pesticide-free production system, it was compared with the conventional production system, in which synthetic chemicals were used throughout the study, and the products details used in this research were summarized in another study (Dogan et al., 2016).

2.3. Fruit samples

Kapia-type sweet red peppers (*Capsicum annuum* L. cv. Urartu) were harvested with calyx at commercial harvest maturity [total soluble solids (TSS) 5.90 or 7.07% and titratable acidity (TA) 0.29 or 0.22% for pesticide-free and conventionally-grown peppers, respectively, and red stages] at mid-June after 278 days from planting. The fruit quality characteristics at harvest were given in Table 1. On the same day, harvested fruit were immediately transported to the postharvest laboratory of the Department of Horticultural Science and cold storage unit at Akdeniz University in Antalya, Turkey. From the initial sorting, damaged, poor quality (blemishes or defects) and non-uniform fruit were removed. The remaining peppers of medium size (15–17 cm high, 4–6 cm wide), with red color and weighing 70–100 g were used in the experiment.

2.4. Fruit packaging procedures

After harvest the fruit were divided randomly into four different groups for different postharvest applications. The first group of peppers was stored in regular atmosphere and was designated as control group. The second group of peppers was stored by replacing the peppers in styrofoam plates containing 1 kg fruit and wrapped by cling film (CF). The third group of peppers was stored in modified atmosphere packaging (MAP) containing 5 kg of peppers. The packaging material used was low-density polyethylene film (Xtend® film, Patent no: 6190710, StePac Co., Antalya, Turkey). The fourth group of peppers was stored in CA storage system containing 50 kg of fruit in a Palliflex™ (PL) with an atmospheric compositon of 2 kPa O_2 + 3 kPa CO_2 levels. After packaging, all the fruit groups were stored at 8 ± 0.5 °C temperature with 90 ± 5% RH for 45 d. After 0, 15, 30, and 45 days of storage, 36 fruit from each experimental unit were transferred to an evaluation room; 18 of the peppers (six fruit per replication) were assessed and analyzed while the rest (18 fruit)

Table 1
Influence of production systems on fruit quality and characteristics at harvest.

Production systems	Mean yield (kg da^{-1})	Mean fruit weight (g)	Mean fruit width (cm)	Mean fruit length (cm)	TA (%)	TSS (%)	TSS/TA	Total phenolics (mg GAE 100 g^{-1})	Ascorbic acid (mg 100 g^{-1})
Pesticide-free	7386.7b	78.00a	4.91a	16.39a	0.29a	5.90b	20.34b	114.6a	123.5a[a]
Conventional	7906.7a	72.00b	4.82b	15.61b	0.22b	7.07a	32.14a	105.9b	114.2b

TA, titratable acidity; TSS, total soluble solids.
[a] Different letters in the same column indicate statistical significant difference at $P \leq 0.05$ by Duncan's multiple range test.