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Cultivation approach for comparing the nutritional quality of two pepper cultivars grown under different agricultural regimes

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The aim of this study was to assess the influence of the cropping system (organic or conventional) and the growth medium (soil or soilless) on the antioxidant content of peppers from Almuden and Quito cultivars. This cultivation study complements a previous farm study. For both cultivars, organic cultivation led to higher fruit lipophilic antioxidant content than conventional management but differences in the hydrophilic fraction were not observed. The effect of the growth medium on pepper composition depended on the studied cultivar. In Almuden, neither the hydrophilic nor the lipophilic fractions were affected by the growth medium, while in Quito most compounds showed higher values in soil-grown plants. Taking into account the results from the present and the previous farm study we conclude that the effect of organic *vs.* conventional cultivation on pepper quality can be attributed to the different nutritional regimes and other factors associated with the agricultural system. However, both aspects are not necessarily different in organic and conventional commercial crops. The effect of the growth medium (soil or soilless) on pepper quality depended on the cultivar: Almuden was not affected by the growth medium and Quito was seen to be less suitable for soilless cultivation.

1. Introduction

In recent years, consumer interest in health has increased, as has the demand for organic food, which is considered to be more nutritious and safer than conventionally grown products. However, while the demand for organic products is steadily increasing, organic food has still not been shown to provide a higher nutritional quality from a scientific point of view. A wide range of studies have attempted to investigate whether there are differences in the nutritional value of organically and conventionally cultivated crops, but the results are controversial. Whereas some authors have reported that the cropping system adopted has a crucial effect on fruit composition (Hallmann & Rembialkowska, 2012; Kim et al., 2010), others have reported results that contradict this assumption (Chassy, Bui, Renaud, Van Horn, & Mitchell, 2006). In order to obtain more conclusive results, Magkos, Arvaniti, and Zampelas (2003) proposed carrying out comparative studies of three different types: retail market studies, farm studies and cultivation studies (research centre study approaches). The present work is included in the cultivation studies category, which is considered the most accurate method since plants are cultivated in similar soils, under similar climatic conditions and are sampled at the same time. This study forms part of a larger research project in which a comparative farm study was carried out to realistically reflect the production system (Flores, Hellin, Lacasa, López, & Fenoll, 2009a, 2009b). In addition to organic and conventional cultivation, our research includes soilless cultivation due to its growing importance because of the increased productivity that it provides the accurate control of irrigation and plant nutrition that it permits and the reduction in labor requirements compared with soil cultures. In spite of these advantages, comparative studies on crop quality usually do not include soilless cultivation and, consequently, there is little information about the nutritional quality of vegetables cultivated in soilless cultivation compared with those from other agricultural systems. Another crucial aspect that is not always considered when studying fruit quality and composition is the influence of the harvesting period on these parameters. Pepper has a long cultivation cycle that begins in about April and continue to the following September, with several peak harvesting periods. The period in which fruits are harvested has been shown to affect pepper yield and quality parameters, such as fruit weight, phenolic compounds and the ascorbic acid content (Martí et al., 2011). In addition, a previous work studying the influence of the agricultural management system on the sensory attributes and the mineral composition

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of pepper showed that the influence of the harvesting time on the studied parameters was, in several cases, more pronounced than that of the cropping system (López, Fenoll, Hellín, & Flores, 2013). Therefore, comparative studies should include fruit harvested at different periods in order to evaluate possible interactions between the studied factors and the harvesting time. Pepper (*Capsicum annuum* L.) is an important horticultural crop in many regions of the world. In addition to its economic importance, pepper is considered an excellent source of phytochemicals with health-promoting effects, such as carotenoids, vitamin C and phenolic compounds. The dietary intake of carotenoids is associated with decreased risks of cancer, cardiovascular disease, macular degeneration and cataract formation (Abdel-Aal, Akhtar, Zaheer, & Ali, 2013; Giordano et al., 2012; Polesel et al., 2013). Vitamin C acts as line of defence against oxidative stress and may therefore prevent chronic diseases, such as diabetes, cancer and cardiovascular disease (Jomova & Valko, 2011). Moreover it is involved in many biological processes such as the synthesis of collagen and certain hormones (Li & Schellhorn, 2007) and enhances iron bioavailability. Phenolics are considered to play an important role in human health and disease prevention due to their antioxidant and antiproliferative activities (Eberhardt, Lee, & Liu, 2000). The present study focuses on the effect different agricultural systems (organic *vs.* conventional and soil *vs.* soilless cultivation) on the resulting antioxidant and bioactive composition of two different pepper cultivars at different harvesting periods throughout the cultivation cycle.

2. Materials and method

2.1. Study site and experimental design

The study plot was established in the "Torreblanca" experimental farm located in Torre-Pacheco (Murcia), SE Spain, which has a semi-arid type Mediterranean climate. Weather data during the growing season were collected from a meteorological station close to the experimental greenhouse (Table 1). The peppers (*C. annuum* L.) were grown according to different farming systems, conventional (C), organic (O) and soilless (SL), in adjacent plastic greenhouses with the same characteristics to control the influence of environmental conditions (climate and soil characteristics). Plants were distributed in two different plots, eleven rows per plot, separated by 0.4 m within rows and with 1 m between rows. For C and O treatments, plants grown in soil with a clay-loam texture, pH = 7.7. For SL system, plants were grown 30 L pots filled with perlite (30%) and coconut fiber (70%). Two experiments were carried out in two consecutive growing seasons in order to achieve the proposed objectives: the first compared organic and conventional systems and the second compared soil (S) *vs.* soilless (SL) systems. Both studies were performed using two pepper cultivars: Almuden, which is a Lamuyo-type pepper, and Quito, which is a California-type pepper. Plants were grown along one crop cycle to compare their response to the agricultural system.

2.2. Crop management

Before transplanting, soils in conventional and organic farming were prepared by biosolarization (Flores, Lacasa, Fernandez, Hellín, & Fenoll, 2008). For this, ovine and chicken manure was applied at rate of 5 kg/m^2. After manure application the soil was covered with a plastic film and the greenhouse was closed for 3 months during the summer season (August–October). Plants from the organic system were fertilized with organic fertilizers certified according to European Regulation (EC) 834/2007 for use in organic crops. Plants from the conventional system were fertilized following low-input guidelines with synthetic fertilizers: $Ca(NO_3)_2$, KH_2PO_4, NH_4NO_3, KNO_3 and $MgSO_4$. These fertilizers were applied at rate of 373 N, 56 P, 485 K, 65 Ca and 26 Mg kg/ha, respectively. For the soilless system, a modified Hoagland's solution was used as fertilizer. The nutrient solution used for irrigation had the following macronutrient composition (mM): NO_3^-, 18.0; $PO_4H_2^-$, 1; SO_4^{2-}, 1; Ca_2^+, 5.5; K^+, 6.5; and Mg_2^+, 1.7. The micronutrient concentration (mg L^{-1}) was as follows: Fe, 2; Mn, 1; Zn, 0.1; B, 0.3; Cu, 0.1; and Mo, 0.06. Pest control was performed according to the Integrated Production Protocol for pepper crops (B.O.R.M., 2007).

2.3. Sampling and sample preparation

In the experiments, pepper fruits were sampled on three (experiment 1) or two (experiment 2) occasions during the growing season during two of the peak pepper harvesting periods. Full-sized fruit of a homogeneous green color (with no appreciable brown or red parts) were selected, and damaged fruits were discarded. At each harvesting time, six replicates per treatment were collected, each consisting of ten fruits from different plants. Fruits were washed with deionized water and the seeds were removed. Each fruit was cut into pieces and mixed with those of fruits belonging to the same replicate. Samples were homogenized with liquid N_2 and frozen at −80 °C until subsequent analysis. Aliquots of 5 g were homogenized with 5 mL of water in a Polytron (PT-MR 3100, Switzerland). Ethyl acetate (10 mL) was added and the mixture was homogenized again. The homogenate was centrifuged at 8000 *g* for 10 min, at 4 °C. The top phase was transferred to a test tube and the pellet was re-suspended in 5 ml ethyl acetate, centrifuged, and the two resulting phases were separated. The lipophilic fraction was used for the determination of chlorophyll, total carotenoids and lipophilic antioxidant activity (LAA). The hydrophilic fraction was used for analyzing soluble sugars, organic acids, total phenolic compounds and hydrophilic antioxidant activity (HAA).

2.4. Analytical procedure

2.4.1. Soluble sugars

Sugars were analyzed using a Hewlett–Packard mod. 1100 HPLC system (Waldbronn, Germany) equipped with an index detector. The separations were performed on a 300 × 7.8 mm i.d., CARBOSep

Table 1
Weather data during the growing season.

	Average radiation (W/m^2)	Maximum radiation (W/m^2)	Accumulated hours of sunshine	Average temperature (°C)		
				Monthly	Minimum	Maximum
February	143	976	205	12.2	7.8	15.1
March	213	1229	287	12.4	9.0	15.8
April	211	1372	281	14.6	11.4	19.5
May	297	1266	353	19.1	13.7	21.8
June	322	1316	352	21.9	19.7	24.4
July	320	1374	345	23.7	22.3	25.1
August	208	1282	328	25.6	21.8	27.8