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Influence of high lycopene varieties and organic farming on the production and quality of processing tomato

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ABSTRACT

The effect of conventional integrated pest management and organic farming production systems on the agronomic performance and quality of standard and high lycopene tomato cvs. has been evaluated for two years in two of the main processing tomato producing areas of Spain (Extremadura and Navarra). As an average, the production under organic farming was on average 36% lower than in conventional integrated pest management. Organic farming tended show reduced contents of citric and glutamic acid. Although the contents in sugars were not significantly affected, the ratios sucrose equivalents to citric and glutamic acid increased. Nevertheless, a strong influence of the environment and interactions were detected and under certain conditions (e.g. Extremadura), organic farming may increase the contents in glucose and fructose. The levels of lycopene were not affected by the cultivation system, while beta-carotene contents were higher under organic farming. High lycopene cvs. 'Kalvert' and 'ISI-24424′ registered the highest lycopene levels, but with 27.6 and 28.1% lower production levels compared to 'H-9036′, the cv. with the best agronomic performance. 'Kalvert', with high accumulation of sugars and high ratios sucrose equivalents to citric and glutamic acid and high lycopene contents would be an ideal material for supplying quality markets. 'H-9997′ with intermediated levels of lycopene accumulation proved to be a good material combining production levels and functional quality. 'CXD-277′ offered the higher values in variables related with organoleptic quality with intermediate lycopene accumulation but with lower production.

1. Introduction

Consumers are increasingly concerned about the capacity of food to improve health and prevent diseases, accordingly there is an increasing demand for foods with an improved functional value (Granato et al., 2010). It is not clear, though, if marketing efforts have spurred this interest or vice versa, but the industry has made a clear emphasis in the promotion of 'healthy' agricultural food products and in the improvement of the contents of functional compounds (Goldman, 2011). In the case of tomato, one of the vegetables with the highest levels of economic value and consumption, the functional value is mainly determined by the contents in the carotenoids beta-carotene and lycopene, vitamin C and polyphenols.

It has been a long time since the cultivars with high vitamin C content such as 'Doublerich' were released, though with a limited success due to reduced fruit size (Stevens and Rick, 1987). More recently, and with higher success, high lycopene cultivars have been developed. Those with higher efficiency include mutations such as high pigment, which increase the global content of carotenoids (up to 2- 3-fold the content of a standard cultivar). Additionally, these materials may have the collateral effect of increasing the levels of flavonoids and vitamin C, though at the expense of a reduced yield (reviewed by Cebolla-Cornejo et al., 2013).

Nevertheless, the commercialization of products with high functional value cannot ignore taste, one of the general success factors for the marketing of foods (Menrad, 2003). In the case of tomato,

Abrreviations: SEq, Sucrose equivalents.

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taste is mainly determined by sugars, organic acids and the relation between them. Among the key sugars, fructose and glucose represent up to 65% of the total soluble solids (TSS) content (Stevens et al., 1977), while the content in sucrose at the red stage is very low (Thakur et al., 1996). Among the key organic acids, as in other fruits, citric and malic acids are the most important, especially the former.

Traditionally, organoleptic quality in tomato has been evaluated using basic determinations such as TSS content or total titratable acidity, but during the last decade, the individual determination of specific compounds, or the use of derived variables such as sucrose equivalents or its relation with acid contents, has shown higher correlations with acceptability or sweetness (Baldwin et al., 1998; Cebolla-Cornejo et al., 2011). The possible role of glutamic acid and its ratio with sucrose equivalents has also been considered (Bucheli et al., 1999).

Consumer interests are not only focused on organoleptic and functional quality, but the concern on environmental quality or the minimization of the effects of agriculture on the environment and on the produces is also growing. In fact, the European Union is clearly supporting the development of production systems based on a reduced use of chemicals, such as integrated pest management or organic farming, and consumers are concerned not only with the final characteristics of food, but also with the way in which it has been produced (Biguzzi et al., 2014).

At the moment, quite a lot of the cultivars used in organic farming or other low input systems have been bred under conventional high input systems. These varieties are not expected to have the ideal characteristics of materials targeted to a low input agriculture (Lammerts van Bueren et al., 2011), though in fact little is known about the performance of this type of material under organic farming conditions (Döring et al., 2012). It is necessary to advance in the knowledge of the performance of available high input cultivars under these agricultural systems and on the effects of this type of agriculture on characteristics such as the organoleptic or functional value.

In this context, this paper analyses the performance and quality of standard and high lycopene tomato cultivars under conventional integrated pest management (IPM) and organic farming conditions in two of the main processing tomato growing areas of Spain (Extremadura and Navarra) with clearly differentiated environmental conditions. This information will be valuable in order to establish the conditions that maximize the consumer demands of higher organoleptic and functional quality in order to develop quality markets.

2. Material and methods

2.1. Plant material and experimental design

Six processing tomato cultivars were grown under conventional integrated pest management and under organic farming conditions in two sites, Extremadura (at the Southwest of Spain) and Navarra (in the Northeast of Spain), during two consecutive years (2012 and 2013). The cultivars were 'CXD-277′ (Campbell's seeds), 'Heinz(H)-9661′, 'H-9997′, 'H-9036′ (Heinz Seed), 'ISI-24424′ (Diamond seeds S.L.; Isi Sementi S.P.A.) and 'Kalvert' (Esasem S.P.A.). 'H-9036′ and 'H-9661′ are highly demanded by local farmers due to their agronomical performance and were considered as standard controls. The cultivation under organic farming and conventional IPM of Extremadura was carried out in the fields of the research center Finca "La Orden-Valdesequera" in Badajoz (Spain) and in the case of Navarra conventional management was applied in the research fields of INTIA in Cadreita (Navarra, Spain). In the case of Navarra, conventional IPM was carried out in the research fields of INTIA, in Cadreita (Spain), whereas the organic farming was located in a field provided by the local organic farming business GUMENDI, in Lodosa (Spain). The edaphoclimatic conditions of the fields in Cadreita and Lodosa were as similar as possible in the area. In both sites, we have tried to use fields with the maximum similarity in soil characteristics (Supplementary Table 1) and as close geographic proximity as possible.

Plants were planted with four true leaves and good sanitary conditions. In Navarra the crop was planted on May 10th in 2012 and May 23rd in 2013, under polyethylene plastic mulching of 15 μm, a plant density of 35,714 plants ha^{-1} in the conventional system. For the organic farming system, the plants were planted on May 4th in 2012 and May 17th in 2013, with a biodegradable plastic Mater-Bi® of 15 μm and the same plant density. In Extremadura planting dates were April 24th in 2012 and May 2nd in 2013, with a plant density of 33,333 plants ha^{-1} with bare soil. For each cultivation system, a randomized complete block design with 3 blocks per condition was used, with 25 plants per block and condition.

Standard conventional IPM growing and organic farming practices were followed in each cultivation site. In both sites, drip irrigation was used. Hydric requirements were calculated as a function of crop evapotranspiration following FAO56 methodology (Allen et al., 1998).

A single harvest was made for each variety and cultivation system, considering commercial practices. The field was sampled sequentially until 85% of the fruits reached the red-ripe fruit stage in a sample, upon which the decision to harvest was made. Then, the harvest decision was taken. In Extremadura all the varieties were harvested on August 21st in the conventional system and on August 6th and 10th in the case of organic farming. In 2013 the plants were harvested on August 20th (conventional) and August 23rd (organic). In Navarra, for both systems, plants were harvested between August 21st and 29th and, in 2013, between September 16th and 26th (conventional) and on September 18th (organic).

Climate conditions were recorded using a HMP45C temperature and relative humidity probe (Vaisala, Helsinki, Finland) in Navarra and Extremadura, and a CMP3 pyranometer (Kipp&Zonen, Delft, the Netherlands) in Extremadura and a 110/S pyranometer (Skye, Powys, United Kingdom) in Navarra.

2.2. Analysis of organoleptic and functional quality

Two representative red-ripe fruits were collected from each of the 25 plants of the replicates. Fruits were pooled and homogenized obtaining a single sample, thus obtaining a biological mean of the replicate that was kept at −80 °C until analysis.

On each homogenate the following basic quality parameters were determined: pH, TSS estimated by refractometry of the juice (average of two determinations) using a digital refractometer (ATAGO PR-1, Tokyo, Japan) with 0.1° Brix precision (results expressed as °Brix at 20 °C) and Hunter a and b parameters (results expressed as Hunter a/b rate) using a digital colorimeter (CR 300, Minolta, Japan).

The contents of the carotenoids beta-carotene and lycopene were determined using reversed phase HPLC. A 1200 Series HPLC system (Agilent Technologies, Waldbronn, Germany), equipped with a quaternary pump, a degasser, a thermostatic autosampler and a diode array detector (DAD), was used to separate the analytes. The method followed was developed by García-Plazaola and Becerril (1999) with small modifications (Cortés-Olmos et al., 2014).

Samples were thawed in the dark at 4 °C and 100 mg of the homogenate were extracted with 14 ml of a 8:6 v/v, ethanol/hexane solution at 4 °C, during 24 h at 200 rpm using an horizontal shaker (Platform Rocker STR6, Viví, Stuart). Hexane was complemented with 0.05% butylated hydroxytoluene (BHT). Hexane supernatant