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Agronomic characteristics and carotenoid content of five Bola-type paprika red pepper (*Capsicum annuum* L.) cultivars

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Abstract

The production of sweet paprika in Spain uses exclusively fruit of Bola-type *Capsicum annuum* L. This work describes the evaluation of the agronomic behaviour of five new cultivars of the Bola-type paprika red pepper, selected in the Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA), and grown in Extremadura for 3 years. The colour and the pigment content of the paprika elaborated following the traditional procedure of La Vera were also studied.

The cultivars studied are very similar in morphology of the plants, and precocity of the crop, also presenting few differences in their yield of fresh and dry red fruit. The cultivars RR-1 and RR-2 had the best yields in dry red fruit, weight of fruit, ripening synchronicity, and resistance of the fruit against rotting. With respect to the parameters of the paprika's quality, the cultivars RR-5, RR-4 and RR-3 stood out in ASTA colour and pigment content. RR-1 and RR-2 are recommended according to the pepper yield, however RR-5, RR-4 and RR-3 cultivars are the best in colour. The recommended cultivars to the growers will depend on the payment criteria of the industry, yield or colour.

Keywords: *Capsicum annuum*; Red pepper; Paprika; Agronomic traits; ASTA; Carotenoids

1. Introduction

Paprika is the spice that is obtained from drying and grinding the fruit of red pepper, which have an intense red colour and a fairly thin pericarp. Its use as a spice is fundamentally because of the colour that it confers to the food due to its high carotenoid content (Govindarajan, 1986; Revilla and Quintana, 2005). Spain is one of the main European countries producing paprika red pepper. The production is principally in Extremadura, in particular, the district of La Vera accounts for 47% of the country's output, with a total of 3105 t distributed over 1350 ha (MAPA, 2005). By far, most of the production is under the Protected Denomination of Origin "Pimentón de La Vera", which has great prestige as a spice of high quality. It is worth noting that the product is both grown and processed in the region, with the resulting increased value added of the product.

For the production of the "agridulce" (bittersweet) type of paprika, Extremadura's paprika sector uses the Jaranda and Jariza cultivars, of high agronomic and industrial quality (Rodríguez et al., 1993). For the production of sweet paprika, however, it uses the Bola-type populational variety. This is a highly variable material on which very little work of selection has been carried out. This thus represents a problem for the sector in this region. Improved cultivars are needed, adapted to the zone's particular soil and climate conditions and with high levels of yield and colour.

The intense red colour of the ripe peppers and their processed products is due to the presence of carotenoid pigments. All the carotenoid pigments present in the pepper are C_{40} isoprenoids containing nine conjugated double bonds in the

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central polyenic chain, although with different end groups, which change the chromophore properties of each pigment, allowing them to be classified into two isochromic families: red and yellow. The red fraction contains the pigments exclusive to the *Capsicum* genus (capsanthin, capsanthin 5,6-epoxide, and capsorubin), and the yellow fraction comprises the rest of the pigments (zeaxanthin, violaxanthin, antheraxanthin, β-cryptoxanthin, β-carotene, and cucurbitaxanthin A).

The ASTA (AOAC International, 2002) method is the most widely used to measure the commercial quality of paprika. This quantifies the total carotenoid content indirectly, and has been used as a parameter of quality in selection, breeding, and cultivar characterization work (Costa et al., 2001; Kim et al., 2002). It has also been used to analyze the influence of the cultivation conditions on the colour-systems of protection of the crop (Gómez-Ladrón et al., 1998), planting density (Cavero et al., 2001), and TSWV virus attack (Lacasa et al., 1996) and to study the evolution of the colour during the fruit ripening (Hornero-Méndez et al., 2002) and during the storage of the paprika under diverse conditions (Ramesh et al., 2001; Pérez-Galvez et al., 2004). The carotenoid pigments are quantified and separated by high-performance liquid chromatography (HPLC) applied both to the fresh pepper and to the dry product and oleoresins (Hornero-Méndez et al., 2002; Pérez-Galvez et al., 2004).

The aim of this work was to evaluate the agronomic characteristics of five cultivars of Bola-type paprika red pepper, and the colour and carotenoid pigment content of the corresponding paprika.

2. Materials and methods

A 3-year trial of paprika red pepper cultivars was conducted on the Research Farm ''La Orden'', belonging to the Junta (Regional Government) of Extremadura. Five of them were Bola-type (RR-1, RR-2, RR-3, RR-4, and RR-5) from the selection work of the Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA) in Murcia. The soil used for cultivation was alluvial of a sandy-loam texture, slightly acidic, and with a low organic matter content. The experimental design was in random blocks with four replicates. Each elementary plot was 12 m^2 in area with a total of 60 plants (density 5 plants m^{-2}).

Transplanting was done on June 15 in year 1, May 24 in year 2, and June 13 in year 3. Cultivation was with drip irrigation, applying top dressing fertilizer with the irrigation, the remaining cultivation techniques being those usual in the zone.

To check that the phenology of these cultivars was suited to the conditions of Extremadura, data were recorded on the precocity of each cultivar (the date when all the plants had at least one red fruit), and their morphological characteristics – height and uniformity (plant size and shape) – in order to characterize their growth habit.

The harvesting dates were: November 7 (for the cultivars RR-3, RR-4, and RR-5) and November 15 (for RR-1 and RR-2) in year 1, October 16 in year 2, and October 22 in year 3. Harvesting in years 1 and 3 was begun when the lower-node fruit had begun dehydrating and had a wrinkled aspect. In year 2 this date had to be delayed, because there were problems with the availability of drying barns.

The red, green, and rotting fruit were harvested separately, and the yield and synchronization of ripening were recorded, the latter expressed as percentage of fresh red fruit at harvest. For the initial laboratory determinations, a sample of 50 red fruit was taken from each elementary plot, and the length and width were measured on 10 of them. Then the entire sample was weighed fresh, dried at 55 °C in a forced air-flow oven, model Selecta 2005141 (JP Select SA, Barcelona, Spain), and the mean weight of the dry fruit and the percentage of dry matter determined. The yield of dry red fruit was calculated from the yield of fresh red fruit and the percentage of dry matter.

For each cultivar, the red peppers harvested from the four elementary plots were dried together in the La Vera zone, in a traditional vertical air-flow drying barn, in which the peppers are dried by the action of the heat and smoke resulting from the combustion of holm-oak or deciduous oak firewood, which confers the paprika a characteristic smoked flavour and a great colour stability.

Samples of 2 kg dried red pepper were taken from each cultivar. For 300 g of each sample, the pericarp was separated manually from the seeds and the peduncle. The pericarp was ground separately in a Grindomix GM-100 mill (Retsch GmbH & Co. KG, Haan, Germany) at 5000 rpm. For the rest of each sample, only the peduncles were removed, and seeds and pericarp were ground together, followed by sieving at 0.5 mm in order to obtain the paprika.

For both the pericarp and the paprika, the ASTA colour was determined following the official AOAC method (AOAC International, 2002). The absorbance at 460 nm of an acetone paprika extract was measured in a Shimadzu UV-2401 PC UV–vis spectrophotometer (Shimadzu Scientific Instruments, Inc., Columbia, MD, USA). The carotenoid composition was determined by HPLC (Mínguez-Mosquera and Hornero-Méndez, 1993), paprika is extracted with acetone, saponified overnight, and the obtained extract is injected in an HP 1100 chromatograph (Agilent Technologies Inc., Palo Alto, CA, USA), equipped with an RP-18 Lichrosorb column of 10 μm, 200 mm × 4.6 mm, and a diode-array detector (460 nm). The initial mobile phase was acetone:water (75:25) for 5 min, raised to (95:5) over 10 min. The pigments were quantified by the external standard technique, determining capsorubin, capsanthin, zeaxanthin, β-cryptoxanthin, and β-carotene.

The data were analyzed statistically by analysis of variance and Tukey's multiple range test for comparison of means and least significant differences (LSD) ($p < 0.05$), using the SPSS 10.0 program (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

The precocity of the cultivars was sufficient to ensure ripening of the fruit under the climatic conditions in which the work was carried out. In the 3 years, the earliest were RR-5 and RR-3, followed closely by RR-4, and last RR-1 and RR-2 which were found to be 8–10 days later than the first (data not shown).