Effect of deficit irrigation on the sugar and acid profile of processing varieties of tomato

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Abstract
Water deficit on tomato taste-related components was studied in standard and high lycopene cultivars. The treatment was applied once the fruits were set to avoid drastic effects on yield. Despite applying considerable reductions in water doses down to 50%ETc, the contents of fructose, malic and citric acid remained unaffected. Only glucose concentration increased with lower irrigation doses in one of the locations used for the study. The variety effect has a major impact in taste-related components, which might be shaded by location effects. Deficit irrigation during the last part of the growing cycle may contribute to a better water management while offering little or positive effects on the taste profile of processing tomato varieties.

INTRODUCTION

There is a growing concern regarding the impact of agriculture on the environment. Among other measures it has been suggested the necessity to promote a better management of water use in agriculture. In fact, insufficient water supply for irrigation will imply a shift from maximizing production per unit area towards production per water unit (Fereres and Soriano, 2007). Controlled water deficit irrigation would not only reduce the use of this resource but it may also result in an increase organoleptic quality of the fruit (Mitchell et al., 1991). This is precisely the purpose of this work: to evaluate the sugar and acid profile of raw tomatoes grown under controlled deficit irrigation, as these compounds and the ratios between them have been related with consumer preference in sensory evaluations.

MATERIALS AND METHODS

Plant material and experimental design

Four varieties of processing tomato (H9997, H9661, ISI24424 and H9036) were used. The cv. ISI24424 and H9997 were selected for their high and intermediate to high lycopene content (Lahoz et al., 2013). The cv. H9036 and H9661 were selected considering their high yield in the production areas considered for the assay (Macua et al., 2002). Plants were

irrigated considering evapotranspiration under standard conditions (100%ETc) until all the plants had completed fruit set. Then three irrigation strategies were applied; 100% ETc (control), 75% ETc and 50% ETc.
The assays were performed during the 2012 campaign in two sites representing the main growing conditions for processing tomato in Spain: Extremadura (Centro de Investigación Finca "La Orden-Valdesequera" in Badajoz) and Navarra (Finca Experimental of INTIA in Cadreita).
A complete random block experimental design with three replicates in each condition was followed. Two representative fruits were collected from 25 plants in the replicate. Fruits were pooled and homogenized obtaining a single sample, thus offering a biological mean of the replicate.

Analysis
The sugar and acid profile of the samples was obtained quantifying contents of malic, citric and glutamic acids and the sugars fructose, glucose and sucrose (though only traces were found). The method described by Cebolla-Cornejo et al. (2012) based on capillary electrophoresis was followed. The variables sucrose equivalents (SEq), and the ratios SEq to citric acid and SEq to malic acid (Cebolla-Cornejo et al., 2011) were also calculated, considering their relation with the sensory perception by the consumer.

Statistics
The effects of location, variety and cultivation system as well as their interactions were studied with ANOVA analysis. For a more comprehensive analysis, the variety and cultivation effect on each location was also studied using MANOVA biplots. With this graphical methodology, the similarity between groups can be measured as function of its distance on the graph and the angle between variables can be interpreted as an approximation of its correlation. Bonferroni confidence circles are added to the group markers in such a way that the projections of the circles onto the direction representing a variable approximate a confidence interval. Checking the overlapping of two projections allows the identification of the significance of the difference between groups over a particular variable. This analysis was performed using the free-licensed software MultBiplot from Salamanca University Prof. Vicente-Villardon (2014).

RESULTS AND DISCUSSION

The factors location and variety had significant effects on the accumulation of citric, malic and glutamic acids, while the irrigation dose did not affect significantly their concentration (Table 1). Higher levels of citric and glutamic acids were found in Navarra while a higher concentration of malic acid was obtained in Extremadura. Malic acid has a low impact on titratable acidity compared to citric acid, while it is sourer than citric (Debruyn et al., 1971) and its effect on pH is more relevant (Fulton et al., 2002). In the case of glutamic acid, lower levels would be preferred considering that the sugar to glutamic acid ratios are positively correlated with consumer preference (Bucheli et al., 1999).
The acid profile was different among the varieties evaluated. ISI24424 tended to show higher levels of malic acid, while H9036 and H9661 tended to show higher amounts of citric acid and H9997 high levels of both compounds (Fig. 1). Varieties H9036 and H9661 also tended to show higher levels of glutamic acid. The location effect tended to slightly

modify these trends. For example, variety H9997 showed higher accumulation of citric acid in Navarra and higher accumulation of malic acid in Extremadura.

Only the factor variety significantly affected glucose accumulation, though a strong variety x irrigation dose interaction was detected (Table 1). Higher amounts were detected in the variety H9036. Considering the interaction mentioned, the statistical analysis was repeated separately for each location. In this case higher glucose contents (p=0.007) were found with lower irrigation doses in Navarra (Fig. 2), while no significant differences were found in Extremadura (p=0.619). Patanè and Cosentino (2010) also observed that the effects of soil water deficit vary between sites, demonstrating that soil and climatic characteristics would strongly influence the quality traits of the crop.

In the case of fructose, the factors location and variety and their interaction were significant. Higher fructose contents were identified in Navarra and in the varieties H9036, ISI24424 and H9997. The profile determined by sucrose equivalents and the ratios sucrose equivalents to citric and glutamic acids was strongly influenced by the variety factor. The sucrose equivalents are usually better correlated with sensory perception of sweetness and the sugar to acid ratios have also been correlated with consumer acceptance (Baldwin et al., 1998; Bucheli et al., 1999; Fulton et al., 2002). In this case, the variety ISI24424 stood out with higher values of these ratios and the variety H9036 with higher sucrose equivalents (Fig. 1).

Our results suggest that a considerable water deficit treatment once the fruits are set has a limited impact on fruit quality, with small increases in fructose in certain locations. Veit-Köhler et al., (1999) found that small reductions in water supply increased the levels of hexoses and titratable acids. On the other hand, Kirda et al., observed no significant effects on titratable acidity of water deficit, applied via partial root drying or conventional deficit irrigation up to 50% reduction in irrigation doses. Mitchell et al. (1991) found increased citric acid contents under water deficit, but only in certain years, while malic acid content remained unaffected. In their review of water stress on the acid content of fleshy fruits, Etienne et al. (2013) suggested that water stress would tend to increase organic acid content though dilution/dehydration effects or by osmotic adjustment (increasing contents to lower osmotic potential and preventing a decrease in cell turgor pressure). Sugars, also tend to increase during water deficit, with the greatest positive impact obtained in water deficits applied near the ripening stage (Ripoll et al., 2014). The impact on the sugar to acid ratio is difficult to predict, though Bertin et al., 2000 described an increase in the ratio under high air-vapour pressure deficit.

CONCLUSIONS

The variety factor has a prominent influence on the profile of taste related compounds and variables, that can be modified or shaded by a location effect. In this context, a considerable reduction in the irrigation dose once the fruits are set enables a more efficient water management while it has no significant effect on the accumulation of the sugars and acids, nor in derived variables. Nevertheless, in some environmental conditions it may result in increased glucose content. It seems then, that standard irrigation doses in the whole growing cycle may be excessive. Thus, deficit irrigation during the last part of the cycle may contribute to a more efficient water use while offering little or positive effects on the profile of taste-related compounds. Previous results have also confirmed that this irrigation strategy has a limited impact on yield for most varieties.

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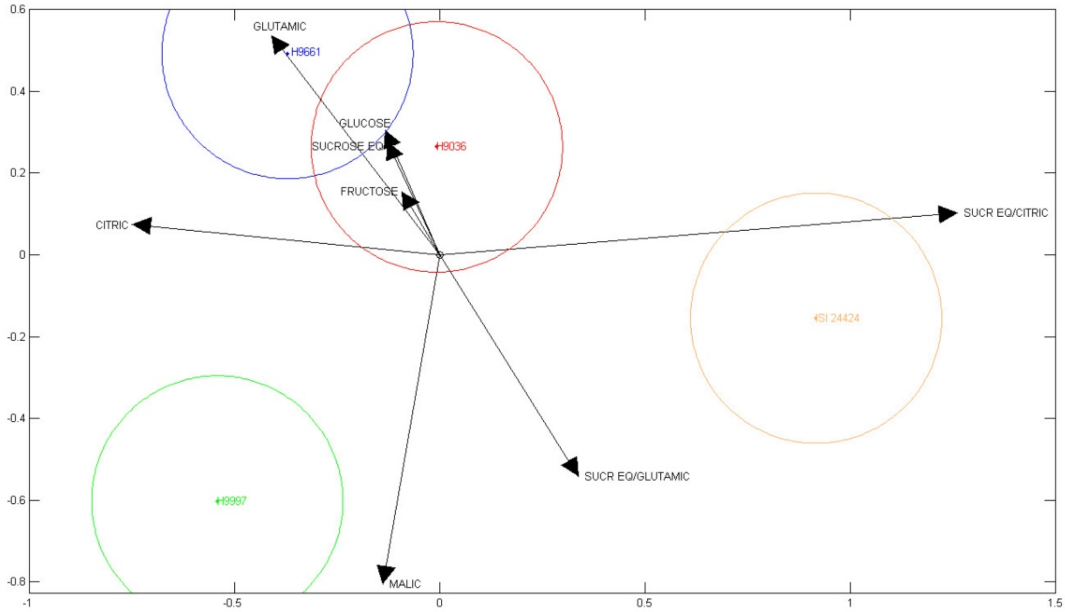
Tables

Table 1. Influence of the factors analysed on taste-related variables (ANOVA p-values).

Factor	Malic acid	Glutamic acid (GLUT)	Citric acid (CIT)	Fructose	Glucose	Sucrose equivalents (SEQ)	SEQ/CIT	SEQ/GLUT
Location (L)	0.018	$<10^{-4}$	$<10^{-4}$	0.021	0.192	0.09	$<10^{-4}$	$<10^{-4}$
Variety (V)	0.001	$<10^{-4}$	$<10^{-4}$	0.011	0.012	0.012	$<10^{-4}$	$<10^{-4}$
Irrigation (I)	0.485	0.516	0.325	0.512	0.136	0.344	0.257	0.157
L x V	0.033	0.007	0.932	0.017	0.284	0.126	0.018	0.588
L x I	0.647	0.289	0.297	0.848	0.022	0.174	0.593	0.053
V x I	0.914	0.355	0.679	0.429	0.276	0.314	0.734	0.974
L x V x I	0.326	0.664	0.426	0.195	0.583	0.466	0.307	0.510

Figures

a



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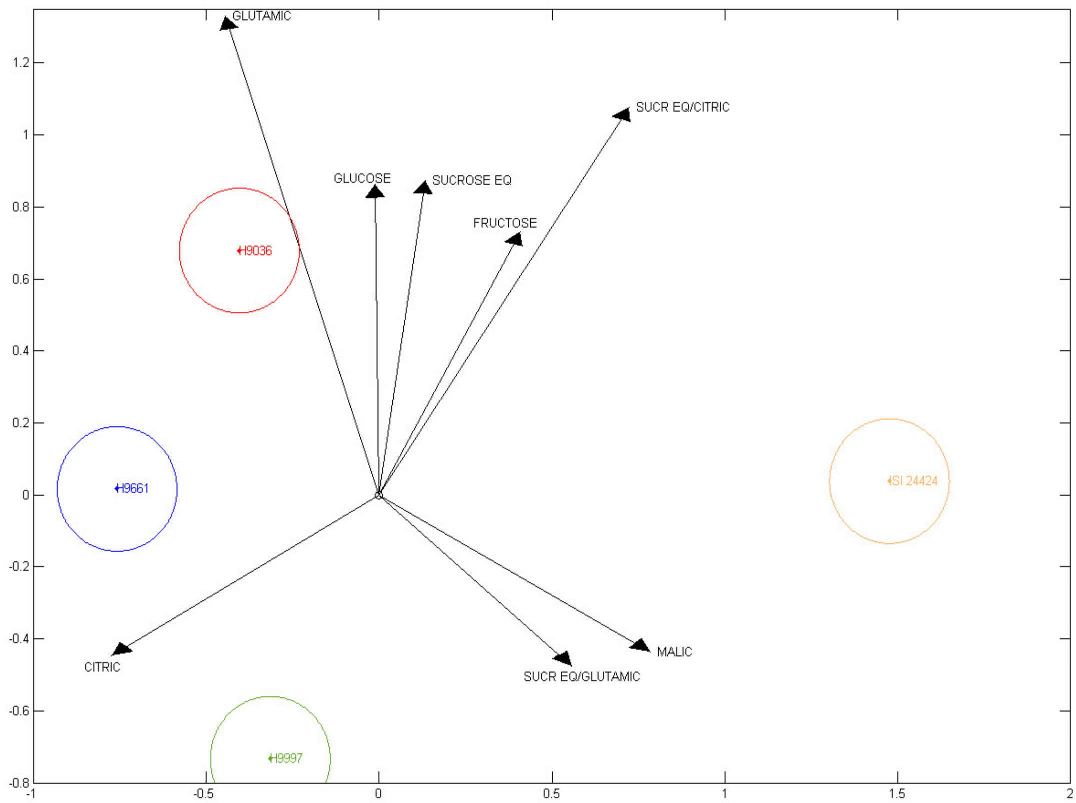

Fig. 1. MANOVA biplot analysis of the variety effect on taste-related variables in Extremadura (a) and Navarra (b)

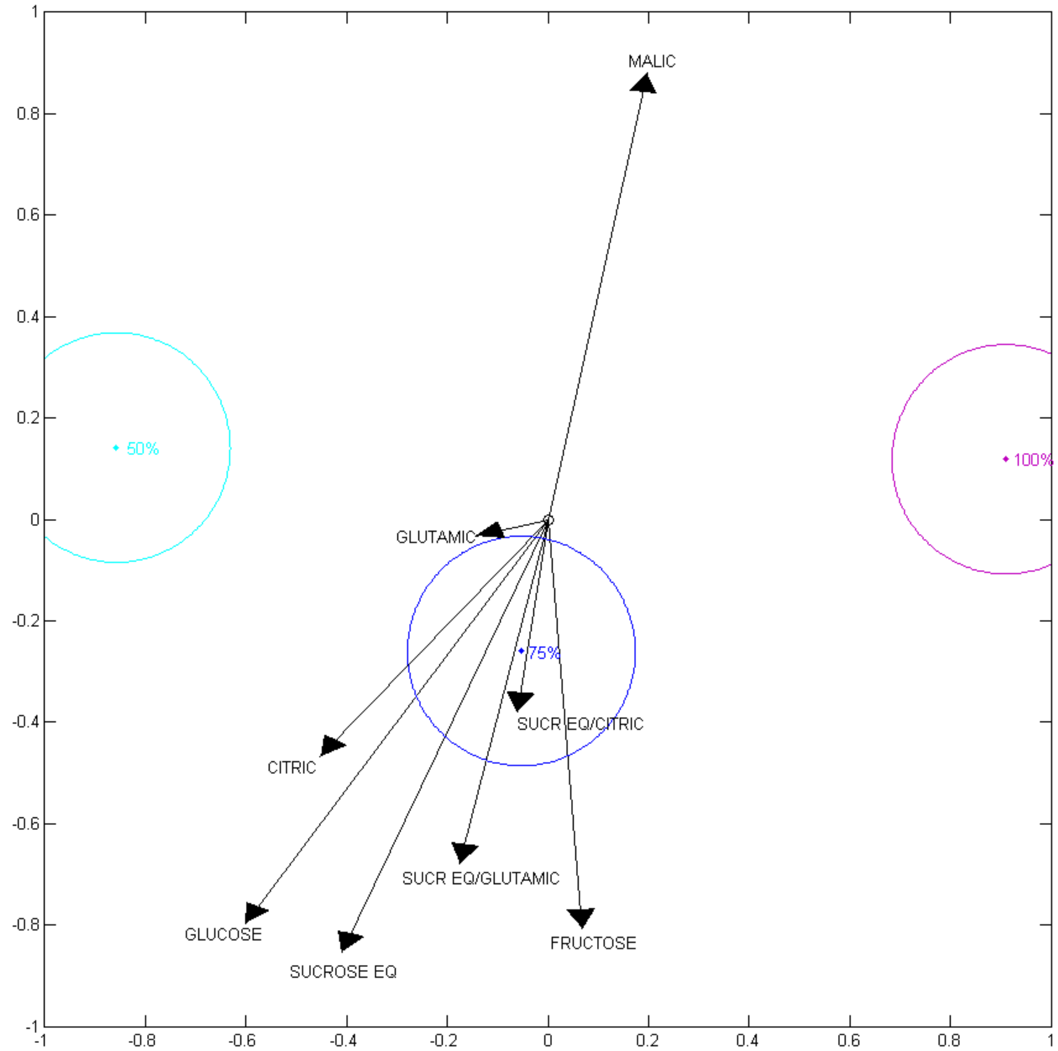

Fig. 2. MANOVA biplot analysis of the irrigation effect on taste-related variables in Navarra.