Food Research International 50 (2013) 409–419

Contents lists available at SciVerse ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Investigating physicochemical, volatile and sensory parameters playing a positive or a negative role on tomato liking

Paola Piombino [a], Fiorella Sinesio [b], Elisabetta Moneta [b], Maria Cammareri [c], Alessandro Genovese [a], Maria Tiziana Lisanti [a], Maria Rita Mogno [d], Marina Peparaio [b], Pasquale Termolino [c], Luigi Moio [a], Silvana Grandillo [c,*]

[a] Department of Food Science, University of Naples Federico II, P.co Gussone, 80055 Portici, Napoli, Italy
[b] National Research Institute for Food and Nutrition (INRAN), Via Ardeatina 546, 00178 Roma, Italy
[c] Italian National Research Council, Institute of Plant Genetics (CNR-IGV), Research Division Portici, Via Università 133, 80055 Portici, Napoli, Italy
[d] Monsanto Agricoltura Italia SPA, Strada Canneto Di Rodi, 1034, Latina, Italy

ARTICLE INFO

Article history:
Received 4 August 2012
Accepted 23 October 2012

Keywords:
Consumer overall liking
Physicochemical parameters
Tomato
Sensory evaluation
Volatiles

ABSTRACT

This study aimed at providing further insights into the positive and negative drivers of tomato liking. For this purpose, 13 tomato cultivars representing different typologies were characterized for physicochemical parameters and aroma volatiles, and were assessed by a trained panel for sensory descriptors, and by Italian consumers for liking. The relationships among the different parameters and their effects on consumer liking were studied by Partial Least Squares (PLS) analysis. Among physicochemical traits and sensory descriptors, seeds, reducing sugars, firmness, thick epicarp, soluble solids, sour taste, total acidity, citrate, herbaceous aroma and brightness were found to be drivers of liking, whereas pulp thickness, humidity, fruit weight, diacetyl-like odor and mealiness showed an opposite influence. For the aroma volatiles, 2-isobutylthiazole played a key role on liking and its positive contribution seemed to be supported by (Z)-3-hexen-1-ol, but suppressed by 6-methyl-5-hepten-2-ol, especially when tomatoes had a poor volatile fraction. These results represent a contribution to the knowledge that could lead to more effective breeding strategies aimed at improving tomato sensory quality.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetables in the world, and its popularity among consumers has made this crop an important source of essential nutrients, including different antioxidant molecules (e.g. vitamin C and carotenoids) with recognized positive effects on human health (Shidfar et al., 2011). However, over the past decades consumers have started to complain about a decrease in flavor quality of modern tomato varieties. This can be considered in part as an indirect consequence of breeding programs that have traditionally focused on yield, fruit size and shelf-life traits, but it is also a consequence of commercial harvesting and post-harvest handling procedures (Krumbein, Peters, & Bruckner, 2004). In order to satisfy consumers' expectations, tomato breeders are now pursuing sensory quality as one of their major objectives. Nevertheless, the polygenic nature of most of the sensory traits (Zanor et al., 2009), the chemical complexity of liking, and the lack of efficient objective flavor selection criteria make the improvement of sensory quality still a challenging task.

Tomato fruit quality for fresh consumption depends on numerous traits relating to visual appearance, flavor and texture. While the initial consumer's choice is mainly driven by visual appearance, eating quality becomes the major influencing factor in subsequent purchases. Flavor of tomato fruits is chemically determined by a complex mixture of primary and secondary metabolites mainly including sugars, acids, minerals and volatile compounds that are measured by the taste and olfactory systems (Baldwin, Scott, Shewmakert, & Schuch, 2000). Although these chemicals are largely known, the way they integrate to produce the specific tomato flavor is not yet understood.

Several methodologies for sensory characterization have been developed (Varela & Ares, 2012). Among these techniques the classical descriptive analysis is the most powerful tool as it provides a complete description of the sensory characteristics of products, i.e. it detects differences in intensity of specific sensory attributes. Descriptive sensory analysis by trained panels, coupled with consumer tests, represents an

Abbreviations: HPLC, high-performance liquid chromatography; HPLC–UV, high-performance liquid chromatography–ultraviolet detection; GC/MS, Gas chromatography–mass spectrometry; LLME, Liquid–Liquid Micro Extraction; NaOH, Sodium hydroxide; $(NH_4)_2SO_4$, Ammonium sulfate; CH_2Cl_2, dichloromethane; S, sulfur compounds; K, ketones; OH, alcohols; F, furans; Ald, aldehydes; Ac, acids; E, esters; Ph, phenols; CIEL*a*b*, color space; L*, lightness; CLT, Central Location Test; ANOVA, analysis of variance; SD, standard deviation; Duncan's MRT, Duncan's Multiple Range Test; PLS, Partial Least Squares; PCs, principal components; VIP, variable importance for the projection.

* Corresponding author. Tel.: +39 081 2539489, +39 081 2539026; fax: +39 081 7753579.
E-mail address: grandill@unina.it (S. Grandillo).

0963-9969/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodres.2012.10.033

efficient approach to describe the properties underlying tomato fruit quality for fresh consumption. However, such sensory assessment is expensive and time-consuming, and therefore there is the need to identify clear instrumental targets that could be more easily used by breeders for selection and manipulation of tomato flavor.

Several studies have attempted to establish the relationships between sensory descriptors and instrumental measurements in order to understand the contribution of individual components to tomato flavor (Carli et al., 2009; Causse, Buret, Robini, & Verschave, 2003; Zanor et al., 2009). It is generally accepted that a sufficient amount of soluble solids, mostly reducing sugars (glucose and fructose) and organic acids (citrate, malate and glutamate) in an appropriate balance of sweet and sour is a necessary, although not sufficient, condition for good flavor (Malundo, Shewfelt, & Scott, 1995; Tandon, Baldwin, Scott, & Shewfelt, 2003).

Flavor complexity is, however, determined by the olfactory system as volatiles clearly determine odor (orto-nasal) and aroma (retro-nasal) perception in tomatoes (Baldwin et al., 2000). The impact of a chemical on olfactory perception is determined by both its concentration and odor threshold in that matrix (odor units). Although over 400 aroma volatiles have been identified in tomato and tomato products (Petro-Turza, 1987), several studies have shown that only 16 aroma volatiles are present in sufficient quantities to be detected by the olfactory system, and hence are generally accepted to contribute to tomato flavor (Baldwin et al., 2000). However, minor volatiles with negative log-odor units should not be neglected as they may still contribute to the overall flavor as backgrounds notes (Baldwin et al., 2000). In addition, interactions among volatiles and also those involving the taste and olfactory systems, further complicate flavor, as specific aroma volatiles perceived by the retro-nasal olfactory system can affect the perception of sweetness or sourness and vice versa (Baldwin, Goodner, & Plotto, 2008; Tieman et al., 2012). These results underline the limitations of traditional flavor research based exclusively on odor units of individual volatiles; these models, in fact, cannot explain all the synergistic and antagonistic interactions that take place in complex foods such as tomato (Tieman et al., 2012).

A better knowledge of all the factors influencing tomato consumer's preferences is required in order to be able to improve fruit quality and to diversify this product. Preference mapping studies conducted at the European level have shown that consumer segments exist which differ in their liking of tomato varieties, and that diversification of flavor and texture is required to satisfy all consumers' expectations (Causse et al., 2010; Sinesio et al., 2010). In addition, Berna, Lammertyn, Buysens, Di Natale, and Nicolai (2005) reported that Flemish consumer segments, identified on the basis of preference differences, were highly correlated to specific aroma volatiles. Recent research conducted with a large number of heirloom varieties, using consumers in United States, confirmed that there is no “best”-tasting tomato, as preferences could be separated by age, sex, body mass and genetics; although the collected data should allow defining the parameters for a consensus best tomato in the United States (Tieman et al., 2012).

The aim of the present study was to gain further knowledge regarding key drivers of tomato liking and disliking, through the determination of physicochemical, aroma volatile and descriptive sensory profiles of tomato cultivars representing different segments. The use of a two-step regression model allowed the identification of multiple sensory and compositional parameters that could become targets for breeding strategies aimed at improving not only yield, adaptation and shelf-life traits but also sensory quality.

2. Materials and methods

2.1. Plant material

Thirteen cultivars belonging to different tomato segments were grown during Spring 2009 at Monsanto Research and Development Centre, Latina (Table 1). The local variety Principe Borghese (P.BO), famous for sun drying, was included in the experiment for its expected rich volatile profile (Lisanti, Piombino, Genovese, Pessina, & Moio, 2008). A total of 120 plants for each cultivar were grown in greenhouse, heated at minimum temperature of 8 °C with black mulching, using integrated pest management and bumble bees pollination.

Fruits were harvested over three consecutive weeks from different trusses: 2nd truss on May 18 (week 21), 3rd truss on May 25 (week 22) and 4th truss on June 3 (week 23). The harvest of May 18 was used for sensory pre-sessions (panelist agreement on descriptors and scale). The samples collected in weeks 22 and 23 were used for sensory profiling, hedonic tests and analytical measurements. Sampling was done selecting fruits at the red-ripe stage of maturity, without any visual defects or disease symptoms. Samples were harvested at the same stage of maturity with the aim of being able to analyze the relationships among physical, compositional and sensory variables. For each cultivar, fruits were pooled and then they were randomly separated into four groups and delivered to each test location within the harvesting day, at a temperature of 12 °C. For physicochemical analyses, as well as for descriptive and hedonic evaluations, after delivery, the fruits were stored in a cold room at 12 °C and were taken out to acclimatize to room temperature (22 ± 2 °C, for 12 h) prior to evaluations (which took place within 36 h from harvesting). For tomato volatile analysis, immediately after delivery, the fruits were stored at −20 °C. For the analyses, batches of fruits homogeneous for size and color were selected for each cultivar.

2.2. Physicochemical measurements

For each cultivar and for each harvest replicate (May 25 and June 3) two samples of at least 6 fruits each were measured. The

Table 1
Descriptive list of tomato cultivars used in the present study.

Cultivar	Type	Fruit shape	Average fruit weight (g)	Company
Albenga (ALB)	Cuore di Bue (local variety)	Typical ribbed hearth-shape	227	–
Carlota (CAR)	Cluster	Round	90	Monsanto
Climberly (CLI)	Cluster	Round	143	S&G-Syngenta
Delizia (DEL)	Marmande	Ribbed flat-round	259	Clause
Globo (GLO)	Cluster	Round	82	Enza Zaden
Licorossa (LIC)	Large cocktail	Round	103	Monsanto
Maribel (MARI)	Cluster	Round	99	Enza Zaden
Marmandino One (MARM)	Marmande	Ribbed flat-round	231	Hild Samen
Murano-San Marzano2 (MUR)	San Marzano (local variety)	Elongated-typical San Marzano shape	89	La Semiorto Sementi
Panarea (PAN)	Cherry Truss	Round	21	Monsanto
Principe Borghese (P.BO)	Cocktail (local variety)	Cocktail high-round nippled	35	La Semiorto Sementi
Red Delight (RED)	Cocktail	Round	51	Sakata Seeds
TyTy (TYT)	Cherry Truss	Round	28	S&G-Syngenta