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Do Organic Cherry Vine Tomatoes Taste Better than Conventional Cherry Vine Tomatoes? A Sensory and Instrumental Comparative Study from Ireland

Shortened Title: Tomato Taste

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ABSTRACT

A consumer panel was able to distinguish a perceptible difference between organically farmed and conventionally produced tomatoes, and preferred the taste of the conventional tomatoes. The sensory evaluation results of the trained panel revealed that the conventional tomatoes were sweeter and less sour than the organic tomatoes. In addition to this, the conventional tomatoes showed significant differences for ^{o}Brix, reducing sugars and electrical conductivity. No significant differences were observed between the organic and conventional tomato samples for color, size, firmness, pH and dry matter values.

KEYWORDS *Tomato; Organic; Conventional; Sensory; Physicochemical*

INTRODUCTION

Organically farmed foods have seen a significant rise in popularity worldwide over the past decade, with the global market for organic food estimated at $42/€33 billion in 2007 (Sahota, 2009). In Ireland, organic food sales reached almost $127/€100 million in 2010 (Department of Agriculture, Fisheries and Food, 2011a). This increased preference for organically farmed food is attributable to the perception that it is healthier, tastier, safer and more environmentally friendly than conventionally produced food (Bourne and Prescott, 2002; Magkos, Arvaniti and Zampelas, 2006; Winter and Davis, 2006).

In Ireland, organic fruit and vegetables comprise the largest segment of the organic food market (Bord Bia, 2008). The tomato (*Lycopersicon esculentum*) is the most important protected vegetable crop in Ireland in terms of production (Glas Ireland, 2011) and the trend in this segment is diversification into profitable niches such as vine tomatoes (Department of Agriculture, Fisheries and Food, 2009).

Tomato fruit quality is often evaluated objectively, by means of physical and chemical analyses, and/or subjectively via sensory analysis. Color, firmness and flavor are the principle sensory parameters which affect the consumer's perception of tomato fruit quality (Thybo, Bechmann and Brandt, 2005).

Color is a particularly important sensory characteristic for tomatoes, since color is the first parameter which is assessed by the consumer (López Camelo and Gómez, 2004). Texture is another crucial sensory marker which plays a major part in a consumer's decision to purchase one tomato over another. The degree of tomato fruit firmness is often used as an indicator of tomato fruit quality (De Ketelaere, Howarth, Crezee, Lammertyn, Viaene, Bulens and De Baerdemaeker, 2006).Tomato taste is critical to the consumer and its characteristic flavor is attributed to the dry matter content of a tomato (Malundo, Shewfelt and Scott, 1995). The dry matter content of the tomato is composed mainly of sugars and acids, but it is also made up of free amino acids, minerals, pigments and vitamins (Petró-Turza, 1987). The sugars are primarily the reducing sugars, fructose and glucose, while the main acids found in the tomato are citric acid and malic acid (Davies and Hobson, 1981). Sweetness is often correlated with soluble solids, whereas sourness is generally correlated with pH (Auerswald, Schwarz, Kornelson, Krumbien and

Brückner, 1999). Electrical conductivity (EC) also plays an important role in tomato fruit flavor (Dorais, Papadopoulous and Gosselin, 2001)

Although, there is widespread belief among consumers that organically farmed foods have superior sensory qualities when compared to conventionally produced foods, research studies have given conflicting results on whether they have superior sensory quality when compared to conventionally cultivated produce (Basker, 1992; Bourne and Prescott, 2002; Zhao, Chambers, Matta, Loughin and Carey, 2007).

The aims of this study were to determine if consumers could distinguish, by tasting, between organic and conventional Irish grown cherry vine tomatoes (*cv Amoroso*), and to identify if panelists have a preference for organically farmed or conventionally produced cherry vine tomatoes, as well as to compare the sensory and physicochemical properties of Irish grown organic cherry vine tomatoes, with those of conventional cherry vine tomatoes.

MATERIALS AND METHODS

Plant Material

Irish grown organic and conventional cherry vine tomatoes (*cv*. Amoroso) harvested at the red ripe stage were selected and tested using sensory and instrumental analyses.

Both the organically farmed and conventionally produced cherry vine tomatoes were collected from two sites in County Dublin, Ireland. The tomatoes were selected according to commercial specifications from nine harvest times over a period of three months.

The organic cherry vine tomatoes were grown in brown earth soils and were fed with a commercial organic liquid seaweed fertilizer. Greenfly and whitefly were controlled using parasitic wasps (*Encarsia formosa*).

The conventional cherry vine tomato plants were planted in Rockwool slabs (Grodan, Roermond, Holland). The nutrient solution supplied to the tomato crop contained $Ca(NO_3)_2$, KNO_3, $(NH_4)_2SO_4$, K_2SO_4, $(NH_2)_2CO$, $MgSO_4$, $(NH_4)(NO_3)$, Fe, Mg, Zn, Cu, Mo, B and Mn. The average EC value of the nutrient solution was 3 dSm^{-1} and the average pH of the nutrient solution was 5.5. Pests were controlled using parasitic wasps (*Encarsia formosa*) and predatory insects (*Macrolophus caliginosus*).

Sample Preparation

On arrival to the food processing laboratory the cherry vine tomatoes were washed in cold water, gently dried with paper towels and their size measurements were taken. Following this, the organic and conventional cherry vine tomatoes were stored in a refrigerator (Hotpoint, Iced Diamond, Peterborough, UK) at $39^oF/4^oC$ for 18 hours prior to sensory and instrumental testing.

Instrumental Analysis

Size Specifications

The longitudinal diameter (stem scar to blossom end) and cross-sectional diameter (transverse diameter) were measured on whole tomatoes using a calipers (5921, Measy 2000, Switzerland).

Color Analysis

The color of the tomato fruits was determined using a Color Quest XE colorimeter (Hunter Lab, Northants, UK). Before measuring, the colorimeter was calibrated using a white reference tile. The illuminant chosen was D_{65} and the observer used was 10^{o}. Measurements were made at three different places on the fruit surface (one at the blossom's end and two in the equatorial zone).

The CIELAB system as specified by the Commission Internationale de l'Eclairage (CIE) was used to determine the colour of the tomato samples. The L*(L*=0 indicates black, while L*=100 signifies white), a*(a positive a* value indicates red colour, while a negative a* value suggests a green colour), and b*(a positive b* signifies a yellow colour, whereas a negative b* value signifies a blue colour) values were documented. From these readings, the a*/b* value was determined.

Texture Measurement

Tomato fruit firmness was measured using an Instron Universal Testing Machine, model 4464 (Instron Limited, High Wycombe, UK). The tomatoes were punctured using a 7mm-diameter probe at a crosshead speed set at 200mm/min. A load cell of 500N was used. The tomatoes were sliced in half from the stem scar through to the blossom's end. Measurements were made at two different places on the fruit surface both in the equatorial region. The maximum puncture force (N) was recorded. The data was analyzed using Instron Series IX software (Version 8.25, Illinois, USA).

Determination of Dry Matter

The dry matter content of both the organic and conventional tomato samples was determined using a method as outlined by AOAC (1990).

pH Analysis

The pH was measured directly from the juice of the tomatoes using a calibrated pH meter (Orion pH meter Model 420A, USA).

^{o}Brix Measurement

The soluble solids content (^{o}Brix) was measured using a refractometer (VWR Handheld Refractometer, 0-50% Brix ATC, Germany).

Sugar Analysis

Glucose, fructose and sucrose were quantified using an enzymatic kit (K-SUFRG, Megazyme, Ireland).

Determination of Electrical Conductivity

The electrical conductivity of the organic and conventional tomato samples was determined using a method as outlined by Buret, Gormley and Roucoux (1983). Whole tomatoes were macerated for 1 minute using a blender (Morphy Richards Limited, Mexborough, UK). The samples for testing were prepared by diluting 10 ml vegetable puree with 90 ml distilled water. The electrical conductivity was measured using a conductivity meter (Jenway 4330 Conductivity Meter, Staffordshire, UK) and the results were expressed in microSiemans (µS).

Sensory Analysis

Consumer Panel

For the consumer study, the panel participated in two separate sensory tests, a triangle test and a paired preference test. The triangle test was chosen to determine whether or not a perceptible difference would exist between the organic and conventional cherry vine tomatoes. According to Lawless and Heymann (1998) this method is better at detecting small differences between samples than intensity rating tests. Preference testing was selected because it is quick and easy to use (Hein, Jaeger, Carr & Delahunty, 2008) and that it allows the selection of one product that is preferred over another.

The consumer panel (*n*=72) consisted of students and staff (39 female and 33 male) from the Dublin Institute of Technology, Ireland. Prior to sensory testing, the untrained subjects received verbal and written instruction regarding the testing procedure. Each sensory booth was equipped with an overhead light source, ballot papers and pens. The subjects worked in single booths under defined conditions of $68^{o}F/20^{o}C$. The subjects were unaware that they were sampling organic and conventional tomatoes. Water ($23^{o}C/73^{o}F$) was provided for the subjects to cleanse their palates in between samples.

The triangle test was conducted according to the guidelines set out in ISO 4120:2004 (ISO, 2004). The subjects were presented with three tomato samples and were advised that two of the samples were identical and one was different. 108 organic cherry vine tomato samples and 108 conventional cherry vine tomato samples were prepared to make 72 sample sets that were distributed at random among the subjects using 12 each of the combinations ABB, BAA, ABB, BBA, ABA and BAB. The subjects were asked to taste each sample from left to right and select the odd sample. The subjects were forced to make a decision. Having completed the triangle test, the panelists were required to participate in a paired preference test.

For the paired preference test, panelists received two tomato samples in simultaneous presentation, half in the order A-B, the other half B-A. Samples were pre-coded with three digit random numbers. The subjects were asked to identify their preferred sample.

Trained Panel

The trained panel consisted of 14 assessors (nine female and five male) from the Dublin Institute of Technology, Ireland. The assessors worked under the same conditions as the consumer panel. The sensory tests were delivered using Compusense five (Version 4.4; Compusense Inc., Guelph, Ontario, Canada). Pre-coded whole tomato samples were presented randomly to the trained panel on white paper plates. Sensory attributes were selected from those previously reported in the literature (Stommel, Abbott, Saftner and Camp, 2005; Meilgaard, Civille and Carr, 2007). The panel evaluated two appearance attributes (color, size), three texture attributes (finger feel firmness, juiciness and texture during mastication), one aroma attribute (intensity of tomato aroma), and four taste attributes (sweetness, sourness, bitterness and aftertaste). The assessors were instructed to look at, feel, bite into, and taste each fruit sample before marking their scores. The assessors recorded their results on eight-point line scales.

Statistical Analysis

Statistical analysis was performed using Excel 2003 and S.P.S.S version 13 for Windows (SPSS Inc., Chicago, USA). All instrumental and objective sensory data were subject to independent t-tests to assess the significance of treatment means at the 5% significance level. The results of the paired preference tests were analysed using binomial probability and the frequency procedure, as outlined by Rhee, Myers and Waldron (2003), was used to determine the number of consumers who correctly identified the odd sample in the triangle test.

RESULTS AND DISCUSSION

Instrumental Analysis

A comparison between both types of cherry vine tomato found no significant difference for the longitudinal (stem scar to blossom end) and the cross-sectional (transverse diameter) dimensions of the tomato (Table 1).

No statistical differences were recorded between the organic and conventional cherry vine tomatoes for the CIE L*, a*, b* color values. The mean values recorded for L*, a* and b* (Table 1) were similar to those reported in the literature for tomatoes ripened on the vine (Arias, Lee, Specca and Janes, 2000). Similarly, no significant differences were recorded between the organic and conventional cherry vine tomatoes for the a*/b* color ratio.

With regards to firmness values, a comparison between both types of cherry vine tomato found no significant difference for firmness and both types of tomato would have been considered as being firm (Table 1). Harrington and Gormley (1999) noted that tomatoes with a firmness value of greater than 20 Newtons were considered as having a good degree of firmness, while tomatoes with a firmness value of less than 20 were considered of a poor firmness quality.

No statistical differences were recorded between the organically farmed cherry vine tomatoes and conventionally produced cherry vine tomatoes for percentage dry matter content (Table 1). These results are consistent with previous studies conducted on the dry matter content of organic and conventional tomatoes (Thybo, Bechmann and Brandt, 2005; Hernández Suárez, Rodríguez Rodríguez and Díaz Romero, 2008).

A comparison between both types of cherry vine tomato found no significant difference for pH value.

Mean values for soluble solids expressed as ^{o}Brix are listed in Table 2. A comparison between both types of cherry vine tomato found a significant difference for ^{o}Brix, with the conventional tomato sample having a higher mean value. Similarly a significant difference was observed between the organic and conventional tomato cherry vine tomatoes for sugar content.

These results maybe attributable to the conventional cultivation system. Heeb, Lundegårdh, Savage and Ericsson (2006) reported that salt stress can increase the content of sugar in tomatoes. In our study, the conventional tomatoes were treated with a nutrient solution that contained a number of salts, such as $Ca(NO_3)_2$, KNO_3, $(NH_4)_2SO_4$, K_2SO_4, $(NH_2)_2CO$, $MgSO_4$, $(NH_4)(NO_3)$. Nutrients from organic fertilizers are released more slowly and steadily, and therefore cause less stress to the plant (Montagu and Goh, 1990). This finding was supported by several other authors (Dorais, Papadopoulous and Gosselin, 2001; Heeb, Lundegårdh, Ericsson and Savage, 2005; Heeb, Lundegårdh, Savage and Ericsson, 2006).

In addition to the taste properties, the flavour of tomatoes is also attributed to aroma. To acquire knowledge of the compounds responsible for tomato flavour and how they are influenced by cultivation systems, it is necessary to study the composition of volatiles present in the organic and conventional tomatoes. Differences in the volatile composition of the organic and conventional cherry vine tomatoes were not considered for this paper, but the authors duly acknowledge that they may also have a profound effect on the flavour of the tomatoes.

Mean values for electrical conductivity are also listed in Table 2. Gormley and Egan (1984) reported that tomatoes with an electrical conductivity value of >800 µS generally have very good tomato fruit flavor, while tomatoes having an electrical conductivity value of <550 µS are considered as having a poor tomato fruit flavor.

A significant difference was reported for electrical conductivity, with the conventional cherry vine tomato samples having a higher value (895µS) than the organic cherry vine tomatoes (681µS).

Sonneveld and Welles (1988) also supported this finding by stating that tomato fruit quality, in particular flavor, was improved by increased electrical conductivity values. While, Serio, De Gara, Carretto, Leo and Santamaria (2004) found that the soluble solids content of a tomato increase with increased electrical conductivity.

Sensory Analysis

The results of the triangle test indicated that there was a significant difference between the organic and conventional cherry vine tomatoes (Table 3). More than half (53%) of the consumers correctly identified the odd sample, while 47% could not discriminate between the organic and conventional cherry vine tomatoes.

In addition to this the results of the paired preference test showed a significant preference for the conventional cherry vine tomatoes. 58 consumers (81%) favored the conventional cherry vine tomatoes compared to 14 consumers (19%) who preferred the organic cherry vine tomatoes. The main reason for choosing the conventional cherry vine tomato as their preferred choice was sweet taste.

The results of the trained panel, indicated there were significant differences found between the organic and conventional cherry vine tomatoes for the sensory attributes of sweetness and sourness.

The conventional cherry vine tomato obtained a higher sweetness score compared to the organic cherry vine tomato. While, the organic cherry vine tomato had a higher sourness score compared to the conventional cherry vine tomato (Table 5).The sweetness could be explained by the higher glucose and fructose content in the conventionally farmed cherry vine tomatoes. Baldwin and Thompson (2000) reported that tomatoes with higher levels of sugars would be perceived to be sweeter and less sour than those with less sugar.

No significant differences were observed for the sensory attributes of bitterness, aftertaste and tomato aroma intensity. In addition to this, no significant differences were reported for the appearance, aroma and texture sensory attributes of the organically farmed and conventionally produced cherry vine tomatoes (Table 4).

Currently, Irish consumers are paying significant price premiums for organically farmed cherry vine tomatoes based on some cases of unscientifically sound and biased media coverage. Chang and Zepeda (2004) consumers believe that the higher prices charged for organic foods are justified based on the perception about quality. The results of this study have shown that organically farmed cherry vine tomatoes were not superior in sensory quality to Irish grown conventional cherry vine tomatoes. These findings may be of particular interest to consumers who choose to pay higher prices for organic tomatoes over their conventional counterparts.

CONCLUSIONS/IMPLICATIONS

The conventional growing conditions appear to have significantly affected the taste properties of the cherry vine tomatoes in this study. The results indicated there were differences in the physicochemical properties of the Irish grown organic and conventional cherry vine tomatoes, and both the trained and consumer panel perceived the conventional cherry vine tomatoes to be notably sweeter than their organic counterparts. The preference for conventional cherry vine tomatoes was influenced by sugar content and sweetness. This proves to be most interesting because research studies have shown that Irish consumers perceive organic food to be tastier than conventional produce, and are willing to pay premium prices to obtain it.

Until now, there was no validated information available to say whether or not, Irish grown organic cherry vine tomatoes were superior in sensory quality to Irish grown conventional cherry vine tomatoes. It is important that the government and the food industry work together to ensure consumers are assured that in terms of sensory quality Irish grown conventional cherry vine tomatoes are as good as Irish grown organic cherry vine tomatoes.

FUTURE RESEARCH

Volatile compounds directly affect the sensorial quality of tomatoes. Despite this, studies conducted on the sensory quality of organic and conventional tomatoes, have not been directly linked with volatile analysis. Future research studies will focus on the interaction of aroma compounds with sugars and acids, as well as the identification of volatile compounds as quality markers for Irish grown organic and conventional cherry vine tomatoes.

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