International Journal of

Agricultural Research

ISSN 1816-4897

Academic
Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 1 (5): 452-461, 2006
ISSN 1816-4897
© 2006 Academic Journals Inc., USA

Physico-Chemical Changes During Ripening of Conventionally, Ecologically and Hydroponically Cultivated Tyrlain (TY 10016) Tomatoes

[1]J. Rodríguez, [2]D. Ríos, [1]E. Rodríguez and [1]C. Díaz
[1]Department of Analytical Chemistry, Food Science and Nutrition,
University of La Laguna. Avda. Astrofísico Francisco Sánchez,
s/n 38201, La Laguna, Santa Cruz de Tenerife. Spain
[2]Agriculture Extension Service, Cabildo Insular of Tenerife, Plaza de España,
s/n. 38001, Santa Cruz de Tenerife, Spain

Abstract: The following physico-chemical parameters: hardness, moisture, Brix degree, ash, pH, acidity, ascorbic acid, total phenol compounds were determined in tomato samples belonging to Tyrlain cultivar cultivated conventionally, ecological and hydroponically (in tuff and cocoa fiber) and in several points of ripening. A clear tendency in the reduction of hardness and acidity and an increase of Brix degree/acidity ratio and ash was observed when the tomatoes ripened. The overripe tomatoes presented a lower ascorbic acid content than the green or commercial tomatoes. No detectable changes were found in the total phenolic compounds. Ecological tomatoes showed higher moisture content and lower Brix degree, ascorbic acid and total phenolic compounds than conventional and hydroponic cultivations. Hydroponic tomatoes presented a higher mineral content than those ecologically and conventionally cultivated. Many significant correlations were found between the physico-chemical parameters studied for the conventionally and the two hydroponically cultivated tomatoes. Hardness correlated positively with the acidity in all the methods of cultivation and after graphic representation, the overripe tomatoes tend to differentiate from the green and ripen tomatoes. Applying multivariate analysis the tomato samples tend clearly to differentiate according to the ripening stage and to a lesser extent, according to the type of cultivation.

Key words: Tyrlain tomatoes, physicochemical changes, ripening stage, cultivation type

Introduction

One of most important crops around the world is the tomato, *Lycopersicon* species with an annual production of more than 115 million tons, as reported in 2004 (FAO, 2005). Tomato quality depends on many factors such as cultivar, growing conditions and ripening on or off the plant. Sensory characteristics and objective measurements such as texture, refraction index, colour and total acid content have been determined in tomatoes to find out the variation of tomato quality according to harvest time, electrical conductivity, growth medium (soil *versus* rockwood), cultivar and maturity (Thybo *et al*., 2005). For most characteristics simultaneous sensory evaluations were more sensitive for detection of small differences than corresponding objective measurements, while objective measurements obtained better significance in comparisons of different harvest time (Thybo *et al*., 2005). Tomato ripening is characterized by softening of the fruit, increase in the

Corresponding Author: Carlos Díaz Romero, Department of Analytical Chemistry, Nutrition and Food Science, University of La Laguna, 38201-Santa Cruz de Tenerife, Spain
Tel: 00 34 922 318050 Fax: 00 34 922 318003

respiration rate and ethylene production, acid, sugar and lycopene synthesis and chlorophyll degradation. There is a general belief that tomatoes ripened on the vine are of better quality, mainly in terms of flavour, which leads to an increase in the price of this commodity. This popular perception has been confirmed by some investigators (Kader, 1993) who have found better nutritional characteristics in the tomatoes ripened on the vine than those ripened off the vine. Tomatoes collected in the green stage presented a lower vitamin C content and are sensitive to dehydratation processes (Kader, 1993). However, from a commercial point of view, ripening on the vine is not very productive. Jha and Matsuoka (2005) have determined the post-harvest storage life of tomato fruits. A critical storage periods of 48 h at 30°C, 120 h at 20-25°C and more than 144 h at 15°C of storage temperature and 90% relative humidity were obtained. Tomatoes are usually harvested at the mature green stage and ripened off the vine during transit to the final point of sale. Ripening off the vine reduces the time for harvesting, increases turnover, allows longer time for transportation and distribution and increases shelf life. The characterization of tomatoes ripened off vine and its comparison with the nutritional characteristics of tomatoes ripened on the vine, may help the post-harvest handling and treatment, extending shelf life and improve their quality.

Tomato Yellow Leaf Curl Virus (TYLCV), which is transmitted by the whitefly *Bemisia tabaci*, has recently been found in the Canary Islands. Tyrlain (TY10016) cultivar of tomatoes is being assayed in the Canary Islands as a possible alternative cultivation of tomatoes resistant to the TYLCV. This tomato belongs to the *Syngenta* commercial seeds and it is resistant to the TYLCV, tomato mosaic virus, *Verticillium* sp. nematodes, *Fusarium oxysperum* f.sp. licopersi races 0 and 1 and *Fusarium oxysperum* radicis-lycopersici. It is a round tomato, Canary type, with white "neck" (Ríos Mesa and Santos Coello, 2005).

The present study determined and compared the physico-chemical characteristics of the Tyrlain cultivar, which was cultivated conventionally, ecologically and hydroponically (in tuff and cocoa fiber) in several points of ripening, in order to find out differences among the groups of tomatoes indicated. Multivariate analysis were applied to differentiate the tomato samples according to the ripening stage and type of cultivation.

Materials and Methods

System for Cultivation

Tomatoes belonging to the Tyrlain (TY 10016) grown, from February to May 2004, using four methods: conventional, ecological and hydroponic with tuff and with cocoa fiber were collected. All the tomatoes were grown in the S.A.T. Acevedo Reig and the C.B. Dracaena belonging to a network of experimental farms from the Excmo. Cabildo Insular of Tenerife. So, all the tomato samples came from one cultivation zone with the same ecosystem and irrigation water. The same nutritive solution was used for both hydroponic cultivations (tuff and cocoa fiber) and the main characteristics are shown in the Table 1 (Ríos Mesa, 2003). For conventional cultivation the same nutritive solution was utilized as irrigation water decreasing the conductivity to 1,000-1,100 $\mu S\ cm^{-1}$ and increasing the pH to 8.7-8.9. The ecological cultivation was carried out with usual methods of the producers of the zone, in accordance with the norms established (Reglament N° 2254, 2004). Ecological and conventional cultivation soils had a pH near to 7.5 and the conductivity varied between 4 and 5 $dS\ m^{-1}$. The soil for ecological cultivation had higher organic matter and K exchangeable, surpassing the maximum recommended of 12% for the Canary Islands (Hernández Abreu *et al*., 1980).

Table 1: Characteristics of the nutritive solution used in the hydroponic cultivations

Physicochemical parameter	
Conductivity (mS cm^{-1})	2.800-3.000
pH	5.8-6.2
Nitrate (m mol L^{-1})	12-13
Ammonium (m mol L^{-1})	0.5-1.0
Calcium (m mol L^{-1})	4.0-5.0
Magnesium (m mol L^{-1})	1.5-2.0
Potassium (m mol L^{-1})	6.0-7.5
Sodium (m mol L^{-1})	5.0-7.0
Chloride (m eq L^{-1})	2-2.5
Phosphate (m mol L^{-1})	1.5-2.0
Sulphate (m mol L^{-1})	2.5-3.0

Tomato Sampling and Sample Preparation

Four sampling of tomatoes belonging to the Tyrlain (TY 10016) were collected from February to May 2004. Tomatoes samples cultivated using four methods conventional, ecological and hydroponic with tuff and with cocoa fiber were taken in each sampling. Each tomato sample consisted of approximately 1 kg. Table 2 shows the number and the average weight per tomato in each sampling. When the sampling was carried out, all the cultivations had a similar phenological stage. Mature green tomatoes (ripening point 2-3) were taken from the second cluster at a height of 1 m, from a minimum of 12 randomly selected plants. Tomatoes were allowed to ripen in laboratory and sub-samples corresponding to the ripening points of 3, 5, 6, 7, 8 and 10 of the ripening colour chart were successively taken for analysis. These ripening points were grouped in the following three ripening stages: 1st stage (green tomatoes; ripening points 3 to 5); 2nd stage (ripe or commercial tomatoes; ripening points 6, 7 and 8); 3rd stage (overripe tomatoes; ripening point 9 and 10).

Table 2: Descriptions of the tomato samples according to the type of cultivation

Sampling date	N° tomatoes	Tomato weight (g)
Conventional tomatoes (Total yield 9.5 kg ha^{-1})		
1	19	55.6
2	15	51.8
3	12	57.5
4	24	78.2
Overall	70	60.8±11.9
Ecological tomatoes (Total yield 4.5 kg ha^{-1})		
1	18	95.6
2	15	70.2
3	17	87.7
4	14	81.8
Overall	64	83.8±10.7
Hydroponic (cocoa fiber) tomatoes (Total yield 14 kg ha^{-1})		
1	17	75.6
2	15	66.1
3	15	46.9
4	36	71.8
Overall	83	65.1±12.7
Hydroponic (tuff) tomatoes (Total yield 15 kg ha^{-1})		
1	19	76.3
2	36	56.5
3	21	46.6
4	21	55.8
Overall	97	58.8±12.5

Analytical Determinations

The following parameters were determined: Hardness, moisture, Brix degree, ash, pH, acidity, ascorbic acid and total phenols. The analytical methods used were Association Official of Analytical

Chemists (AOAC) or similar. All the methods were assayed and optimized for these samples. All the analytical determinations were carried out in duplicate on fresh and homogenized tomato samples, except for moisture and ash, which were determined in triplicate on frozen tomato sample homogenized earlier. Firstly, the tomatoes were cleaned, weighed and, their hardness was determined with a urometer (Durofel, Agro Technologie, Tarascon, France). Ascorbic acid was determined by the dichlorophenol indophenol titration procedure (AOAC, 1990). In order to avoid oxidation ascorbic acid was immediately extracted using an acetic acid and metaphosphoric acid solution. The homogenization process was realized after the introduction of the pieces of tomato into this solution extraction. The pH was determined by potentiometric measurement made at 20°C with pH meter (AOAC, 1990). The acidity was determined by titration with NaOH 0.1 N until pH 8.1, expressing the results in g of anhydrous citric acid (AOAC, 1990). The Brix degree were determined by means of refractometric measurement at 20°C in the juice (AOAC, 1990). Total phenolic content was determined by the Folin-Ciocalteu's reagement at 750 nm according to the procedure described by Kujala *et al.* (2000), expressing the results in g of gallic acid. Moisture was determined by desiccation at 105°C for 24 h (AOAC, 1990) and the ash was determined by ashing the residue of moisture determination at 550°C for 24 h (AOAC, 1990).

Statistics

All the statistics were obtained by means of the SPSS version 12.0 software for Windows. The Kolmogorov-Smirnov test was applied to verify whether the variables had a normal distribution ($p<0.05$). Mean values obtained for the variables studied in the different groups were compared by One-Way ANOVA (Duncan's multiple range) assuming there were significant differences among them when the statistical comparison gives $p<0.05$. Simple linear and logarithmic correlation analysis was used to indicate a measure of the correlation and the strength of the relationship between two variables. Factor analysis, using principal components as the method for extraction of factors, was used to summarize the information in a reduced number of factors, Linear discriminant analysis (LDA) was used to classify the samples according to several criteria. Two processes are commonly applied in LDA: 1) Step-wise LDA that selects the quantitative variables that enhance discrimination of the groups established by the dependent variable; and 2) Introduction of all independent variables. The objective of this second process is to use all the information although the system obtained is more complex.

Results and Discussion

Table 3 shows the results (mean±standard deviation) relative to the analyzed parameters differentiating the type of cultivation and the ripening stage. The results of ANOVA analysis for the comparison between the mean values in the ripening point are also included in this table. An important variation of the some physico-chemical parameters with the ripening stage was observed. There was a dramatic decrease of hardness and acidity when the tomatoes ripened for all the cultivation methods considered. Logically, significant increases of the mean pH were also detected in all the cultivation methods. An increase of the Brix degree was also found in the conventional and hydroponic tomatoes in tuff soil when the ripening stage increased, however, no significant differences were found in the cocoa fiber hydroponic and ecological tomatoes. The tendency to the Brix degree increase could be explained by the enzymatic attack on the starch (Hobsen and Davies, 1971; Chamorro Lapuerta, 1999) that implies the glucose liberation. This produces the typical increase in sweetness in the ripening process. Martínez-Barajas (2003) indicated that most of the sugars in ripe

Table 3: Results of physico-chemical parameters analysed grouping the tomato samples according to the type of cultivation and the ripening stage

	Moisture ($g\ kg^{-1}$)	Ash ($g\ kg^{-1}$)	Brix degree	Hardness (%)	pH	Acidity ($g\ kg^{-1}$)	Brix degree/ acidity	Ascorbic acid ($mg\ kg^{-1}$)	Total phenolic Compounds ($mg\ kg^{-1}$)
Conventional tomatoes									
Green	914±10[a]	5.38±0.83	63.7±7.6	60.8±1.1	4.10±0.10	6.88±0.76	9.3±1.4	121±22	207±63
Commercial	917±11	5.66±0.95	63.8±11.4	54.9±3.1	4.16±0.05	5.79±0.76	11.1±1.8	139±26	196±59
Overripe	913±15	6.18±0.66	77.0±4.7	39.7±2.5	4.21±0.08	5.09±0.57	15.3±1.6	119±11	217±69
p*	0.532	0.114	0.003	0.000	0.002	0.000	0.000	0.024	0.686
Ecological tomatoes									
Green	930±10	5.10±0.94	52.2±8.5	59.9±1.2	4.08±0.07	6.31±0.64	8.4±2.1	103±18	176±53
Commercial	934±7	5.68±0.60	50.7±6.3	54.1±4.0	4.15±0.05	5.58±0.52	9.2±1.4	116±17	166±51
Overripe	935±3	5.82±0.82	53.3±22.4	40.0±3.1	4.27±0.12	4.71±0.82	11.8±6.2	102±10	154±34
p	0.278	0.036	0.841	0.000	0.000	0.000	0.033	0.027	0.590
Hydroponic (cocoa fiber) tomatoes									
Green	913±16	5.67±1.08	61.4±8	60.6±0.8	4.10±0.07	6.69±0.59	9.2±1.0	122±14	209±56
Commercial	917±13	6.40±0.84	59.1±11	56.0±2.1	4.13±0.06	6.26±0.75	9.6±2.0	119±17	182±53
Overripe	921±9	6.51±0.67	59.4±16	44.4±3.8	4.17±0.08	5.31±0.74	11.6±4.5	108±10	182±89
p	0.322	0.029	0.818	0.000	0.046	0.000	0.054	0.095	0.363
Hydroponic (tuff) tomatoes									
Green	914±15	5.64±0.81	58.3±9.6	60.7±0.6	4.08±0.07	6.81±0.95	8.6±1.0	112±14	181±50
Commercial	914±12	6.55±0.77	70.2±15.5	56.6±4.2	4.17±0.06	5.97±0.65	11.7±2.0	125±21	212±71
Overripe	927±7	6.00±0.43	69.8±16.3	43.9±2.5	4.23±0.10	4.87±0.57	11.6±4.5	103±10	161±55
p	0.044	0.007	0.030	0.000	0.000	0.000	0.000	0.006	0.092

*p: Signification level; [a]The mean values and standard deviation correspond to 4 sampling date × 2 or 3 determinations

fruits are taken from the plant during ripening. The sugar and organic acid contents are major factors in determining greater sweetness, bitterness and overall flavour intensity of ripe tomatoes. So, the ratio Brix degree/acidity was proposed as an indicator of ripening stage (Scott and Walls, 1947) and it is commonly used to know the ripening stage. Clear increases were observed during ripening in all the types of cultivation considered, with no significant differences for the hydroponic cultivation in cocoa fiber. Commercial tomatoes with high quality must have a Brix degree/acidity ratio higher than 10 (Scott and Walls, 1947). The Brix degree, acidity and Brix degree/acidity ratio were higher than 3, 0.3 and 10% respectively in all the tomato samples belonging to conventional and hydroponic (tuff) tomatoes. The acidity and sweetness were balanced and the tomatoes were of a good quality. However, the mean values of the Brix degree/acidity ratio in the ecological and hydroponic (cocoa fiber) tomatoes were lower than 10. Therefore, these methods of cultivations do not seem to be suitable for the Tyrlain cultivar. Mean ash concentration significantly changed with the ripening stage for all the cultivation types, except for conventional cultivation. Green tomatoes presented lower mean ash content than the commercial and overripe tomatoes. The variation of ash content could be produced by changes of moisture and other compounds in the ripening process.

The mean ascorbic acid concentrations in the overripe tomatoes were significantly lower than those concentrations detected in commercial tomatoes for all the types of cultivation considered except for hydroponic (cocoa fiber) cultivation. This agrees with data reported by Tünk *et al*. (1993) who indicated that the ascorbic content reached a maximum value when the tomatoes were yellow and then decreased because of its antioxidant role. Similar results were reported (Abushita *et al*., 1997) although no significant differences were observed. On the other hand, these results contrast with some authors (Cano *et al*., 2003), who found the ascorbic acid remained practically unchanged. Other authors (Raffo *et al*., 2002) found no changes in the vitamin C content in ripening of tomatoes, but an increase of the reduced form (dehydroascorbic acid) was detected. It has been shown that both the concentration and the localization of phenolic compounds vary during ripening (Senter *et al*., 1988).

The content of total phenolic compounds did not vary significantly in all the cultivations considered during the ripening stage. Only the commercial tomatoes from the tuff hydroponic cultivation had higher mean values than those overripe tomatoes. Cano *et al*. (2003) found an increase in aqueous phenol during ripening. In contrast, a decrease of the total phenolic compounds was observed at the later stage of ripeness (Raffo *et al*., 2002). The behaviour differs depending on the phenolic compound considered (Buta and Spaulding, 1997). So, chlorogenic acid declined whereas no changes were observed in rutin and *p*-coumaric-rutin.

On the other hand, large differences in most of the physico-chemical parameters were observed in ecological tomatoes and conventional and the hydroponic cultivations. This contrast with the results reported in a study (Kunsch *et al*., 1994) on the quality of soilless and conventionally produced tomatoes of the cultivar Max. These investigators deduced that the physiological state of the tomato plant had a mores pronounced influence on physicochemical parameters such as firmness, sugars, ascorbic acid and dry matter than the cultivation methods. Chemical composition and differences in the management of the substrates and soils for cultivation could influence on the physico-chemical parameters. Besides, total yield tomatoes significantly varied as a function of the cultivation method, which could explain some physico-chemical parameters (Table 2). The hydroponic tomatoes had the highest productions, with 14 and 15 kg ha^{-1} for the cocoa fiber and tuff hydroponic tomatoes. The conventional tomatoes showed a intermediate total yield (9.5 kg ha^{-1}), while ecological tomatoes exhibited the lowest total yield (4.5 kg ha^{-1}). So, ecological tomatoes presented higher ($p<0.05$) moisture mean concentrations and a lower Brix degree, ascorbic acid and total phenolic compounds than the other two cultivation systems. These clear differences could be related to the higher ($p<0.05$) mean weight found in the ecological tomatoes (Table 2). The ecological and conventional in commercial and overripe state were slightly but significantly softer than the two hydroponic cultivations, which is in agreement with the results indicated by others. The two hydroponic types of tomatoes had higher ($p<0.05$) mean ash concentrations than the ecological and conventional tomato cultivations. These differences increased in the mature and overripe tomatoes and could be explained by the balanced and high mineral content of the nutritive liquid used in the hydroponic cultivation. No significant differences in Brix degree/acidity ratio were found between the two hydroponic cultivations and the conventional and ecological ones. This does not agree with that reported by other authors Kunsch *et al*., 1994, who observed a larger sugar/acidity ratio in soilless produced tomatoes. When the two hydroponic cultivations were compared, one can deduce that the physico-chemical characteristics for both types of cultivation were fairly similar. The only result to be pointed out is that the tuff hydroponic tomatoes had higher ($p<0.05$) mean values of Brix degree. The higher Brix degree values in the tuff hydroponic tomatoes, mainly in the commercial ripening stages, can explain that the higher price (1 pound more per commercial box of 6 kg of tomatoes) obtained in the United King market for this type of hydroponic tomatoes versus other types of cultivations. This could be explained for differences in the management of both hydroponic cultivations. So the capacity of water retention for the cocoa fiber is substantially higher than the capacity of the tuff. Thus, the amount and frequency of water irrigation and the cationic exchange is different for both types of hydroponic cultivations.

A statistical correlation study for each cultivation type was carried out on the physico-chemical parameters analyzed. The physico-chemical parameters were considered as being direct and after double logarithmic transformation, obtaining better coefficients of correlation using the direct variables. High and negative correlation coefficients were obtained between pH and acidity ($r>-0.600$ and $r<-0.850$; $p<0.000$), which is a consequence of the clear relationship between both parameters for all type of cultivation. Hardness correlated positively ($p<0.05$) with acidity in all the types of cultivation ($r>0.450$ and $r<0.600$) and negatively ($p<0.05$) with pH in all the types of cultivation

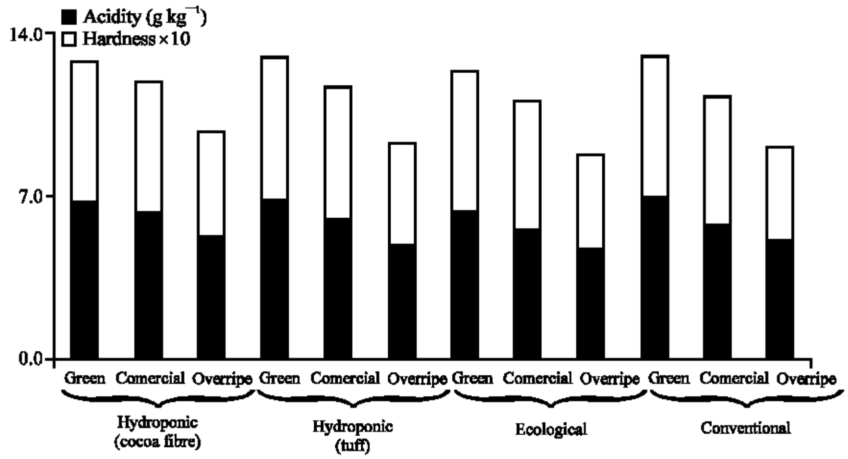

Fig. 1: Mean values of hardness and acidity differentiating the tomato samples according the type of cultivation and ripening stage

Table 4: Factor matrix obtained after a Varimax rotation

	Factor 1	Factor 2	Factor 3
Cumulative variance (%)	31.3	56.5	72.6
Acidity	0.893	0.249	-0.059
pH	-0.869	-0.049	0.217
Hardness	0.781	-0.272	0.246
Ash	-0.091	0.792	-0.114
Brix degree	-0.043	0.788	0.266
Moisture	-0.399	-0.779	-0.218
Ascorbic acid	-0.010	0.123	0.782
Total phenol compounds	-0.035	0.058	0.779

(conventional r = -0.513; ecological r = -0.606; tuff hydroponic r = -0.463) except for cocoa fiber hydroponic cultivated. Zambrano *et al*. (1995) found out some relation between hardness and acidity and pH for Italian tomatoes. Representing the mean values of hardness and acidity for the three ripening stages in all the cultivation methods considered (Fig. 1), one can observe that there is a decrease the acidity and hardness with the ripening in all the types of cultivation. So, the tomatoes tend to be more vulnerable to external conditions.

Factor analysis was applied to all the tomato samples studied to obtain a more simplified view of the relationship among the chemical compounds considered. Considering all the data the first three factors were chosen (72.6% of the total variance) because their eigenvalues were higher than 1 (Table 4). After Varimax rotation, it was observed that the first factor, explaining a 31.3% of the total variance, is positively associated with acidity and to a lesser extent, negatively with pH and positively with hardness, which are correlated between them. The second factor is positively associated with ash and brix degree and negatively with moisture and the third factor with ascorbic acid and total phenolic compounds. Representing the scores of the tomato samples in the factors 1 and 3, one can observe that the tomato samples belonging to the overripe tomatoes graphically tend to separate from the other two tomato samples, commercial and green stages (Fig. 2). However, no clear separation of the tomato samples was observed when the type of cultivation was considered. Therefore, the ripening stage has a higher influence on the chemical composition than the type of cultivation.

Discriminant analysis (DA) considering the ripening stage (green, commercial and overripe) and the quantitative variables studied was performed. After application of the Step-wise DA to the data, four discriminant functions were extracted selecting four variables: ash, hardness, acidity and ascorbic

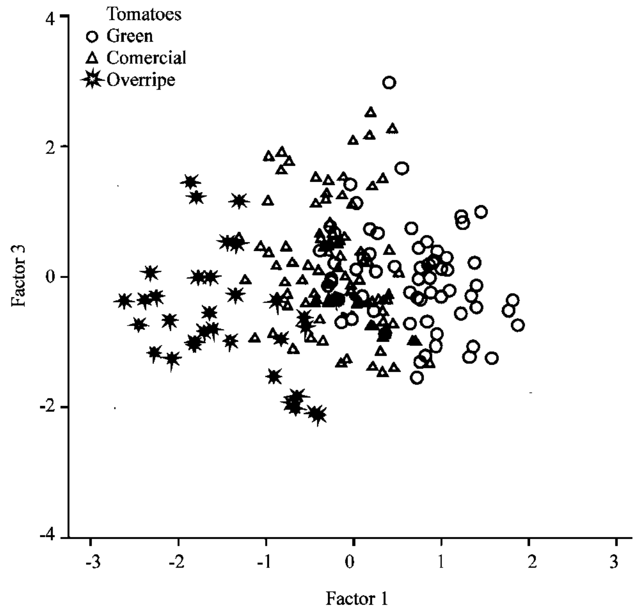

Fig. 2: Scores of the tomato samples on axes representing the second and third factors according to the ripening stage

acid. A moderately high percentage (88.5 and 88.0% after cross-validation) of correct classification was obtained. When the Step-wise DA was repeated on the data of each cultivation in an independent manner the correct classifications, according to the ripening stage, were above 85% for all the types of cultivation. All the overripe tomatoes were well classified in the four types of cultivations considered. Hardness was selected for all the types of tomatoes and the acidity was also selected in all the cultivation methods considered except in ecological tomatoes. A clear tendency to the separation of the tomato samples as a function of the ripening stage was observed in all the types of cultivation considered.

Besides, new Step-wise DA were applied to differentiate the cultivation methods. Low percentages of correct classifications of the two hydroponic cultivations (cocoa fiber and tuff) were obtained. Considering the data of the three ripening stages in a independent manner the differentiation of green tomatoes, commercial tomatoes and overripe tomatoes presented low percentages of correct classification. The same DA was carried out to differentiate conventional and ecological tomato samples. Moderate percentages of correct classifications were obtained for the total (86.5 and 86.5% after cross-validation) and considering the three ripening stages independently (green: 87.5 and 84.4% after cross-validation; commercial: 87.5 and 83.3% after cross-validation; and overripe: 87.5 and 87.5% after cross-validation). The moisture was selected in all the ripening stage considered. Therefore, it can be confirmed that moisture content is the variable that allows a better differentiation between the conventional and ecological tomatoes Tyrlain (TY 10016) of this study.

Conclusions

The concentrations of physico-chemical parameters in the tomatoes varied as a function of the cultivation method and ripening stage. The influence of ripening was higher than the influence of the type of cultivation. Tomatoes increased the Brix degree/acidity ratio and decreased the pH and hardness with the ripening. The ascorbic acid in the overripe tomatoes was lower than in commercial tomatoes. Ecological cultivation was the type of cultivation with the most differences in the physico-chemical parameters, with an emphasis on their higher moisture contents. Tyrlain cultivar does not seem appropriate for ecological cultivation. Significant correlations were observed between many physico-chemical parameters for each type of cultivation. Hardness correlated positively with the acidity in all the cultivation methods and after graphic representation the overripe tomatoes differentiated from the green and ripen tomatoes. The ripening stage had a higher influence on the physico-chemical parameters than the type of cultivation. Factor and discriminant analysis tend to differentiate the tomatoes as a function of the ripening stage in all the tomato samples and within each type of cultivation. Besides, discriminant analysis make it possible to reasonably distinguish between conventional and ecological tomatoes.

Acknowledgements

The present study was financed by the Project (I+D) Reference AGL 2003-09559 of the National Plan for Scientific Research, Development and Technological Innovation, Spain. We gratefully acknowledge the collaboration of Belarmino Santos in the sampling of tomatoes and the help of Patrick Dennis for improving the English in this study.

References

Abushita, A.A., E.A. Hebshi, H.G. Daood and P.A. Biacs, 1997. Determination of antioxidant vitamins in tomatoes. Food Chem., 60:207-212.

AOAC, 1990. Association Official of Analytical Chemists. Official Methods of Analysis of AOAC: Food Composition; Additives; Natural Contaminants, (Ed.) K. Helrich, AOAC, Arlington, Vol. 2.

Buta, J.G. and D.W. Spaulding, 1997. Endogenous levels of phenolics in tomato fruit during growth and maturation. J. Plant Growth Regul., 16:43-46.

Cano, A., M. Acosta and M.B. Arnao, 2003. Hydrophilic and lipophilic antioxidant activity changes during on-vine ripening of tomatoes (*Lycopersicum esculentum* Mill.). Postharvest Biol. Technol., 28:59-65.

Chamorro Lapuerta, J., 1999. Anatomy and Physiology of the Plant. In: the Cultivation of the Tomato, (Ed.) Nuez, F. Ed. Mundi-prensa, Madrid, pp: 793.

FAO, 2005. Food and Agricultural Organization. Statistics Division. Agricultural data of FAOSTAT. http://faostat.fao.org.

Hernández Abreu, J.M., J. Mascarell Inta, S. Duarte Minguez, A. Pérez Regalado, J.L. Santana Ojeda and A.R. Socorro Monzón, 1980. Seminario sobre interpretación de análisis químicos de suelos, aguas y plantas, pp: 101.

Hobsen, G.E. and J.N. Davies, 1971. The Biochemistry of Fruits and Their Products, (Ed.) Hulme, A.C. Academic Press, New York, Vol. 2.

Jha, S.N. and T. Matsuoka, 2005. Determination of post-harvest storage life of tomato fruits. J. Food Sci. Technol. Mys., 42: 526-529.

Kader, A.A., 1993. Postharvest Handling, in the Biology of Horticulture: An Introductory Textbook, (Ed.) Preece, J.E. and P.E. Read. John Willey and Sons, Inc., New York, pp: 353-377.

Kujala, T.S., J.M. Loponen, K.D. Klika and K. Pihlaja, 2000. Phenolics and betacyanins in red beetroot (*Beta vulgaris*) root: Distribution and effect of cold storage on the content of total phenolics and three individual compounds. J. Agric. Food Chem., 48: 5338-5342.

Kunsch, U., H. Scharer, P. Durr, J. Hurter, A. Martinón, G. Jelmini, H. Sulser and B. Seeger, 1994. Quality assessment of tomatoes from soilless and conventional glasshouse production. Gartenbauwissenschaft, 59: 21-26.

Martínez-Barajas, E., 2003. Analysis of the accumulation of sugars in pericarps of two wild genotypes of jitomate (*Lycopersicum esculentum*). Agrociencia, 37:363-370.

Raffo, A., C. Leonardi, V. Fogliano, P. Ambrosino, M. Salucci, L. Gennaro, R. Bugianesi, F. Giuffrida and G. Quaglia, 2002. Nutritional value of cherry tomatoes (*Lycopersicon esculentum* cv. Naomi F1) harvested at different ripening stages. J. Agric. Food Chem., 50:6550-6556.

Reglament (CE) N° 2254, 2004. For the one that modifies the Regulation (EEC) N° 2092/91 of the Council on the agrarian ecological production and their indication in the agrarian and nutritious products.

Ríos Mesa, D. and B. Santos Coello, 2005. Comparison of the behavior of sensitive and tolerant cultivares of export tomato to TYLCD in Tenerife. Agrícola Vergel., pp: 225-233.

Ríos Mesa, D., 2003. Unpublished data. Exmo. Cabildo Insular de Tenerife, Santa Cruz de Tenerife.

Scott, L.E. and E.P. Walls, 1947. Ascorbic acid content and sugar-acid ratios of fresh fruit and processed juice of tomato varieties. Proc. Am. Soc. Hortic. Sci., 50: 269-272.

Senter, S.D., R.J. Horvat and W.R. Forbus, 1988. Quantitative variation of total phenols in fresh market tomatoes as three stages of maturity. J. Food Sci., 53:639-640.

Thybo, A.K., I.E. Bechmann and K. Brandt, 2005. Integration of sensory and objective measurements of tomato quality: quantitative assessment of the effect of harvest date as compared with growth medium (soil versus rockwood), electrical conductivity, variety and maturity. J. Sci. Food Agric., 85: 2289-2296.

Tunk, R., V. Seniz, N. Özdemir and M.A. Süzen, 1993. Change in chlorophyll, carotenoid and lycopene content of tomatoes in relation to temperature. Acta Hortic., 398: 856-862.

Zambrano, J., J. Moyeja and L. Pacheco, 1995. Effect of the state of maturity in the composition and quality of tomato fruits. Agron. Tropic., 46:61-72.