Available online at www.sciencedirect.com
ScienceDirect
Postharvest Biology and Technology 44 (2007) 271–276
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

# Segregation of plum and pluot cultivars according to their organoleptic characteristics

Carlos H. Crisosto[a,*], Gayle M. Crisosto[a], Gemma Echeverria[b], Jaume Puy[c]

[a] *Department of Plant Sciences, University of California, Davis, CA 95616, USA*[1]
[b] *Centre UdL-IRTA, Rovira Roure, 191, Lleida 25198, Spain*
[c] *Departament de Química, Rovira Roure, 191, Lleida 25198, Spain*

Received 19 June 2006; accepted 9 December 2006

**Abstract**

Cultivar segregation according to the sensory perception of their organoleptic characteristics was attempted by using trained panel data evaluated by principal component analysis of 12 plum and four pluot cultivars as a part of our program to understand plum minimum quality. The perception of the four sensory attributes (sweetness, sourness, plum flavor intensity, plum aroma intensity) was reduced to three principal components, which accounted for 98.6% of the variation in the sensory attributes of the tested cultivars. Using the Ward separation method and PCA analysis (PC1 = 49.8% and PC2 = 25.6%), plum and pluot cultivars were segregated into groups (tart, plum aroma, and sweet/plum flavor) with similar sensory attributes. Fruit source significantly affected cultivar ripe soluble solids concentration (RSSC) and ripe titratable acidity (RTA), but it did not significantly affect sensory perception of plum flavor intensity, sourness, sweetness, and plum aroma intensity by the trained panel on fruit harvested above their physiological maturity.

Based on this information, we recommend that validation of these organoleptic groups should be conducted using “in store” consumer tests prior to development of a minimum quality index within each organoleptic group based on ripe soluble solids concentration (RSSC). This organoleptic cultivar classification will help to match consumer preferences and enhance current promotion and marketing programs.


*Keywords:* Sensory attributes; PCA; Ripe fruit quality attributes; Minimum quality index

## 1. Introduction

In the last decade, plum per capita consumption has remained the same or even decreased in the USA (Anon., 2004) and some European countries (Liverani et al., 2002). In the USA, plum consumption is lower than in European countries declining from 0.64 kg per capita per year in 2001 to 0.50 kg per capita per year in 2004. In Italy, plum consumption varies from 1.2 to 0.90 kg per capita per year according to geographic location; for example, 1.2 kg for Italian consumers that live in the central area, 1.14 kg for consumers in the northwestern area and 0.90 kg for consumers in the south and islands (Macchi, 2006). On both continents, consumers' complaints included “off flavor”, lack of ripening, astringent, flesh browning and textural characteristics associated with low quality and chilling injury symptoms (Ceponis and Cappellini, 1987; Streif, 1989; Taylor and Jacobs, 1993; Taylor and Rabe, 1995; Abdi et al., 1998; Crisosto et al., 1999; Plich, 1999; Argenta et al., 2003). At the same time, costs of production are increasing while prices are not. Postharvest handling practices with an emphasis on temperature management recommendations to avoid plum chilling injury have been proposed as part of the solution in California (Mitchell, 1987; Crisosto et al., 1999) and in other areas of the world (Streif, 1989; Taylor and Rabe, 1994). Ripening protocols at the shipping and receiving end have been developed, promoted and established as an attempt to enhance flavor or even give an added value to plums (Crisosto, 2005).

The creation and establishment of a generic minimum quality index based on ripe soluble solids concentration (RSSC) and/or ripe titratable acidity (RTA) as an approach to protect consumers and increase consumption is being pursued by several postharvest physiologists and private companies. However, it has been claimed that for some plums titratable acidity, characteristic flavor, aroma, astringency and texture become as important

* Corresponding author. Tel.: +1 559 646 6596; fax: +1 559 646 6593.
*E-mail address:* carlos@uckac.edu (C.H. Crisosto).
[1] Located at Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648, USA.

0925-5214/$ – see front matter 
doi:10.1016/j.postharvbio.2006.12.005

as RSSC in determining consumer acceptance. The interaction between RSSC and RTA has been well illustrated for a high acid, early dark plum (Crisosto et al., 2004), i.e. within the same RSSC range (10.0–11.9%) combined with three RTA ranges (RTA ≤ 0.60%, RTA 0.61–0.99%, and RTA ≥ 1.00%) the mean degree of liking by consumers decreased significantly ($p < 0.0001$) as the RTA range increased, 6.2, 5.3 and 3.3, respectively. This relationship has also been reported for early grapes (Nelson et al., 1963; Crisosto and Crisosto, 2002), cherries (Kappel et al., 1996; Crisosto et al., 2003) and 'Hayward' kiwifruit (Crisosto and Crisosto, 2001; Marsh et al., 2004).

Other approaches to fuel consumption have been taken by plant breeders, who are developing and introducing new plum and plum type (pluot) cultivars with different chemical and sensory characteristics than current commercial plum cultivars. Pluots are interspecific hybrids of complex crosses of plum and apricot with predominantly plum parentage typically with smooth skin. Thus, in the last decade a large number of cultivars with notable flavor characteristics, i.e. strong plum flavor, a blend of apricot and plum flavors, very sweet and high antioxidant capacity have been released (Wills et al., 1983; Tomas-Barbera et al., 2001).

In this study, we tested the hypothesis that plum and plum type cultivars could be consistently segregated based on their predominant sensory characteristics: sweetness, sourness, flavor and aroma intensity (plum), using a trained panel (Crisosto et al., 1998, 2003, 2006). As plums and pluots are currently reaching new domestic and overseas markets with diverse consumer ethnic groups, this proposed organoleptic classification may help to match fruit flavor characteristics to consumers' specific flavor characteristic requirements, i.e. sweet, balanced sweet/tart, strong plum flavor and/or aroma, tart, etc., thus enhancing marketing and promotion activities.

Our sensory research program involved the following steps: verify the variability of sensory attributes in current plum and pluot cultivars, segregate cultivars into organoleptic groups, validate organoleptic groups with consumer perception of sensory attributes, describe the chemical attributes of each organoleptic group, propose a minimum quality index within each organoleptic group, and understand the relationship between consumer preferences and these proposed organoleptic groups. In this work we reported information on the first two steps.

## 2. Materials and methods

### 2.1. Trained panel

Cultivar segregation studies focused on the organoleptic description of 12 plum and four pluot cultivars (Table 1) were carried out by a trained panel of nine (2003) or 10 (2004) trained judges selected for their taste acuity (O'Mahony, 1986; Lawless and Heymann, 1998). Four sources (orchards) per cultivar were used for nine plum and one pluot cultivar and only one source per cultivar for three plum and three pluot cultivars. Plum and pluot cultivars with diverse quality attributes, (low and high acidity, high soluble solids concentration (SSC) and strong plum flavor) originating from different breeding programs were selected for this study. Training sessions were conducted to instruct the judges on measuring the perception of sweetness, sourness, plum flavor intensity and plum aroma intensity using references (O'Mahony, 1986). At each session, judges evaluated no more than a maximum of eight cultivar-source combinations for aroma and taste attributes. All testing was carried out at room

Table 1
Means (*X*) and standard deviations (S.D.) of ripe soluble solids concentration (RSSC) and ripe titratable acidity (RTA as percent malic acid) for plum and pluot cultivars from one to four different sources per cultivar

| | Cultivar code | Plant breeding program | RSSC[a] (%) | | RTA[a] (%) | |
|---|---|---|---|---|---|---|
| | | | *X* | S.D. | *X* | S.D. |
| Plum cultivar | | | | | | |
| Betty Anne | BA | Zaiger | 16.8 | 0.4 | 0.43 | 0.16 |
| Blackamber | BK | USDA/UC | 12.4 | 1.2 | 0.36 | 0.14 |
| Catalina[b] | CA | Krause | 16.7 | 0.6 | 0.38 | 0.08 |
| Earliqueen | EQ | Zaiger | 9.0 | 0.9 | 0.87 | 0.21 |
| Fortune | FO | USDA | 11.8 | 1.9 | 0.70 | 0.18 |
| Friar[b] | FR | Weinberger | 17.2 | 0.7 | 0.18 | 0.04 |
| Hiromi Red | HR | Zaiger | 13.6 | 1.7 | 0.62 | 0.22 |
| Joanna Red | JR | Zaiger | 11.0 | 2.3 | 0.45 | 0.13 |
| October Sun | OS | Chamberlin, Sr. (Met. Life Ins.) | 19.8 | 1.3 | 0.29 | 0.03 |
| Purple Majesty | PM | Bradford | 13.7 | 0.6 | 0.81 | 0.22 |
| Royal Zee | RZ | Zaiger | 11.2 | 1.3 | 0.42 | 0.10 |
| Simka[b] | SI | Kazarian | 14.3 | 1.4 | 0.59 | 0.02 |
| Pluot cultivar | | | | | | |
| Dapple Dandy[b] | DD | Zaiger | 19.1 | 1.1 | 0.40 | 0.02 |
| Flavor Grenade[b] | FG | Zaiger | 16.9 | 0.2 | 0.42 | 0.04 |
| Flavorich | FLR | Zaiger | 17.0 | 1.3 | 0.58 | 0.13 |
| Flavorosa[b] | RS | Zaiger | 12.4 | 1.5 | 0.43 | 0.13 |

[a] RSSC and RTA measured on ripe fruit (8.8 N) using a penetrometer with an 8 mm tip.
[b] One source per cultivar.

temperature (20 °C) in individual booths illuminated with fluorescent lighting. Samples were presented in random order in 162.6 mL soufflé cups labeled with three digit random numbers. For each cultivar-source, fruit were harvested at the peak size and California Well-mature for that cultivar, and then held at 0 °C for approximately 7–10 days until ripened. Prior to testing, the fruit were ripened at 20 °C in a temperature-controlled room for 1–5 days until a subsample measured 8.8–13.2 N flesh firmness. On each fruit for tasting, a piece of skin 2 cm in diameter was removed from one cheek and the flesh firmness measured with a UC firmness tester (Western Industrial Supply, San Francisco, CA) equipped with an 8 mm tip. If the fruit was ripe, i.e. 8.8–13.2 N, it was labeled, the firmness recorded and used for taste. A sample for aroma consisted of one whole, ripened (selected by touch for ripeness), unblemished fruit of the cultivar-source to be tested. A sample for taste consisted of two longitudinal slices cut from the stem end to the blossom end of the fruit on the cheek opposite the flesh firmness measurement of the cultivar-source to be tested. Judges scored a sample for each sensory attribute by circling a hatch mark placed at increments of 0.5 on a 10-cm horizontal line anchored 1 cm from both ends of the line by "none" and "more" (plum aroma and flavor intensity) or "less" and "more" (sweetness and sourness). Labeled references at room temperature (20 °C) were provided at each session: sweet less (SSC = 8.1%, TA = 0.72%), sweet more (SSC = 16.0%, TA = 0.71, sour less (SSC = 11.0%, TA = 0.31%), sour more (SSC = 11.0%, TA = 1.19, flavor none (water), flavor more (100% Kern's peach nectar), aroma none (water), and aroma mid (100% Kern's peach nectar). Judges cleansed their nostrils between samples by inhaling and exhaling deeply two to three times. Judges cleansed their palates between samples and references with drinking water. After the aroma and taste evaluation, flesh firmness was measured on the aroma samples (2004) as previously described. Then, on all of the previously labeled fruit samples (aroma and taste), a longitudinal wedge was removed from the same area as the flesh firmness measurement, placed between two layers of cheesecloth and the juice expressed for subsequent soluble solids concentration (SSC) and titratable acidity (TA) measurements. TA was measured with an automatic titrator (Radiometer, Copenhagen, Denmark) and expressed as percent malic acid.

### *2.2. Data analysis*

The relationship between cultivar-source and perception of sensory attributes by a trained panel and fruit chemical composition (SSC and TA) was calculated by using the SAS program. Data were subjected to ANOVA and correlation analysis. After that means were separated using LSD means separation at the 5% and 1% levels using the SAS statistical software (SAS Institute, Cary, NC). As source did not affect the perception of sensory attributes, cultivars were segregated into groups according to the average of their sources by organoleptic characteristics by using an agglomerative hierarchical clustering (AHC) protocol (XLSTAT version 5.1, Addinsoft, New York, USA). This analysis was applied to the data in order to identify particular clusters of cultivars with similar sensory attributes. These calculations were made using the Euclidian distance with Ward's method as segregation criterion. The coordinates of the cluster centroids were used to calculate a principal component analysis (PCA) in order to characterize the attributes of each cluster of cultivars (Serrano-Megías and López-Nicolás, 2006; Ward, 1963).

## 3. Results and discussion

In general, early season plum cultivars had lower RSSC than late season plum cultivars while RTA was not related to time of season (Table 1). Mean RSSC measured on the ripe plum cultivars (8.8–13.2 N) ranged from 9.0% ('Earliqueen') to 19.8% ('October Sun') and mean RTA ranged from 0.18% ('Friar') to 0.87% ('Earliqueen'). In the four pluot cultivars tested, RTA was similar among them at approximately 0.40% and the RSSCs were greater than or equal to 12.4%. 'Flavorosa', an early season pluot, had a higher RSSC and lower RTA than the early season plums, 'Earliqueen' and 'Royal Zee' (Table 1). In all these cultivars, the RTAs were lower than the values (∼0.70–1.00%) measured on other typical early season California plums ('Blackamber') over many years. Source significantly affected the RSSC and RTA levels within each cultivar, except for 'Purple Majesty' in which source did not affect RSSC and 'October Sun' in which source did not affect RTA (Table 2).

In all of the cultivars tested, harvesting above their physiological maturity and within the tested quality attribute parameters, source did not significantly affect sweetness, plum flavor inten-

Table 2
Significance (*p*-values) of correlation between four sources each per cultivar of plum and pluot cultivars and perception of sensory attributes by a trained panel and fruit chemical composition

| Species | Cultivar | Sweetness | Sourness | Flavor | Aroma | RSSC | RTA |
|---|---|---|---|---|---|---|---|
| Plum | Betty Anne | 0.13 | 0.16 | 0.34 | 0.58 | <0.0001 | <0.0001 |
| Plum | Blackamber | 0.36 | 0.33 | 0.56 | 0.45 | <0.0001 | <0.0001 |
| Plum | Earliqueen | 0.15 | 0.10 | 0.12 | 0.008 | <0.0001 | <0.0001 |
| Plum | Fortune | 0.61 | 0.80 | <0.018 | 0.78 | <0.0001 | <0.0001 |
| Plum | Hiromi Red | 0.24 | 0.31 | 0.12 | 0.20 | <0.0001 | <0.0001 |
| Plum | Joanna Red | 0.22 | 0.69 | 0.15 | 0.007 | <0.0001 | 0.0035 |
| Plum | October Sun | 0.76 | 0.97 | 0.89 | 0.92 | <0.0001 | 0.55 |
| Plum | Purple Majesty | 0.49 | 0.93 | 0.57 | 0.16 | 0.08 | <0.0001 |
| Plum | Royal Zee | 0.30 | 0.76 | 0.25 | 0.38 | 0.002 | <0.0001 |
| Pluot | Flavorich | 0.20 | 0.04 | 0.68 | 0.91 | <0.0001 | <0.0001 |

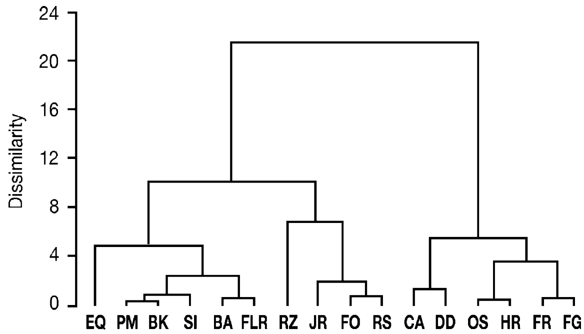


Fig. 1. Dendrogram of 12 plum and four pluot cultivars originating from different breeding programs according to their organoleptic characteristics as perceived by a trained panel and segregated according to Ward methodology. (Letter codes represent cultivars listed in Table 1).

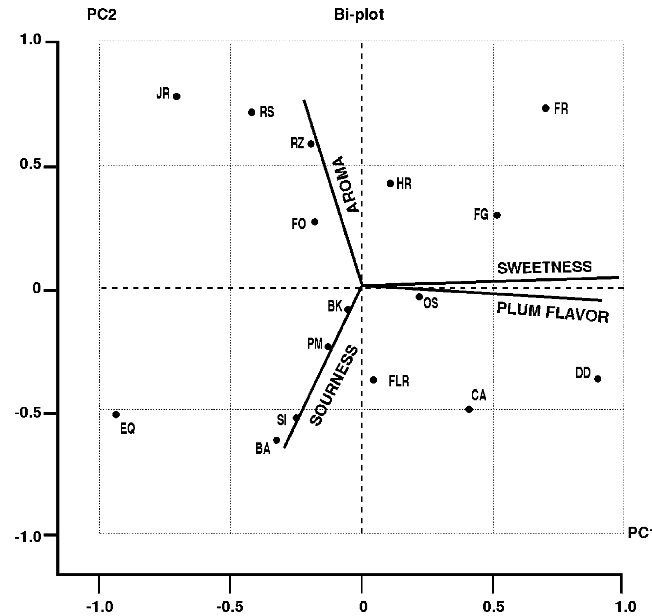


Fig. 2. Segregation of 12 plum and four pluot cultivars originating from different breeding programs according to their organoleptic characteristics as perceived by a trained panel and determined by principal component analysis (PCA). PC1 (49.8%) is plotted on the *X*-axis and PC2 (25.5%) on the *Y*-axis with the vectors representing the loadings of sensory data along with the principal component scores.

sity, plum aroma intensity or sourness perception even though sources differed significantly in RSSC and RTA (Table 2).

### 3.1. Organoleptic segregation

Principal component analysis was used to segregate cultivars into different organoleptic groups after using the agglomerative hierarchical clustering (Fig. 1). The perception of the four sensory attributes (sweetness, sourness, plum flavor intensity, and plum aroma intensity) was reduced to three principal components, which accounted for 98.6% for plums and pluots of the variation in the sensory attributes of the tested cultivars. PC1 accounted for 49.8% of the variability and it was positively loaded for sweetness (0.697) and plum flavor (0.668). In this model, sourness (−0.212) and plum aroma (−0.150) had little representation. Similar to PC1, PC2, which accounted for 25.5% of the variation, had high positive loading (0.731) for plum aroma and low for sweetness (0.160), while sourness was very high but negative (−0.678) and plum flavor (−0.068) was very low. Contrary to PC1 & PC2, in the PC3 model, all of the loading components were positive; sweetness (0.686) and plum aroma (0.662) had the highest values (Table 3).

By plotting the 12 plum and four pluot cultivars sensory attributes in the two most important principal components (PC1 = 49.8% and PC2 = 25.6%) they were segregated into three groups: tart, plum aroma, and sweet/plum flavor (Fig. 2). Cultivars plotted near the vector representing the sensory loading for sourness and distant from the sweetness and plum flavor vectors were classified in the tart group. These cultivars, ‘Earliqueen’, ‘Purple Majesty’, ‘Blackamber’, ‘Simka’, ‘Betty Anne’, and ‘Flavorich’ were characterized by high sourness and low sweetness/plum flavor. Cultivars plotted near the vector representing the plum aroma were classified in the plum aroma group. These

Table 3
Component loadings for sensory attributes and component scores for 12 plum and four pluot cultivars

| Attribute | Component loadings | | | Component scores | | | |
|---|---|---|---|---|---|---|---|
| | PC1, $\lambda = 49.8\%$ | PC2, $\lambda = 25.5\%$ | PC3, $\lambda = 23.3\%$ | Cultivar | PC1 | PC2 | PC3 |
| Sweetness | 0.697 | 0.160 | 0.071 | BA | −0.853 | −1.330 | −0.576 |
| Sourness | −0.212 | −0.678 | 0.686 | BK | −0.055 | −0.250 | 0.736 |
| Plum flavor | 0.668 | −0.068 | 0.293 | CA | 1.217 | −1.042 | −0.020 |
| Plum aroma | −0.150 | 0.731 | 0.662 | DD | 2.654 | −0.799 | 0.627 |
| | | | | EQ | −2.658 | −1.091 | 0.139 |
| | | | | FG | 1.517 | 0.534 | −0.329 |
| | | | | FLR | 0.185 | −0.820 | −0.664 |
| | | | | FO | −0.463 | 0.475 | −0.354 |
| | | | | FR | 2.072 | 1.402 | 0.160 |
| | | | | HR | 0.352 | 0.787 | −1.068 |
| | | | | JR | −2.003 | 1.479 | −1.063 |
| | | | | OS | 0.675 | −0.152 | −1.496 |
| | | | | PM | −0.318 | −0.527 | 0.029 |
| | | | | RS | −1.150 | 1.364 | 0.273 |
| | | | | RZ | −0.510 | 1.088 | 2.485 |
| | | | | SI | −0.664 | −1.119 | 1.121 |

Table 4
Coefficients of determination ($r^2$) between ripe fruit chemical attributes and sensory attributes as perceived by a trained panel for 12 plum and four pluot cultivars

| | Sweetness | Sourness | Flavor intensity | Aroma |
|---|---|---|---|---|
| RSSC | 0.32** | NS | 0.27** | 0.48*** |
| RTA | NS | NS | NS | NS |
| RSSC/RTA | 0.29** | NS | 0.28** | NS |

** Significant at 1% level.
*** Significant at 0.1% level.

cultivars, ‘Royal Zee’, ‘Joanna Red’, ‘Fortune’, and ‘Flavorosa’ were characterized by a strong plum aroma. Cultivars plotted near the vectors representing the sensory loadings for sweetness and plum flavor vectors were classified in the sweet/plum flavor group, and included cultivars ‘Catalina’, ‘Dapple Dandy’, ‘October Sun’, ‘Hiromi Red’, ‘Friar’ and ‘Flavor Grenade’.

The relationships between fruit chemical composition and perception of sensory attributes were significant and similar for plums and pluots (Table 4). For cultivars picked above their physiological maturity, RSSC was significantly correlated with the perception of sweetness, plum flavor and plum aroma intensity, but not to sourness. The RSSC:RTA was correlated only with sweetness and plum flavor intensity but not with aroma intensity or sourness. These relationships were significant, but their levels were very low. The fact that RTA did not affect any sensory attribute can be explained by the low RTA of the cultivars used in this study. We previously reported that for ‘Blackamber’, an early season dark plum with high acidity, RTA (≥1.00%) played a significant role in consumer acceptance only on fruit with RSSC less than 12.0% (Crisosto et al., 2004). However, the RTA influence disappeared on fruit with RSSC ≥12.0%. For another important plum cultivar, ‘Fortune’ a full red plum with moderate acidity, RTA did not play a role at all. Thus, our recent “in store” consumer tests carried out using ‘Blackamber’ (tart group) and ‘Fortune’ (plum aroma group) indicated that fruit with RSSC ≥12.0% resulted in high consumer acceptance and it was controlled by RSSC (Crisosto et al., 2004). Further execution of more “in store” consumer tests to develop a minimum quality index and a survey of the chemical composition of other cultivars should be tested in our proposed system. In the meantime, a minimum quality index of 12.0% RSSC is being proposed for California plum cultivars based on our “in store” consumer work (Crisosto et al., 2004). Our information suggests that an electronic sorting device that measures RSSC could be used to segregate fruit populations based on consumer acceptance during the packing line operation. Near infrared (NIR) spectroscopic techniques have been developed for nondestructive assessment of internal quality characteristics of produce such as soluble solids content and total solids content (Slaughter and Abbott, 2004). This NIR technology to sort fruit based on RSSC is commercially available but implies an extra cost. Therefore, prior to installing a NIR detector, it is important to determine how much of your cultivars’ fruit population will exceed any proposed quality index. For example, according to the RSSC variability measured in our cultivar samples, 100% of the fruit from 10 out of the 14 tested cultivars would exceed this 12.0% RSSC. However, 60% of the ‘Blackamber’ and ‘Flavorosa’ fruit had RSSC ≥12.0%, while only 27% of the ‘Royal Zee’ and none of the ‘Earliqueen’ fruit were above our proposed quality index. Several techniques such as harvest date, crop load adjustments, training system, irrigation and others can be used to increase the population of fruit exceeding a proposed RSSC, but each cultivar has a limited RSSC and/or RTA range (Crisosto et al., 1997). Currently, breeding programs are producing early ripening cultivars with low RTAs and high RSSCs to increase the sweetness and plum flavor.

Because fruit source did not affect cultivar organoleptic classifications when fruit were harvested above their physiological maturity, this proposed organoleptic classification should be attempted after validation with “in store” consumer tests.

According to our current knowledge on plum quality attributes, we recommend a postharvest handling system that delivers plum and pluot cultivars that exceed 12.0% RSSC, grouped according to their organoleptic characteristics and delivered to consumers close to their “ready to eat” stage. The establishment of this delivery system will assure satisfaction of a high percentage of consumers, help match consumer preferences, enhance consistent flavor delivery, and, therefore, increase plum and pluot consumption.

## Acknowledgements

The California Department of Food and Agriculture (CDFA) and the California Agricultural Technology Institute, California State University, Fresno provided economic support for this work.

## References

Abdi, N., McGlasson, W.B., Holford, P., Williams, M., Mizrahi, Y., 1998. Responses of climacteric and suppressed-climacteric plums to treatment with propylene and 1-methylcyclopropene. Postharvest Biol. Technol. 14, 29–39.

Anon., 2004. Fruit and tree nuts: situation and outlook yearbook. United States Department of Agriculture, Economic Research Service, TFS-271.

Argenta, L.C., Krammes, J.G., Megguer, C.A., Amarante, C.V.T., Mattheis, J., 2003. Ripening of ‘Laetitia’ plums following harvest and cold storage as affected by inhibition of ethylene action. Pesqui. Agropecu. Bras. 38 (10), 1139–1148.

Ceponis, M.J., Cappellini, R.A., 1987. Disorders in plum, peach, and nectarine shipments to the New York market, 1972–1985. Plant Dis. 71 (10), 947–952.

Crisosto, C.H., 2005. Plum ripening. Cent. Valley Postharvest Newslett. 14 (4).

Crisosto, C.H., Crisosto, G.M., 2001. Understanding consumer acceptance of early harvested ‘Hayward’ kiwifruit. Postharvest Biol. Technol. 22, 205–213.

Crisosto, C.H., Crisosto, G.M., 2002. Understanding American and Chinese consumer acceptance of ‘Redglobe’ table grapes. Postharvest Biol. Technol. 24, 155–162.

Crisosto, C.H., Johnson, R.S., Day, K.R., DeJong, T., 1997. Orchard factors affecting postharvest stone fruit quality. HortScience 32 (5), 820–823.

Crisosto, C.H., Crisosto, G., Watkins, M., 1998. Chemical and organoleptic description of white flesh nectarines and peaches. Acta Hortic. 465, 497–505.

Crisosto, C.H., Mitchell, F.G., Ju, Z., 1999. Susceptibility to chilling injury of peach, nectarine, and plum cultivars grown in California. HortScience 34, 1116–1118.

Crisosto, C.H., Crisosto, G.M., Metheney, P., 2003. Consumer acceptance of 'Brooks' and 'Bing' cherries is mainly dependent on fruit SSC and visual skin color. Postharvest Biol. Technol. 28, 159–167.

Crisosto, C.H., Garner, D., Crisosto, G.M., Bowerman, E., 2004. Increasing 'Blackamber' plum (*Prunus salicina* Lindell) consumer acceptance. Postharvest Biol. Technol. 34, 237–244.

Crisosto, C.H., Crisosto, G.M., Echeverria, G., Puy, J., 2006. Segregation of peach and nectarine (*Prunus persica* (L.) Bastch) cultivars according to their organoleptic characteristics. Postharvest Biol. Technol. 39, 10–18.

Kappel, F., Fisher-Fleming, B., Hogue, E., 1996. Fruit characteristics and sensory attributes of an ideal sweet cherry. HortScience 31, 443–446.

Lawless, H.T., Heymann, H., 1998. Sensory evaluation of food: principles and practices. In: Food Science Texts Series. Chapman & Hall, New York, 827 pp.

Liverani, A., Giovannini, D., Brandi, F., 2002. Increasing fruit quality of peaches and nectarines: the main goals of ISF-FO (Italy). Acta Hortic. 592, 507–514.

Macchi, E., 2006. I Consumi delle famiglie. In calo I consume. Acquista al dettaglio di susine in Italia. Frutticoltura 3, 4–5.

Marsh, K., Attanayake, S., Walker, S., Gunson, A., Boldingh, H., Macrae, E., 2004. Acidity and taste in kiwifruit. Postharvest Biol. Technol. 332, 159–168.

Mitchell, F.G., 1987. Influence of cooling and temperature maintenance on the quality of California grown stone fruit. Rev. Int. Froid 10, 77–81.

Nelson, K.E., Baker, G.A., Winkler, A.J., Amerine, M.A., Richardson, H.B., Jones, F.R., 1963. Chemical and sensory variability in table grapes. Hilgardia 34 (1), 1–42.

O'Mahony, M., 1986. Sensory Evaluation of Food. Marcel Dekker Inc., New York.

Plich, H., 1999. The effect of storage conditions and date of picking on storability and quality of some plum (*Prunus domestica* L.) cultivars. Acta Hortic. 485, 301–307.

Serrano-Megías, M., López-Nicolás, J.M., 2006. Application of agglomerative hierarchical clustering to identify consumer tomato preferences: influence of physiochemical and sensory characteristics on consumer response. J. Sci. Food Agric. 86, 493–499.

Slaughter, D.C., Abbott, J.A., 2004. Analysis of fruits and vegetables. In: Near-Infrared Spectroscopy in Agriculture. Agronomy Monograph No. 44. Am. Soc. of Agronomy, Crop Sci. Soc. of Am. Soil Sci. Soc. of Am. Madison, WI, USA.

Streif, J., 1989. Storage behavior of plums. Acta Hortic. (Wageningen) 258, 177–184.

Taylor, M.A., Jacobs, G., 1993. Physiological factors associated with overripeness, internal breakdown and gel breakdown in plums stored at low temperature. J. Hortic. Sci. 68 (5), 825–830.

Taylor, M.A., Rabe, E., 1994. Effect of storage regimes on pectolytic enzymes, pectic substances, internal conductivity and gel breakdown in cold stored 'Songold' plums. J. Hortic. Sci. 69 (3), 527–534.

Taylor, M.A., Rabe, E., 1995. Effect of harvest maturity on pectic substances, internal conductivity, soluble solids and gel breakdown in cold stored 'Songold' plums. Postharvest Biol. Technol. 5 (4), 285–294.

Tomas-Barbera, F.A., Gil, M.I., Kader, A.A., 2001. HPLC–DAD–ESIMS analysis of phenolic compounds in nectarines, peaches, and plums. J. Agric. Food Chem. 49, 4748–4760.

Ward, J.H., 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58, 236–244.

Wills, R.B.H., Scriven, F.M., Greenfield, H., 1983. Nutrient composition of stone fruit (*Prunus* spp.) cultivars: apricot, cherry, nectarine, peach and plum. J. Sci. Food Agric. 34 (12), 1383–1389.