HARVESTING AND FIELD PACKING OF TREE-RIPENED PEACH FRUITS, CRITICAL EVALUATION

A. GUARNIERI, R. MARTELLI*, A. BERARDINELLI and L. VANNINI
Department of Agricultural and Food Sciences, University of Bologna, Viale Fanin 50, 40127 Italy
*Corresponding author: roberta.martelli@unibo.it

ABSTRACT

To satisfy consumer demand for riper fruits, a system for field packing stone fruits was set up based on an experimental electrical traction platform. Tree-ripened peaches and nectarines were sorted and field packed in plastic clamshell containers and delivered directly to retail outlets. Productivity and fruit characteristics such as size, flesh firmness and soluble solids concentration were evaluated. While the observed working capacity was comparable to that of conventional harvesting systems, the fruit characteristics (size and flesh firmness) did not always meet the required consumer-oriented higher quality standards.

- Keywords: consumer acceptance, field packing, flesh firmness, *Prunus persica*, ripeness, soluble solids concentration -

INTRODUCTION

In a standard supply chain, after harvesting, fresh fruits are transported to packing houses where they are sorted, packed and sometimes refrigerated before marketing (SHEWFELT and PRUSSIA, 2009). The sorting and packing processes are usually performed automatically by machines which play a major role in the occurrence of skin damage and product down-grading (RAGNI and BERARDINELLI, 2001). According to the European Commission Regulation (EC, 1221/2008) on marketing standards, there should be no mechanical injuries with the possible consequent degenerative processes on fresh fruits belonging to the "extra" categories (tolerance of 10%).

These quality standards are met by harvesting at an early stage of maturity as higher values of flesh firmness reduce the probability of damage (BERARDINELLI *et al.*, 2006), but this practice precludes the achievement of ideal ripeness (ROBERTSON *et al.*, 1992).

The determination of stone fruit maturity depends on the combination of parameters such as ground color, firmness and size (CRISOSTO, 1994). Fruit flesh firmness and soluble solids concentration (SSC) are the main indices related to quality as perceived by the consumer. The SSC at the same acidity level, is related to the perception of fruit sweetness intensity; values higher than 9.5% identify peaches with an acceptable taste for quality fruit production (ALAVOINE *et al.*, 1988). Flesh firmness is one of the best indicators of ripeness and a predictor of shelf life (CRISOSTO, 1994). Even if it is not possible to define universally accepted values of flesh firmness which identify the fruit maturity level, CRISOSTO (2002) reported that fruit are considered "ready to buy" at 26.5-35.3 N and "ready to eat" at 8.8-13.2 N and DI MICELI *et al.* (2010) indicated that values higher than 53.9 N always resulted in unacceptable fruit. However, when the product has little handling or is sorted and packed directly in the field the reference range that provides improved organoleptic characteristics can reach lower values of firmness (CRISOSTO and VALERO, 2008).

Several researches have shown that the intensity and gradation of skin color, fruit size, together with eating quality (flavor, taste and texture), influence consumer acceptance and therefore sales (BRUHN, 1991a, b; HARKER, 2001; GARITTA *et al.*, 2008) and that very often flavor components never reach levels that can provide an acceptable or good flavor (BASSI and SELLI, 1990; CRISOSTO *et al.*, 2001). More generally consumer dissatisfaction is mainly related to the lack of ripeness (HERRERO-LANGREO *et al.*, 2012) and especially to flesh hardness and lack of flavor (CRISOSTO *et al.*, 2006; IGLESIAS and ECHEVERRÍA, 2009). This dissatisfaction is reflected directly on consumption. For example, CLARETON (2000) reports that as many as 80% of consumers in France are dissatisfied with peach quality. The reduction in peach consumption observed in Italy in recent years was also mostly attributed to the low product quality which was not appreciated by consumers because harvested when unripe or characterized by a heterogeneous maturity level (DELLA CARA, 2005). The quality of peaches can be improved if the fruits are harvested at a later stage of physiological maturity. In fact, early harvesting compromises quality and disappoints consumer expectations since peach flavors are only produced on the plant at the advanced maturity stage (ROBERTSON *et al.*, 1992). Consumer demand for a ripe product contrasts with the current methods of harvesting in big containers such as field bins or crates, which are not suitable for tree-ripened fruits that are to be delivered directly to retail outlets.

To improve the organoleptic quality of fresh fruits and consumer satisfaction some post-harvest processes such as sorting and packing could be done directly in the field during the harvest, which would allow more mature fruit to be picked. It is evident that this "freshly picked fruit" product has a limited shelf life, requires specific packaging and should be delivered directly to retail outlets through a suitable supply chain. Field packing systems for vegetables and fruits are gaining importance mainly due to the lower cost compared to packinghouse facilities and fewer injuries to the product because of reduced handling (KADER, 2002; CRISOSTO and VALERO, 2008). Few studies have considered the efficiency of field packing systems of fruits in terms of consumer-oriented quality improvement. A type of fruit called "Tree Ripe" was evaluated on the U.S. market that are usually harvested when more mature and packed on small, labor intensive hand packing lines, because they cannot withstand the rigors of typical commercial packing lines (MITCHELL *et al.*, 1989).

SHEWFELT *et al.* (1989) verified that harvesting of more mature peaches with packing in the orchard results in a quality superior to packinghouse peaches even if losses for field packed peaches were higher than packinghouse fruits, probably due to a lack of careful grading by the pickers in the orchard. However, the authors do not describe the field packing method considered.

In many typical areas for the production of stone fruits in Italy, it has become customary to set up the harvester for the housing of single-layer wooden boxes to field pack fruits and obtain more mature produce that is easy to sell. Preliminary economic analysis were carried out to evaluate the efficiency of these harvesting systems (VANNINI, 1999). Studies have also shown that high-quality stone fruits may obtain higher prices than lower quality fruits harvested beyond the minimum maturity stage (BRUHN, 1991a; JORDAN *et al.*, 1990; PARKER *et al.*, 1990).

Based on the concept of providing the consumer with optimum quality, the Growers Cooperative Terremerse (Ravenna, Italy) and a large-scale retail trade company Coop Italia (Bologna, Italy), as part of the project "Appena Colta" (*freshly picked*), involved some local farms in marketing fruits with a high level of ripeness. Firmness values in the range 14.7-34.3 N were considered suitable for stone fruits for immediate consumption without further handling (MAZZINI *et al.*, 2007). In collaboration with the Cooperative Terremerse, this paper assesses a system for harvesting stone fruits with a high level of ripeness using an experimental electrical traction platform set up for field harvesting, sorting and packing peaches and nectarines.

MATERIALS AND METHODS

The harvesting, sorting and packing operations were carried out by a self propelled experimental field packing system. The vehicle was a platform with electrical traction constituted by two components (Fig. 1). The first was a self-propelled working platform manually operated by a shaft. Manual sorting and packing were done on this component. These operations were performed by two pickers, one on either side of the platform, who separately picked, sorted and packed according to three size classes: AAA (80 and over but under 90 mm), AA (73 and over but under 80 mm) and A (67 and over but under 73 mm) (EC, 1221/2008). The second component was a farm cart used to transport the empty packaging and the packaged product.

The field testing was conducted on a farm in the province of Ravenna, northeast Italy, considering two cultivars of *Prunus persica* (L.), Batsch

Fig. 1 - Platform for sorting, harvesting and packing fruits. 1, self-moving working platform; 2, farm cart for transport.

Fig. 2 - Sorting and packaging operations.

Rome Star (peach) and Sweet Red (nectarine), and two growers highly experienced in the selection of freshly picked fruits. Both orchards were 4 years old, trained to delayed vase, and planted with a distance of 5.5 m between rows and 3.5 m between trees on a row. The agronomic management of the orchards was aimed at obtaining fruits with a high level of flavor. In particular, the nitrogen fertilization and pruning were done before the fruit stone hardening and when fruits were 8-10 mm in diameter, respectively. These were followed by green pruning.

The picking, sorting and packing processes were conducted with the vehicle in stationary mode by two pickers who assessed the maturity level on the basis of their experience. The pickers worked in the inter-row area on either side of the platform. After picking, they placed the fruits on a side support attached to the packaging area by a revolving arm. After reaching a weight of 2-3 kg (about 25 peaches), the fruits were sorted using a fixed metallic sizer and packed in different clamshell plastic containers (jardipack®, Groupe Guillin, Ornans, France) according to size class (Fig. 2). The boxes, containing 4 fruits each, were then placed in collapsible crates (0.60 x 0.37 m, CPR System, Bologna, Italy) (6 boxes per crate). The tasks that completed the field operations involved placing the empty packaging and the packaged product on the second component of the vehicle, then transferring the crates onto an open lorry.

To assess the productivity of the field harvesting, handling and packing processes, the following working parameters were measured:
time(s) required for vehicle relocation;
time(s) required for fruit picking and basket filling;
time(s) required for fruit sorting;
time(s) required for fruit packaging;
time(s) required for transferring crates from the second component onto the open lorry;
global working time(s), including the time required

for placing the empty packaging on the platform; mass (g) of the total harvested product.

Work quality assessment was conducted considering both cultivars, two pickers and three size classes (A, AA, AAA), the mass (g) and diameter (mm) were measured on samples of 12 randomly selected fruits. The flesh firmness (N) was determined using a fruit texture analyzer (Guss Manufacturing Ltd., Strand, South Africa) and soluble solids concentration SSC (%) was assessed using a digital refractometer (Atago, Model PR 101). The mean value of two measurements conducted on two different peeled sides of the same fruit was considered. Data were statistically analyzed using SPSS software (SPSS 13.0 for Windows, IBM SPSS Statistics). Statistical differences between means were tested by Analysis of Variance (ANOVA) according to Tukey's HSD ($P<0.05$). Levene's test ($P<0.05$) was used to test the homogeneity of variances.

RESULTS AND DISCUSSION

Working capacity

Sorting and packing phases required more time (52.2%) than that necessary for fruit picking and basket filling (35.8%). On the whole, the main operations (fruit picking, basket filling, sorting and packaging) required 88% of the total working time. The remaining 12% was equally distributed between the complementary processes: vehicle relocation (3.3%), packaging transfer (4.2%), other times (4.4%).

A mean working capacity of 87.8 kg$\times$h^{-1} (396.5 fruits$\times$h^{-1}) and 82.1 kg$\times$h^{-1} (393.2 fruits$\times$h^{-1}) was observed for Rome Star and Sweet Red cultivars, respectively.

Quality parameters

Average values, standard deviations, min and max values calculated for the mass (g) and diameter (mm) of the sampled fruits together with the percentage of fruits belonging to each class are summarized in Table 1. Most packed fruits were in size class AA (54% for "Rome Star" and 47% for "Sweet Red"), while classes A (17%) and AAA (9%) were the least represented for Rome Star and Sweet Red cultivars respectively. The correspondence between the effective diameter of packed fruit and that indicated on the packaging is shown in Table 2. For the size classes A and AA, about 10% of fruits differed in size from that indicated on the packaging, apart from "Rome Star" class A (19%). For size class AAA, the correspondence between the declared and effective classification was very low: 52% of "Rome Star" and 56% of "Sweet Red" fruits were erroneously packed. The pickers were inclined to overestimate the fruit size and wrongly pack more than 50% of fruits in class AAA when in fact they corresponded to class AA. In size class AAA about 52% of fruits of both cultivars had a smaller diameter (3 mm less) than that indicated. However, according to the European Regulation (1221/2008/EC), a maximum of 10% of fruits with a diameter less than that declared meets the criteria of tolerance. Analyzing the fruit size distribution within the same cultivar, picker and size class (Table 3), no significant dif-

Table 1 - Peach cultivar size attributes (mass and diameter) and percentage of fruits in each box size class.

Cultivar	Size class	Mass (g)				Diameter (mm)				N° of fruits (%)
		X	SD	Min	Max	X	SD	Min	Max	
Rome Star	A	180	16	154	240	71	2	66	79	17
	AA	217	15	190	254	76	2	68	80	54
	AAA	261	17	232	312	80	2	77	86	29
Sweet Red	A	182	13	154	206	69	2	66	72	47
	AA	225	13	196	250	75	2	72	78	44
	AAA	276	20	240	330	80	2	75	87	9

Table 2 - Percentage of fruits corresponding to the size class declared on the packaging.

Declared size	Cultivar	A			AA			AAA		
		Picker 1	Picker 2	Total	Picker 1	Picker 2	Total	Picker 1	Picker 2	Total
Corresponding	Rome Star	75	88	81	100	83	92	50	46	48
	Sweet Red	88	92	90	96	83	90	33	54	44
Overestimated	Rome Star	8	4	6	0	17	8	50	54	52
	Sweet Red	13	8	10	4	17	10	67	46	56
Underestimated	Rome Star	17	8	13	0	0	0	0	0	0
	Sweet Red	0	0	0	0	0	0	0	0	0

Table 3 - Fruit diameter (mm) by picker within different size classes.

Cultivar	Picker	A				AA				AAA			
		X	SD	Min	Max	X	SD	Min	Max	X	SD	Min	Max
Rome Star	1	71.4 a	2.6	66.8	78.8	76.0 a	1.5	73.5	78.7	80.4 a	2.0	77.7	85.7
	2	69.9 b	1.9	66.1	74.3	75.5 a	2.7	68.3	80.0	80.2 a	2.0	77.0	83.5
Sweet Red	1	69.2 a	1.5	66.0	71.5	74.3 a	1.3	72.5	77.0	79.6 a	2.2	74.5	84.0
	2	69.2 a	1.8	65.5	72.0	74.9 a	1.9	71.5	78.0	80.0 a	2.7	75.5	87.0

Different letters indicate significant differences within the same cultivar and size class according to Tukey's HSD, P<0.05.

Table 4 - Flesh firmness (N) within different size classes.

Cultivar	A				AA				AAA			
	X	SD	Min	Max	X	SD	Min	Max	X	SD	Min	Max
Rome Star	48.5 a	18.3	6.0	78.7	51.1 a	19.0	8.5	80.8	44.8 a	16.5	11.3	65.8
Sweet Red	43.7 a	18.3	8.3	71.8	34.0 b	14.2	4.8	51.3	18.1 b	11.0	4.5	40.6

Different letters indicate significant differences between cultivars according to Tukey's HSD, P<0.05.

Table 5 - Soluble solids concentration (%) within different size classes.

Cultivar	A				AA				AAA			
	X	SD	Min	Max	X	SD	Min	Max	X	SD	Min	Max
Rome Star	11.6 a	1.4	9.1	14.7	11.4 a	1.1	9.1	13.4	12.4 a	1.1	9.6	14.2
Sweet Red	13.3 b	1.0	11.4	14.9	13.6 b	0.8	12.1	15.2	14.0 b	0.8	12.4	15.5

Different letters indicate significant differences between cultivars according to Tukey's HSD, P<0.05.

Table 6 - Percentage of fruits within flesh firmness classes.

Cultivar	Size class	Flesh firmness classes (N)				
		0-14.7	14.7-34.3	34.3-53.9	53.9-73.6	>73.6
Rome Star	A	8	8	46	33	4
	AA	8	8	29	46	8
	AAA	4	21	38	38	0
	Total	7	13	38	39	4
Sweet Red	A	13	13	42	33	0
	AA	17	25	58	0	0
	AAA	50	38	13	0	0
	Total	26	25	38	11	0

ferences were observed apart from "Rome Star" class A. In this case, picker no.1 selected fruits with a significantly larger diameter.

Average values of fruit flesh firmness and soluble solids concentration are given in Tables 4 and 5. In general, "Rome Star" packed fruits showed significantly higher mean values in terms of flesh firmness (N) than the Sweet Red cultivar apart from class A. On the contrary, in terms of SSC (%), highest mean values were observed for "Sweet Red" packed fruits. For flesh firmness the range of variation appeared especially wide for class A (7.6-78.7 N for "Rome Star" and 8.3-71.8 N for "Sweet Red"). A lower range of variation was measured for class AAA (15.5 - 65.8 N for "Rome Star" and 6.4 - 40.6 N for "Sweet Red"). A wide range of variation was also measured for the soluble solids concentration, especially for "Rome Star" class A (9.1-14.7).

The percentages of fruits within flesh firmness and soluble solids concentration classes are shown in Tables 6 and 7 respectively. For the flesh firmness 13% of "Rome Star" and 25% of "Sweet Red" fruits showed values corresponding to the recommended range (14.7-34.3 N). Most "Rome Star" packed fruits showed flesh firmness in the 34.3-53.9 N and 53.9-73.6 N classes and 7% of the packed product was overripe.

Table 7 - Percentage of fruits within soluble solids concentration classes.

Cultivar	Size class	Soluble solids concentration classes (%)				
		<10	10-11	11-12	12-13	>13
Rome Star	A	13	25	29	17	17
	AA	5	40	35	10	10
	AAA	4	8	25	38	25
	Total	7	24	30	21	17
Sweet Red	A	0	0	17	25	58
	AA	0	0	0	17	83
	AAA	0	0	0	8	92
	Total	0	0	6	17	78

For "Sweet Red" fruits, the 34.3-53.9 N class was over represented (38%) while 26% of the product was overripe.

For the soluble solids concentration, about 68% of the "Rome Star" cultivar fruits showed values higher than 11% and overall, the data showed a higher level of SSC related to the fruits of larger diameter. In fact, about 87.5% of the fruits in class AAA had an SSC higher than 11%. The percentage of fruits (7%) with values of SSC lower than 10% is in any case not negligible. For Sweet Red cultivar, no fruits had an SSC lower than 11% (class A) and 12% (classes AA and AAA) while 80% of fruit in classes AA and AAA had an SSC>13%.

Significant differences emerged between mean values calculated for the two pickers in terms of flesh firmness and SSC, apart from the flesh firmness for Sweet Red cultivar (Table 8).

CONCLUSIONS

The retail trade is paying increased attention to providing fruits of high quality to satisfy the consumer demand, especially in terms of a higher level of ripeness that is the primary criterion for the selection of fresh fruits by consumers (NICHOLS, 1993). The proposed system of field packing allows fruit handling and the time between harvesting and consumption to be reduced and is thus suitable for highly perishable tree-ripened fruits.

The average harvesting rates of 76.2 and 88.6 $kg \times h^{-1}$ per picker are comparable to those reported in literature for fruit harvest-aid (REID, 1976; VANNINI, 1999).

With regard to the ability of the pickers to correctly identify the fruit size and place them in clamshell boxes with the right diameter class, the results are not satisfactory and the correspondence between the declared and effective classification decreased passing from the first two classes (A and AA) to the third (AAA). In fact the pickers, even if skilled, were inclined to overestimate the fruit size, assigning a high percentage (> 50%) to the larger size class AAA, even if the mistake involved mainly fruits (52%) that were only 1 mm smaller than the minimum diameter of the class.

In terms of flesh firmness, harvested fruits did not show the required maturity characteristics. In fact, only 12% of "Rome Star" and 25% of "Sweet Red" packed fruits can be considered suitable for distribution as "freshly picked fruit". This is related to the fact that the maturity stage was assessed by a visual observation of the fruit color. These operations are undoubtedly subjective and depend on the experience and sensitivity of the picker (SLAUGHTER *et al.*, 2006). Furthermore, during the sorting process, the pickers also have to check for a wide range of potential defects making this a challenging inspection task (STUDMAN, 1998).

Since the evaluation of fruit ripeness based on skin background color has proved to be inadequate the field packing system should include rapid and non-destructive methods on the harvesting platform for an objective assessment of size and quality parameters (VALERO *et al.*, 2007). Examples of well-known techniques are those based on computer vision for the fruit size (LI *et al.*, 2011; MOREDA *et al.*, 2009) and VIS-NIR (visible-near infrared) spectroscopy for the internal quality parameters (BERARDINELLI *et al.*, 2010; SLAUGHTER, 1995; ZERBINI *et al.*, 2006; ZIOSI *et al.*, 2008).

Given that the manual sorting required a lot of time (23% of the total), the application on the harvesting platform of these evaluation systems of fruit size and ripeness could reduce sorting times and, at the same time, improve the quality of the packed product. In any case the field packing system has been shown to be lacking an expert crew leader to continuously monitor the orchard, de-

Table 8 - Average values of fruit flesh firmness and soluble solids concentration for the two pickers.

Cultivar	Picker	Flesh firmness (N)				Soluble solids concentration (%)			
		X	SD	Min	Max	X	SD	Min	Max
Rome Star	1	42.6 a	16.3	7.8	69.6	11.5 a	1.1	9.1	14.2
	2	53.7 b	18.2	5.9	80.4	12.1 b	1.4	9.1	14.7
Sweet Red	1	30.0 a	16.0	6.5	54.5	14.0 a	0.78	12.1	15.5
	2	33.8 a	20.0	4.5	71.8	13.3 b	0.98	11.4	15.2

Different letters indicate significant differences between pickers and within the same cultivar and parameter according to Tukey's HSD, P<0.05.

termine the optimum harvest maturity stage and oversee the sorting and packing by the field workers. The expert should be considered essential and integral to the field packing process (CRISOSTO and VALERO, 2008) and should be a skilled technician with a decision-making role who could be provided by the growers cooperative that acquires the fruits. So, with the integration of the proposed automated measurement systems, the supervision of an expert and eventually a penalty on the price paid to the producers who do not meet the quality standards, the system could be a good solution for field packing freshly picked peach fruits. Finally, given that the system could convey part of the valued added directly to the growers, the higher costs incurred for the improved sorting process may be balanced by increased revenue compared to that from traditional fruits.

ACKNOWLEDGEMENTS

The research was carried out within the "Appena Colta" (freshly picked) project in collaboration with Cooperative Terremerse (Italy).

REFERENCES

Alavoine F., Crochon C., Fady C., Fallot J., Moras P. and Pech J.C. 1988. Taste quality in fruit practical methods of analysis. Aixen-Provence: Cemagref.

Bassi D. and Selli R. 1990. Evaluation of fruit quality in peach and apricot. Adv. Hort. Sci 4, 107-111.

Berardinelli A., Donati V., Giunchi A., Guarnieri A. and Ragni L. 2006. Mechanical behavior and damage of pink lady apples. Appl. Eng. Agric. 22: 707-712.

Berardinelli A., Cevoli C., Silaghi F.A., Fabbri A., Ragni L., Giunchi A. and Bassi D. 2010. FT-NIR spectroscopy for the quality characterization of apricots (*Prunus Armeniaca* L.). J. Food Sci. 75(7): 462-468.

Bruhn C.M. 1991a. Consumer perception of quality. Perish. Handl. Newsl. 72: 4-9.

Bruhn C.M. 1991b. Consumer perceptions of quality: apricots, cantaloupes, peaches, pears, strawberries and tomatoes. J. Food Sci. 14: 187-195.

Clareton M. 2000. Peach and nectarine production in France: trends, consumption and perspectives. In: Summaries Prunus Breeders Meeting, 83-91. EMBRAPA, clima temperado Pelotas (RS), Brazil.

Commission Regulation (EC) No. 1221/2008 of 5 December. 2008. Amending Regulation (EC) No. 1580/2007 laying down implementing rules of Council Regulations (EC) No. 2200/96. (EC) No. 2201/96 and (EC) No. 1182/2007 in the fruit and vegetable sector as regards marketing standards. Official Journal of the European Union. Vol. 51. L336.

Crisosto C.H. 1994. Stone fruit maturity indices: a descriptive. Postharvest News and Information 5(6): 65-68.

Crisosto C.H., Slaughter D., Garner D. and Boyd J. 2001. Stone fruit critical bruising thresholds. J. Amer. Pomolog. Soc. 55: 76-81.

Crisosto C.H. 2002. How do we increase peach consumption? Acta Hort. 592: 601-605.

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

Crisosto C.H. and Valero D. 2008. Harvesting and postharvest handling of peaches for the fresh market. Chapter 22, pages 575-596. In: Layne and Bassi (Eds.), The Peach: Botany, Production and Uses. CAB International.

Della Cara R. 2005. In calo i consumi e l'export de pesche e nettarine italiane. Rivista di Frutticoltura 7-8: 19-20.

Di Miceli C., Infante R. and Inglese P. 2010. Instrumental and sensory evaluation of eating quality of peaches and nectarines. Acta Hort. 962: 473-480.

Garitta L., Hough G. and Hulshof E. 2008. Determining optimum ripening time of fruits applying survival analysis statistics to consumer data. Food Qual. Prefer. 19: 747-752.

Harker R. 2001. Consumer response to apples. In Proceedings of the Washington Tree Fruit Postharvest Conference. WSU-TFREC Postharvest Information Network.

Herrero-Langreo A., Fernández-Ahumada E., Roger J.M., Palagós B. and Lleó L. 2012. Combination of optical and non-destructive mechanical techniques for the measurement of maturity in peach. J. Food Eng. 108: 150-157.

Iglesias I. and Echeverría G. 2009. Differential effect of cultivar and harvest date on nectarine colour, quality and consumer acceptance. Sci. Hortic.-Amsterdam 120: 41-50.

Jordan J.L., Shewfelt R.L., Garner J.C. and Variyam J.N. 1990. Estimating the value of internal quality aspects to consumers. Acta Hort. 259: 139-144.

Kader, A.A. (Ed.), 2002. Postharvest technology of horticultural crops, third ed. Cooperative Extension of University of California, Division of Agriculture and Natural Resources, University of California, Davis, CA, Publication no. 3311.

Li P., Lee S.H. and Hsu H.Y. 2011. Review on fruit harvesting method for potential use of automatic fruit harvesting systems. Procedia Engineering 23: 351-366.

Mazzini C., Brasina M., Cecconi R., Bindi V. and Secchi E. 2007. "Appena colta". La filiera corta di Coop e Terremerse. Agricoltura, Regione Emilia-Romagna, Supplemento 35: 25-27.

Mitchell F.G., Mayer G., Biasi W., Gulli D. and Faubion D. 1989. Selecting and handling high quality stone fruit. In: 1989 Research Reports for California Peaches and Nectarines, California Tree Fruit Agreement. Sacramento, California, USA. 15 pp.

Moreda G.P., Ortiz-Cañavate J., García-Ramos F.J. and Ruiz-Altisent M. 2009. Non-destructive technologies for fruit and vegetable size determination. A review. J. Food Eng. 92: 119-136.

Nichols J.P. 1993. Quality in U.S. fruit and vegetable marketing. TAMRC. Series TAMRC Consumer and product market research Report pp. 48.

Parker D.D., Moulton K., Zilberman D. and Johnson R.S. 1990. The profitability of gearing production toward selected quality characteristics in tree fruit. In: Final Report, California Tree Fruit Agreement.

Ragni L. and Berardinelli A. 2001. Mechanical behaviour of apples, and damage during sorting and packaging. J. Agr. Eng. Res. 78: 273-279.

Reid J.T. 1976. The Development of a Harvest-Aid For Tree Wall Peaches T. ASAE 19(2): 222-226.

Robertson J.A., Meredith F.I., Forbus W.R. and Lyon B.G. 1992. Relationship of quality characteristics of peaches (*cv.* Loring) to maturity. J. Food Sci. 57: 1401-1404.

Shewfelt R.L., Prussia S.E. and Garner J.C. 1989. Potential for quality improvement in 'Elberta' peaches by field packing. Acta Hort. 254: 271-274.

Shewfelt R.L. and Prussia S.E. 2009. Chapter 2: Challenges in handling fresh fruits and vegetables. In Postharvest Handling: A Systems Approach, Second edition, Academic Press, USA.

Slaughter D.C. 1995. Nondestructive determination of internal quality in peaches and nectarines. T. ASAE 38: 617-623.

Slaughter D.C., Crisosto C.H., Hasey J.K. and Thompson J.F. 2006. Comparison of instrumental and manual inspection of clingstone peaches. Appl. Eng. Agric. 22: 883-888.

Studman C. 1998. Ergonomics in apple sorting: A pilot study. J. Agric. Engng. Res. 70: 323-334.

Valero C., Crisosto C.H. and Slaughter D. 2007. Relationship between nondestructive firmness measurements and commercially important ripening fruit stages for peaches, nectarines and plums. Postharvest Biol. Tec. 44: 248-253.

Vannini L. 1999. Prove di raccolta organizzata su drupacee. Rivista di Frutticoltura 61: 83-85.

Zerbini P.E., Vanoli M., Grassi M., Rizzolo A., Fibiani M., Cubeddu R., Pifferi A., Spinelli L. and Torricelli A. 2006. A model for the softening of nectarines based on sorting fruit at harvest by time-resolved reflectance spectroscopy. Postharvest Biol. Tec. 39: 223-232.

Ziosi V., Noferini M., Fiori G., Tadiello A., Trainotti L., Casadoro G. and Costa G. 2008. A new index based on vis spectroscopy to characterize the progression of ripening in peach fruit. Postharvest Biol. Tec. 49: 319-329.

Paper received August 26, 2013 Accepted December 4, 2013