Peach Quality and Postharvest Technology

C.H. Crisosto
Department of Plant Sciences
University of California
Davis
USA

Keywords: peach and nectarine consumption, chilling injury, “in-store” consumer acceptance, flavor code, industry surveys, preconditioning, GRAS chemicals

Abstract

New peach cultivars are being planted that have markedly different flavor qualities (low acid, high acid, high soluble solids concentration, highly aromatic, non-melting, etc.), and are reaching new markets with diverse consumer groups. Short- and long-term approaches to maintain flavor are being tested. In the short-term, proper temperature management for packers, shippers, buyers and receivers; and preconditioning/preripening treatments at the shipping point are commercially used with success in California and Chile. Educational and promotional programs on peach handling/ripening for peach shippers, buyers, retailers and consumers have been established as well. In the long-term, programs must address understanding the genetic and biochemical basis of flavor, antioxidant pathways, and the genetic control of chilling injury using available molecular genetics technology. The use of this new information and techniques will allow breeding programs to develop peach cultivars with acceptable flavor, improved antioxidant content and freedom from chilling injury. In addition to the basic research described above, there is the need for applied research focusing on understanding and describing peach quality through sensory evaluation, nondestructive sensors, and industry quality surveys. The role of orchard factors on peach quality also requires study. A classification of current peach cultivars into different organoleptic/flavor groups would be useful. The creation of these specific and well-defined peach flavor groups can be used for promotion and marketing activities focused toward different ethnic groups. Work on postharvest decay control screening different food additives and low-toxicity chemicals as potential alternatives or complements to synthetic fungicides for the control of the most important postharvest pathogens is being carried out. This work needs to be developed further as pesticide residues on produce will become an even greater consumer concern in the future.

INTRODUCTION

Americans eat approximately 2.0 kg of peaches per capita per year. Even though these fruits are seasonal, this value is small in comparison to other fresh fruit consumption such as apples (≈16 kg) and bananas (≈9 kg). One approach to increase peach fruit consumption has been to determine what factors are leading to consumer dissatisfaction and to deal with these issues. Following this approach, research, education and promotional programs must be targeted to respond to these issues. An earlier survey conducted by UC Davis researchers indicated that hard fruit (unripe), mealiness, lack of taste, and failure to ripen are the main reasons consumers do not eat more stone fruit. These complaints are a consequence of two main problems: the fact that consumers do not understand the difference between mature and ripe (“ready to eat”) fruit, and the expression of chilling injury (CI) called internal breakdown (IB) symptoms. After solving these two main problems, a detailed research program focusing on understanding peach quality attributes including sensory evaluation studies using trained panels and consumer tests, industry quality surveys, and evaluation of the role of orchard factors on peach quality attributes should be pursued. A classification of the current peach cultivars into different organoleptic/flavor groups may be accomplished and useful (Peach Flavor

Code). The creation of these specific and well-defined peach flavor groups can be used for promotion and marketing activities focused on different ethnic groups; especially for new peach and nectarine cultivars which are currently being planted that have different organoleptic characteristics than the existing cultivars (Giovannini et al., 2000; Liverani et al., 2002; Byrne, 2003; Crisosto et al., 2004).

SHORT- AND LONG-TERM SOLUTIONS

In the short-term: proper temperature management for packers, shippers, transportation, buyers and receivers, and preconditioning/preripening treatments at the shipping point are commercially used with success in California; and educational promotional programs on peach handling/ripening for peach shippers, buyers, retailers and consumers have been established.

As a long-term solution, programs to understand the genetic and biochemical basis of flavor, antioxidant pathways, and genetic control of CI by using available molecular genetics technology are being developed. The use of this new information and techniques for breeding programs will allow the development of peach cultivars with new flavors and improved antioxidant attributes and freedom from CI susceptibility.

RIPENING PROTOCOLS AT THE RECEIVERS

In California, peaches and nectarines are normally picked when ripening has been initiated (high mature stage), thus producing sufficient ethylene to carry on ripening upon arrival to the warehouse. Therefore, stone fruits harvested at the "high maturity stage" do not need ethylene exposure to ripen properly. The rate of fruit ripening varies among peach cultivars and it is controlled by temperature. A fast rate of ripening is achieved at 20 to 25°C and a low rate of ripening is accomplished by using lower temperatures. Temperatures higher than 25°C will reduce the rate of ripening, inducing off flavors and promoting irregular ripening. White flesh peaches have a fast rate of softening. Flesh firmness is the best indicator of ripening and one predictor of the potential shelf life. Fruits that reach 0.27-0.36 N flesh firmness are considered "ready to buy." Fruits that reach 0.09-0.14 N are considered ripe ("ready to eat"). Thus, the end of ripening is determined by the firmness. We recommend that fruit that arrives in your warehouse or retail store should be tested for flesh firmness using a standard fruit penetrometer (8-mm tip). A ripening protocol based on warming should be established according to the anticipated consumption schedule (fruit turning schedule). Soft fruit is more susceptible to bruising than hard fruit. To reduce potential physical damage occurring during transportation from the warehouse to retail stores and handling at the retail stores, we suggest transferring fruit to the retail store before fruit reaches 0.27-0.36 N for peaches (transfer/shipping point). The establishment of these transfer/shipping points is based only on our previous experience with fruit damage during retail handling. As bruising incidence varies among different retailer operations and among cultivars, you should fine-tune your own transfer points for your conditions. Thus, temperature conditions for peaches during and after ripening should be adjusted according to the desired speed of ripening. The rate of fruit softening (number of days to reach 0.09-0.14 N) varies among peach cultivars and can be controlled by the storage temperature used. For example, high mature California 'O'Henry' peaches are usually harvested and shipped with flesh firmness between 0.45-0.63 N. If these 'O'Henry' peaches arrive at the distribution center with an average firmness of 0.51 N and are placed in the 20ºC room, they will reach 0.09-0.14 N ("ready to eat") after 6 days. To reduce bruises, we recommend that stone fruits be delivered to the retail store before they soften below 0.23-0.27 N. Thus, the 'O'Henry' peach should be delivered to the retail store by day 3 after arrival. These peaches will be ready to eat (0.09 N) by 48 hours after delivery to the retail store. As stone fruits will continue to ripen in the display case, they should be checked often and the softest fruit be placed at the front of the display. Checking fruit firmness daily is highly recommended to control ripening rate. To slow down ripening speed, stone fruits should be kept at low temperatures. Peaches, plums, and nectarines harvested at a lower maturity stage than the "high mature stage" may need added ethylene (100 ppm for 24 hours or longer) to ripen evenly.

PRECONDITIONING AND/OR PRERIPENING (RIPENING AT ORIGIN)

A commercial controlled delayed cooling or preconditioning treatment at the point of origin was developed to extend peach market life of the most popular California peach cultivars. In most of the cases, a 48-h cooling delay at 20ºC was the most effective treatment for extending market life of internal breakdown susceptible peach cultivars without causing fruit deterioration. This treatment increased minimum market life by up to 2 weeks in the cultivars tested (Table 1). Weight loss and softening occurred during the controlled delayed cooling treatments, but did not reduce fruit quality. Detailed monitoring of these fruit quality changes during the delayed cooling period and proper use of fungicides is highly recommended for success in this new fruit delivery system. Rapid cooling after preconditioning is important to stop further fruit deterioration such as flesh softening, senescence, decay and weight loss. Controlled delayed cooling can also be used to pre-ripen susceptible and non-susceptible peaches in order to deliver a "ready to buy" product to the consumer.

This commercial treatment that limits CI and allows flavor expression when applied correctly is being carried out successfully with consistent results under Californian and Chilean conditions (Crisosto, 2001; Crisosto et al., 2004). Currently, there are several companies that are offering high quality delivery programs using this controlled delayed cooling treatment. This new system allows the potential for delivering to retail stores peaches that are "ready to buy" or "ready to eat" with low occurrence of internal breakdown symptoms and high consumer acceptance. Preconditioned fruit will tolerate very well short-term temperature exposure within the "killing temperature range" during postharvest handling. Due to physical and chemical changes occurring in the fruit during the preconditioning treatment, fruits are allowed to express their potential eating quality. A controlled preconditioning/preripening treatment induces fruit softening to the "ready to buy" stage (approximately 0.36 N for peaches). If the program is not properly monitored, decay development, shriveling, and excessive softening may become commercial problems. Fast cooling and maintaining the temperature prior to and during shipment are essential to protect fruit quality from rapid deterioration. A high refrigeration capacity may be needed for this program. The product should be packed to specific marketing requirements depending on customer desires, such as being stickered with PLU (tree-ripe codes) and packed in attractive display-ready pre-print cartons that are either single layer or double layer in depth. Aggressive marketing, promotion and educational programs are required. Retailer and consumer education on the handling of preconditioned/preripened fruit is important to increase the demand for this new high quality fruit delivery system.

MINIMUM QUALITY INDEX AND/OR FLAVOR CODE

After solving the CI problem and lack of ripening issues (Crisosto, 2000, 2001; Crisosto et al., 2004), a detailed research program focusing on developing a minimum quality index for different peach cultivars should be pursued. As production of new cultivars with diverse flesh colors, flavors, soluble solids concentrations (SSC), and titratable acidities (TA) is increasing in California, understanding the relationship between SSC and TA and consumer acceptance is more critical. Early work associated high consumer acceptance of fruit with high SSC in sound peaches (Parker et al., 1991). However, the role of TA, SSC:TA and/or peach flavor in consumer acceptance has not been well established. SSC and TA in peaches are determined by several factors such as cultivar (Kader, 1992), environmental conditions, canopy position (Crisosto et al., 1997), crop load, ripening, fruit maturity (Crisosto et al., 1995), and rootstock (DeJong et al., 2002). However, currently we do not have enough reliable information from different peach cultivars over several seasons to justify the establishment of SSC as a single quality index. We have such a diversity of potential flavors in our current 200+ peach cultivars that we cannot simplify this complex issue by choosing SSC without the support of solid research over a long period of time. Thus, our program involves the following steps: first, an industry quality survey of initial fruit quality attributes. This information will reveal the range of fruit quality attributes within the industry. Second, an ongoing program focusing on understanding the role of orchard factors in relation to these parameters. Third, utilization of a trained panel to identify the important sensory attributes of peach fruit quality such as sweetness, sourness, aroma, texture, firmness, and overall peach flavor intensity and to segregate cultivars into flavor groups based on the perception of these attributes. This information is necessary in order to design "in store" consumer tests to define the quality index(es). After the completion of this program, the peach industry will have more information to determine if the establishment of this/these index(es) will help to consistently deliver peaches of high eating quality.

PEACH AND NECTARINE FLAVOR CODE

Cultivar segregation according to the sensory perception of organoleptic characteristics was attempted by using trained panel data evaluated by principal component analysis of four sources per cultivar of 23 peach and 26 nectarine cultivars as a part of our program to develop minimum quality indexes. Fruit source significantly affected cultivar RSSC and RTA, but it did not significantly affect sensory perception of peach or nectarine flavor intensity, sourness or aroma by the trained panel. For five out of 49 cultivars tested, source played a role in sweetness perception. In all of these cases when a source of a specific cultivar was not classified in the proposed organoleptic group it could be explained by fruit being harvested outside the commercial physiological maturity (immature or over-mature) for that cultivar. The perception of the four sensory attributes (sweetness, sourness, peach or nectarine flavor intensity, peach or nectarine aroma intensity) was reduced to three principal components which accounted for 92 and 94% of the variation in the sensory attributes of the tested cultivars for peach and nectarine, respectively. Season did not significantly affect the classification of one cultivar that was evaluated during these two seasons. By plotting organoleptic characteristics in PC1 and PC2 (~76%), for peach and nectarine, cultivars were segregated into groups (balanced, tart, sweet, peach or nectarine aroma and/or peach or nectarine flavor) with similar sensory attributes; nectarines were classified into five groups and peaches into four groups. Based on this information, we recommend that cultivars should be clustered in organoleptic groups and development of a minimum quality index should be attempted within each organoleptic group rather than proposing a generic minimum quality index based on RSSC. This organoleptic cultivar classification will help to match ethnic preferences and enhance the current promotion and marketing programs.

USE OF FOOD ADDITIVES AND LOW-TOXICITY CHEMICALS AS POTENTIAL ALTERNATIVES TO SYNTHETIC POSTHARVEST FUNGICIDES

Economic losses caused by postharvest diseases are among the most important concerns for growers. Postharvest fruit decay has typically been controlled by application of synthetic fungicides. However, important problems associated with the massive use of these chemicals, such as the proliferation of resistant strains of the pathogens and concerns about public health and environmental contamination, have increased the need for alternatives, especially in the context of Integrated Pest Management (IPM) practices. We are undertaking the evaluation of a wide range of food additives and low-toxicity chemicals as potential alternatives to synthetic fungicides for the control of the most important postharvest pathogens of stone fruits. These compounds leave low or undetectable residues on the fruit and are approved for many industrial and agricultural applications by Federal and State regulations. Many of them are registered as Generally Recognized as Safe (GRAS) by the EPA, or are included in the National List of substances allowed as ingredients in products labeled as organic. In the first year, we performed an initial screening of 25 chemicals on seven stone fruit cultivars against seven pathogens (*Botrytis cinerea*, *Monilinia fructicola*, *Geotrichum candidum*, *Penicillium expansum*, *Alternaria alternata*, *Rhizopus stolonifer*, and *Mucor piriformis*) in vivo (Table 2). Eighteen GRAS or low toxicity compounds were eliminated in the screening due to lack of effectiveness in controlling pathogens or damage to fruit. Six compounds [2 deoxy-D-glucose (as glucosamine), potassium carbonate, potassium sorbate, sodium carbonate, sodium sorbate, sodium benzoate] were advanced to phase 2 (Table 3). In this phase we evaluated the most effective solution temperature, chemical concentration, and immersion period to control decay caused by the two main stone fruit postharvest pathogens (*M. fructicola* and *G. candidum*). At ambient temperatures, all but glucosamine had activity against *M. fructicola*, though none consistently distinguished itself from the others. The efficacy of the GRAS/low toxicity chemicals increased with solution temperature (up to 55-60ºC). However, hot water dips were nearly as effective at reducing disease expression. Damage to some fruit was observed at treatment temperatures of 60ºC or greater (Table 4).

CONCLUSIONS

Preliminary observations suggest that peach and nectarine consumption may be increasing as results of the proper establishment of ripening and preconditioning protocols (short-term solutions). However, the impact of these ripening protocols should be evaluated under commercial situation.

Based on our ongoing work, we recommend that cultivars should be classified in organoleptic groups and development of a minimum quality index should be attempted within each organoleptic group rather than proposing a generic minimum quality index based on RSSC.

Our preliminary "in store" consumer tests indicated that high consumer acceptance is attained with our mid-season cultivars when peaches are free of chilling injury and "ready to eat" prior to consumption.

The use of adequate cultural practices and the careful determination of the harvest date should be applied properly to assure that the majority of fruit would exceed this proposed minimum quality index.

After initial screening few food additives and low-toxicity chemicals are showing promising results as potential alternatives to synthetic fungicides for the control of the most important postharvest pathogens of stone fruits.

Intensive research to identify cultivars' important sensory attributes, "in store" consumer acceptance, industry quality potential, and the role of preharvest factors (orchards and climatic conditions) to meet these potential quality standards should be pursued prior to any quality index(es) being established.

Basic research programs to understand the genetic and biochemical basis of flavor, antioxidant attributes pathways, and chilling injury genetic control by using available molecular genetics technologies should be economically supported.

Literature Cited

Byrne, D. 2003. Breeding peaches and nectarines for mild-winter climate areas: State of the art and future directions. In: F. Marra and F. Sottile (eds.), Proc. 1st Mediterranean Peach Symposium, Agrigento, Italy, 10 September.

Crisosto, C.H. 2000. Optimum procedures for ripening stone fruit. Management of fruit ripening. Postharvest Horticulture Series. No. 9, April.

Crisosto, C.H. 2001. The preconditioning program. Tree Fruit Postharvest Workshop, May 15, 2001 at the Kearney Agricultural Center, Parlier, California.

Crisosto, C.H., Mitchell, F.G. and Johnson, R.S. 1995. Factors in fresh market stone fruit quality. Postharvest News and Information 6(2):17N-21N.

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

Crisosto, C.H., Garner, D., Andris, H.L. and Day, K.R. 2004. Controlled delayed cooling extends peach market life. HortTechnology 14:99-104.

DeJong, T.M., Johnson, R.S., Bryla, D., Doyle, J.F. and Ramming, D. 2002. Evaluation of size controlling rootstocks for California peach production. 2001 Research Report to the California Tree Fruit Agreement p.113-120.
Giovannini, D., Liverani, A. and Brandi, F. 2000. Indagine sulla qualità commerciale delle pesche prodotte in Romagma: Metodi di valutazione e possibilità di miglioramento p.145-151. In: S. Sansavini (ed.), Per una nuova peschicoltura: produzione, orrganizzazione, mercato, XXIV Convegno Peschicolo, Cesena, 24-23 Febbraio.
Kader, A.A. 1992. Postharvest technology of horticultural crops. 2nd Edition, Univ. of California Division of Agri. and Natural Resources, Publ. 3311.
Liverani, A., Giovannini, D. and Brandi, F. 2002. Increasing fruit quality of peaches and nectarines: the main goals of ISF-FO (Italy). Acta Hort. 592:507-514.
Parker, D., Ziberman, D. and Moulton, K. 1991. How quality relates to price in California fresh peaches. California Agri. 45:14-16.

Tables

Table 1. Increase (↑) or decrease (↓) in market life of preconditioned peaches at 20ºC compared to untreated (no cooling delay) based on development of chilling injury (CI) during storage at 0 or 5ºC.

Cultivar/ Delayed cooling treatment	Change in maximum market life at 0ºC (weeks)	Change in minimum market life at 5ºC (weeks)
'Flavorcrest' (1999)		
24 h at 20ºC	0	0^{1}
48 h at 20ºC	0	↑ 1+
'Elegant Lady' (1999)		
24 h at 20ºC	0	0
48 h at 20ºC	0	↑ 1+
'Summer Lady' (2000)		
24 h at 20ºC	0^{1}	↑ $2^{1,2}$
48 h at 20ºC	↑ 1+	↑ $2^{1,2}$
'O'Henry' (1999)		
24 h at 20ºC	0^{1}	0^{1}
48 h at 20ºC	↑ 1+	↑ 1+
'Zee Lady' (2000)		
24 h at 20ºC	0	↑ 1+
48 h at 20ºC	0	↑ 1+
'Ryan Sun' (2000)		
24 h at 20ºC	0^{1}	↑ $1^{1,2}$
48 h at 20ºC	↑ 2+	↑ 2^{2}

End of market life based on chilling injury (CI) determined when ≥ 25% of the fruit became mealy or leathery[1], or had flesh browning[2]. Superscript indicates limiting condition.

Table 2. GRAS chemicals and concentrations evaluated in primary screening trials, 2002-2003.

Chemical	Concentrations evaluated	Advanced to next stage
Acetic acid (vapor)	300 mM at 200µL 3.6×10^{-3} g/15 L	Possible. Good activity against pathogens, delivery system needs work
Ammonium bicarbonate	100, 200, 400 mM	No. No control at any concentration
Ammonium carbonate	100, 200, 400 mM	No. Slight control of a few pathogens
Ammonium molybdate	8, 16, 100 mM	No. Some control, damages and stains
Ascorbic acid	100 mM	No. Little control of most pathogens
Deoxy-D-glucose	25, 50, 100 mM	Yes. Good control of most pathogens
Deoxy-D-ribose	25, 50, 100 mM	No. No control except of *Geotrichum*
Hydrogen peroxide	30, 140, 340 mM	No. Damage to tissue at all conc.
Lactic acid	8 mM	No. Damage to tissue, increases infection
Potassium acetate	30, 100, 300 mM	No. No control of pathogens
Potassium benzoate	20, 100, 200 mM	No. Some control of *Botrytis* at high conc.
Potassium bicarbonate	100, 200, 400 mM	No. No control of pathogens
Potassium carbonate	100, 200, 250 mM	Yes. Some control of *Botrytis*, *Monilinia*
Potassium propionate	20, 100, 200 mM	No. No control of pathogens
Potassium sorbate	20, 100, 200 mM	Yes. Some control of *Botrytis*, *Monilinia*
Sodium acetate	100 mM	No. No control except *Geotrichum*
Sodium benzoate	20, 100, 200 mM	Yes. Some control of pathogens
Sodium bicarbonate	100, 200, 400 mM	No. No control of pathogens
Sodium carbonate	100, 200, 400 mM	Yes. Some control of *Botrytis*, *Monilinia*
Sodium citrate	100 mM	No. No control of pathogens
Sodium lactate	100 mM	No. Damage to tissue, increases infection
Sodium molybdate	12.5, 50, 100 mM	No. Some control, damages and stains
Sodium propionate	30, 100, 300 mM	No. Some control of *Botrytis* at high conc.
Sodium sorbate	20, 100, 200 mM	Yes. Some control of pathogens
Sodium tartrate	100 mM	No. No control of pathogens

Table 3. GRAS/low toxicity chemicals and concentrations evaluated in secondary screening trials, 2004.

Chemical	Concentrations evaluated	Advanced to next stage
Deoxy-D-glucose as Glucosamine	1%, 2%, 3%	No. Deoxy-D-glucose was effective against most pathogens in stage 1 trials, but its cost prohibits commercial use. This year we evaluated its chemical precursor, glucosamine which is considerably less expensive, but it had no activity in this form
Potassium carbonate	100, 200 mM	Yes. Some control of *Monilinia* and *Geotrichum* at 200 mM
Potassium sorbate	100, 200 mM	Yes. One of the more effective compounds with some control of *Monilinia* and *Geotrichum* at 200 mM
Sodium benzoate	100, 200 mM	Yes. Another of the more effective compounds with some control of *Monilinia* and *Geotrichum* at 200 mM
Sodium carbonate	250, 400 mM	Yes. Some control of *Monilinia* and *Geotrichum* at 400 mM
Sodium sorbate	100, 200 mM	Yes. Some control of *Monilinia* and *Geotrichum* at 200 mM

Table 4. 'Casselman' plums were wound-inoculated with *Monilinia fructicola* 24 h prior to a 30 or 60 s dip in 24, 55, 60, 65 or 70ºC water, and then observed after 3 and 5 d incubation at 20ºC for incidence and severity of decay.

Treatment	Decay			
	3 d at 20ºC		5 d at 20ºC	
	Severity (mm)	Incidence (%)	Severity (mm)	Incidence (%)
Water temperature				
24ºC	12.8	91.3	15.1	99.3
55ºC	3.9	37.3	4.9	43.3
60ºC	0.8	9.3	1.9	9.3
65ºC	0.0	0.0	0.0^{z}	0.0^{z}
70ºC	0.0	0.0	0.0^{y}	0.0^{y}
P-value	<0.0001	<0.0001	<0.0001	<0.0001
$LSD_{0.05}$	0.8	5.6	1.4	4.8
Dip duration				
30 s	4.3	34.7	8.7	37.6
60 s	2.7	20.5	7.8	23.2
P-value	<0.0001	<0.0001	0.0036	<0.0001
$LSD_{0.05}$	0.5	3.6	1.1	3.0
Interaction				
24ºC 30 s	13.1	93.3	15.5	98.7
24ºC 60 s	12.5	89.3	14.7	100.0
55ºC 30 s	7.0	62.7	8.5	70.7
55ºC 60 s	0.9	12.0	1.3	16.0
60ºC 30 s	1.5	17.3	2.0	18.7
60ºC 60 s	0.1	1.3	0.0	0.0
65ºC 30 s	0.0	0.0	0.0^{z}	0.0^{z}
65ºC 60 s	0.0	0.0	0.0^{z}	0.0^{z}
70ºC 30 s	0.0	0.0	0.0^{y}	0.0^{y}
70ºC 60 s	0.0	0.0	0.0^{y}	0.0^{y}
P-value	<0.0001	<0.0001	<0.0001	<0.0001
$LSD_{0.05}$	1.1	8.0	3.9	6.8

[z] Slight to moderate damage on skin.

[y] Moderate to severe damage on skin.