Evaluation of Fruit Quality of Apricot Cultivars and Selections

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ABSTRACT. Four experimental apricot selections and four commercial apricot cultivars were evaluated for various physical and chemical characteristics. The eight apricot accessions were divided into three categories based upon their average dates of fruit maturation (based on flesh firmness) in California's San Joaquin Valley. Within maturity groups, apricot accessions evaluated in this study had diverse fruit weight, Brix, titratable acidity, and color of both flesh and skin. Profiles of volatile constituents extracted from the eight accessions did not follow any consistent pattern. Alcohols, however, were the dominant group of volatiles present in each sample, and linalool was highest within each profile. The results obtained from this research demonstrate that several of the experimen-

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tal apricot selections had better fruit size, Brix and fruit color characteristics than commercial apricot cultivars of the same fruit maturity in the same ripening season. *[Article copies available from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworth.com]*

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INTRODUCTION

Prunus armeniaca L. has been cultivated in California orchards since the early 1900's. Compared with European or Central Asian orchards, California's acreage might be considered small with approximately 7,000 bearing hectares of apricots currently cultivated to supply consumer demands for fresh, dry, and canned products (Tippett et al., 1992). The number of high quality cultivars suitable for the fresh market are limited. 'Castlebrite,' 'Katy,' and 'Patterson' are the major cultivars grown for fresh market apricot production in California. Several breeding programs in the United States currently are developing and testing new selections with the objective of providing consumers with higher quality fruit during a longer ripening season than existing cultivars.

The production and successful marketing of fresh apricots is a dilemma of opposing priorities. Premium prices are received by growers for more mature fruit, yet growers are motivated to harvest early, prior to optimum fruit maturity, because of low supply and higher prices in the early season. Growers harvesting more mature fruit risk a higher cull rate and more rejected shipments at retail outlets. As a consequence, consumers receive a product of inferior quality which may reduce repeat sales and weaken market demand later in the season. Due to the characteristics of cultivars currently used for fresh marketing in California, only a small harvest window exists where both the needs of growers and consumers are satisfied.

Buyers and consumers of apricot and other soft fruits are keenly aware of fruit firmness and its effect on eating quality and shelf life. Fruit harvested too firm may shrivel and fail to ripen normally. Harvested fruit which lacks firmness may have an initial high eating quality, but will undoubtedly have a shorter shelf-life (Mitchell, 1986). To optimize both shelf-life and eating quality, personnel involved with the fruit harvest need standards to identify those fruit which are immediately ready for harvest. Various field maturity standards have been proposed in the past. Criteria used to determine the correct harvest maturity in apricot have included fruit ground color (Sud et al., 1979), or a combination of flesh firmness and ground color (Varady-Burghetti et al., 1983; Visagie, 1985; Brown and Walker, 1990). Since the per unit value of harvested apricots is highly dependent upon the fruit quality and shelf-life perceived by wholesale buyers, producers must carefully choose the maturity standards adopted by fruit pickers, to insure that they are reliable and consistent for the variety to be harvested.

Apricot breeding has been ongoing at the Horticultural Crops Research Laboratory in Fresno, California since the 1950's. Investigation is continuing in the development of new apricot cultivars with enhanced quality. Weinberger (1963) named and released the cultivar 'Castleton' for its improved resistance to 'pit-burn,' caused by high temperatures during fruit maturation. The cultivar 'Castlebrite' was introduced as an early-season apricot with exceptional color and firmness (Ramming and Tanner, 1978). Because of consumer dissatisfaction with fruit quality (Bruhn et al., 1991), we have endeavored to select and evaluate our apricot germplasm for quality at a less developmentally mature state. Recent studies in peaches have demonstrated that while fruit color and firmness are well correlated during fruit growth and maturation, there is no relationship between them at harvest maturity (Génard et al., 1994). Also observed in peaches of harvest maturity was that flesh firmness and the concentration of reducing sugars were independent of each other and of fruit skin color. Brown and Walker (1990) found that while skin ground color adequately estimated physiological fruit maturity of 'Moorpark' apricot within a single orchard, it was a poor measure of maturity between different orchards. Flesh firmness was one of three practical criteria observed to be a valid measure of physiological maturity of 'Moorpark' apricot among different orchard environments. Since it appears that the levels of both acidity and soluble solids, as well as both flesh firmness and fruit color are independent of one another in fruit of harvest maturity, we have attempted to identify and evaluate apricot selections with higher soluble solids, deeper flesh coloration, lower acidity, and larger quantities of the distinct apricot flavor compounds while fruit flesh is still relatively firm. Hence, this study was undertaken to evaluate and compare physical and chemical characteristics of four commercial apricot cultivars grown in California with advanced apricot selections of our breeding program.

MATERIALS AND METHODS

All evaluations described in this study were obtained from fruit grown and harvested during the 1993 season. Throughout this study, fruit from the peak packout size distribution (average fruit size) of each accession was used for analysis. The eight apricot accessions were divided into three groups based on their fruit ripening dates. The early-season group consisted of 'Castlebrite' and K123-32; mid-season accessions included 'Suapritwo,' K505-50, 'Katy,' and B51-77; and the remaining accessions, K210-35 and 'Patterson,' were considered to be late-season. Selection K123-32 was produced and harvested at the Horticultural Crops Research Laboratory in Fresno, CA. Rio Vista Fruit Farms, Reedly, CA, provided fruit from ARS selections B51-77, K505-50, and K210-35. 'Suapritwo' (Honeycot®, Patent No. 7550) was produced by Sun World Int. Inc., Wasco, CA. The cultivars 'Castlebrite,' 'Katy,' and 'Patterson' were obtained from Fowler Packing Co., Fresno, CA. Although fruit accessions were obtained from different orchards, all accessions were produced in the San Joaquin Valley within a distance of no greater than 85 miles.

Physical Measurements

Six replicates of ten intact fruit were used to measure fruit size, flesh firmness, and both skin and flesh color profiles. Flesh firmness was measured using a hand-held penetrometer (D. Ballauf Mfg. Co., Washington, DC) equipped with an 8-mm tip. Penetrometer readings were obtained from a freshly cut surface of fruit flesh (skin removed). A Minolta Chroma Meter CR-200 (Minolta Camera Co., Ltd., Osaka 541, Japan) was used to obtain CIELAB coordinates 'L*,' 'a*,' and 'b*' for both apricot flesh and skin ground color. As suggested by McGuire (1992), these coordinates were used for the calculation of hue angle (h^o) and Chroma (C*), which have been accepted as more intuitively understandable color variables. L*, C*, and h^o were then used to identify the Royal Horticultural Society's (1986) color chip with the least significant difference from the fruit flesh and skin samples. When comparing color readings of fruit surfaces with those from matte finish paint chips, we found it necessary to give ho ten times the weight of L* or C* in order to obtain visual color matches consistently.

Chemical Analysis

Values for Brix, titratable acidity, and Brix:acid ratio were based on three replicates of six fruit each. For these analyses, fruit were pitted and juiced. Degrees Brix of the fruit juice was obtained from a hand-held refractometer. A 5-g aliquot of the juice then was titrated with 0.1 N NaOH to a pH of 8.1. Values presented represent percent acid of the fresh fruit tissue. Brix:acid ratio was calculated using refractometer readings and percent acid values from each replicate.

Aromatic Profiles

For the characterization of aromatic profiles, three 0.5 kg fresh fruit samples were extracted and analyzed for each accession. Simultaneous steam distillation-hexane extraction was performed using a modified Likens-Nickerson extraction apparatus. Characterization of extracts from the replicated samples was performed using gas chromatography-mass spectrometry (Gómez et al., 1993). Although complete chromatograms were obtained for each accession, only compounds particularly important to the apricot aroma were tabulated for this study.

Statistical Analysis

One-way analyses of variance were performed on all evaluation variables. Analyses of variance were always performed only among those accessions within a fruit ripening season and never among all eight accessions. When no significant difference was observed in flesh firmness between apricot accessions within a ripening season, these accessions were considered to be of equal maturity. Valid comparisons could then be made between these accessions for other physical and chemical characteristics. A Macintosh version of SYSTAT® (Systat, Inc., Evanston, IL 60201) was used for data processing.

RESULTS AND DISCUSSION

Diversity existed among the apricot accessions within each of the ripening seasons (Table 1). The average fruit weight of 'Castlebrite' was significantly larger than selection K123-32 in the early season, and selection K210-35 was significantly larger than 'Patterson' in the late season. Among the mid-season accessions, K505-50 was the largest, and 'Suapritwo' was significantly smaller than the others. 'Katy' and B51-77 were intermediate and not significantly different in fresh fruit weight.

Since K123-32 and 'Castlebrite' did not differ significantly in flesh firmness (Table 1), these accessions could be compared directly for their other physical and chemical characteristics. While K123-32 was significantly smaller than 'Castlebrite,' it was also significantly higher in Brix and significantly lower in acidity, as compared to 'Castlebrite.' These differences translated to a Brix:acid ratio of K123-32 being over three

TABLE 1. Physical and chemical characteristics of eight apricot accessions from the San Joaquin Valley, California.[z]

Accession	Harvest date	Fresh fruit weight (g)	Flesh firmness (N)	Brix (º)	Titratable acidity (% acid)	Brix: acid ratio
			Early season			
K123-32	8 May	48 b	30.4 a	15.8 a	0.58 b	27.4 a
Castlebrite	10 May	65 a	32.4 a	8.6 b	1.14 a	7.6 b
			Mid season			
Katy	16 May	83 b	39.2 a	10.1 d	1.32 a	7.7 c
B51-77	17 May	80 b	17.6 b	11.4 c	1.09 b	10.4 b
Suapritwo	19 May	69 c	11.8 b	16.6 a	1.12 b	14.9 a
K505-50	23 May	153 a	32.4 a	14.1 b	1.20 b	11.7 b
			Late season			
K210-35	3 June	133 a	22.6 b	11.3 a	1.18 a	9.6 a
Patterson	7 June	64 b	47.1 a	10.0 a	1.18 a	8.6 a

[z] Mean separation within a column maturity season by Tukey's HSD, P = 0.05.

times higher than 'Castlebrite.' Furthermore, orange color of both flesh and skin was significantly deeper in K123-32 than in 'Castlebrite' (Table 2). The combination of these factors with its high eating quality lead us to the opinion that consumer acceptance would be high for this accession.

With regard to flesh firmness among the mid-season accessions, 'Katy' and K505-50 were significantly firmer than B51-77 or 'Suapritwo.' These differences in flesh firmness did not allow for direct comparison of other physical or chemical characteristics among all four mid-season accessions. Comparisons could be made, however, between the accessions not differing in flesh firmness. K505-50 was significantly larger, had a higher Brix value and lower titratable acidity than 'Katy.' Hue angle values of 'Katy' were significantly higher than K505-50 for both fruit skin and flesh. Lower hue angles are more indicative of a deeper orange coloration. Flesh firmness measurements also allowed direct comparison of B51-77 and 'Suapritwo.' While no significant differences existed between these accessions in hue angle of fruit skin or flesh or titratable acidity, 'Suapritwo' had significantly higher Brix values. It must also be pointed out that while flesh firmness of K505-50 was significantly higher than B51-77 and 'Suapritwo,' titratable acidity did not differ significantly among these accessions. This point is of particular significance since it demonstrates that diversity exists within these accessions regarding levels of firmness and acidity, as well as corroborating the results of Génard et al. (1994), that the relationship between flesh firmness and itratable acidity is independent in peaches near harvest maturity.

The late-season cultivar 'Patterson' had the highest flesh firmness of all eight accessions, and was significantly firmer than K210-35. Therefore, direct comparisons of other characteristics were not valid since fruit from these accessions were at different states of harvest maturity. It must again be noted that while these accessions differed significantly in flesh firmness, no significant differences existed between these accessions in Brix, titratable acidity, or Brix:acid ratio.

Apricot accessions varied in the quantities of specific aromatic compounds present in the fruit flesh (Table 3). In the early-season accessions, K123-32 had significantly higher levels of many important aromatic constituents than 'Castlebrite' including α-terpineol, geraniol, 2-hexenal, hexyl acetate, β-ionone, γ-decalactone, and γ-dodececalactone. Nearly twice the total aromatic constituents were extracted from K123-32 as compared with 'Castlebrite' under identical distillation-extraction conditions. Among the mid-season apricots, aromatic profiles of B51-77 and 'Suapritwo' could be compared directly due to their non-significant difference in flesh firmness. 'Suapritwo' apricots had significantly higher levels of all the

TABLE 2. Hue angles and Royal Horticultural Society colour chip designation of apricot skin and flesh from eight San Joaquin Valley apricot accessions.[z]

	Skin		**Flesh**	
Accession	Hue angle[y]	RHS colour chip (fan, page, chip)	Hue angle[y]	RHS colour chip (fan, page, chip)
		Early season		
K123-32	74.7 b	4, 163, A	68.0 b	4, 167, D
Castlebrite	83.4 a	1, 22, C	78.3 a	4, 164, B
		Mid season		
Katy	85.4 a	4, 163, C	82.7 a	4, 163, B
B51-77	72.2 b	1, 24, B	66.5 b	1, 26, B
Suapritwo	73.4 b	4, 163, A	69.5 b	1, 26, B
K505-50	76.8 b	4, 164, B	67.6 b	4, 167, C
		Late season		
K210-35	72.7 b	1, 24, B	68.3 b	1, 26, B
Patterson	78.5 a	1, 23, C	75.4 a	4, 163, A

[z]Mean separation within a column and maturity season by Tukey's HSD, $P = 0.05$.

[y]Hue angle = arctan b^*/a^*, where a^* and b^* are CIELAB coordinates obtained from a Minolta Chroma Meter CR-200. Numerical values are indicative of the following general guides: Hue angle (0° = red-purple, 90° = yellow, 180° = bluish green, 270° = blue).

important alcohols listed in Table 3, as well as heptanal, butyl acetate, and hexyl acetate. B51-77 apricots yielded significantly more phenylacetaldehyde than 'Suapritwo.' The aromatic profiles of the two firmer mid-season accessions ('Katy' and K505-50) were more similar to each other than were the two softer acquisitions (B51-77 and 'Suapritwo'). While phenylacetaldehyde and decanal were significantly higher in 'Katy,' heptanal and butyl acetate levels of K505-50 were significantly higher as compared to 'Katy.' Although significant differences in flesh firmness were apparent, late season accessions appeared more similar in their aromatic profiles than early- or mid-season accessions. An important exception was the significantly higher level of esters in K210-35.

Some of the observed differences in the aromatic profiles of these apricots might be explained by differences in fruit maturity. We have observed a general increase in the levels of extractable ketones and lactones with concomitant decreases in levels of extractable alcohols and aldehydes as apricots develop from the mature green (flesh firmness of 62.8 N) to the tree ripe (flesh firmness of 6.7 N) stage. The changes of the levels of these volatiles through the final period of fruit maturation is also closely associated with a dramatic decrease in both flesh and skin hue angle, increases in degrees Brix, and decreases in titratable acidity (Gómez and Ledbetter, unpublished data). Similar results have been reported by Chapman et al. (1991) with 'Majestic' peach samples taken throughout the fruit development period.

Odor units for 13 apricot aroma constituents from the eight accessions, as well as odor threshold values for each of these impact constituent are presented in Table 4. As defined by Guadagni et al. (1966) an odor unit is simply the concentration of a volatile compound divided by its odor threshold value. Based on odor threshold values reported by Takeoka et al. (1992), 2-hexenal, 6-methyl-5-hepten-2-one, α-terpineol, and geraniol were undetectable in all apricots. Linalool and β-ionone appeared to produce the most dominant odors in all the samples. In the early season, K123-32 showed elevated odor values for these constituents as compared with 'Castlebrite.' In the late season, both accessions were very close regarding odor values except that ß- ionone was higher in K210-35. Odor unit profiles of the mid-season apricots did not follow a consistent pattern. While both 'Suapritwo' and 'Katy' had very high odor units for linalool, ß-ionone odor units were high in B51-77 and 'Suapritwo.' γ-Decalactone was only above its odor threshold in samples of B51-77. The level of 2,4-decadienol reached 590 odor units in K505-50. This value was four times higher than the next closest apricot, 'Katy.'

Consumer dissatisfaction with apricot quality at the retail level cannot

TABLE 3. Concentration of important volatile constituents (μg/kg fresh fruit weight) extracted from eight apricot accessions.[z]

	Early season		Mid season				Late season	
Constituent	K123-32	Castlebrite	Katy	B51-77	Suapritwo	K505-50	K210-35	Patterson
Alcohols								
linalool	2942	1721	3031 ab	1256 b	5741 a	1542 b	2612	3306
α-terpineol	763 a	389 b	71 b	272 b	1660 a	318 b	458	663
nerol	191	112	193 b	131 b	534 a	52 b	135	162
geraniol	496 a	203 b	404 b	130 b	1053 a	145 b	238	352
Aldehydes								
hexanal	21	32	24	26	53	28	38	22
2-hexenal	69 a	12 b	13 b	35 a	54 a	1 b	19	18
heptanal	1	2	– b	– b	7 a	2 b	–	–
2-heptanal	7	8	10	4	8	3	–	–
phenylacetaldehyde	237	154	163 a	167 a	– c	40 b	145	166
nonanal	4	25	25	26	48	5	35	30
decancal	– b	13 a	10 a	– b	– b	– b	1	12
2,4-decadienal	4	7	2	1	10	–	–	–
Esters								
butyl acetate	2	–	– b	– b	6 a	6 a	11 a	– b
hexyl acetate	17 a	– b	– b	– b	13 a	– b	21 a	– b
Hydrocarbons								
limonene	50	24	35	44	91	20	32	43

Ketones								
6-methyl-5-hepten-2-one	17	23	27	74	94	15	40	11
β-ionone	131 a	44 b	30 b	160 a	229 a	73 ab	73	40
Lactones								
γ-decalactone	301 a	4 b	53 b	137 a	83 ab	41 b	1	10
γ-docecalactone	105 a	- b	19	30	11	17	-	-

[z] Means separations within a row and maturity season by Tukey's HSD, P = 0.05. Tabulated values listed within a maturity season and without mean separations are indicative of no significant difference between apricot accessions for that specific volatile constituent.

TABLE 4. Odor units for 13 apricot impact compounds from eight San Joaquin Valley apricot accessions.

Impact	Odor	**Early season**		**Mid season**				**Late season**	
compound	threshold[z]	K123-32	Castlebrite	Katy	B51-77	Suapritwo	K505-50	K210-35	Patterson
hexanal	5	4	6	8	5	10	6	8	4
2-hexenal	17	5	0.5	0.6	2	0.3	0.3	0.7	1
6-methyl-5-hepten-2-one	50	0.3	0.3	0.7	1	1.8	0.3	0.8	0.3
hexyl acetate	2	5	0	0	0	7	1	10	0
phenylacetaldehyde	4	56	33	64	42	0	10	36	39
linalool	6	460	336	714	210	785	257	435	472
nonanol	1	3	25	44	26	44	5	35	29
α-terpineol	49	13	8	23	6	25	6	9	11
geraniol	40	9	5.3	15	3	19	4	6	7
2,4-decadienol	0.07	58	67	136	21	110	590	0	0
γ-decalactone	11	25	0	7.7	12	6	4	0.3	0.8
β-ionone	0.07	1600	576	629	2286	2848	1043	1048	633
γ-dodecalactone	7	25	0	4	4	3	2	0	0

[z]Odor threshold values (parts per billion) from Engel et al. (1988) and Takeoka et al. (1990, 1992).

be overemphasized. Recent surveys indicated that consumers feel that the ease of shipping and marketing has taken precedence over taste in the development of new cultivars. Thirty percent of consumers felt that lack of flavor was the major reason for their dissatisfaction (Bruhn et al., 1991). At the same time, over 50% of consumers surveyed were willing to pay 10% to 20% more for a more fully tree-ripened product. This survey is in agreement with Romani and Jennings (1971) who observed a strong correlation between the degree of fruit maturation and consumer acceptability in both apricot and peach.

A limited number of laboratory personnel sampled each of the accessions used in this study. They judged K123-32 and 'Suapritwo' to be the most acceptable for fresh marketing during the early- and mid-season groups, respectively. Opinions of K210-35 and 'Patterson' were less clear. While personnel agreed that K210-35 was larger and more deeply colored than 'Patterson,' many comments indicated that the flavor of the two apricot samples was similar.

The intent of this research was to examine thoroughly some of the ARS advanced apricot selections for a variety of important chemical and physical characteristics and compare them with apricot cultivars currently grown for fresh market fruit production. The results of these evaluations will be used, along with yield data from area producers, to provide the information necessary to make informed decisions with regard to cultivar release. We have shown in this study that some of the advanced selections have enhanced fruit quality as measured by higher Brix, lower acidity, and higher concentrations of important volatile compounds than the commercial apricot cultivars ripening in the same season. If selections can be identified which have these quality attributes in fruit which are less physiologically mature, it will be a benefit to consumers and apricot producers alike.

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