Journal of the American Pomological Society 64(4): 226-233 2010

Relationship Between 'Honeycrisp' Crop Load and Sensory Panel Evaluations of the Fruit

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Abstract

A two-year study was conducted to determine if sensory evaluation panels could detect color and taste differences among 'Honeycrisp' fruit grown at varying crop loads. In 2007, consumer panelists who were polled at a metropolitan farmer's market preferred the appearance of fruit from trees with moderate crop loads to those with high crop loads. A panel of market professionals participated in a parallel sensory evaluation study, and the color ratings and percent acceptance levels followed a similar trend. It was notable that the market professionals were able to distinguish even smaller differences in fruit color due to crop load. In 2008, 100 Penn State Food Science Sensory Laboratory consumer panelists evaluated both the color and taste of 'Honeycrisp' from trees with varying crop loads. The panelists also evaluated 'Honeycrisp' harvested at varying harvest dates. Consumer preferences were influenced by both crop load and harvest date. The taste rankings of high crop load 'Honeycrisp' were significantly lower than the rankings of moderate and low crop load fruit. As with the farmer's market and market professional panel evaluations, the color rankings of moderate crop load 'Honeycrisp' were higher than the color rankings of the high crop load and low crop load apples. The panelists preferred the taste of mid-season and late harvested 'Honeycrisp' to early harvested fruit and the color of late harvested fruit to either early or mid-season harvested fruit. The results of the sensory evaluation trials suggest that consumers can readily detect the inferiority of apples harvested immature or from heavily or lightly cropped trees.

'Honeycrisp' is a premium apple (*Malus* × *domestica* Borkh.) cultivar in the marketplace. When grown well and harvested at peak condition, the fruit are extraordinarily juicy and crisp. Honeycrisp also is a challenging cultivar to grow properly, and several of its problems are directly linked to crop load (4). The bearing habit of 'Honeycrisp' tends to be biennial, and it produces excessively large fruit that are prone to bitter pit in the small crop or "off" year and small, poorly colored fruit with insipid flavor in the full crop or "on" year.

While 'Honeycrisp' is not difficult to thin chemically (6), researchers in New York (5) reported that return bloom, fruit color, and fruit quality can be achieved only at a lower crop load than that required for annual production and fruit quality of most other commercially grown cultivars. Researchers in Nova Scotia (1) found that a combination of management practices is required to promote annual production of high quality fruit, including spurwood pruning, blossom thinning, and green fruit hand thinning. In research conducted in two regions of Michigan, Flore et al. (2) demonstrated that regulation of return bloom also is influenced by fruit position. Lateral 'Honeycrisp' fruit were larger and had more seeds than king fruit.

The mid-Atlantic region is considered to be at the southern limit for 'Honeycrisp' production because of the challenge in obtaining marketable red fruit color while maintaining the cultivar's optimum eating characteristics. Determining the appropriate crop load for 'Honeycrisp' is critical to the ability to compete with more northerly regions. The objective of this study was to assess the crop load range for mid-Atlantic-grown 'Honeycrisp' with respect to market preferences for color and taste.

Materials and Methods

Research was conducted in 2007 and 2008 to determine if sensory panels could detect color and taste differences among 'Honeycrisp' fruit grown at varying crop loads. In each year, a commercial orchard with heavy

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initial fruit set was selected for the crop load treatments. Five single tree replicates were hand thinned to 12.0, 10.8, 9.6, 8.4, 7.2, 6.0, 4.8, 3.6, and 2.0 fruit/cm^2 trunk cross-sectional area. Fruit samples were collected at three harvest dates based on fruit starch levels, firmness, and ethylene content. In 2007, 60 subsamples per crop load treatment were collected from the second harvest date and placed in regular atmosphere storage at 0°C. Half the apples in the subsamples were used for sensory evaluation tests with consumers attending a metropolitan farmer's market, and half the apples were used for sensory evaluation tests with fruit market professionals (packers, shippers, department of agriculture promotion agents) who had experience with marketing 'Honeycrisp.' The sensory evaluation tests with consumers were conducted 14 days after harvest in Baltimore, Maryland, and the sensory evaluation tests with fruit market professionals were conducted 90 days after harvest at the Penn State Fruit Research and Extension Center. In 2008, 200 subsamples for each of three crop load treatments (10.8, 7.2, and 3.6 fruit/ cm^2 trunk cross-sectional area) were collected from the second harvest date. In addition, 200 subsamples were collected from the moderate crop load treatment at each harvest date. The apples were held in regular atmosphere storage at 0°C for 60 days and then were transported to the Penn State Food Science Sensory Evaluation Laboratory for consumer panel tests the following day. In all studies, the apples were of uniform size and had no significant defects.

Farmer's market consumer panel evaluations. Forty farmer's market customers were randomly selected to evaluate 'Honeycrisp' color in fall 2007. With one set of samples from the nine crop load levels, the cultivar was not identified and the panelists were asked to rate overall color on a 1 to 10 scale, with 10 being the most preferred color. With a second set of samples from the various crop load levels, the cultivar was identified as 'Honeycrisp' and the panelists were asked to look at trays of 20 apples each and to identify which ones had acceptable appearance based on color. The same sets of samples in the same orientations were shown to all panelists, and they were asked not to consider any characteristic other than color. The panelists indicated why they did not consider certain apples acceptable and afterwards completed a demographic survey. Percent blush and Commission Internationale d'Eclairage L*, a*, b*, hue angle, and chroma were measured on the first set of samples (3). The chromaticity measurements were conducted on the blush and green sides of the fruit (one measurement per side at a mid-point location of representative color) with a Konica Minolta 2600d spectrophotometer (Konica Minolta Sensing, Tokyo Japan). Statistix 9 Analytical Software (Tallahassee, Fla.) was used to conduct linear regression analyses to compare color evaluations and chromaticity values to the nine crop load levels.

Market professional sensory panel evaluations. Fifteen market professional panelists participated in a parallel study during the same marketing season. With one set of samples the panelists were asked to rate overall color on a 1 to 10 scale, with 10 being the most preferred color. With a second set of samples the panelists were asked to look at trays of 20 apples each and to identify which ones had acceptable color. This sensory panel knew both sets of samples were 'Honeycrisp,' and they were to base evaluations on their experiences with market acceptability of 'Honeycrisp' color attributes. The panelists indicated why they did not consider certain apples acceptable and then participated in a focus group discussion. Percent blush and Commission Internationale d'Eclairage L*, a*, b*, hue angle, and chroma were measured on the apple samples used for the color ratings using the same procedure as for the consumer panel samples. Regression analyses were conducted to compare color ratings and percent acceptance to the various crop load levels.

Food science sensory laboratory consumer panel evaluations. One hundred trained panelists from the Penn State University Park campus participated in the 2008 study con-

ducted at the university's food science sensory evaluation laboratory. Taste evaluations were conducted in addition to color evaluations. The panelists were screened for liking apples and indicated that they ate sliced apples. Three sets of taste tests and two sets of color evaluations were conducted, and neither the cultivars nor the treatments were revealed to the panelists. The panelists compared both the taste and color of 'Honeycrisp' fruit from trees with high, moderate, and low crop load, corresponding to 10.8, 7.2, and 3.6 fruit/cm^2 trunk cross-sectional area, respectively (Fig. 1). The consumer panelists also compared the taste and color of 'Honeycrisp' fruit that were harvested early (3 to 4 SI, based on Blanpied and Silsby generic starch-iodine index chart), mid-season (4.5 to 5.5 SI), or late (6 to 7 SI). In a third taste test, the panelists compared 'Gala,' 'Golden Delicious,' and mid-season-harvested 'Honeycrisp' apples.

For the taste tests, individual apples were cut into 10 slices of similar size, and two slices of apple from each treatment were presented in plastic cups labeled with 3-digit codes in a counter-balanced arrangement. Within each sample set, panelists were asked to taste the samples and rank them in order of preference (1 to 3, from most preferred to least preferred). Apples were sliced just prior to sampling to prevent browning. For the color evaluations, sample sets were presented as images within the questionnaire with each sample labeled with 3-digit codes (Fig. 1). Panelists were asked to rank the samples based on color (1 to 3, from most preferred to least preferred). After evaluating the apple samples, panelists were asked to answer demographic questions. Evaluations took place in individual testing booths with individual computers using Compusense® Five software (Guelph, Ont.). Treatment rank was analyzed using Friedman Analysis of Rank, and means were separated by Tukey's Honestly Significant Difference (HSD) Test at p=0.05.

Results and Discussion

The 2007 sensory evaluation trials demonstrated that consumers and market professionals can detect differences in color related to

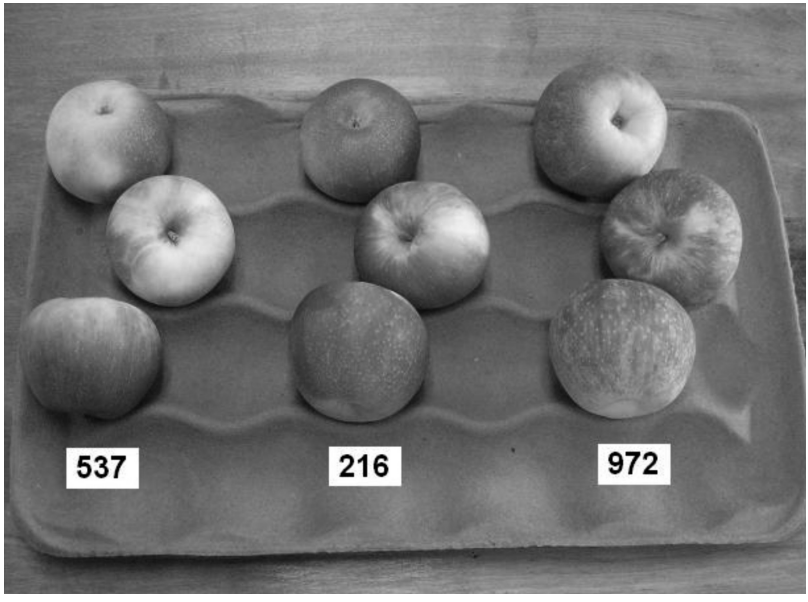

Fig. 1. 'Honeycrisp' apple samples from trees of high, medium, and low crop load (left to right) evaluated for color by 100 Food Science Sensory Laboratory panelists, 2008.

Table 1. Farmer’s market consumer panel demographic characteristics, 2007 (n=40).

Demographic characteristics	Consumer responses (%)			
Sex	Female 65	Male 35		
Age	18-35 yr 26	36-65 yr 65	>65 yr 9	
Taste preference	Tart 42	Sweet 26	Both 32	
Importance of flavor vs. texture	Flavor 17	Crispness 20	Equally important 63	
Purchase frequency	Weekly 68	Bi-monthly 10	Monthly 22	
Purchase locations	Farmer’s market 38	Supermarket 50	Orchard 11	Other 1

tree crop load. The 2008 sensory evaluation trials indicated that consumers not only perceive differences in color associated with crop load but also differences in taste. Harvest timing also affected taste and color preferences.

Farmer’s market consumer panel evaluations. The demographic questions answered by the participants in the metropolitan farmer’s market sensory study revealed that two thirds were female, and the median age range was 36 to 65 (Table 1). The majority of the panelists preferred a tart over a sweet apple, and over

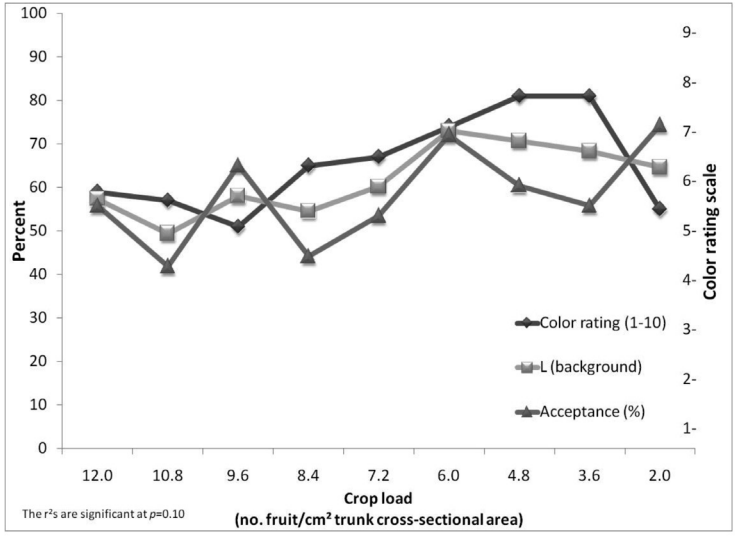

Fig. 2. Consumer color rating, chromaticity L * (lightness), and consumer acceptance of ‘Honeycrisp’ apples sampled from five single-tree replicates for each of nine crop load levels, 2007 (n=40). Cultivar unspecified for color rating. Color rating scale 1 to 10 with 10 being the most preferred. Cultivar specified for acceptance. Acceptance was the % of panelists who considered a crop load sample suitable for purchase based on appearance.

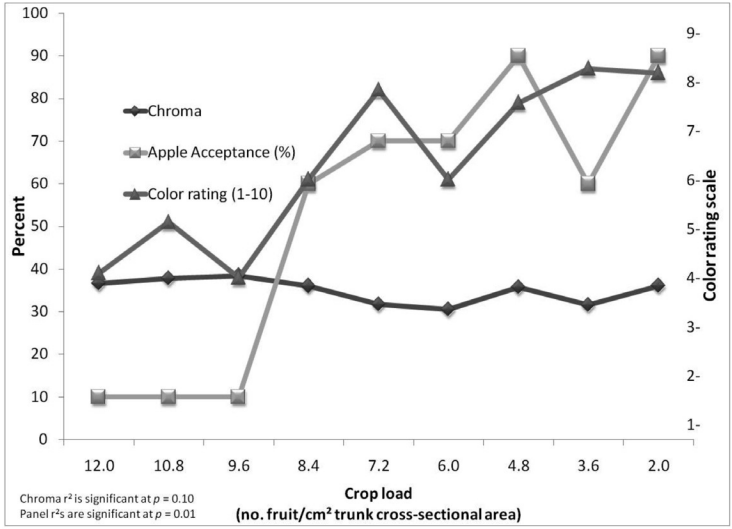

Fig. 3. Chroma color measurement ($\sqrt{a^{*2} + b^{*2}}$) and market professional color rating and acceptance of 'Honeycrisp' apples sampled from trees with nine crop load levels, 2007 (n=15). Chroma for the blushed side of the fruit was the only chromaticity value associated with crop load (r^2=0.15; p=0.10). Color rating scale 1 to 10 with 10 being most preferred. Acceptance was the % of panelists who considered a crop load sample suitable for purchase based on appearance. Cultivar specified for both color ratings and acceptance, as market professionals recognized 'Honeycrisp.'

60% considered flavor and crispness equally important. Sixty-eight percent of the consumers purchased fruit weekly—most commonly at a supermarket or farmer's market.

When the cultivar was not identified and panelists rated overall color on a 1 to 10 scale, they indicated a preference for fruit from 'Honeycrisp' trees that had a moderate crop load—in the range of 3.6 to 8.4 fruit/cm^2 trunk cross-sectional area (Fig. 2). With a second set of samples in which the cultivar was identified as 'Honeycrisp,' the panelists were more accepting of fruit from higher crop loads. Regression analyses indicated that color rating and color acceptance were inversely related to crop load (r^2=0.78; p=0.10). Neither percent blush nor any of the chromaticity measurements on the blush side of the fruit were correlated to crop load. However, L* (lightness) on the shaded, or green, side of the fruit was related to crop load (r^2=0.14; p=0.10) and also to color rating (r^2 =0.27; p=0.10). Hue angle on the green side of the fruit was related to color rating at p=0.05, and the coefficient of determination was 0.48. This is consistent with the most common reason panelists gave for finding apple color unacceptable, which was "they appeared too green which in their perceptions indicated inferior flavor." The lack of a relationship with chromaticity measurements on the blushed side of the fruit with visual ratings is in contrast to colorimeter work on cultivars with a higher percentage of red color on the fruit surface (7). In these studies there often was a correlation to hue angle, which is the angle formed by plotting the a* (redness if positive, green if negative) and b* (yellowness) values and drawing a line through the origin.

Market professional sensory panel evaluations. The panel of packers and other market professionals who participated in the parallel sensory study were able to distinguish smaller differences in color associated with crop load (Figs. 3 and 4). Percent acceptance dropped sharply above 8.4 fruit/cm^2 trunk

cross-sectional area. Whereas the consumer coefficients of determination (r^2) comparing crop load to either color rating or acceptance were 0.26 and 0.58, respectively, the packer r^2s were 0.78 and 0.76, and the level of significance was 0.01. The market professionals provided very detailed explanations when asked why the color of certain apples was unacceptable. Often there were at least three reasons, with comments centering on a range of color characteristics such as red color pattern, intensity of color, background color, and percent color. Chroma (blushed side of fruit) was the only chromaticity value associated with crop load, and the relationship was weak (r^2=0.15; p=0.10). Again, this contrasts with colorimeter studies on apple cultivars that must have an attractive overall color to be marketable. During the focus group session, the market professionals discussed how 'Honeycrisp' had changed consumer purchase habits from being appearance-based to taste-based. The group also provided input for the taste and color sensory evaluations that were subsequently conducted by the Penn State food science department. The market professionals suggested that in addition to evaluating effects of crop load on color and taste that the effects of harvest date be evaluated. They also recommended the inclusion of 'Gala' and 'Golden Delicious' as taste standards.

Food science sensory laboratory consumer panel evaluations. The demographic characteristics of the Penn State faculty, staff, and students who participated in the food science laboratory panel evaluations are found in Table 2. The panelists were mainly female and ranged in age from 36 to 65, as in the farmer's market survey. The main factors they considered when purchasing apples were appearance and taste (equally important) and also crispness. Their favorite apple was 'Gala,' which has all three of the favored characteristics. The consumer group indicated that they generally purchase apples weekly or bi-monthly from supermarkets, farmer's markets, and orchards. Although organic, locally grown, and eco-friendly were factors the panelists said they didn't consider as much as taste, color, texture, and price, 50% said their purchases of locally grown apples had increased over the previous two years (data not shown).

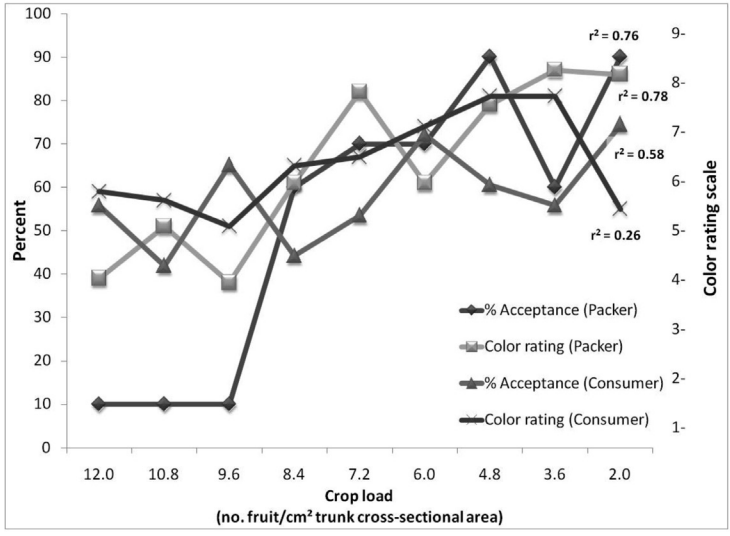

Fig. 4. Market professional visual ratings of 'Honeycrisp' color compared to consumer color ratings (p=0.10 and 0.01 for consumer and packer evaluations, respectively).

Table 2. Food science sensory laboratory consumer panel demographic characteristics, 2008 (n=100).

Demographic characteristics	Consumer responses (%)						
Sex	Female 81			Male 19			
Age	18-35 yr 25		36-65 yr 73		>65 yr 2		
Favorite apple	Delicious 11	Gala 19	Golden Delicious 13	Honeycrisp 11	McIntosh 15	Other 31	
Main purchasing considerations	Appearance 26	Organic/ eco-friendly 1	Crispness 18	Locally grown 6	Price 16	Size 7	Taste 26
Purchase frequency	Daily 2		Weekly 36	Bi-monthly 34	Monthly 28		
Purchase locations	Farmer's market 23		Supermarket 51	Orchard 23	Other 3		

Food science panel preferences were influenced by both crop load and harvest date (Tables 3 and 4; p=0.05), but the taste rankings of 'Gala,' 'Golden Delicious,' and 'Honeycrisp' (harvested mid-season from trees with a moderate crop load) were not significantly different (data not shown). The taste rankings of high crop load 'Honeycrisp' were lower than the rankings of moderate and low crop load fruit. The color rankings of moderate crop load fruit were higher than the color rankings of either the high crop load or the low crop load 'Honeycrisp.' The consumer panelists preferred the taste of mid-season and late harvested 'Honeycrisp' to early harvested fruit and the color of late harvested fruit to either early or mid-season harvested fruit.

The results of evaluations from the sensory laboratory support the hypotheses proposed by the focus group of market professionals. Consumers can readily detect the inferiority of apples harvested immature or from heavily or lightly cropped trees. This was demonstrated with controlled taste and color tests. Furthermore, the 2007 sensory evaluations and follow-up questions related to fruit acceptability suggest that consumers are learning to assess potential eating quality from fruit appearance. The implication of the three studies for the grower community is that even when a cultivar

Table 3. Food science sensory laboratory consumer panel preferences for 'Honeycrisp' harvested from trees with high, moderate, or low crop load, 2008 (n=100).

	Consumer panel ranking (1-3)[y]	
Crop load[z]	Color	Taste
High	2.5 b[x]	2.5 b
Moderate	1.3 a	1.8 a
Low	2.2 b	1.7 a

[z] Fruit/cm^2 trunk cross-sectional area were 10.8, 7.2, and 3.6 for high, moderate, and low crop load, respectively.
[y] Ranking scale was 1 to 3, with 1 being most preferred.
[x] Mean separation within columns by Friedman Analysis of Rank and Tukey's Honestly Significant Difference Test, p=0.05.

Table 4. Food science sensory laboratory consumer panel preferences for 'Honeycrisp' harvested early, mid-season, or late, 2008 (n=100).

	Consumer panel ranking (1-3)[y]	
Harvest time[z]	Color	Taste
Early	2.8 c[x]	2.3 b
Mid-season	2.0 b	1.9 a
Late	1.2 a	1.8 a

[z] Harvest times were first, second, and third picking for early, mid-season, and late, respectively. Fruit selected for "early" were slightly immature based on background color, and fruit samples selected for "late" were slightly over-mature.
[x] Ranking scale was 1 to 3, with 1 being most preferred.
[w] Mean separation within columns by Friedman Analysis of Rank and Tukey's Honestly Significant Difference Test, p=0.05.

has strong consumer appeal, it is important to harvest fruit at optimum flavor and color. Both crop load and fruit maturity at harvest are management issues directly controlled by the fruit producer. The strong demand and good prices the industry has enjoyed with 'Honeycrisp' are based on the extraordinary eating experience provided to consumers, and mid-Atlantic producers can potentially increase the percentage of marketable 'Honeycrisp' by giving particular attention to the details of crop load management and harvest timing.

Acknowledgements

Special appreciation extended to Katy Lesser Clowney, Katie Hess Reichard, Maggie Reid, Melanie Schupp, Julie Peterson, Russell Rohrbaugh, Christina Anders, Kuhn Orchards, the State Horticultural Association of Pennsylvania Research Committee, and the Pennsylvania Apple Marketing Board.

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