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Maturity Index for the Color Grade of Canned Dark Sweet Cherries[1]

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Additional index words. Prunus avium, reflectance color, anthocyanins, soluble solids, titratable acidity

Abstract. **Highly significant correlations were obtained for reflectance color (Agtron) with anthocyanin content in both fresh and canned dark sweet cherries (*Prunus avium* L.) and also for both reflectance color and anthocyanin content with subjective USDA color. Soluble solids, titratable acidity, pH, and a soluble solids/titratable acidity ratio were not good indicators of color development in sweet cherries. Reflectance color could be used to predict USDA color from fresh or canned dark sweet cherries.**

To a large degree the USDA grade and consumer acceptance of canned dark red sweet cherries depends on the color of the fruit and syrup, and subjective evaluation of skin color of the fresh fruit is only as good as the observer. A more accurate measurement of skin color would be useful in determining the maturity that is needed to produce a highly colored canned product.

Proper maturity for the fresh market has been the goal of most maturity indices. Soluble solids, acidity, soluble solids/acidity ratios, skin color, and firmness have all been used as indices of maturity (1, 2, 5). Very few studies have been concerned with the proper maturity for canned fruit. Chemical analysis of anthocyanins (6), or raw fruit absorbance at 520 nm, has been proposed as a maturity index for canned fruit. This chemical procedure is quick, simple, and requires only limited analysis, but it was developed before widespread use of reflectance color instrumentation. The use of a reflectance color instrument has been proposed to measure color development in cranberries, strawberries, and grapes (4, 7, 9). Reflectance color of cranberries was not correlated with pigment content and could not be used to predict the color of a processed product, but could be used to measure the degree of coloring at harvest.

Reflectance instruments for color determination are now used by most processing plants for quality control. The use of reflectance color as a reliable maturity index for dark sweet cherries would be most useful. This study was conducted to determine the feasibility of using reflectance color as a maturity index for the harvesting of dark sweet cherries for canning, and as an objective measurement of color for grading canned cherries.

Materials and Methods

Fruit from 'Bing', 'Chinook', 'Lambert', and 'Van' cherry trees growing at or near the Washington State University, Irrigated Agriculture Research and Extension Center, Prosser, WA, were used. During the 1977 to 1980 growing seasons fruit was harvested at 7-day intervals starting when the fruit had reached maturity for fresh shipment. Plots consisted of 8 trees each of 'Bing' and 'Chinook', and 3 trees each of 'Lambert' and 'Van', for each growing season. Due to the known effects (3) of butanedioic acid mono-(2,2-dimethylhydrazide) (daminozide) on

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Table 1. Correlation coefficients between reflectance color (Agtron) and anthocyanin content; reflectance color, anthocyanin content, absorbance and USDA color; and various maturity indices and USDA color, 1977 to 1980.

Variables, correlated	Correlation coefficient (r)			
	Bing	Van	Lambert	Chinook
Agtron (fresh)–Fruit TAcy cont. (fresh)	-.79**	-.68**	-.73**	-.86**
Agtron (fresh)–Fruit TAcy cont. (can.)	-.93**	-.79**	-.93**	-.88**
Agtron (can.)–Fruit TAcy cont. (can.)	-.93**	-.80**	-.78**	-.79**
Agtron (can.)–Fruit TAcy cont. (can.)	-.96**	-.89**	-.94**	-.92**
Agtron (can.)–Syrup absorbance (can.)	-.93**	-.81**	-.77**	-.56
Agtron (fresh) – USDA color	-.90**	-.75**	-.87**	-.94**
Agtron (can.) – USDA color	-.90**	-.75**	-.84**	-.97**
Fruit TAcy cont. (fresh)–USDA color	.91**	.87**	.77**	.87**
Fruit TAcy cont. (can.)–USDA color	.92**	.89**	.85**	.92**
Syrup absorbance (can.)–USDA color	.68*	.86**	.71**	.76**
Soluble solids (fresh)–USDA color	.67*	.64*	.32	.44
pH (fresh)–USDA color	.13	.25	.12	.44
Titratable acidity (fresh)–USDA color	-.16	.21	.15	.29
SS/TA ratio (fresh)–USDA color	.66*	.69*	.58*	.42

*,** Statistically significant at 5% (*) or 1% (**) level.

the color of sweet cherries, 4 each of the 8 'Bing' and 'Chinook' trees were treated with 2000 ppm of daminozide about 2 weeks after full bloom in each season. The trees were uniform in age, size, and vigor within each cultivar.

The fresh fruit were analyzed on the day harvested. A weighed amount of fruit was filled into 303 × 406 cans and covered with 200 ml of 20° brix sucrose syrup at 93°C. The cans were exhausted for 5 min at 93°, closed, and processed at 100° for 18 min. Processed fruit was evaluated and a USDA grade determined after 60 days in storage at ambient temperature.

Reflectance red color of the whole fruit was determined with an Agtron, Model 300, reflectance spectrophotometer, calibrated with disks 00–33 in the red mode. Color of the canned syrup diluted 1:10 (v/v) was measured at 520 nm, with distilled water as a blank, using a Bausch and Lomb Spectronic 100. Anthocyanin (TAcy) concentration of the fruit was determined colorimetrically (6). Soluble solids, pH, and titratable acidity were determined on a 500 g sample of macerated tissue. Soluble solids content was determined with a refractometer. Acids were titrated to pH 8.2 with 0.1 N NaOH and expressed as percent malic acid. USDA inspectors graded the canned fruit using USDA standards (8). Equivalencies between instrument values and USDA colors were derived through correlation and development of a standard curve, 1977 to 1980.

Results and Discussion

Significant correlations were obtained for reflectance color (Agtron) on fresh or canned fruit with the respective TAcy content for the 4 cultivars during 3 seasons (Table 1). This is in contrast to the results with cranberries (4), where reflectance color did not correlate with pigment content. Correlation coefficients for 'Bing' were higher than for the other cultivars, but all correlations were significant, except between Agtron color of canned fruit and syrup absorbance for 'Chinook'.

Correlations of fruit Agtron color, fresh and canned, fruit TAcy content, fresh and canned, and syrup absorbance with USDA color were all significant. The highest correlations were those of USDA color with Agtron color and fruit TAcy content. The correlation of syrup absorbance with USDA color was significant but was not high enough to be useful.

Correlations of the traditional parameters for ripeness (soluble solids, pH, titratable acidity, and soluble solids/titratable acidity ratio (SS/TA) with USDA color were not acceptable. Only the correlation coefficients for soluble solids and the SS/TA ratio were significant and then only for 'Bing' and 'Van'.

The significant correlations obtained for Agtron color with USDA color and for fruit TAcy content with USDA color indicated that either of these measurements could be used to predict USDA color from the fresh or canned product. Either of these measurements (Agtron or fruit TAcy content) are easy to obtain and relatively inexpensive.

Comparisons of the color predicted from fresh fruit Agtron values and TAcy content, with actual USDA color are shown in Table 2. In most instances the difference between predicted and actual USDA color was slight regardless of whether the equation for Agtron color or fruit TAcy content was used. Accuracy of the predicted color from fresh fruit Agtron values was excellent (Table 2). We feel that to be acceptable, the difference between predicted and actual USDA color should be less than 2.0 units, because a very narrow point spread is allowed between color

Table 2. Actual USDA color scores and error of prediction from Agtron and TAcy values[z], 1979 and 1980.

Cultivar	Treatment	Harvest	USDA color 1979	USDA color 1980	Agtron (Fresh) Prediction error 1979	Agtron (Fresh) Prediction error 1980	TAcy (fresh) Prediction error 1979	TAcy (fresh) Prediction error 1980	Agtron (Canned) Prediction error 1979	Agtron (Canned) Prediction error 1980	TAcy (Canned) Prediction error 1979	TAcy (Canned) Prediction error 1980
Bing	Control	Early	24	21	0	+1	+1	+1	-2	+3*	+2	+2
		Late	28	26	−1	+2	0	-2	0	+2	0	-4*
	Daminozide	Early	24	27	0	+1	+1	-1	-1	+1	-3*	-3*
		Late	28	30	-1	-2	0	+3*	0	-2	-2	-5*
Chinook	Control	Early	23	23	+1	0	0	0	-1	-2	0	0
		Late	27	27	0	0	-1	0	0	0	0	-10*
	Daminozide	Early	24	25	+1	0	0	+4*	0	0	-1	+3*
		Late	28	27	0	0	0	0	0	+1	0	+12*
Van		Early	21	26	0	+1	0	+2	0	+2	-1	-4*
		Late	25	27	0	0	0	+2	0	+1	0	-2*
Lambert		Early	17	22	+2	-2	+3*	-4*	+1	0	+3*	-3*
		Late	22	25	0	+2	-1	+1	0	+2	+1	0

[z](Values predicted from regression of USDA score on Agtron or TAcy value) – (actual USDA score)
*Significant difference, 5% level

grades by the USDA standards (8). The extreme limits of an acceptable prediction error, using fresh fruit Agtron values, occurred most often with 'Lambert'. 'Lambert' cherries develop color at a slower rate than the other cultivars (6), and this could be the reason for the prediction error. The prediction error limit also occurred with 'Bing' but only in 2 of 8 instances. Prediction errors were small with 'Chinook' and 'Van' cherries.

Predicted color developed from fresh fruit Agtron values was more accurate than predicted color developed from fresh fruit TAcy content (Table 2). Prediction error limits occurred for 'Lambert', 'Bing', and 'Chinook' cherries and were overestimated in most instances except for 'Lambert' in 1980. The larger differences in the prediction error when using fresh fruit TAcy content rather than Agtron color is perhaps because eyes see a reflected color such as the Agtron and not total pigment. The use of daminozide increases fruit TAcy content (3).

Predicted color values from canned fruit Agtron or TAcy values were not as accurate as those Agtron or TAcy values from fresh fruit. Differences between predicted values from canned fruit and actual USDA color values occurred more often and were larger.

Predicted values from canned fruit Agtron values were acceptable in most instances, except for 'Bing' cherries that were harvested early. The predicted color for early harvested 'Bing' cherries was overestimated by 3 points in 1980. Predicted values from canned fruit Agtron values were good for 'Chinook', 'Van', and 'Lambert' cherries.

When canned fruit TAcy content was used to predict color (Table 2) differences were numerous and in some cases extreme (-4.0 to ± 12.0). The most extreme differences occurred for cherries harvested in 1980. Predicted color from canned fruit TAcy content was unacceptable for all 4 cultivars.

The prediction of color was less reliable in 1980 than 1979, regardless of whether fresh or canned Agtron color or fruit TAcy content was used. This may be due to the very unusual growing season during 1980 when environmental factors placed additional stress on the cherry trees and advanced maturity.

Fig. 1 displays a regression model for the prediction of USDA color from fresh fruit Agtron color. The model for the Agtron (fresh) color of 'Bing', 'Chinook', and 'Van' was almost identical and for field use, or rough estimations, could be considered as equal. If predictions of color for 'Lambert' from Agtron color are required, a separate standard should be used. The color of 'Lambert' cherries develops at a slower rate than that of the other cultivars. Regardless of the cultivar, fresh fruit Agtron values less than 20 are equivalent to 'A' color grade.

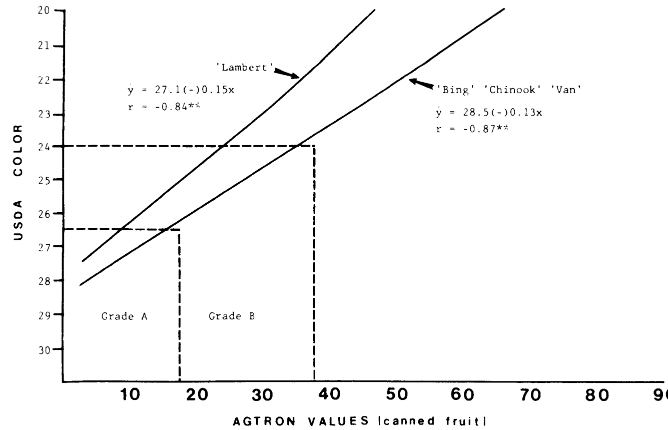

Fig. 2. Regression model for predicting USDA color from canned fruit Agtron values, 1977 to 1980.

Regression models for the prediction of USDA color from processed fruit Agtron color are presented in Fig. 2. The models are very similar for 'Bing', 'Chinook', and 'Van'; 'Lambert' requires a separate regression model. In this study reflectance color as measured by the Agtron and calibrated with disks 00-33, must be less than 20 for 'Bing', 'Chinook', or 'Van', and less than 10 for 'Lambert' before a color grade of 'A' is assigned.

Color prediction from fresh fruit TAcy content is possible, and a model for this is presented in Fig. 3. The fresh fruit TAcy content for 'Bing' and 'Chinook' were similar, and the fruit TAcy for 'Van' and 'Lambert' were similar, so only 2 models are required. In this study, a fruit TAcy content greater than 45 was required by all 4 cultivars before an 'A' color grade was assigned. The prediction of color from processed fruit TAcy content was too variable (Table 2) and cannot be used if reasonable accuracy is required.

Conclusions

Due to individual and instrumental differences, no minimum reflectance color (Agtron) or fruit TAcy content that will produce an exact calculated USDA grade is proposed. However, it appears that an objective color standard can be developed that agrees with and is more exact than subjective color.

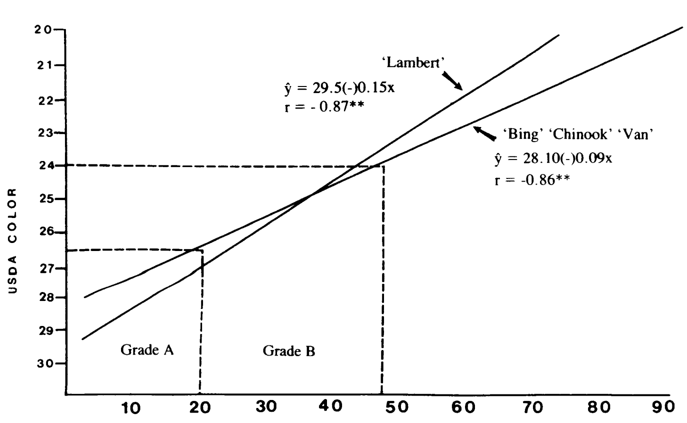

Fig. 1. Regression model for predicting USDA color from fresh fruit Agtron values, 1977 to 1980.

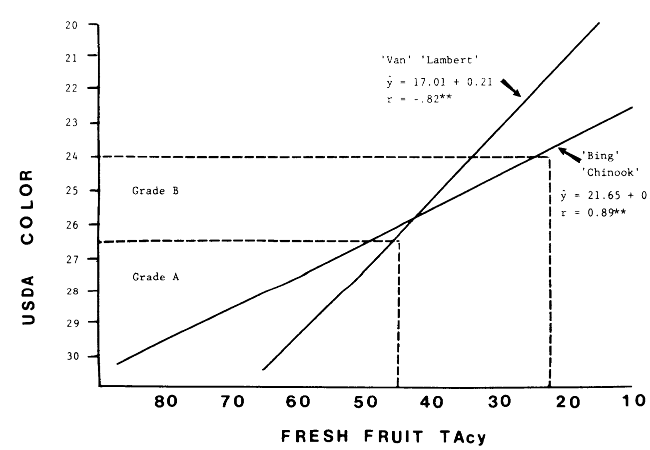

Fig. 3. Regression model for predicting USDA color from fresh fruit TAcy, 1977 to 1980.

Reflectance color and fruit TAcy development can be very useful for evaluation of unfamiliar cultivars and for better accuracy in maturity determinations when a more exact prediction of end product grade is required. Either Agtron color or fruit TAcy content is easy to obtain and relatively inexpensive. Agtron color measurements would require less training of an individual, and more color samples could be determined in a shorter time period. Using fresh or processed Agtron color or fresh fruit TAcy to predict canned product color would be useful for processors and graders.

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Phenolic Compounds in Two Size-controlling Apple Rootstocks[1]

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Additional index words. benzoic acid, *p*-hydroxybenzoic acid, 4-hydrohydroxycinnamic acid, protocatechuic acid, *p*-coumaric acid, caffeic acid, ferulic acid, phloretic acid, phloretin, phloridzin, chlorogenic acid, *Malus* sp.

Abstract. **One-year-old Malling (M) 26 and Malling Merton (MM) 111 apple rootstocks (*Malus* sp) were planted in pots in a greenhouse in March and harvested monthly from May to October. Samples of the shoot tip, stem bark, and new and old roots were collected for PVP-bonded and simple phenol analyses. The PVP-bonded phenols were highest in the shoot tip and lowest in the old roots. There was no consistent relationship with rootstock or time of collection. Five phenols were found in the shoot tip, 8 in the bark, and 8 in the new roots, including protocatechuic, ferulic, and benzoic acids. Benzoic acid was found only in the new roots. Phloridzin composed more than 90% of all the simple phenols found and was higher in MM 111 than in M 26 rootstock. The other phenols were not consistently higher in either rootstock and had few trends with time of collection. No direct relationship was found between phenol levels and dwarfing characteristics.**

Phenolic compounds have been implicated in the dwarfing mechanism of apple rootstocks and interstocks (5, 11). Various phenolic compounds are present in apples, mainly in the stem bark, root bark, shoot tips, and leaves with little in the wood (5). The shoots contain caffeic acid, *p*-coumaric acid, *p*-hydroxybenzoic acid, sinapic acid (7), phloretic acid, phloretin, phloridzin and phlorol (10). The stem bark contains kaempferol, phloretin, phloridzin, and quercitin (15). A more complete review of phenols in apple trees is given by Lockard and Schneider (5). Most phenols are found as glycosides or esters (13, 14), and do not seem to be translocated (2, 13), indicating that they function in the cells where synthesized.

Phloridzin has been reported to be higher in M 16 (non-dwarfing) than in M 9 (dwarfing) rootstock (6). Phloridzin is highest in the bark of apple trees during deep dormancy (10) or just before spring growth commences and decreases during periods of rapid growth.

The objective of this investigation was to determine the phenols in apple rootstock stem bark, shoot tips, and roots in a semi-dwarfing and a dwarfing rootstock over a growing season to determine if there was any correlation between phenols and the dwarfing characteristic.

Materials and Methods

One-year-old M 26 and MM 111 rootstocks were obtained from a nursery and planted in 20-cm plastic pots in a greenhouse in March. The pots were filled with a mixture of 1 soil: 1 peat: 1 perlite (v/v/v) and placed 20 cm apart on a bench. When planted, the rootstock MM 111 had about 60 cm of stem above the soil and M 26 had 30 cm of stem above the soil. Plants were watered twice a day and fertilized with 20 N-8.6 P-16.6 K once a week at a con-

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