Amaranthus Betacyanin Pigments Applied in Model Food Systems

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ABSTRACT

Amaranthus **betacyanin pigments and commercial colorants were evaluated to determine color characteristics and stability at different temperatures in jelly, ice cream, and a model beverage. The betacyanin exhibited brighter color characteristics than red radish anthocyanin, with similar color stability during 20-wk storage (≤ 14 °C) or during the initial 4-wk storage (≤ 25 °C), but was less stable than red radish anthocyanin at 37 °C. The betacyanin was not as stable as synthetic Food, Drug, and Cosmetics Red No. 3 under most storage conditions. Ascorbic acid had a protective effect on** ***Amaranthus*** **pigments. Excessive sucrose (≥ 16%) decreased stability of the pigments. The betacyanin tested may be a feasible natural colorant for jelly, higher pH beverages, and ice cream under selected conditions.**

Key Words: *Amaranthus*, betacyanins, jelly, ice cream, beverage

INTRODUCTION

NATURAL PIGMENTS FROM PLANT TISSUE INCLUDE CHLOROphylls, carotenoids, flavonoids, anthocyanins, quinones, and betacyanins (von Elbe and Schwartz, 1996). Betacyanins occur in about 10 plant families of the order Centrospermae, such as the genera *Beta* and *Amaranthus*. Betacyanins from beet (*Beta vulgaris*) have been extensively studied and are widely used (e.g., von Elbe, 1977; Freund et al., 1988; von Elbe and Schwartz, 1996). Red beet powder has been permitted as a color additive (von Elbe et al., 1974b).

There have been several reports on the red-violet betacyanins from leaves of a vegetable amaranth species (*Amaranthus tricolor*) (Shen and Hwang, 1985; Huang and von Elbe, 1986; Chen, 1992; Yue et al., 1993). However, more than 60 species of the genus *Amaranthus* are known to occur (Schnetzler and Breene, 1994), but information is scarce on the betacyanins of species other than *A. tricolor*. During research on *Amaranthus* genetic resources from 38 countries and regions (Cai et al., 1998a, b), we found that many genotypes of grain amaranth (*A. cruentus*, *A. caudatus*, and *A. hybridus*) had more betacyanin in tissues than found in *A. tricolor*. Such grain amaranths had much higher biomass and better regenerative ability after cutting. Our results indicated that *Amaranthus* betacyanin pigments could be produced economically on a large scale under many common agricultural conditions in China.

Amaranthus pigments have been used to color beverages, bread, and other foods in various locations, e.g., southwestern United States, Mexico, Bolivia, Ecuador, and Argentina (Lehmann, 1990). Teutonico and Knorr (1985) reported that a red-colored extract of amaranth leaves had been used to color foods throughout the world. Pigments from vegetable amaranth (*A. tricolor*) are approved for food use in China (Hygienic Standards for Food Additives in China, GB2760-89) (Jin, 1990), yet *Amaranthus* pigments have not been used as commonly as red beet pigments.

Amaranthus pigments are very similar to beet pigments (betanine) in structure and properties. Thus, likely applications include: yogurt, sherbert, ice cream, frozen fruit desserts, candies, frostings, puddings (Freund et al., 1988); bacon, sausage (von Elbe et al., 1974a); and beverages and canned fruit (Huo and Guo, 1994). There has been little information published on food applications of *Amaranthus* pigments.

Our objective was to evaluate the performance of *Amaranthus* pigments as a colorant in jelly, ice cream, and a model beverage, compared to another natural colorant, red radish anthocyanin, and to a synthetic colorant, Food, Drug, and Cosmetic (FD&C) Red No. 3.

MATERIALS & METHODS

Materials

Dried *Amaranthus* pigments. An *Amaranthus cruentus* genotype (Cr072) of Indian origin was selected for its favorable pigment yield, color, and stability in preliminary experiments (Cai et al., 1998a, b). Dried pigment extract was prepared following Cai et al. (1998b): selecting inflorescence sample, washing, chilling (4 °C, 30 min), cutting into small pieces, blanching, and extracting (80 °C, 5 min), followed by centrifugation, concentrating, and vacuum drying (< 40 °C). The dried pigment was packed in stoppered glass bottles and stored at 4 ºC until use.

Pigment checks. Dried red radish pigment was obtained from Shanghai Food Additives Joint Co. (Shanghai, China). FD&C Red No. 3 (erythrosine), a synthetic colorant, was obtained from Borthwicks Flavours Co. (Northants, U.K.).

Commercial jelly powder and ice cream powder. Jelly powder (natural extracts from marine algae, sugar, citric acid, sodium) and ice cream powder (milk, butter, egg, sugar, sodium citrate) without pigment were provided by Tianjing Unison Food Co. Ltd. (Tianjing, China) and Chongqing Milk Co. (Chongqing, China), respectively.

pH values in experimental food systems

The optimum pH for different colorants varies. *Amaranthus* betacyanins are stable at pH 4.0 to 7.0, similar to red beet betacyanins reported by Freund et al. (1988) and Francis (1999). *Amaranthus* pigments had greatest stability at pH 5.0 to 7.0, at 25 °C, especially at pH 5.6 (Cai et al., 1998a). So pH values for *Amaranthus* pigments were studied at 5.0 to 6.0 in jelly and ice cream, and 5.6 in the beverage. The stable range for anthocyanins is usually pH < 4.0 (Francis, 1999), so for red radish anthocyanins, we used pH 3.0 in the three experimental food systems. FD&C Red No. 3 is quite stable under alkaline conditions but has poor solubility under acid conditions (Francis, 1999), so the pH value for it was > 7.0 in the three foods studied.

Preparation of jelly and ice cream

Jelly solution and ice cream liquid were made with jelly powder or ice cream powder by dissolving in boiling water, in the ratio

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of 1:5 and 1:3 (w/v), respectively. The pH was 5.0 to 6.0 when using *Amaranthus* pigments, 3.0 for red radish pigments, and 7.0 to 8.0 for FD&C Red No. 3. Accurate amounts of pigment were incorporated by blending below 60 °C, and then pouring into 70-mL plastic cups (4.5 cm dia, 5.5 cm depth), sealed with screw caps (Biolab Scientific Pty. Ltd., Australia) and refrigerated.

Preparation of model beverage systems

The model beverage (Bassa and Francis, 1987; Teh and Francis, 1988) was formulated with McIlvaine buffer solution containing 13% sucrose and selected amounts of colorants for *Amaranthus* pigments (at pH 5.6), red radish anthocyanins (at pH 3.0), and FD&C Red No. 3 (at pH 7.8). The McIlvaine buffers were made from 0.1 M citric acid and 0.2 M sodium phosphate dibasic in appropriate ratios for the required pH. Sucrose and colorant were dissolved in the buffer solution, blended, and poured into 70-mL plastic cups.

Experimental design and storage

For jelly, five levels of *Amaranthus* pigment (0.105, 0.204, 0.250, 0.370, and 0.404 g/L), two levels of red radish (0.250 and 0.370 g/L), and two levels of FD&C Red No. 3 (0.040 and 0.250) were used. For the beverage 0.300 g/L of *Amaranthus* pigment and red radish pigment, and 0.040 g/L of FD&C Red No. 3 was used. For the ice cream 0.602 g/L of *Amaranthus* pigment and red radish pigment, and 0.040 g/L of FD&C Red No. 3 were used. Also, for the jelly, six levels of ascorbic acid (0%, 0.05%, 0.10%, 0.25%, 0.50%, and 1.00%) were used. For the beverage eight levels of ascorbic acid (0%, 0.01%, 0.05%, 0.10%, 0.25%, 0.50%, 0.75%, and 1.00%), eight levels of sucrose (0%, 3%, 7%, 10%, 13%, 16%, 20%, and 23%), and interactions of ascorbic acid (0.05%, 0.10%, and 0.25%) vs sucrose (7, 13, 20%) were used. All samples were made in triplicates. Plastic cups and other materials were sterilized to prevent microbial growth during storage. Samples of jelly and beverage were stored in the dark in absence of oxygen at 4 °C and 14 °C for 6 mo and at 25 °C and 37 °C for 3 mo. Samples of ice cream were stored in the dark and in absence of oxygen at –18 °C for 6 mo.

Color and spectral analysis

Color measurements were made with a reflectance spectrophotometer (Chroma Meter CR-301, Minolta Co. Ltd., Osaka, Japan). Jelly and ice cream color was determined through the bottom of the plastic cups containing experimental samples, and beverage color was determined through a square plastic optical cell (50 mm × 50 mm, 5 mm depth). Ultra-violet-visible spectra of beverages containing the pigments were measured by a spectrophotometer (Spectronic Genesys 5, Milton Roy, N.Y., U.S.A.). Absorbance spectra of the beverages in 1.0 cm pathlength quartz cuvettes were recorded from 200 to 700 nm.

Color results were expressed as tristimulus parameters (L*, a*, b*, C, H°, ΔE^*_{ab}). H° (hue angle = $\tan^{-1}$ b*/a*) indicates sample color (0° or 360° = red; 90° = yellow; 180° = green; 270° = blue), and C [Chroma = $(a^{*2} + b^{*2})^{1/2}$] indicates color purity or saturation (high values are more vivid). ΔE^*_{ab} indicates the total color difference between two samples, calculated as $[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ (Francis, 1985).

Betacyanin content determination

Tinctoral strength (*TS*), used to express coloring power, is defined as the absorbance at the maximum absorbance wavelength (Hong and Wrolstad, 1990) and was measured with a spectrophotometer at λ_{max} = 536 nm. $TS = A_{536} \times DF\ (abs)$, where *DF* = dilution factor.

Since amaranthine and isoamaranthine, with same λ_{max} and similar structure, are the major components of *Amaranthus* betacyanins (Cai et al., 1998b), *Amaranthus* betacyanin content (AC) in beverages could be expressed as mg of amaranthine/L model beverage:

$$AC = TS \times MW \times 10^3/\epsilon \times L\ (mg/L)$$

For amaranthine, $\epsilon = 5.66 \times 10^4$ cm^{-1} mol^{-1} l (Piattelli et al., 1969), and MW = 726.6 g mol^{-1}. Where TS = tinctoral strength (abs); L (pathlength) = 1.0 cm.

Calculation of pigment or color retention (%) and half-life ($T_{1/2}$)

Pigment retention (%) for beverages was calculated from betacyanin content (*AC*) measurements made at zero storage time and at *X* storage time (*AC at X time* × 10^2/*AC at 0 time*), while color retention (%) for jelly and ice cream was calculated by the formula: *C-value at X storage time* × 10^2/*C-value at zero storage time*. Half-life value ($T_{1/2}$) was calculated by the methods of Saguy et al. (1978) and Shen and Hwang (1985) using regression analysis of *ln* (pigment or color retention %) vs storage time.

Statistical analysis

Data analysis and statistical computations for analysis of variance (ANOVA) and Duncan's test were performed with the Statistical Analysis System (SAS Institute Inc., Cary, N.C., U.S.A.). Significance of differences was defined at $p \leq 0.05$.

RESULTS & DISCUSSION

Color characteristics of jelly, ice cream, and model beverage

Prior to storage, jelly and ice cream samples containing *Amaranthus* pigments appeared red-violet, while samples containing commercial pigments (red radish and FD&C Red No. 3) were orange-red or pink-red (Table 1). For jelly samples with increasing amounts of *Amaranthus* pigments, a* and C values were increased while L*, b*, and H° values were reduced. The higher the pigment dosage, the darker (L*), more red-violet (H°), and more saturated (C) were the samples. Comparison between *Amaranthus* and check pigments in jelly revealed major differences in tristimulus parameters and ΔE^*_{ab} values (Table 1). For jelly samples at the same pigment levels (0.250 g/L), the color with *Amaranthus* pigments was darker (lower L*), more saturated, and more violet-red (lower hue angle H°) than red radish, but lighter, less saturated and less yellow-red than with FD&C Red No. 3. The total color difference (ΔE^*_{ab}) between the two natural pigments (*Amaranthus* and red radish) was smaller than the differences between the natural pigments and FD&C Red No. 3. In addition, *Amaranthus* pigments in jelly and ice cream at lower levels exhibited similar color characteristics to red radish at higher levels but were little brighter than FD&C Red No. 3 at very low dosage (0.04 g/L). *Amaranthus* and red radish pigments had generally similar relative effects on the beverage as on ice cream (Table 1), but both natural pigments gave low values of C compared to the FD&C Red No. 3.

Color stability of *Amaranthus* pigments in jelly and ice cream

Since L* and C values correlated with pigment content, the color change or color retention of pigments and half-life ($T_{1/2}$) could be studied by determining L*, a*, b*, and calculating C values (Table 2) for jelly containing *Amaranthus* and commercial pigments during storage at 4 °C, 14 °C, 25 °C, and 37 °C, and ice cream at –18 °C. Great color changes in jelly containing *Amaranthus* pigments were found with different storage temperatures. Jelly samples had high color retention (78.1%) and longer half-life (23.9 wk) at 4 °C, compared to 72.2% and 18.2 wk at 14 °C, after 18-wk storage. The color retention of jelly samples after 4-wk storage at 25 °C declined to 61.5%. Hue angle (H°) increased with a

Table 1—Color characteristics of jelly, ice cream, and beverage with *Amaranthus* pigments[a] (at zero storage time)

Food type	Colorants	Pigment level (g/L)	Color	L*	a*	b*	C	H°	$\Delta E^*_{ab}1$	$\Delta E^*_{ab}2$
Jelly	*Amaranthus* pigment	0.105	Light purple	30.0	4.7	–1.2	4.9	346 (–14)	10.9	2.7
		0.204	Light purple	29.8	5.1	–1.5	5.3	344 (–16)	10.8	3.1
		0.250	Red-violet	29.8	5.4	–1.8	5.7	342 (–18)	10.8	3.5
		0.370	Red-violet	28.7	5.5	–2.2	5.9	338 (–22)	11.0	4.3
		0.404	Red-violet	28.1	6.7	–2.6	7.1	339 (–21)	10.5	5.2
	Red radish pigment	0.250	Light red	30.4	4.3	1.5	4.5	19	10.0	0.0
		0.602	Orange-red	30.1	5.1	1.8	5.5	20	8.9	1.0
	FD&C Red No. 3	0.040	Orange-red	31.1	7.9	2.2	8.2	16	6.6	3.7
		0.250	Orange-red	29.0	13.1	5.7	14.3	24	0.0	9.9
	Check (no pigment)	0.000	Transparent	45.2	-0.4	1.8	1.9	103	21.4	15.5
Ice cream	*Amaranthus* pigment	0.602	Red-violet	47.9	20.9	–2.0	21.0	355 (–5)	8.5	5.1
	Red radish	0.604	Pink-red	50.9	18.9	1.6	18.9	5	6.4	0.0
	FD&C Red No. 3	0.041	Pink-red	54.3	24.2	2.6	24.3	6	0.0	6.4
	Check (no pigment)	0.000	Milk-white	62.2	-3.1	9.7	10.2	108	29.2	25.9
Beverage	*Amaranthus* pigment	0.301	Red-violet	43.1	11.3	–1.4	11.4	353	14.3	9.8
	Red radish	0.302	Orange-red	50.8	7.1	2.7	7.6	21	17.2	0.0
	FD&C Red No. 3	0.040	Orange-red	44.2	21.2	8.8	23.0	23	0.0	16.8
	Control (no pigment)	0.000	Transparent	57.6	–0.1	0.7	0.7	98	26.5	10.1

[a]From *Amaranthus* genotype "Cr072"; L*, a*, b* values from triplicate determinations; $\Delta E^*_{ab}1$ and $\Delta E^*_{ab}2$ calculated relative to FD&C Red No. 3 and red radish, respectively.

Table 2—Color stability of jelly and ice cream with *Amaranthus* (genotype Cr072) and commercial pigments[a]

Storage temp	Dosage Pigments	(g/kg)	At 18 wk storage time[b] L*	a*	b*	C	H°	Color retention[c] (%)	Half-life $T_{1/2}$ (wk)
Ice cream at –18 °C	*Amaranthus*	0.602	48.7	19.8	–1.5	19.8	356	94.4	—
	Red radish	0.604	52.1	18.3	1.9	18.4	6	97.4	—
	FD&C Red No. 3	0.041	54.1	23.3	3.4	23.6	8	96.9	—
Jelly at 4 °C	*Amaranthus*	0.404	30.7	4.3	–1.2	4.5	345	78.1	23.9
	Red radish	0.602	30.8	4.0	1.6	4.3	22	79.3	24.8
	FD&C Red No. 3	0.040	30.9	7.1	2.3	7.4	18	91.2	—
Jelly at 14 °C	*Amaranthus*	0.404	31.8	4.9	–1.7	5.2	341	72.2	18.2
	Red radish	0.602	31.2	3.5	1.5	3.8	23	70.3	17.9
	FD&C Red No. 3	0.040	31.4	6.9	2.3	7.3	18	89.2	—
			At 12 wk storage time						
Jelly at 25 °C	*Amaranthus*	0.404	32.3	1.4	1.0	1.70	38	23.8	4.2
	Red radish	0.602	32.7	1.1	1.0	1.49	41	27.3	4.7
	FD&C Red No. 3	0.040	31.7	6.8	2.4	7.22	19	88.5	—
			At 4 wk storage time						
Jelly at 25 °C	*Amaranthus*	0.404	31.3	3.4	–0.7	3.5	349	61.5	4.2
Jelly at 37 °C	*Amaranthus*	0.404	35.8	0.5	0.9	1.0	58	14.2	1.3
	Red radish	0.602	36.1	1.2	1.0	1.6	41	29.8	3.2
	FD&C Red No. 3	0.040	31.9	7.0	2.3	7.4	18	90.7	—

[a]L*, a*, b* values by triplicate determinations.
[b]Initial values of L*, a*, b*, C, H° at zero storage time are shown in Table 1.

less orange shade of red. At increased storage temperature and extended storage time, jelly samples had very low color retention and half-life, e.g., 23.8% and 4.1 wk at 25 °C after 12-wk storage, and 14.2% and 1.28 wk at 37 °C after 4-wk storage. Hue angle rapidly increased to 37.6° and 57.6°. The color changed from purplish-red to orange-red to very light yellow. Thus, samples with *Amaranthus* pigments had good color stability only at the lower temperatures (–18 °C for ice cream; 4 °C, 14 °C for jelly). Higher temperatures (over 25 °C) greatly accelerated betacyanin degradation and color fading in jelly. This confirmed the report of Driver and Francis (1979) on stability of betanin from *Beta vulgaris* in dessert gels. However, the level of stability (61.5% color retention) after 4 wk at 25 °C indicated that *Amaranthus* pigments might be useful as jelly colorants even at room temperature with reasonable shelf life.

Red radish containing acylated-anthocyanins has been reported as a natural pigment with favorable stability (Giusti and Wrolstad, 1996). Compared to those with red radish pigment, jelly samples containing *Amaranthus* pigment had similar color retention (%) and half-life ($T_{1/2}$) during storage at 4 °C , 14 °C, and 25 °C, but not at 37 °C (Table 2). But the *Amaranthus* pigments were much less stable in jelly samples than FD&C Red No. 3, which had the highest color retention (about 90%) during all temperatures of storage. Stored at the very low –18 °C, ice cream samples containing *Amaranthus* pigments, like the samples containing the two other pigments, were reasonably stable, with the highest color retention at 18 wk being 94.4%, with comparable color to that prior to storage ($H°_{0wk} = 355°$, $H°_{18wk} = 356°$).

Ascorbic acid addition had little immediate effect on the color of *Amaranthus* pigments in jelly (at 0 wk), but had a slight positive effect on the pigments after 18-wk storage (results not shown). The positive effect was less than that of ascorbic acid on the pigment in the model beverage (see below). This may have been due to the influence of other jelly components on the stability of ascorbic acid.

Color stability of *Amaranthus* pigments in a model beverage

At 4 °C the changes in L*, C, H° and pigment retention values were very slight during 20 wk storage for all three colorants (Fig. 1). At 25 °C, the changes were quite large during 12 wk of storage for samples containing *Amaranthus* or red radish pigment, especially during the initial 6 wk. These changes were consistent with observed color changes from purplish-red or orange-red to light red and very light yellow. At lower temperature (4 °C) *Amaranthus* pigments had good stability as did red radish during 20 wk storage. At higher temperature (25 °C) *Amaranthus* pigments, like red radish, had 60% pigment retention during the first 4 wk storage, but thereafter decreased rapidly in stability and became somewhat less stable than red radish. Neither *Amaranthus* or red radish pigments were as stable as FD&C Red No. 3 at any temperature.

The addition of ascorbic acid and sucrose affected the betacya-

Table 3—Influence of ascorbic acid (Vc) and sucrose (Su) on effect of *Amaranthus* (genotype Cr072) pigments in a model beverage[a]

Treatments	λ_{max} (nm)	Betacyanin content (mg/L) 0 wk	20 wk	Pigment retention (%)
0.00% Vc	536	13.7 ± 0.02	9.1 ± 0.06	66.2
0.01% Vc	536	14.0 ± 0.05	9.1 ± 0.05	66.8
0.05% Vc	536	13.9 ± 0.03	9.9 ± 0.05	72.1
0.10% Vc	536	13.9 ± 0.05	10.2 ± 0.09	74.8
0.25% Vc	536	13.7 ± 0.10	10.2 ± 0.02	74.5
0.50% Vc	536	13.8 ± 0.06	10.5 ± 0.05	76.6
0.75% Vc	536	13.6 ± 0.04	9.6 ± 0.07	70.5
1.00% Vc	536	13.6 ± 0.05	8.1 ± 0.05	58.9
0% sucrose	536	13.7 ± 0.02	9.1 ± 0.05	66.3
3% sucrose	536	13.7 ± 0.04	9.0 ± 0.06	65.7
7% sucrose	536	13.7 ± 0.03	8.8 ± 0.05	64.2
10% sucrose	536	13.6 ± 0.05	8.8 ± 0.06	64.0
13% sucrose	538	13.6 ± 0.03	8.8 ± 0.02	64.5
16% sucrose	538	13.3 ± 0.02	8.5 ± 0.05	62.4
20% sucrose	539	13.0 ± 0.02	8.2 ± 0.04	60.2
23% sucrose	539	12.9 ± 0.02	8.1 ± 0.05	59.1
0.05% Vc, 7% Su	538	13.8 ± 0.09	9.6 ± 0.10	70.1
0.05% Vc, 13% Su	538	13.5 ± 0.02	9.2 ± 0.06	67.5
0.05% Vc, 20% Su	538	13.2 ± 0.07	9.3 ± 0.06	67.9
0.10% Vc, 7% Su	538	13.7 ± 0.04	9.7 ± 0.09	70.7
0.10% Vc, 13% Su	538	13.6 ± 0.02	9.6 ± 0.10	70.4
0.10% Vc, 20% Su	538	13.6 ± 0.05	9.4 ± 0.08	68.4
0.25% Vc, 7% Su	538	13.8 ± 0.02	9.8 ± 0.02	72.0
0.25% Vc, 13% Su	538	13.8 ± 0.06	9.6 ± 0.05	70.5
0.25% Vc, 20% Su	538	13.6 ± 0.12	9.7 ± 0.04	70.8
LSD (P < 0.05)	0.154	0.237	1.74	

[a]All beverage samples stored at 14 °C in dark and absence of oxygen. Data are means of triplicate determinations.

nin content after 20 wk (Table 3). Previous studies (Pasch and von Elbe, 1979; Bilyk et al., 1981) reported that antioxidants (ascorbic acid or its isomer) affected the betacyanins of beet (*Beta vulgaris*). An optimum concentration of ascorbic acid had a positive effect on *Amaranthus* betacyanin stability in the model beverage. Samples containing 0.10% to 0.50% ascorbic acid had higher pigment retention (74.5% to 76.6%) after 20-wk storage, as compared with 66.2% with the control (0.00% Vc). However, at 1.00% ascorbic acid, samples had only 58.9% pigment retention, due to damage to the betacyanins by the high concentration.

Sucrose at 3% to 13% concentration had almost no effect, or a slight negative effect, on *Amaranthus* betacyanin stability in the model beverage. With > 13% sucrose, the betacyanin content decreased. After 20-wk storage, samples containing 16% to 23% sucrose retained 62.4% to 59.1% of the betacyanins. Wrolstad et al. (1990) reported sucrose addition had a protective effect on anthocyanin pigment content in frozen strawberries, but the mechanism is not known. When determining the spectral and color properties, we observed that *Amaranthus* betacyanins seemed to show a slight red shift of the maximum absorbance wavelength (λ_{max}) and color (hue angle) change in beverage samples containing sucrose (see λ_{max} values, Table 3).

Sucrose plus ascorbic acid addition also affected the pigments during storage (Table 3). However, the interaction effect of ascor-

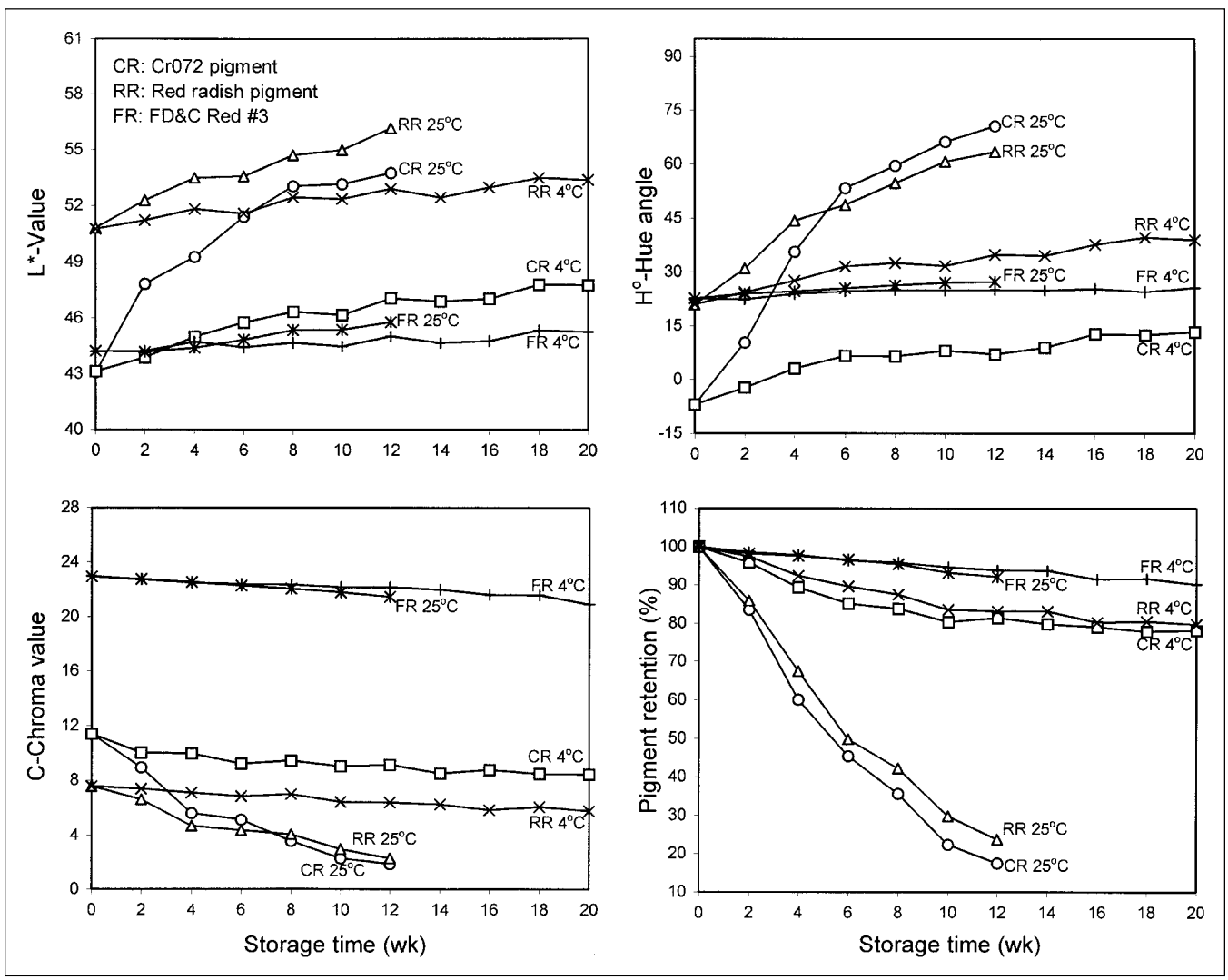

Fig. 1—Color stability of *Amaranthus* pigments and commercial pigments in a model beverage at different temperatures.

bic acid and sucrose was not significant at 0 wk or 20 wk (ANOVA results not shown). This indicates that optimally high concentration of ascorbic acid, combined with lower concentration of sugar, might reduce the negative effects on *Amaranthus* betacyanins in beverages.

The pH values in our experiments were based on the most stable ranges for each pigment, in order to adequately compare their color characteristics and stability. However, the pH 5.0 to 6.0 for *Amaranthus* pigments is not typical for most commercial beverages, such as fruit juices (pH 2.2 to 4.7) and soft drinks (Casolari, 1989; Varnam, 1994). Some beverages may be prepared at higher pH, and, even at lower pH, *Amaranthus* pigment color may be stable, since the color of amaranthine solution was unchanged in the pH range of most foods (3.0 to 7.0) (Huang et al., 1986). Betacyanins from red beet, similar to *Amaranthus* betacyanins, can be used in beverages at pH 4 to 7 (Warner-Jenkinson Company, product specification for No. 3600 beet powder, 1996, St. Louis, Mo., U.S.A.). *Amaranthus* pigment thermal stability in lower pH beverages needs further study. Betacyanins are also generally considered not as stable as anthocyanins, especially acylated anthocyanins. Early studies reported acylated betacyanins in plants of the order Centrospermae, including the Amaranthaceae family (Heuer et al., 1992). Schliemann et al. (1998) reported that acylated betacyanins showed a reduced racemization and enhanced stability. Our earlier study (Cai et al., 1998a) on pigments of 21 *Amaranthus* genotypes showed large differences of color stability, perhaps caused by structural differences in acyl group substitutions. The *Amaranthus* pigment (Cr072 genotype) we tested, chosen for high color stability, was close in stability to acylated anthocyanins from red radish, although most other *Amaranthus* betacyanins were less stable than red radish.

CONCLUSION

AMARANTHUS PIGMENTS HAVE HIGH POTENTIAL FOR USE AS colorants in products such as jelly, ice cream, and higher pH beverages. *Amaranthus* betacyanins could exhibit better color characteristics than red radish anthocyanins at the same levels but were not as bright as a synthetic colorant. At lower temperature (< 14 °C), *Amaranthus* betacyanins had comparable color stability to red radish and to the synthetic colorant in jelly, beverage, and ice cream during 20 wk storage. At room temperature (25 °C), *Amaranthus* betacyanins were similar in color stability to red radish and retained > 60% of color during initial 4-wk storage. At higher temperature (37 °C), *Amaranthus* betacyanins were less stable than red radish. Ascorbic acid at 0.10% to 0.50% had a slight protective effect on *Amaranthus* betacyanin stability in jelly, and a positive effect in the model beverage. Sucrose at low concentrations (≤ 13%) had a slight negative influence on *Amaranthus* betacyanin stability in a beverage, but high concentrations of ascorbic acid plus sucrose reduced pigment stability.

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