Color Stability of Strawberry Jam as Affected by Cultivar and Storage Temperature

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ABSTRACT

The stability of three strawberry cultivars was evaluated for changes in jam color quality during processing and storage at 20°, 30° and 37°C for 200 days. Anthocyanin content was determined by HPLC. The effect of cultivar, processing and storage on jam pigments, instrumental color (L*, a*, b*) and consumer preference were also determined. 'Oso grande' jam had the lowest anthocyanin concentration (110 mg/g f.w), higher monomeric pigment degradation during processing and storage, highest pH, least desirable color score from the sensory panel and shortest shelf-life. Similarities were found between jams prepared with 'Chandler' and 'Tudla' cultivars, as well as initial differences in total anthocyanin concentrations (195 and 130 mg/g f.w.).

Key Words: color, strawberry jam, storage temperature, cultivar, anthocyanins

INTRODUCTION

SOME STRAWBERRY CULTIVARS PRODUCE jams with more acceptable and stable color than others. Loss of red color and increased browning during production and/or storage of processed food are influenced by many factors. These include Maillard and enzymatic browning, ascorbic acid degradation and polymerisation of anthocyanins with other phenolics (Abers and Wrolstad, 1979; Wrolstad, 1980; Wrolstad et al., 1990). Other factors affecting color include fruit pH and acidity (Wrolstad et al., 1970), storage temperature (e.g. Adams and Ongley, 1973 ; Irzyniec et al., 1993) and fruit cultivar (Bakker et al, 1994).

The main anthocyanin responsible for strawberry color is pelargonidin 3-glucoside (Sondheimer and Kertesz, 1948). Cyanidin 3-glucoside and pelargonidin 3-glucoside are present in cultivars commonly used by the Spanish canning industry (García-Viguera et al., 1997).

Our objective was to determine the stability of three strawberry cultivars (*viz*. 'Chandler', 'Tudla' and 'Oso Grande'), commonly used in the Spanish canning industry, to monitor changes in jam color quality during processing and storage at different temperatures and to compare instrumental color values with visual assessment by a trained panel of observers.

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MATERIALS & METHODS

Material

Samples of three strawberry (*Fragaria x ananassa*) cultivars (Chandler, Tudla and Oso Grande) at processing maturity, were harvested (Lepe, Huelva Spain) and frozen (at −20°C) on June 8, 1995, in about 3 kg lots. Fruit was processed in Hero S.A., on June 23, 1995. Prior to jam preparation, samples were removed from the bags to allow semi-thawing. Jam was made under the specific conditions of the Industry in order to obtain a final product that contained 450g fruit kg^{-1}, 2g pectin kg^{-1}, 0.4g citric acid kg^{-1} and a final sucrose concentration of 63°Brix. Fruit and sugar were mixed with pectin and citric acid, processed for 15 min at 78°C under vacuum (500 mm Hg), heated at 92°C and allowed to cool to 88°C before filling glass jars (35g). The jars were closed and cooled gradually under tap water and kept overnight at 20°C before initial measurements. Jams were then stored at 20°, 30° or 37°C in the dark, for 200 days.

Anthocyanin extraction

Fruit (5g) was extracted with 15 mL acetone for 5 min at room temperature, in order to produce pectin clotting (García-Viguera et al., 1998a). The extract was filtered, concentrated under vacuum (35°C), and the residue redissolved in 5 mL acidified water (3% formic acid). This aqueous solution was adsorbed onto a C_{18} Sep-Pak cartridge (Waters Associates, Milford, MA). The cartridge was washed with 3% formic acid, and the pigments were eluted with 3% formic acid in methanol. The methanolic extract was concentrated and redissolved in a mixture of aqueous 5% formic acid containing 20% methanol (1 mL) and filtered through a 0.45 μm Type Millex HV 13 filter (Millipore Corp., Bedford, MA) before HPLC analysis. Each jam (5g) was extracted by stirring with 75 mL of a methanol: acetic acid: water (25:1:24) mixture, for 20 min at room temperature, as previously reported (García-Viguera et al., 1997). Three samples were extracted for each jam and mean values are reported.

HPLC analysis of anthocyanins:

For anthocyanin identification the same apparatus as in García-Viguera et al. (1997) was used. For quantitative fruit and jam analyses a Merck-Hitachi L-6200 intelligent pump (Darmstadt, Germany) chromatograph was used, equipped with a Merck-Hitachi UV-VIS detector L-4200 and auto-injector Merck-Hitachi AS-2000 A. Chromatograms were recorded and processed on a D-2500 Chromato-Integrator (Merck-Hitachi). Each sample (20μL) was analysed on a Lichrochart 100 RP-18 reversed-phase column (125 × 4 mm, particle size 5μm) using a mobile phase of 5% formic acid (solvent A) and methanol (solvent B). Elution was performed at 1 mL min^{-1} using a gradient starting with 15% B, increasing to 30% B at 15 min, isocratic elution for 5 min and increasing to 95% B at 25 min. Detection was achieved at 520 nm. All HPLC analyses were done in duplicate and results expressed as mean value (n=6). Reproducibility of the HPLC analyses was *ca* ± 5%

Anthocyanin identification and quantification:

The compounds were characterised by chromatographic comparison with authentic standards (provided by Dr. Bridle, IFR, Reading Laboratory, UK). Cyanidin 3-glucoside was quantified as cyanidin 3-rutinoside and pelargonidin 3-glucoside and 3-rutinoside as pelargonidin 3-glucoside, due to the lack of a sufficient amount of other standards. The total anthocyanins were calculated by addition of the amounts of the anthocyanins detected in each chromatogram, as previously reported (Zafrilla et al., 1998).

Titratable acidity, total soluble solids and pH

Jam (2g) was stirred with 75 mL distilled water for 15 min and acidity was determinated by titration with 0.1N NaOH to pH 8, in a Crison auto-burette model 736 (Barcelona, Spain) and expressed as g. citric acid/ 100 mL extract (AOAC, 1984).

Total Soluble Solids concentration (°Brix)

and pH were measured with an Atago 1T (Japan) refractometer at 20°C and a Crison micropH 2000 (Barcelona, Spain) pH meter with glass electrode. All analyses were done in triplicate and mean values are reported.

Color measurements

A tristimulus color spectrophotometer Minolta CM-508i (Osaka, Japan) was used as previously reported (Zafrilla et al., 1998). Analyses were performed by reflection on a 2.5 mm thick sample, placed on a white surface. $L^*a^*b^*$ values were calculated using illuminant D65 and a 10° observer according to the CIELAB 76 convention (McLaren, 1980). Hue angle (H) was calculated from $H = \arctan b^*/a^*$. Data were recorded and processed on a Minolta ChromaControl S, PC based colorimetric data system. All measurements were done in triplicate and mean values are reported (n=9).

Statistical Analysis:

The influence of time and storage temperature on total anthocyanins of 3 cultivars were determined by analysis of variance and two-way analysis of variance (ANOVA). Significant differences were determined at $p \leq 0.001$. The individual influences of cv and temperature on total anthocyanins were analysed by T-tests (determining least significance difference=LSD at $p \leq 0.05$.

In addition, results of color measurements were subjected to regression analysis. High correlation was assumed for correlation coefficients $r^2 \geq 0.81$ ($\alpha = 0.001$).

Informal Visual Analysis

A visual panel of 6–9 persons (men and women) was used. All were very experienced at assessing strawberry jam on a daily basis and were producers of such jams, selected within the Company and trained. The extent of color deterioration was evaluated according to a 10 point scale in which score 9=excellent and 0=completely unacceptable color characteristics (samples scored under 5 were considered not acceptable). Samples were presented in a 35g jar.

Shelf-life statistical analysis

Based on correlations between shelf-life and color, the shelf-life for each jam was evaluated mathematically using the programme NONLIN (Non-linear Statistical Regression Program) version 3.2, according to the Arrenhius equation (Labuza and Riboh, 1982). The expression describing change in quality attribute a* in a non-linear form for a first order reaction is (Singh, 1994):

$$a^* = a^*_0 \exp\left[-k_0 \cdot t \cdot \exp(-E_a/R \cdot T)\right]$$

where: a*=CIE a* parameter; a^*_0 =CIE a* parameter at time 0; k_0=pre-exponential factor (day^{-1}); t=time (days); E_a=activation energy (cal/mol); R=gas constant (1.987 cal/°K·mol); T=temperature (°K).

RESULTS

Changes in titratable acidity, total soluble solids (TSS) and pH

Titratable acidity was higher for jams produced from 'Chandler' (<1.16, SD60.02) than for those from 'Oso Grande' (<0.77, SD60.02) or 'Tudla' (<0.61, SD60.02). No changes in titratable acidity were observed during storage at 20, 30 and 37°C. In addition, the TSS showed a constant value (<65° Brix, SD60.5) for all samples. Slight decreases in pH (63%) during storage were noticed. Differences were found at the beginning of storage in which 'Chandler' jam had the lowest pH (<2.98, SD60.01), followed by 'Tudla' (<3.15, SD60.03) and 'Oso Grande' jam (<3.39, SD60.02). Those differences were maintained though storage.

Cultivar differences in anthocyanins during processing

No qualitative differences were found in anthocyanin composition of the three cultivars. They were all characterised by the presence of cyanidin 3-glucoside (cy 3-glc), pelargonidin 3-glucoside (pg 3-glc) and pelargonidin 3-rutinose (pg 3-rut). However, quantitative differences were found. 'Oso Grande' had the lowest concentration of total anthocy-

Table 1—Anthocyanins content in fruit and strawberry jams produced with 'Chandler' cultivar, during storage at 20°, 30°, and 37°C[a]

Time	Cy 3-glc ± SD		Pg 3-glc ± SD		Pg 3-rut ± SD		TA ± SD	
				FRUIT				
	6.01	0.43	174.65	22.85	14.8	2.06	195.46	25.34
				JAMS 37°C				
0	4.53	0.60	106.37	10.84	11.92	1.48	122.81	12.93
33	0.15	0.00	4.67	0.88	0.73	0.12	5.55	1.00
66	Nd[c]		0.67	0.10	ND		0.67	0.10
96	ND		0.15	0.03	ND		0.15	0.03
LSD 5%							12.24	
				JAMS 30°C				
0	4.53	0.60	106.37	10.84	11.92	1.48	122.82	12.92
33	1.08	0.33	21.06	5.01	2.28	0.63	5.55	1.00
66	0.30	0.08	5.95	2.04	0.97	0.34	7.22	2.45
96	ND		1.43	0.30	ND		1.43	0.30
120	ND		0.32	0.01	ND		0.32	0.01
150	ND		0.26	0.05	ND		0.26	0.05
LSD 5%							10.21	
				JAMS 20°C				
0	4.53	0.60	106.37	10.84	11.92	1.48	122.82	12.92
33	2.38	0.75	53.75	11.71	6.50	1.90	62.63	14.37
66	1.60	0.21	34.25	0.40	4.63	0.14	40.48	0.74
96	0.69	0.09	15.08	0.66	2.16	0.11	17.93	0.86
120	0.21	0.05	5.74	1.06	0.82	0.14	6.76	1.25
150	0.17	0.00	3.84	0.21	0.51	0.01	4.52	0.22
174	0.16	0.00	3.21	0.37	0.49	0.04	3.87	0.41
200	ND		3.07	0.25	0.48	0.03	3.55	0.29
LSD 5%							11.78	

[a]Values are µg anthocyanin/g fruit or /g fruit in jam (fresh weight). n=6. HPLC reproducibility was ca ±6. SD=standard deviation.
[b]Cy 3-glc: cyan 3-glucoside; Pg 3-glc: pelargonidin 3-glucoside; Pg 3-rut: pelargonidin 3-rutinoside; TA: total anthocyanins.
[c]NS=non-detected.

Table 2—Anthocyanin content in fruit and strawberry jams, produced with 'Tudla' cultivar, during storage at 20°, 30°,and 37°C[a]

Time	Cy 3-glc ± SD		Pg 3-glc ± SD		Pg 3-rut ± SD		TA ± SD	
				FRUIT				
	6.69	0.48	112.39	7.69	10.95	0.74	130.03	8.91
				JAMS 37°C				
0	5.49	1.18	69.71	13.67	7.48	1.45	82.68	16.31
33	0.49	0.15	5.69	1.08	0.95	0.08	7.13	1.32
66	0.21	0.00	0.82	0.30	0.17	0.00	1.20	0.30
LSD 5%							18.86	
				JAMS 30°C				
0	5.49	1.18	69.71	13.67	7.48	1.45	82.68	16.31
33	1.90	0.33	22.94	4.08	3.43	0.63	28.27	5.03
66	0.44	0.12	5.42	1.77	0.91	0.26	6.78	2.15
96	0.33	0.07	2.97	1.16	0.51	0.18	3.81	1.42
120	ND		0.36	0.08	ND		0.36	0.08
150	ND		0.33	0.02	ND		0.33	0.02
LSD 5%							12.51	
				JAMS 20°C				
0	5.49	1.18	69.71	13.67	7.48	1.45	82.68	7.34
33	4.16	0.98	51.38	10.61	6.07	11.26	61.61	12.84
66	2.55	0.41	32.15	5.86	4.37	0.64	39.07	6.90
96	1.35	0.02	16.30	0.51	2.51	0.12	20.17	0.65
120	0.45	0.14	6.13	1.47	0.88	0.17	7.46	1.79
150	0.33	0.01	4.48	0.12	0.72	0.06	5.53	0.20
174	0.27	0.03	3.80	0.33	0.59	0.04	4.67	0.40
200	0.22	0.05	3.22	0.94	0.50	0.13	3.94	1.12
LSD 5%							13.44	

[a]Values expressed as in Table 1.

Table 3—Anthocyanins content in fruit and strawberry jams, produced with 'Oso Grande' cultivar, during storage at 20°, 30°, and 37°C[a]

Time	Cy 3-glc ± SD		Pg 3-glc ± SD		Pg 3-rut ± SD		TA ± SD	
				FRUIT				
	9.01	0.79	92.19	8.66	9.60	0.85	110.80	10.30
				JAMS 37°C				
0	5.83	0.61	50.97	4.83	6.43	0.90	62.23	6.34
33	0.37	0.09	4.10	1.10	0.67	0.15	5.14	1.34
66	ND		0.46	0.04	0.19	0.00	0.65	0.04
LSD 5%							7.46	
				JAMS 30°C				
0	5.83	0.61	50.97	4.83	6.43	0.90	63.23	6.34
33	1.11	0.10	12.10	1.17	2.07	0.41	15.28	1.69
66	0.33	0.11	3.51	1.01	0.60	0.17	4.45	1.29
96	0.21	0.08	1.31	0.35	0.26	0.08	1.78	0.51
120	ND		0.31	0.01	0.04	0.07	0.35	0.08
150	ND		0.23	0.05	ND		0.23	0.05
LSD 5%							4.86	
				JAMS 20°C				
0	5.83	0.61	50.97	4.83	6.43	0.90	63.23	6.34
33	2.16	0.24	29.10	2.10	4.19	0.38	36.45	2.72
66	2.04	0.50	18.20	3.71	2.86	0.65	23.10	4.87
96	0.88	0.14	8.46	1.53	1.37	0.30	10.71	1.96
120	0.24	0.04	3.06	0.56	0.52	0.09	3.82	0.69
150	0.19	0.01	2.93	0.10	0.42	0.01	3.54	0.12
174	0.16	0.03	2.18	0.51	0.38	0.08	2.72	0.63
200	ND		1.43	0.08	0.26	0.03	1.69	0.11
LSD 5%							5.32	

[a]Values expressed as in Table 1.

Table 4—CIE a* values obtained for strawberry jams produced with Chandler, Tudla and 'Oso Grande' cultivars, stored at 37°, 30°, and 20°C

Time	Ch a*	±SD	TD a*	±SD	OG a*	±SD
			37°C			
0	42.71	0.79	42.12	0.33	35.37	1.36
33	33.17	0.59	33.87	1.62	27.40	0.61
66	27.61	0.57	26.34	0.90	22.14	0.97
96	23.90	0.32	22.72	0.41	18.70	0.70
			30°C			
0	42.71	0.79	42.12	0.33	35.37	1.26
33	32.96	0.79	34.18	1.33	26.81	1.71
66	31.72	1.83	30.76	0.60	25.52	0.70
96	27.57	1.08	30.04	1.19	22.85	0.34
120	29.64	3.05	29.15	0.80	23.19	1.03
150	28.31	0.35	25.57	1.19	21.38	0.72
			20°C[b]			
0	42.71	0.79	42.12	0.33	35.37	1.36
33	36.15	2.26	37.79	2.01	30.91	0.92
66	35.17	1.34	35.61	1.35	29.58	0.87
96	34.84	0.83	35.86	1.01	27.96	1.28
120	24.91	1.33	34.81	0.83	28.36	1.36
150	33.65	0.27	33.28	1.32	25.61	0.61
174	30.92	1.32	31.50	0.58	24.53	0.37
200	31.96	0.76	31.54	1.53	25.45	0.76

[a]n=9; SD-Standard deviation; t=time.
[b]At 20°C Chandler: $a^*=39.94-0.048t$ $r^2=0.867^{***}$
Tudla: $a^*=40.03-0.044t$ $r^2=0.816^{***}$
Oso Grande: $a^*=33.46-0.046t$ $r^2=0.905^{***}$

anins (110.80 μg/g fruit) while 'Chandler' had the higher concentration (195.46 μg/g fruit), and Tudla was intermediate (130.03 μg/g fruit) (Tables 1–3). Moreover, the cultivars responded differently to processing. Thus, 'Oso Grande' had the highest anthocyanin degradation (35.30% Cy 3-glc, 44.71% Pg 3-glc and 33.02% Pg 3-rut, 43% TA) during processing. The other cultivars showed losses of ±36%TA, due to similar losses in pg 3-glc. Differences were also found when comparing the percentages of loss of the other 2 anthocyanins in both cultivars ('Tudla': 18% Cy 3-glc and 31.7% Pg 3-rut and 'Chandler' 24.6% and 19.5% respectively). The pg 3-glc was the least table anthocyanin during processing (Tables 1–3).

Effect of storage temperatures on anthocyanins stability

Differences in anthocyanin stability occurred between storage temperatures, being much more stable at the lower temperature ($p<0.001$). No differences were found in degradation kinetics of anthocyanins between cultivars at the same temperature (Tables 1–3). Thus, none of the cultivars showed a significant decrease of TA after 33 days at 37°C, after 66 days at 30°C or after 120 days at 20°C (Tables 1–3, Fig. 1). Two way analysis of variance at 20°C, indicated that 'Tudla' showed higher stability than 'Chandler' for anthocyanin concentration during the first 33 days (Fig. 2) resulting in similar total anthocyanin concentrations in jams prepared with 'Chandler' and 'Tudla' (Fig.2), after one month, although 'Chandler' had higher initial pigment concentration.

Storage temperature was a more significant factor than cv for anthocyanin loss during storage. All the cultivars exhibited a very fast decrease when stored at higher temperature (37°C) and much slower at 20°C (Fig. 1). None of the anthocyanins showed a higher resistance to temperature degradation than the others and all were more degraded at higher temperatures (Tables 1–3).

Effects of storage temperature on color

Different results were obtained when color was analyzed by spectrophotometry. All jams exhibited similar values of L*(39.73, SD±1.31), b*(22.60, SD±2.88) or H (36.20, SD±3.73) for the 3 CVs during storage at different temperatures. Only a* values showed a decrease in response to an increase in storage temperature, giving jams with less red hue. Smaller changes were detected in this value when storage was at 20°C (Table 4). A regression analysis between a* and time demonstrated a linear correlation between those parameters at all temperatures ($p<0.001$). Comparing results at 20°C, following the method of Kleinbaum et al. (1988), the 3 CVs did not show significant differences in slope (indicating the same degradation kinetics). 'Oso Grande' showed significant differences in X axis origen when compared with the other two ($p<0.001$), indicating a jam with less red hue (Table 4).

Comparing these results with anthocyanin concentrations it could be seen that a decrease in pigments was not always correlated with a decrease in a* value (Fig. 1). At 20°C, when <5% of initial anthocyanin concentration remained, only a slight decrease in a* value was noticed (Fig. 1). Lower concentrations of anthocyanins in jams prepared from 'Oso Grande' gave lower a* initial values. No differences were found in initial a* value between 'Chandler' and 'Tudla' jams, although differences in initial total anthocyanins were found (Tables 1–4).

These color values were related to visual panel results (Table 5). Jams prepared with 'Oso Grande', the cultivar with less initial anthocyanin concentration and with lower a* value, received the lowest initial visual score (6.88). None of the 'Oso Grande' jams had acceptable appearance after 2 or 3 mo. at 37° or 30°C. Jams made with 'Tudla' or 'Chandler' were acceptable after 6 mo. storage at 30°C, although anthocyanins concentration had decreased by more than 95% during this period. The visual panel scores appeared to be related to a* value but not with monomeric anthocyanin concentrations.

The shelf life, based on changes in color, was calculated mathematically for each jam (Table 6). The expressions were calculated for each cv (Table 6), and the visual were adjusted by a least square expression. Those

products scored <5 were determined as non-acceptable, and thus we found that CIE a*=23 was the acceptance limit. Results showed that jams would be acceptable for over 400 days only if stored at 20°C and prepared with 'Chandler' or 'Tudla' cultivars. A much shorter shelf-life would be found for those products prepared with 'Oso Grande' (≈230 days).

DISCUSSION

RESULTS WERE IN ACCORDANCE WITH general findings that monomeric pigment concentrations decrease during storage (Spayd and Morris, 1981; Withy et al. 1993). Thus, the stability of anthocyanins was markedly influenced by temperature (Markakis, 1982; Jackman and Smith, 1996). It has also been demonstrated that the concentration of polymeric pigments increased with temperature and storage time, and this has an important effect on color of juices and red wines (Somers, 1971; Adams and Ongley, 1973; Bakker and Timberlake, 1986; Withy et al., 1993).The rate of color loss was slower than the rate of anthocyanin degradation. Some differences were found between cultivars, as 'Oso Grande' jam had the least anthocyanin concentration and least desirable color, while 'Chandler' jam had the highest initial pigment concentration and resulted in jam color similar to 'Tudla'.

As reported by Brouillard (1982), the expression of anthocyanin color is pH dependent. In our results jams prepared with 'Oso Grande' (pH = 3.39) had the lowest concentration of anthocyanins in the flavylium form (red), while those produced from 'Chandler' had the highest anthocyanin concentration and the lower pH (2.98). Still, we could not affirm that pH correlated with color (Rommel et al., 1990). Comparing 'Chandler' and 'Tudla' we found similar a* values for jams prepared with either cultivar (Table 4), and similar scores given by the visual panel (Table 5), although differences in pH were found.

Other factors must be considered in the expression of color in strawberry jams by co-pigmentation or some other physicochemical processes. High concentrations of possible co-pigments such as flavonols (quercetin and kaempferol) have been reported (Henning, 1981). Differences in such co-pigment concentrations could explain the similar red hue found for 'Tudla' and 'Chandler' when different anthocyanin concentrations were detected, but not at the end of storage, when total anthocyanins had decreased to ±5% of the initial value. This type of variation has been reported for red raspberry jams (García-Viguera et al., 1998b). Consequently, comparable color during storage is more likely to be due to polymerization phenomena mediated by flavan 3-ols, similar to that for wines (Somers, 1971, García-Viguera et al., 1994; Rivas-Gonzalo et al., 1995), or by leucoanthocyanidins which have been shown to co-polymerise with anthocyanins in wines (Somers, 1971; Abers and Wrolstad, 1979). Similar reactions could take place in strawberry jams, where the high concentra-

Table 5—Jam color deterioration scored by a visual panel[a]

Time	Chandler Score	±SD	Tudla Score	±SD	Oso Grande Score	±SD
			37°C			
0	7.44	1.01	7.44	1.33	6.88	0.60
33	6.85	0.69	6.85	0.89	5.70	0.75
66	5.75	1.42	5.33	1.15	4.25	1.48
96	4.50	1.08	4.00	1.15	3.00	0.66
			30°C			
0	7.44	1.01	7.44	1.33	6.88	0.60
33	7.00	0.57	7.28	0.75	6.00	0.81
66	6.91	0.99	6.41	0.79	5.50	1.24
96	6.30	0.82	6.30	0.48	4.40	1.34
120	6.50	0.75	6.37	0.91	4.37	1.30
150	5.37	0.74	5.12	0.64	3.75	0.88
			20°C			
0	7.44	1.01	7.44	1.33	6.88	0.60
33	7.57	0.78	7.14	0.37	6.42	0.78
66	7.25	0.78	7.66	0.88	6.16	0.83
96	7.40	0.69	7.50	0.70	6.10	0.73
120	7.33	0.88	7.16	0.93	5.75	1.48
150	7.50	0.75	7.25	0.70	5.50	1.19
174	7.50	0.75	7.50	0.75	5.50	0.92
200	6.71	0.48	7.14	0.69	5.71	0.75

[a]Score of 1 to 9; <5 was considered unacceptable

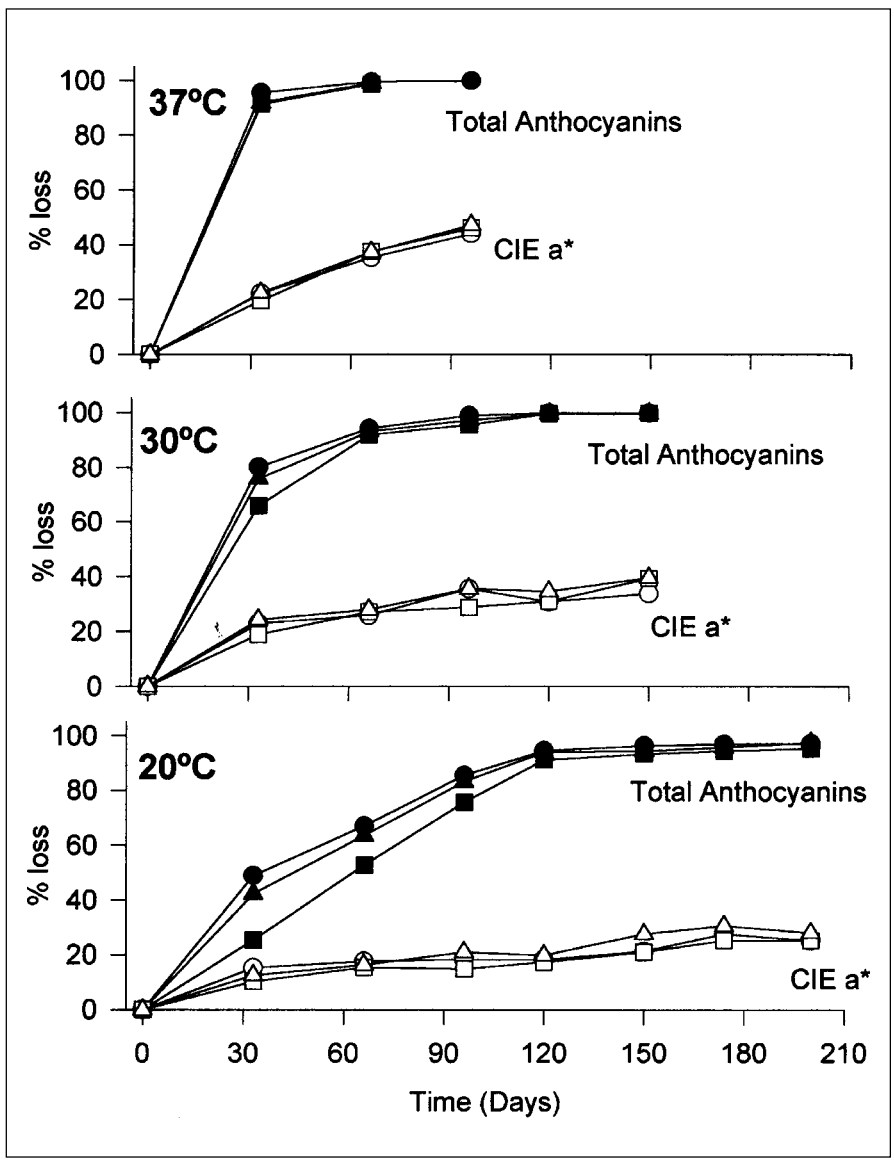

Fig. 1—Percentage of loss of total anthocyanins (black symbols) and CIE a* value (white symbols) for strawberry jams made from 'Chandler' (○), 'Tudla' (□) or 'Oso Grande' (△) cultivars, stored at 37°, 30° or 20°C.

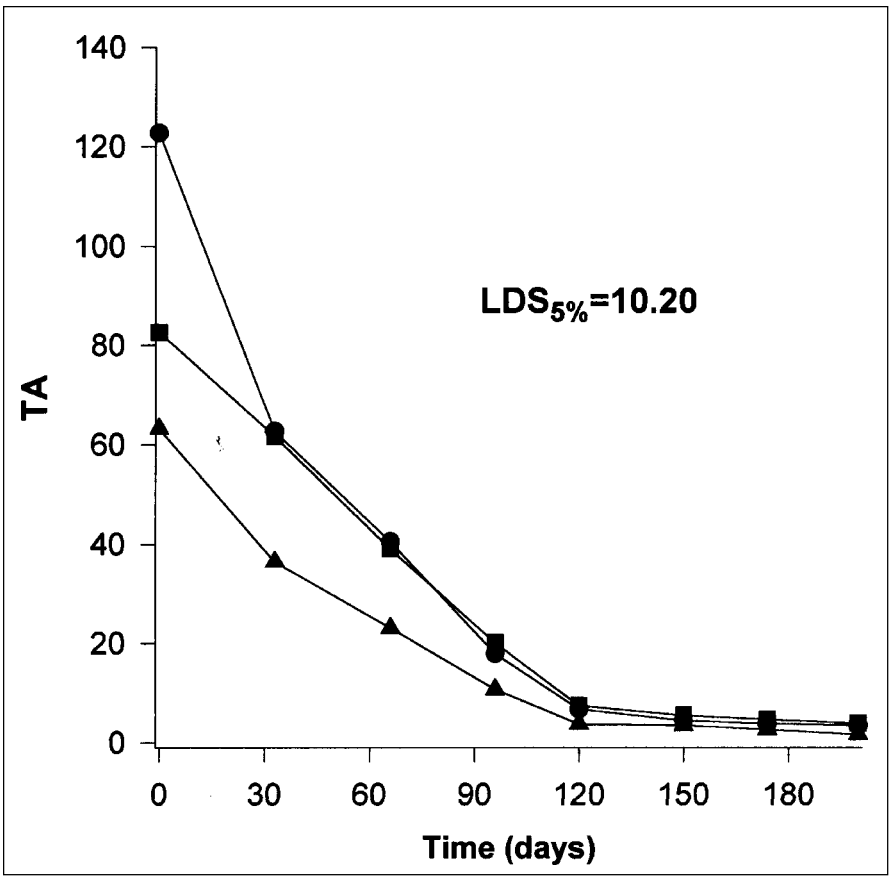

Fig. 2—Total anthocyanin degradation with time, for strawberry jams made from 'Chandler' (●), 'Tudla'(■) or 'Oso Grande' (▲) cultivars, stored at 20°C.

tion of sugar could act as a dehydrating agent as does alcohol in wine. Such mechanism has been suggested for strawberry preserves (Abers and Wrolstad, 1979).

Another important consideration is that general browning is also influenced by PPO (polyphenol oxidase). Probably enzymatic reactions could not take place in jams after high temperature processing. However, it has been reported that catechin and PPO readily react, resulting in reactive quinones which degrade anthocyanins, thereby altering color (Wesche-Ebeling and Montgomery, 1990). Both PPO and catechin have been reported to be present at high concentrations in strawberries (López-Serrano and Ros Barceló, 1995; Stöhr and Herrmann, 1975). Therefore, study of the concentrations of PPO or related enzymes and catechins or related flavan 3-ols in different cultivars would be desired. This may explain the similarities found between 'Tudla' and 'Chandler' anthocyanin concentrations during which resulted in correspondence with jam color quality, even when initial concentrations were different for both cultivars.

CONCLUSIONS

'OSO GRANDE' JAM HAD THE LOWEST ANthocyanin concentration, higher monomeric pigment degradation during processing and storage, highest pH, least acceptable color scores from a visual panel and shortest shelf-life. However, similarities were found between jams prepared with 'Chandler' and 'Tudla' cultivars, even when initial differences in total anthocyanin concentration were found.

Table 6—Shelf-life (days) of jams prepared with different strawberry cultivars, stored at different temperatures

Temperature	Chandler[a]	Tudla[b]	Oso Grande[c]
20°C	422	418	229
30°C	180	171	105
37°C	103	94	63

[a]Chandler: $a^*=40.36\cdot\exp[1.982\cdot10^{8}\cdot t\cdot\exp(-7537.32/T)]$ $R^2=0.8736$.
[b]Tudla: $a^*=40.77\cdot\exp[8.327\cdot10^{8}\cdot t\cdot\exp(-7950.15/T)]$ $R^2=0.9524$.
[c]Oso Grande: $a^*=33.84\cdot\exp[3.142\cdot10^{7}\cdot t\cdot\exp(-6929.01/T)]$ $R^2=0.9251$.

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