PROCESSING QUALITY OF THREE EASTERN-GROWN APPLE CULTIVARS FOLLOWING CA STORAGE

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Background

Apples intended for processing are usually held in common or ordinary cold (RS) storage when there exists a need to extend the processing season much past harvest. Use of controlled atmosphere (CA) storage for processing apples has seldom been utilized due to the added costs involved. Controlled atmosphere fruit sometimes enters the processing channels due to economic considerations within the fresh fruit markets or to the development of some cosmetic conditions which makes the fruit unusable for fresh market. In addition, the steadily increasing costs of raw product and RS storage are tending to close the cost gap between RS and CA storage management to the point where some processors are beginning to reevaluate the latter for long term storage purposes.

The availability of CA storage to extend the life of most apple cultivars is well known. Behavior of CA fruit in the fresh market channels is also well documented. However, utility of CA stored fruit for processing is largely untested. Observations by ourselves and others (1,4) have indicated that fruit immediately out of CA storage may not be at optimum suitability for processing from the standpoint of both yield and quality. Raw product quality with RS fruit can be manipulated by several means to improve suitability for processing. We wish to clarify the problems which exist in the processing of CA fruit from the point of view of both yield and quality, and to evaluate the necessity of specific poststorage preprocessing manipulations to correct these problems.

Procedure

Empire, Red Delicious and Idared apples were early-harvested as if for fresh market storage, and stored under both RS and CA conditions for 4 months. Following removal from CA storage, the fruit was transferred to 0°C RS storage. After additional 6 and 12 week periods, subsamples of the fruit were manufactured into sauce in our Pilot Plant using a previously described "batch" process (2,6) as in Figure 1. For this

operation, the processing equipment was operated under constant conditions to minimize any alterations in the sauce other than that due to the raw commodity. Data collected included raw product analyses (firmness, soluble solids, total acid, and pH), processing efficiency (finisher waste, water added and overall yield), and the finished sauce evaluated objectively (color (Hunter lightness, hue (3), and chroma), consistency (Bostwick), and water holding capacity (7)), and by a trained taste panel for sensory characteristics (aroma intensity, smoothness, grain size, sourness and desirability (5)).

Results and Discussion

The results of the different storage regimes on raw product analyses of the 3 cultivars is indicated in Table 1. Typical improvement in the maintenance of firmness, soluble solids, total acids and pH by CA storage over RS storage are indicated. Marginal soluble solids content in Idared and pH in Red Delicious were experienced as is usual for these cultivars, but otherwise there was little significant difference between either storage.

Table 1. Raw product analyses before and after storage.

	Harvest	0°C, RS (20 Feb)	CA (20 Feb)
Empire	5 Oct.		
Firmness (lbf)	19.3	11.7	13.8
Sol. solids (%)	14.3	13.5	15.2
Total acid (%)*	0.91	0.43	0.54
pH	3.3	3.7	3.8
Red Delicious	18 Oct.		
Firmness (lbf)	18.9	13.8	16.5
Sol. solids (%)	12.5	14.9	15.4
Total acid (%)*	0.26	0.17	0.22
pH	3.7	4.4	4.4
Idared	18 Oct.		
Firmness (lbf)	19.8	12.8	14.9
Sol. solids (%)	12.7	13.1	13.6
Total acid (%)*	0.97	0.70	0.74
pH	3.2	3.7	3.8

* As malic acid

Data collected both immediately poststorage and also following poststorage preprocessing holding on raw product, processing and objective sauce quality for all 3 cultivars is shown in Tables 2, 3 and 4.

In respect to the data for processing fruit immediately poststorage (0 weeks holding), considerable cultivar variation is to be noted. For Empire CA stored fruit (Table 2), slightly less finisher waste, considerably greater amounts of water required to bring to a suitable consistency, and a comparable increase in sauce yield was noted. The finished CA sauce was somewhat lighter, somewhat less yellow in hue, little different in chroma, and little different in final consistency and serum separation. For Red Delicious (Table 3), the CA fruit showed slightly more finisher waste, no difference in the water requirement, and somewhat lower yields. The finished sauce, although definitely more yellow than that from Empire, showed little difference between lightness and chroma but was more yellow in hue. CA fruit was significantly higher in consistency, but also in serum separation. For Idared (Table 4), the CA fruit showed slightly less finisher waste, required less water and yielded less sauce than did the RS fruit. Controlled Atmosphere fruit showed little improvement in any element of color over the RS fruit.

Poststorage treatment response

In respect to poststorage 0°C temperature holding, again some cultivar variation was experienced. Empire maintained its relatively unripe processing characteristics during the holding periods as characterized by relatively low finisher wastes, increased capacity to hold water, and a corresponding increase in yield with holding time. Initial differences between RS and CA fruit were fairly uniform. There was little change in color characteristics of lightness, hue and chroma, and in Bostwick and serum separation.

The effect of poststorage low temperature holding of Red Delicious was somewhat more variable than in Empire. CA fruit decreased in firmness more rapidly than did RS fruit, with a corresponding effect on decreased finisher waste and increased water requirement. Sauce yields were significantly increased, CA fruit slightly more so than RS fruit. There was little significant change in color characteristics of the finished product, but a slight decrease in Bostwick and serum separation.

The effect of poststorage low temperature holding of Idared was somewhat intermediate between that of the preceding 2 cultivars. Low temperature holding decreased the firmness of CA fruit more rapidly than that of RS fruit, but with a somewhat inconsistent effect on finisher waste and water requirement. Yield was more closely related to water requirement than to finisher waste. Color was affected by treatment, particularly in lightness and hue, being more on the lighter and redder side after 6 weeks holding than either shorter or longer holdings at

Table 2. Empire. Summary of objective measurements following 4 months refrigerated (RS) and controlled atmosphere (CA) storage and subsequent 0°C holding prior to processing into sauce.

Holding (weeks)	0		6		12	
Storage	RS	CA	RS	CA	RS	CA
Raw Product						
Firm. (lbf)	11.7	13.8	11.5	12.3	10.4	11.5
Sol. solids (%)	13.5	15.2	11.9	14.0	12.2	13.1
T. acid (%)*	0.43	0.54	0.23	0.47	0.19	0.35
pH	3.7	3.8	4.1	3.8	3.9	3.6
Processing						
Fin. waste (%)	2.71	2.56	2.42	3.93	0.89	0.87
Water add. (%)	12.9	24.3	5.31	14.0	4.65	10.2
TSTP (%)**	0	0	3.0	3.8	3.8	1.6
Yield (%)	86.4	89.5	85.2	95.7	90.5	96.5
Sauce Quality						
Color (L)***	57.8	56.7	59.1	57.5	58.6	57.6
(hue)****	104	99.6	95.3	92.3	99.7	100
(chroma)	20.9	19.8	20.7	18.9	22.1	21.0
Bostwick (cm)	4.0	3.6	4.2	4.5	4.3	4.3
Serum separ. (cm)*****	0.5	0.4	0.7	0.7	0.4	0.4

* As malic acid

** Too soft to peel

*** Hunter

**** $\cos^{-1} \frac{a}{\sqrt{a^2 + b^2}}$

***** USDA Template

Table 3. Red Delicious. Summary of objective measurements following 4 months refrigerated (RS) and controlled atmosphere (CA) storage and subsequent 0°C holding prior to processing into sauce.

Holding (weeks)	0		6		12	
Storage	RS	CA	RS	CA	RS	CA
Raw Product						
Firm. (lbf)	13.8	16.5	13.3	13.6	12.9	10.3
Sol. solids (%)	14.9	15.4	14.7	15.1	15.0	15.1
T. acid (%)*	0.17	0.22	0.13	0.18	0.11	0.16
pH	4.4	4.4	4.6	4.2	4.3	4.0
Processing						
Fin. waste (%)	17.7	18.7	5.7	6.5	1.9	1.6
Water add. (%)	0	0	0	0	9.9	14.4
TSTP (%)**	0	0	0	0	6.0	0
Yield (%)	67.6	61.5	79.3	76.6	91.9	95.7
Sauce Quality						
Color (L)***	53.8	52.9	59.2	57.6	52.4	54.4
(hue)****	95.1	98.8	88.6	92.0	95.4	98.4
(chroma)	22.1	20.6	24.9	23.0	21.6	22.3
Bostwick (cm)	3.7	4.7	2.7	2.6	3.5	3.4
Serum separ. (cm)*****	0.7	0.9	0.6	0.4	0.8	0.5

* As malic acid

** Too soft to peel

*** Hunter

**** $\cos^{-1} \frac{a}{\sqrt{a^2 + b^2}}$

***** USDA Template

Table 4. Idared. Summary of objective measurements following 4 months refrigerated (RS) and controlled atmosphere (CA) storage and subsequent 0°C holding prior to processing into sauce.

Holding (weeks)	0		6		12	
Storage	RS	CA	RS	CA	RS	CA
Raw Product						
Firm. (lbf)	12.8	14.9	12.2	12.0	11.8	11.4
Sol. solids (%)	13.1	13.6	13.1	12.9	12.9	12.3
T. acid (%)*	0.70	0.74	0.65	0.58	0.51	0.45
pH	3.7	3.8	3.6	3.7	3.5	3.5
Processing						
Fin. waste (%)	4.00	3.41	3.28	4.39	1.48	1.61
Water add. (%)	41.4	32.4	46.4	40.9	35.2	28.3
TSTP (%)**	0	0	5.0	0	13.3	10.8
Yield (%)	121	113	125	122	118	112
Sauce Quality						
Color (L)***	52.9	52.4	56.8	56.0	55.3	52.7
(hue)****	100	98.0	89.3	86.3	100	96.1
(chroma)	15.0	15.8	17.0	17.1	17.8	17.5
Bostwick (cm)	3.8	3.2	4.7	3.5	3.4	3.4
Serum separ. (cm)*****	0.6	0.8	1.2	1.1	0.7	1.0

* As malic acid

** Too soft to peel

*** Hunter

**** $\cos^{-1} \frac{a}{\sqrt{a^2 + b^2}}$

***** USDA Template

this temperature. Bostwick (to some extent) and serum separation (to a larger extent) followed this trend.

Finished product sensory analysis

Finished sauce made from the 3 cultivars were evaluated for aroma intensity, smoothness, grain size, sourness and desirability. Samples were evaluated using magnitude estimate techniques and then analyzed using analysis of variants. For each cultivar, specific sensory characteristics were identified as being significant or nonsignificant (Table 5).

Table 5. Significance of sensory characteristics affected by storage conditions by cultivar.

	Aroma	Smoothness	Grain	Sourness	Desirability
Empire	*	NS	NS	**	NS
Red Del.	**	NS	NS	NS	NS
Idared	NS	NS	NS	**	NS

NS - Not statistically significant
* - Significant @ 95% level
** - Significant @ 99% level

For Empire, 2 sensory parameters significantly changed over the course of the study: aroma intensity and sourness. The aroma intensity of CA apples increased to almost double the intensity perceived at harvest (Figure 2). (The initial data point at -15 weeks storage is harvest. Zero weeks storage is the end of CA storage.) Refrigerated storage over the same period failed to increase the aromatics in comparison, although continued low temperature holding did show a sharp increase in aromatics by 30 weeks. Post CA holding at low temperature significantly decreased the aromatics followed by an increase by 12 weeks holding. Sourness in Empire apples dropped at a steady rate throughout the study for both CA and RS fruit during storage and poststorage low temperature holding (Figure 3).

For Red Delicious, aroma intensity was the only sensory parameter that changed significantly over the course of the study. The intensity of the aromatics increased over storage as shown in Figure 4. An increase was seen until a few weeks post CA and then a decrease.

For Idared, sourness was significantly different over the various storage regimes analyzed. None of the other sensory characteristics changed significantly. As indicated in Figure 5, both CA and RS

storages induced a sharp decrease in the sourness followed by a continued decrease with continued low temperature holding.

Conclusions

In general, the overriding conclusion to be drawn from these experimental results is the large cultivar-to-cultivar differences experienced. Although cultivar response to treatment may in some cases be very significant, there is little or no consistency in response between cultivars in specifics. In brief, we conclude as follows:

1. In terms of processing quality and finished product properties, CA Empire had less finisher waste, a higher water requirement for suitable consistency, better sauce yield than its RS counterpart. The finished sauce was lighter and less yellow in color, but otherwise quite comparable to its RS counterpart. CA Red Delicious had correspondingly slightly more finisher waste, no difference in water requirement and lower yields. The finished sauce was more yellow in hue and possessed an increased viscosity and serum separation. CA Idared had less finisher waste, required less water and yielded less finished sauce. There was little or no difference in the quality of the finished sauce.

2. In terms of the effect of additional low temperature holding, CA Empire continued to decrease in finisher waste, increase in water requirement and in sauce yield. CA Red Delicious softened faster than RS fruit in holding, decreased in finisher waste and in water requirement, but increased in sauce yield. The finished sauce showed little significant change over its RS counterpart. CA Idared softened faster, increased in finisher waste, water requirement and final sauce yield over its RS counterpart. CA finished sauce was slightly lighter and redder in coloration.

3. In terms of sensory evaluation of the finished sauce, again cultivar differences were predominant. Overall desirability of the finished sauce of any of the cultivars was not affected by the type of storage used. Aroma intensity and sourness were the two sensory characteristics which did differ, depending on cultivar and storage type.

It is, therefore, obvious that the problems, if any, which arise from processing CA apples of these three eastern grown cultivars into sauce immediately following storage are very much cultivar specific and cannot be generalized at this time. Further, the requirement of some specific poststorage preprocessing handling to correct any such problems as do exist must be worked out with the particular cultivar and its response encountered.

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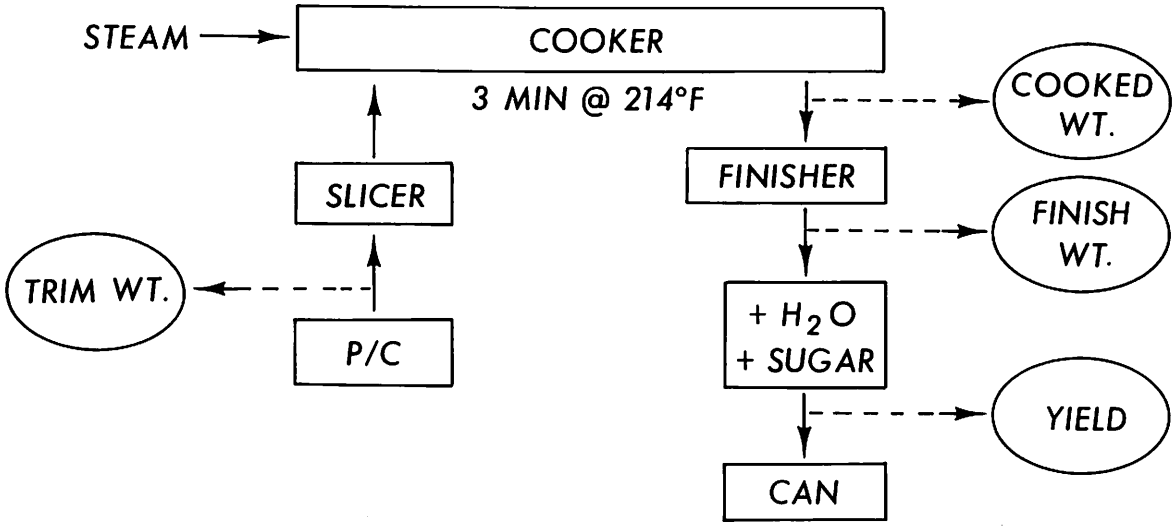

Figure 1. Schematic for pilot plant batch processing for sauce.

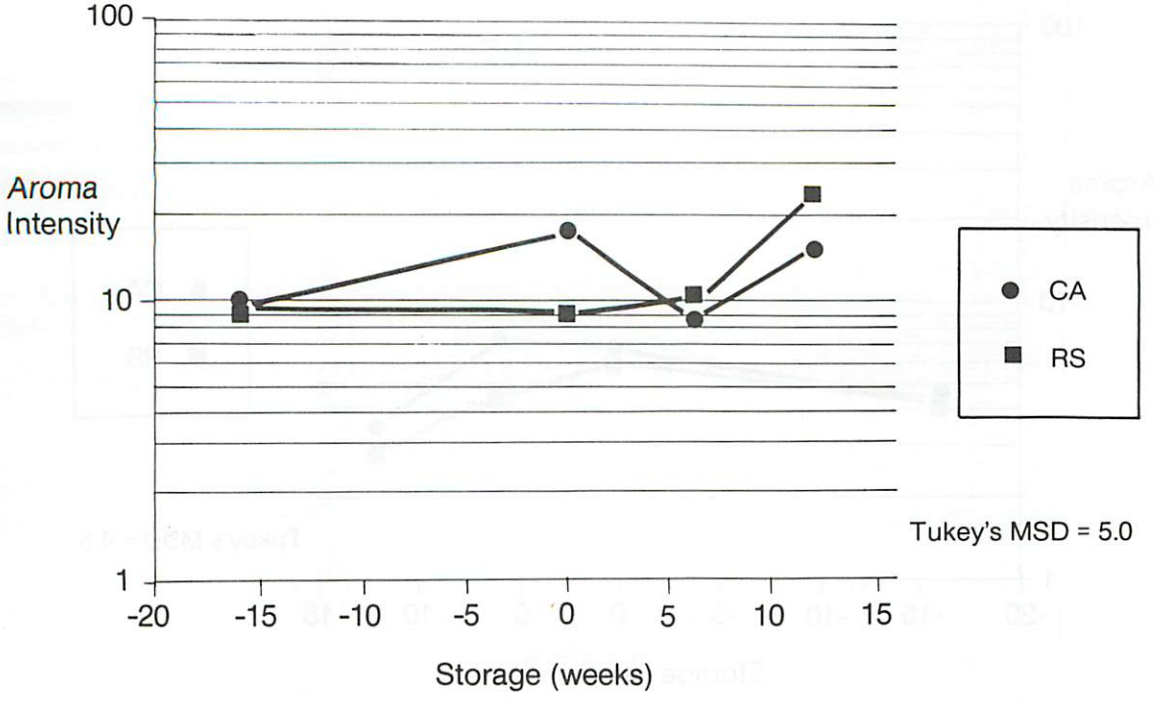

Figure 2. Sensory perception of aroma intensity for Empire Apples

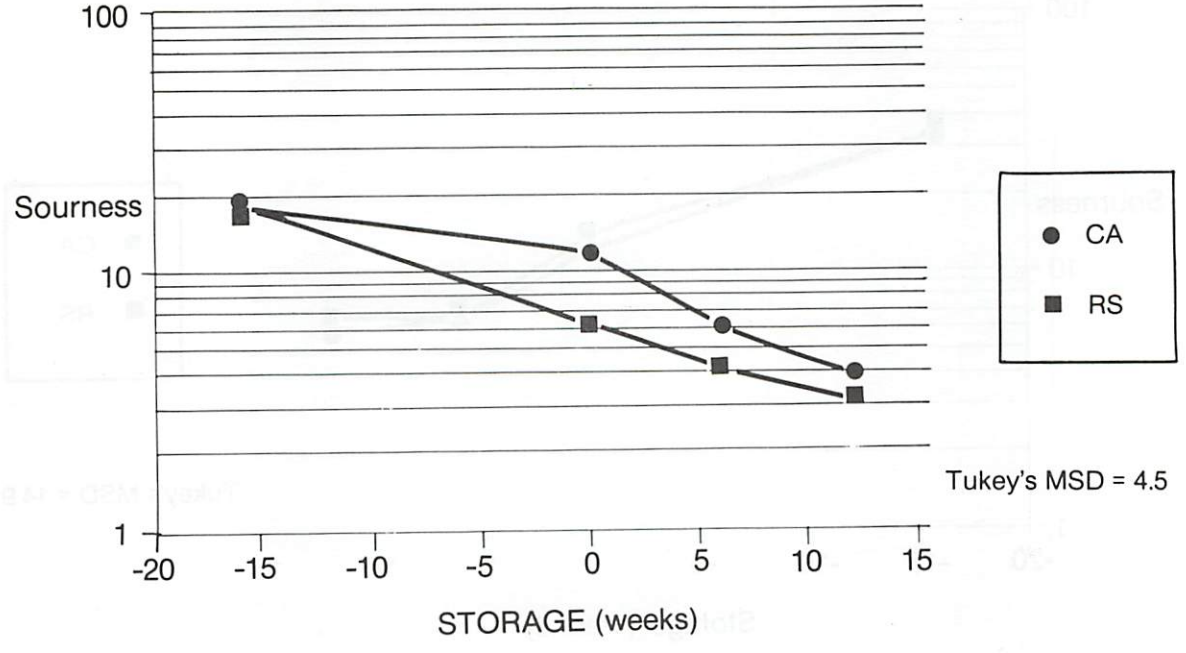

Figure 3. Sensory perception of sourness in Empire Apples

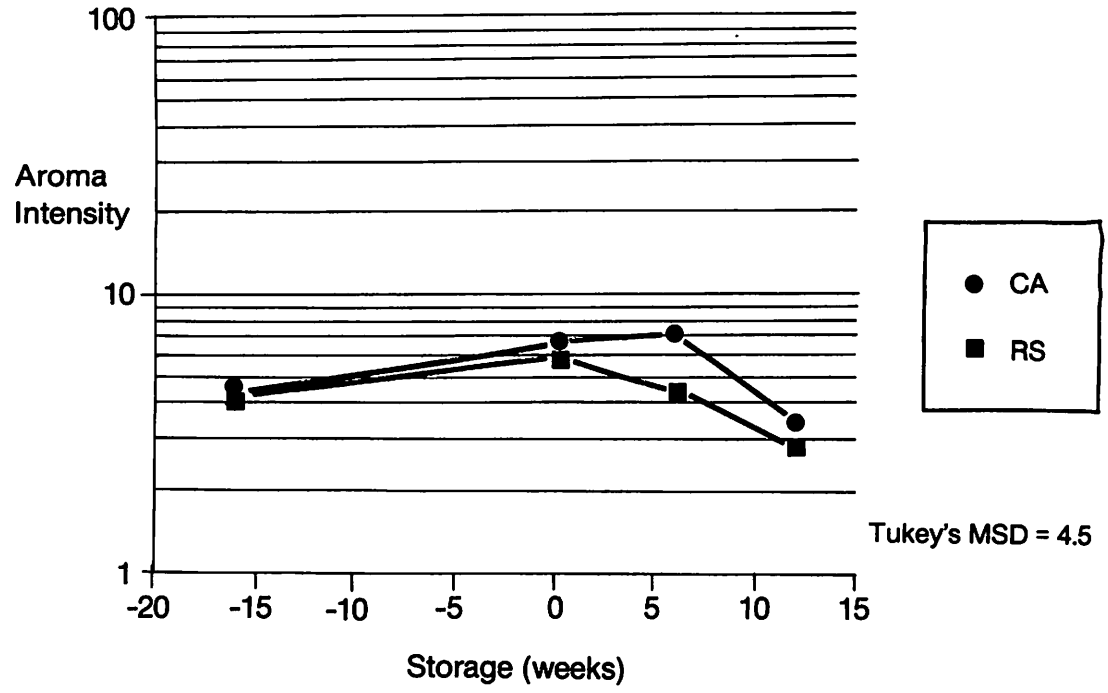

Figure 4. Sensory perception of aroma intensity for Red Delicious apples

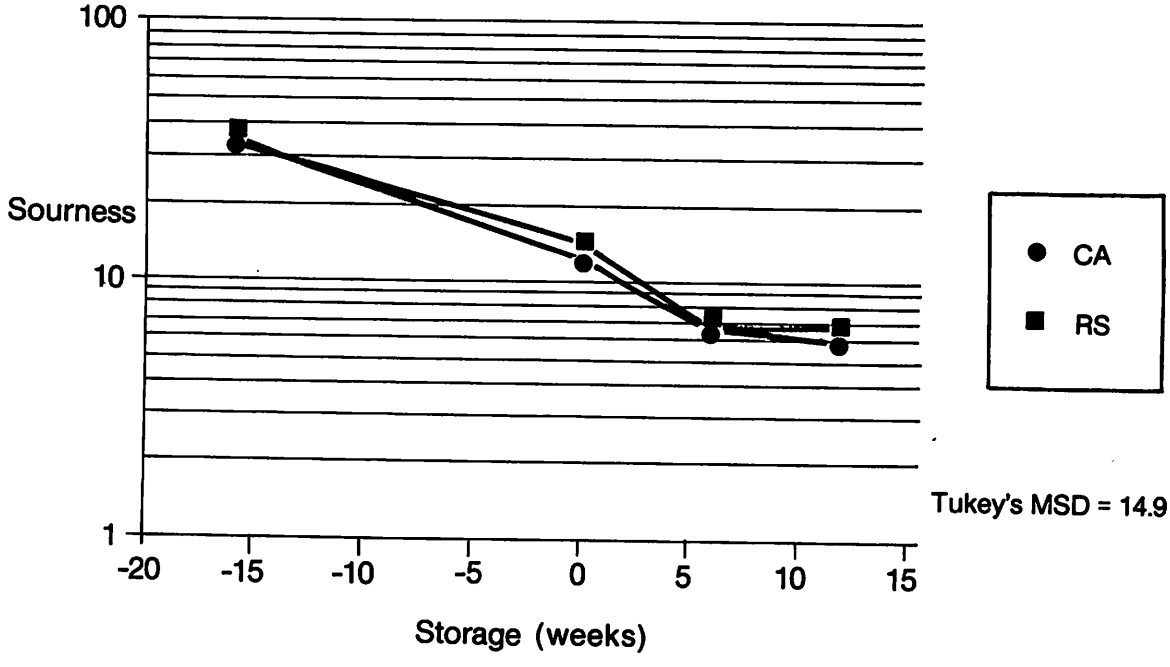

Figure 5. Sensory perception of sourness in Idared Apples