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Low Storage Temperatures as a Mean for Improving Quality, Extending Storage Life, Ripening of Hass and Fuerte Avocado Fruits

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Abstract: Mature fruits of Hass and Fuerte avocado cultivars were stored at 5°C and 9°C for different periods before holding at 20°C for expanding its marketing duration as compared with control fruits only kept at 20°C. Fruit characteristics were evaluated at removal from cold storage and subsequent holding. Cold stored fruits of Hass and Fuerte cvs at 5°C had lower weight loss percent than occurred at 9°C at removal from any tested storage periods as well as after holding. Moreover, Hass fruits could withstand without any change in its firmness up to 2-3 weeks at 5°C, meanwhile Fuerte fruits had no decline in its firmness during 5-7 weeks at 5°C. Respiration rate in both cultivars was greatly decreased due to cold storage especially at 5°C compared to control fruits. Holding of cold stored fruits although showed an increase in respiration rate, they were significantly lower than that occurred in control fruits. Color changes in fruits at cold storage (5°C and 9°C) were delayed for some weeks according to cultivars storage temperature, but color change in control fruits occurred after only one week. External damage did not appear during cold storage at 5°C up to 3 and 5 weeks in Hass and Fuerte cvs respectively. Cellulase activity was increased during cold storage and during holding in both cultivar, meanwhile pectinase activity may have limited role in this concern. From these results it can be concluded that cold storage at 5°C was better than storage at 9°C for expanding the market duration of avocado fruits.

Key words: Persea americana storage, ripening quality, fruit pectinase, cellulase activity

INTRODUCTION

The avocado (Persea Americana Mill) has a long history as both subsistence and marketable fruit in the areas of origin in Central and South America. Avocado varieties divided into three races. Mexican, West Indian, and Guatemalan[1,2]. Some California and Florida cultivars have become international providing the basis for avocado development in many countries. Hass a Guatemalan type is the most widely distributed and grown, replacing Fuerte a Mexican - Guatemalan hybrid[3]. In avocado fruit oil content is relatively high and its increase is closely related to fruit development[4] demonstrated the close relationship between percent oil content and percent dry matter during fruit growth and maturation.

Avocado fruit does not soften while on the tree, but only after it is picked. The period which elapses from picking to softening is a function of the metabolic activity of the fruit, which in turn depends on various factors, one of the most influential being storage temperature[5]. Low temperature storage is the most commonly used method for extending storage life in the avocado, the extent to which the avocado can be chilled depends on the cultivars[6]., temperature of storage and period of storage[7,5]. Low temperatures increase shelf life and slow fruit ripening, maintain fruit firmness during storage[8,9]. The avocado is a subtropical fruit sensitive to chilling injury (CI) when exposed to low but on freezing temperatures. The main symptoms of CI are black spots on the peel and a gray or dark – brown discoloration of the mesocarp[10,11].

Exposure to high or low temperatures can be used as effective methods for non – chemical disinfestations of fruit or as a means of reducing postharvest chilling injury at subsequent low temperatures[12]. Heat treatments were also the most effective in reducing CI symptoms in Fuerte and Hass fruit, when applied on the day of picking[13].

The objectives of this study was to extend the storage life of avocado fruit cultivars (Hass and Fuerte)

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and assessing the effect of different cold storage temperatures on maintaining their quality at storage , ripening and preventing skin external damage development at otherwise injurious temperatures.

MATERIALS AND METHODS

The materials of this study were the two avocado cultivars (Hass and Fuerte) grown in sandy - loam soil at private orchard "Nemous" at El Katta district, Giza Governorate. The study was carried out during two successive seasons 2000-2001and 2001-2002. Avocado trees were 20 years old at the start of study, similar in growth vigor and subjected to the common horticulture treatments

Determination of fruit maturity: samples of 15 fruits in three replicates for each cultivar were picked weekly during July and October for Hass and Fuerte respectively to obtain a range of fruit maturities per assessment some parameters. The following maturity indices were used to determine the fruit harvest date (fruit weight, length and diameter, firmness, dry matter and oil percent on fresh weight basis[14] as show in (Table 1)

Fruits obtained maturity stage after 185-200, 100-110 days from full bloom until harvest at first August and November for Hass and Fuerte respectively.

Effect of storage temperatures on fruit quality during storage and ripening: Mature Hass and Fuerte avocado fruits free from apparent pathogen infection and were uniform in shape, weight and color were harvested, washed, air dried and put in carton boxes (15 fruits in each one).Avocado fruit were stored at either 5°C or 9°C in controlled temperature rooms (Bally sectional Prefab wall, Ins. USA) with relative humidity 85-90 % for 5 and 4 weeks respectively with respect to Hass cultivar and for 7 and 5 weeks respectively in Fuerte cultivar.

At weekly intervals, fruit sample (15 to 20 fruit for each treatment) , were removed from each temperature and holding at 20°C for one week as ripening period. Control fruits were directly stored at 20°C. Fruit quality measurements were assessed at removal from cold storage temperatures and after holding at 20°C for one week in each sample date for both varieties.

Fruit quality assessments: Mass loss percentage: Fruits were weighed at the end of each cold storage period at 5 or 9°C as well as after holding at 20°C and weight loss was recorded for each replicate as percentage in relation to the fruit weight of the same replicate at the beginning of storage or holding.

Fruit firmness: Fruit firmness was determined using Ametek pressure tester, fitted with an 8 mm hemispherical probe (probe penetration 2 mm). Firmness of 5 fruits from each replicate was measured at two opposite points on the equator of each fruit after removing a thin slice of skin from each site. The results were expressed as Ib/inch[15].

Respiration rate: Individual fruits for each treatment were weighed and placed in 2-liter jars, sealed for 24 hr with a cap and a rubber septum. O2 and CO2 samples of the headspace were removed from a septum with a syringe and injected into Servomex Inst. Model 1450C (Food Pack Gas Analyzer) to measure oxygen and carbon dioxide production[16,17]. Respiration rate was calculated as ml CO2/kg./hr

Chlorophyll A and B: They were determined in methanolic extract of one gram fruit skin and calorimetrically measured at 650,665 nm then calculated as adopted by[18].

Oil content: The oil percentage in the dried flesh samples was extracted by means of soxhelt fat - extraction apparatus using hexane (40-60oC boiling point) according to[14].

Enzyme pectinase activity: 5 gram of fruit mesocarp was extracted with citrus pectin and acetate buffer homogenized, filtered and the solute used as the crude extract) were mixed and incubated at 45°C for l0 min. The color can be obtained after heating for ten min. The color was measured at wavelength of 570 nm. One unit of pectinase activity liberates 1 M mol D-galactouronic acid in milliliter per min[19,20]

Enzyme cellulase activity: 5 gram of fruit mesocarp was extracted with carboxy methyl and citrate buffer homogenized, filtered and the solute used as the crude extract were mixed and incubated at 50°C for l0 min. One unit of cellulose activity liberates 1 M mol glucose in milliliter per min[19,21]

Fruit ripening measurements: At the eating soft stage, skin color was assessed as the percentage of the skin surface area with dark purple to black color[22] .

Color index: At the eating soft stage, skin color was assessed as the percentage of the skin surface area with dark purple to black color[22]. Avocado skin color changes from green to brown – black during normal ripening. For color assessment four stages were defined : 1 = green., 2 = light green, 3 = changing to purple, 4 = purple, 5 = dark purple[15].

Table 1: Maturity indices of Hass and Fuerte avocado fruits at harvest.

Avocado Varieties	Harvesting date	Fruit Weight gm	Fruit Firmness (Ib/inch2)	Dry matter %	Oil Percent %
Hass	29/7/2001	128.68	16.90	18.80	11.90
	4/8/2002	122.00	16.90	18.90	12.50
Fuerte	7/11/2001	279.63	16.93	19.10	13.50
	9/11/2002	301.69	16.90	19.73	12.90

Means of two seasons of data, three replicates of five fruits each.

External damage: Fruits which were decayed by different physiological and pathological factors were periodically counted and discarded. Then percentages of decayed fruits were calculated in relation to total number of fruits.

The days to eating soft: (DTES) determined as the number of days from harvest to a hand pressure corresponding to a firmness of 4-6 N. as measured previously and / or 8-5 N = eating ripe according to[23] .

Statistical analysis: All data were subjected to statistical analysis according to the procedures reported by[24]. Treatment means were compared by Duncan's multiple range tests at the 5 % level of probability in the two seasons of study.

RESULTS AND DISCUSSIONS

Fruit maturity: It is commercially important to identify the minimum maturity index that insures acceptable quality when ripe but allows early harvesting to obtain the higher season prices fruit weight, firmness, dry weight and oil percent were used as maturity indices of avocado fruit. From the results shown in (Table 1) it can be concluded that Hass avocado fruits attained maturity stage at late July or early August when its weight 122-128 gm, dry matter 18.8%, fruit firmness 16.9 oil content 11.9-12.5. Fuerte fruits attained maturity stage with 280-300 gm fruit weight, 19.1-19.7% dry matter, 16.9 firmness and 12.9-13.5% oil.

In this concern, oil content was evaluated as accurate maturity index in avocado fruits and its level depending upon cultivars[25-27]. Moreover, the investigators[28-31] agree that dry matter of avocado fruits was correlated with fruit maturity.

Weight loss percent: Fruits of Hass and Fuerte cvs showed gradual and significant increase in weight loss percent during storage at 5 and 9°C as well as after holding at 20°C. At removal from cold storage Hass fruits kept at 5°C had lower percent of weight loss than occurred at 9°C for any tested storage period. The differences were significant at the second season. Holding cold stored fruits for one week at 20°C caused further increase in weight loss percent. However, fruits cold stored at 5°C for 4 or 5 weeks at the two seasons respectively or at 9°C for 3 weeks had the same significant weight loss after holding at 20°C, to control fruits only kept at 20°C for two weeks.

With Fuerte fruits it appeared that cold storage at 5°C for 7 weeks was significantly equal to that stored at 9°C for 5 weeks with respect to weight loss percent at removal. Moreover, holding of fruit at 20°C for one week after 7 weeks storage at 5oC resulted in significant equal weight loss or ever less than that occurred in fruits cold storage at 9°C for 3 weeks before holding and control fruits after 3 weeks storage at 20°C.

Therefore, it can expand the storage period of Hass and Fuerte fruits by cold storage at 5°C for 5 weeks and 7 weeks respectively or cold storage at 9°C for 4 or 5 weeks respectively. In this respect[32] recorded that weight loss of avocado fruits varied directly to ripening temperature and length of storage period[33] obtained the greatest weight loss in Hass avocado fruits after 35 days of storage at 9°C.

Fruit Firmness: Hass fruits could withstand without change in firmness up to 2 and 3 weeks at 5°C and 2 weeks at 9°C in the two seasons. By expanding cold storage period there was gradual and significant decrease in fruit firmness. Holding Hass at 20°C for one week showed sharp decrease in its firmness. Values of control fruits after only one week were significantly equal to that obtained in fruits previously cold stored for 3 weeks at 5°C or 2-3 weeks at 9°C before holding.

Fuerte fruits had no decline in its firmness during 5-7 weeks at 5°C and 2-3 weeks at 9°C in the two seasons. Holding fruits at 20°C although caused great decline in their firmness, clod storage before holding reduced the rate of decrease in fruit firmness. Therefore, fruit firmness of content Fuerte fruits after holding for one week was significantly equal to that recorded in fruits received cold storage for 4 weeks at 5°C or 1-3 weeks at 9°C before holding at 20°C.

These results indicated that beneficial effect of cold storage on expanding marketing period of Hass and Fuerte avocado cultivars. The present results are inconformity with that reported by[34] on avocado fruits as fruit softening was delayed at 5 and 9°C.

Table 2: Effect of low storage temperatures (5 and 9°C) on avocado fruit quality (cv. Hass) after storage and after holding at 20°C for one week.

Storage temperature	Duration (in weeks)	Fruit characteristics											
		Weight loss		Respiration rate		Firmness		Chlorophyll A		Chlorophyll B		Oil percent	
		At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding
5°C	1	3.08 e	5.59 g	16.90 a	6.36 b	5.47 f	9.95 f	0.674 a	0.493 b	0.539 a	0.370 b	44.93 f	46.60 fg
	2	4.96 d	7.83 f	16.90 a	5.91 bc	6.28 ef	11.37 f	0.617 b	0.383 c	0.456 c	0.320 c	46.31 def	48.43 de
	3	5.23 cd	9.64 e	16.81 b	5.26 cd	7.72 de	23.15 d	0.553 c	0.292 e	0.375 d	0.270 d	47.87 bcd	50.27 bc
	4	5.98 bc	11.34 d	16.72 c	4.63 def	8.94 cd	25.83 c	0.454 d	0.189 g	0.256 e	0.210 e	49.65 ab	52.44 a
	5	6.73 ab	13.61 b	15.98 e	4.09 ef	10.25 bc	23.50 d	0.383 e	0.093 hi	0.196 f	0.140 f	50.98 ab	53.10 a
9°C	1	3.64 e	6.18 g	16.90 a	5.93 bc	7.74 de	11.00 f	0.669 ab	0.475 b	0.495 b	0.340 bc	44.49 f	46.21 g
	2	5.49 cd	8.31 f	16.83 ab	5.29 cd	8.86 cd	16.32 e	0.533 c	0.215 f	0.379 d	0.260 d	45.96 af	47.96 def
	3	6.08 bc	12.15 c	16.70 c	4.73 de	10.95 b	25.64 c	0.459 d	0.110 h	0.292 e	0.200 e	47.10 cde	49.43 cd
	4	7.13 a	15.34 a	16.10 d	3.94 f	13.32 a	22.36 d	0.343 e	0.071 i	0.208 f	0.150 f	48.86 bc	51.61 ab
Control	0	-	0.00 i	-	16.90 a	-	14.77 e	-	0.790 a	-	0.646 a	-	43.14 h
	1	-	3.50 h	-	5.10 d	-	30.50 b	-	0.343 d	-	0.320 c	-	45.98 g
	2	-	10.95 d	-	4.33 ef	-	42.39 a	-	0.079 i	-	0.190 e	-	47.13 efg
LSD at 5%		0.878	0.943	0.077	0.713	1.472	1.566	0.054	0.024	0.036	0.036	1.849	1.334

Data are means of three replicates of five fruits (first season)

Table 4: Effect of low storage temperatures(5and 9c) on avocado fruit quality (cv. Furete) after storage and after holding at 20°C for one week (first season).

Storage temperature	Duration (in weeks)	Fruit characteristics											
		Weight loss		Respiration rate		Firmness		Chlorophyll A		Chlorophyll B		Oil percent	
		At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding
5°C	1	1.60 j	3.76 g	16.90 a	8.63 b	4.65 h	8.59 l	0.863 a	0.722 b	0.728 a	0.662 b	51.65 gh	55.10 ij
	2	2.72 i	4.91 f	16.90 a	8.26 bc	5.90 g	16.73 i	0.790 bc	0.698 b	0.693 a	0.589 c	53.87 f	57.43 fg
	3	3.98 g	5.88 e	16.90 a	7.53 cd	6.13 g	22.60 g	0.727 de	0.632 c	0.618 b	0.523 d	56.31 cd	58.13 ef
	4	4.48 f	7.05 d	16.80 ab	6.46 ef	7.18 f	27.00 d	0.695 ef	0.580 d	0.559 c	0.479 e	58.02 b	59.49 cd
	5	5.34 d	7.49 cd	16.70 abc	5.46 gh	8.55 e	34.50 b	0.656 f	0.410 f	0.562 c	0.343 g	59.79 a	61.00 b
	6	6.73 c	8.93 b	16.60 bc	4.98 hij	9.97 d	29.65 c	0.585 g	0.361 g	0.458 d	0.310 gh	60.82 a	62.58 a
	7	7.89 a	10.05 a	16.10 d	4.23 jk	10.58 d	24.73 f	0.545 gh	0.198 h	0.443 de	0.289 hi	58.34 b	60.33 bc
9°C	1	1.71 j	4.65 f	16.90 a	8.00 bc	7.22 f	12.00 k	0.823 ab	0.691 b	0.702 a	0.619 c	50.85 h	54.17 j
	2	3.45 h	6.00 e	16.90 a	7.03 de	8.38 e	18.83 h	0.758 cd	0.586 d	0.638 b	0.528 d	52.46 g	56.00 hi
	3	4.63 f	7.08 d	16.50 c	6.34 ef	13.52 c	24.00 f	0.645 f	0.503 e	0.523 c	0.434 f	54.49 ef	57.38 fg
	4	5.07 e	8.91 b	14.56 e	5.13 ghi	14.65 b	25.80 e	0.570 gh	0.372 fg	0.437 de	0.322 gh	56.76 c	58.90 de
	5	7.47 b	10.24 a	12.80 f	4.00 k	18.00 a	22.53 g	0.528 h	0.189 h	0.414 e	0.232 j	55.43 de	56.80 gh
Control	0	-	0.00 h	-	16.90 a	-	13.60 j	-	0.972 a	-	0.869 a	-	49.00 l
	1	-	6.10 e	-	6.63 ef	-	30.50 c	-	0.633 c	-	0.586 c	-	52.93 k
	2	-	8.03 c	-	5.82 fg	-	42.30 a	-	0.466 e	-	0.333 g	-	54.33 j
	3	-	10.65 a	-	4.45 ijk	-	26.32 de	-	0.202 h	-	0.256 ij	-	52.25 k
LSD at 5%		0.192	0.825	0.277	0.828	0.950	0.981	0.053	0.037	0.038	0.035	1.206	1.151

Data are means of three replicates of five fruits each (first season)

Respiration rate: Respiration rate of Hass and Fuerte fruits was greatly decreased due to storage at 5 and 9°C as compared with fresh control fruits at zero time. However, there was slow but significant increase especially at 9°C by expanding storage. Respiration rate after 2 weeks storage at 9°C was significantly equal that occurred after 4 weeks storage at 5°C. On the other side, holding the previously cold stored fruits for one week at 20°C resulted in an increase in respiration rate. This increase paralleled with expanding cold storage period, but it was greatly less than that occurred in control fruit

Fuerte fruits showed the same previous trend of respiration rate. Fruits clod stored at 5°C for 4 weeks had a significant equal rate of respiration of fruits stored at 9°C for only one week. Moreover, holding of cold stored fruits although showed an increase in respiration rate, they were significantly lower than that occurred in control fruits

Similarly[35-36] on avocado fruits cv Hass found that respiration rate were markedly reduced when fruits stored at 3°C compared with storage at 20°C. Moreover[36] on the same cultivar found that held the fruits at 10°C were beginning the climacteric and ripened after about 4 days at 20°C, but fruits held for 2 weeks at 5°C displayed normal climacteric patterns at 20°C.

Chlorophyll A: There was gradual and significant decrease in chlorophyll A concentration in the peel of Hass and Fuerte fruits with the advance of cold storage period. At the end of cold storage period at 5°C (5 and 7 weeks in Hass and Fuerte cvs respectively) chlorophyll A content was significantly equal to that found at 9°C after 4 and 5 weeks in the two cultivars successively. There is only one exception in Hass cv at two second season.

Holding of cold stored fruits at 20°C for one week resulted in further and significant decline in chlorophyll A content. Maximum reduction was recorded in fruits cold stored for longest period before holding for one week. These values were significantly equal to control fruits (without cold storage) which kept at 20°C for 2 weeks in Hass cvs at two season and 3 weeks in Fuerte cv. at the first season.

Chlorophyll B: Concentration of chlorophyll B also showed significant decrease with expanding cold storage period at 5 and 9°C as well as after holding at 20°C in the cultivars under study (Table2). In Hass cultivars, the minimum values of chlorophyll B were recorded at the 5th week storage at 5°C and the 4th week storage at 9°C with only significant difference at the second season. The season trend was recorded in Fuerte cvs at the 7th week storage at 5°C and the 5th week storage at 9°C without significant different between them at both seasons.

Holding fruits at 20°C for one week after cold storage showed further obtained in chlorophyll B content. Lowest values were obtained with fruits received the longest storage cold period just before holding at 20°C. The values were significantly equal to control fruits of Hass cv. at the season after 2 weeks holding and Fuerte cv. after 3 weeks holding the seasons.

These results could confirm the efficiency of cold storage especially at 5°C in Fuerte fruits retaining the green color for longer period and hence expanding fruit life markets.

Oil content: The percent of oil (on dry weight bases) in both Hass and Fuerte avocado fruits was gradually increased during the progress of cold storage period at 5°C and 9°C as well as during holding at 20°C. Such increase was significantly higher at low storage temperature 5°C that occurred at 9°C. The highest increase was attained after five weeks storage at 5°C in Hass and Fuerte fruits respectively. Holding of these fruits for one week at 20°C resulted in further increase in its oil content. The values of oil content of cold stored fruits were significantly higher than that in control fruits (only kept at 20°C).

These results were in parallel with that found by[33] on Hass fruits as oil content was increased during storage at 4°C and 9°C followed by ten days at ambient temperature (18-20oC)[34] added that oil content in Hass fruits was higher at 5°C storage temperature than that at 20°C, and with increasing storage duration.

Cellulase and Pectinase activities: It can be noticed that Hass avocado fruits had great increase in cellulase activities (Table 6) reached 23.18, 32.69 units/gm F.W. after storage at 5°C and 9°C respectively and 39.82, 45.16 units after holding at 20°C at the 4th week. Meanwhile, pectinase activity decreased after cold storage as well as after holding (7.520 x 103, 6.321x103 and 4.747x103, 2.346x103) at the 4th of cold storage respectively.

Similarly, avocado fruit at Fuerte cv showed increase in cellulase activity throughout storage at 5, 9°C for weeks (20.18, 24.77) and after holding at 20oC (35.12, 41.62) for one week respectively. Also, pectinase activity decreased during storage at 5, 9°C (10.88x103, 10.614x103) and ripening at 20°C (6.152x103, 6.028x103).

Increasing rate of cellulase activity at cold storage and after holding in Hass fruits which had lower storage ability as compared with Fuerte fruits could indicate its major role in softening of avocado fruits. Meanwhile, pectinase activity may have a low effect in this concern as

Table 3: Effect of low storage temperatures (5 and 9°C) on avocado fruit quality (cv. Hass) after storage and after holding at 20°C for one week.

Storage temperature	Duration (in weeks)	Fruit characteristics											
		Weight loss		Respiration rate		Firmness		Chlorophyll A		Chlorophyll B		Oil percent	
		At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding
5°C	1	3.89 g	6.07 f	4.80 e	8.59 h	16.90 a	8.10 b	0.619 a	0.478 b	0.512 a	0.478 b	46.63 ef	49.02 f
	2	4.90 ef	7.49 e	5.36 e	10.73 g	16.88 ab	7.69 b	0.570 a	0.254 b	0.435 b	0.254 cdef	47.80 de	51.14 de
	3	5.68 de	8.89 d	6.27 d	22.51 d	16.80 ab	6.96 c	0.502 b	0.144 cde	0.393 c	0.144 efg	49.57 c	53.21 bc
	4	6.75 bc	10.26 c	7.49 c	24.46 c	16.74 b	5.69 d	0.415 c	0.094 de	0.338 d	0.094 fg	51.14 ab	54.19 bc
	5	7.12 b	12.34 b	9.50 b	22.56 d	16.10 c	4.99 ef	0.352 d	0.168 e	0.295 e	0.041 g	52.00 ab	55.50 a
9°C	1	4.65 fg	7.84 e	6.48 d	10.32 g	16.90 a	7.75 b	0.584 a	0.418 de	0.494 a	0.418 bc	46.19 f	48.85 f
	2	5.28 def	9.16 d	7.66 c	15.20 e	16.81 ab	6.93 c	0.475 b	0.213 bc	0.383 c	0.213 defg	47.13 ef	50.76 e
	3	5.93 cd	12.44 b	9.53 b	24.45 c	16.75 ab	5.83 d	0.346 d	0.098 cde	0.262 f	0.098 fg	48.86 cd	52.33 cd
	4	8.06 a	14.70 a	12.23 a	21.60 d	16.16 c	4.46 f	0.138 e	0.285 e	0.240 f	0.283 cde	50.10 bc	53.15 bc
Control	0	-	0.00 h	-	13.50 f	-	16.90 a	-	0.763 bcde	-	0.763 a	-	45.31 h
	1	-	4.15 g	-	28.93 b	-	6.65 c	-	0.329 a	-	0.329 bcd	-	47.41 g
	2	-	12.15 b	-	39.26 a	-	5.46 de	-	0.091 bcd	-	0.091 fg	-	49.16 f
LSD at 5%		0.906	0.914	0.705	1.379	0.153	0.626	0.210	0.054	0.031	0.185	1.540	1.290

Data are means of three replicates of five fruits cach. (Second season)

Table 5: Effect of cold storage temperature on avocado fruit quality (cv. Furete) after storage and after holding at 20 °C for one week (second season).

Storage temperature	Duration (in weeks)	Fruit characteristics											
		Weight loss		Respiration rate		Firmness		Chlorophyll A		Chlorophyll B		Oil percent	
		At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding	At removal	After holding
5°C	1	1.89 j	3.90 h	16.90 a	9.26 b	3.58 h	7.34 n	0.885 a	0.710 b	0.756 a	0.612 b	50.05 f	52.30 gh
	2	2.95 i	5.15 g	16.90 a	9.12 b	4.99 g	15.17 k	0.798 b	0.689 b	0.688 b	0.598 bc	54.10 d	57.00 e
	3	4.10 g	5.98 f	16.90 a	8.20 c	5.36 g	22.67 h	0.736 c	0.543 c	0.593 cd	0.433 f	56.00 c	59.30 c
	4	4.56 f	7.38 e	16.83 a	7.10 d	6.87 f	26.85 f	0.698 c	0.401 e	0.513 e	0.339 gh	57.80 b	61.18 b
	5	5.50 d	8.09 d	16.80 a	6.60 de	7.65 e	33.74 d	0.558 e	0.320 f	0.486 ef	0.310 hi	58.60 ab	62.98 a
	6	6.95 b	9.10 c	16.76 a	6.12 e	8.79 d	28.46 e	0.521 ef	0.272 g	0.430 g	0.286 i	59.75 a	64.00 a
	7	8.12 a	10.52 b	16.66 a	5.19 fg	9.95 c	26.58 f	0.468 g	0.229 h	0.386 h	0.262 ij	58.73 ab	60.89 b
9°C	1	2.01 j	4.86 g	16.90 a	7.03 d	6.26 f	10.69 m	0.860 a	0.698 b	0.689 b	0.550 cd	48.60 g	52.35 g
	2	3.75 h	6.10 f	16.90 a	6.23 e	7.92 e	17.78 j	0.712 c	0.513 d	0.623 c	0.482 ef	50.25 f	55.00 f
	3	4.98 e	7.38 e	16.76 a	5.33 f	14.85 b	22.20 hi	0.636 d	0.408 e	0.590 d	0.365 g	52.12 e	56.39 e
	4	5.79 c	9.31 c	15.33 b	4.75 g	15.00 b	24.65 g	0.533 ef	0.289 g	0.472 f	0.289 hi	55.73 c	58.50 cd
	5	7.87 a	11.21 a	11.40 c	3.95 h	16.95 a	21.35 i	0.498 fg	0.159 j	0.413 gh	0.212 j	53.99 d	57.40 de
Control	0	-	0.00 i	-	16.90 a	-	12.43 l	-	0.987 a	-	0.888 a	-	46.76 I
	1	-	5.95 f	-	6.83 d	-	58.71 b	-	0.543 c	-	0.512 de	-	51.00 h
	2	-	8.39 d	-	4.92 fg	-	63.15 a	-	0.316 f	-	0.336 gh	-	53.50 g
	3	-	11.25 a	-	4.10 h	-	43.16 c	-	0.189 i	-	0.275 i	-	52.43 g
LSD at 5%		0.277	0.539	0.306	0.554	0.635	0.902	0.038	0.028	0.033	0.053	1.297	1.324

Data are means of three replicates of five fruits each (second season)

it decreases during cold storage and holding of avocado fruits.

Similarly[37] recorded that cellulase is the major constituents of avocado cell walls and consequently it is reasonable to expect cellulase to play a major role in avocado softening. In addition[38] found that cellulase activity was higher in severe injured fruits than that in fruits with highest injury.

Furthermore[39] found that cellulase activity in the preclimacteric fruit, started to increase Just as respiration increased and reached a level two times greater than at the edible soft stage of Fuerte avocado fruits. On the apposite side, both of pectin esterase (PE) activity and pectin methyl esterase (PME) activity were high at the start of avocado fruit storage and declined steeply till the beginning of softening and early in the climacteric[39-41]

Fruit ripening:

1. Color index: Color of avocado fruit skin after holding at 20°C for one week revealed that it changed from green to dark purple in Hass cultivar, meanwhile it became purple in Fuerte cultivar.(Figure 1). Cold storage before holding delayed the change in fruit color of Fuerte fruits up to 4 or 2-3 weeks according the temperature (5°C and 9°C respectively) , but change in color of control fruits was occurred after only one week.

Furthermore, appearance of purple color in Fuerte fruits was noticed after 3 weeks of holding at 20°C in control ,meanwhile it delayed at 7 and 5 weeks further holding period in fruits received cold storage at 5 and 9°C successfully.

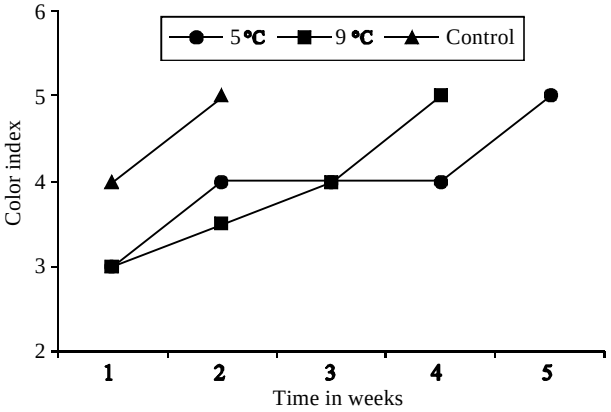

Fig. 1: Skin color development after holding at 20°C for one week. The color index was defined between 1 and 5, where 1 represents a green fruit and 5 represents the dark purple color typical of ripe Hass fruit. (Average of two seasons)

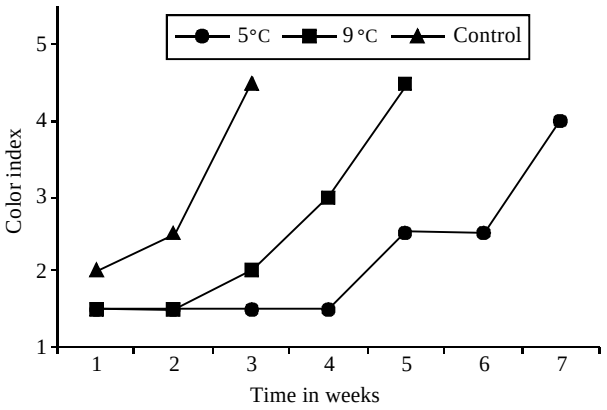

Fig. 2: Skin color development after holding at 2°C for one week. The color index was defined between 1 and 4, where 1 represents a green fruit and 4 represents the purple color typical of ripe Fuerte fruit. (Average of two seasons)

In Hass fruits appearance of dark purple color was recorded after 2 weeks of holding in control fruits, but it delayed up 5 and 4 weeks further those holding period in fruits stored at 5°C and 9°C before holding.

2. External damage: Hass Fruits did not show any external damage during cold storage up to 3 and 4 weeks at 5 and 9°C respectively. Meanwhile, that of Fuerte cv. could withstand in complete healthy up to 5 and 3 weeks at 5 and 9°C respectively. In addition, Hass fruits stored at 9°C for 4 weeks recorded a significant higher external damage percent than that occurred on fruits kept at 5°C for weeks. The same trend was found in Fuerte fruits stored for 3 weeks at 9°C and that kept at 5°C for 6 weeks. These findings were recorded at the two seasons of study.

On the other side, cold storage Hass fruits (5 and 9°C) for two weeks did not show any external damage during holding period (one week at 20°C). Also Fuerte fruits cold stored for 4 weeks at 5°C or three weeks at 9°C were in complete health during period. Meanwhile control fruits of Hass cv holded for week gave 2.83 and 1.93 external damage percent, but that of Fuerte fruits were completely health during the same holding period.

These results indicated the advantage of cold storage treatment especially at 5°C in increasing the shelf life of Hass and Fuerte avocado fruits.

Similarly[36] on Hass avocado fruits found that storage for 4 and 6 weeks at zero and 5°C resulted in the development of chilling injury symptoms in this concern[34,42] found that symptoms of chilling injury in avocado fruits (Pitting and browning of the skin) were observed after storage at 0.0-3°C but not at 6°C. Also[34]

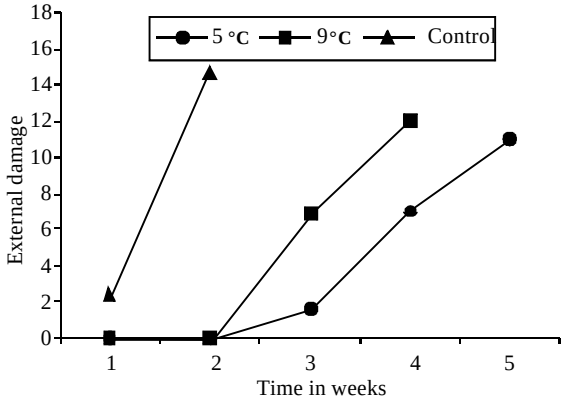

Fig 3: External skin damage (injuries) of Hass avocado fruits as affected by storage durations at 5 and 9°C. The data represents percentage of fruit with visible skin damage. Acceptable commercial external appearance was 10 % skin and nodules damage combined (average two seasons).

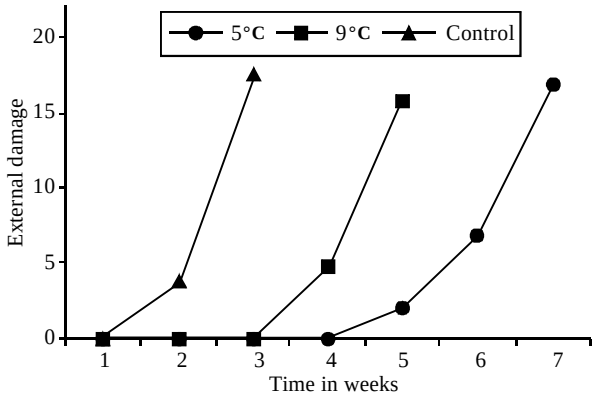

Fig 4: External skin damage (injuries) of Fuerte avocado fruits as affected by storage durations at 5 and 9°C. The data represents percentage of fruit with visible skin damage. Acceptable commercial external appearance was 10 % skin and nodules damage combined (average two seasons).

recorded that storage at 1.1°C caused significant increase in chilling injury avocado fruits compared with 5°C.

Softening: Avocado fruit ripening were assessed in both Hass and Fuerte cultivars after removal from cold Temperatures and held at 20°C for one week. Fruits tended to soft ripe when reached to 4-6 N (fruit firmness). Avocado fruits placed directly at 20°C (control fruits) began to soften after one week and were eating ripe after 2 - 3 weeks in Hass and Fuerte fruits respectively.

Exposure to low storage temperatures tended to hasten ripening of fruits held at 20°C according to

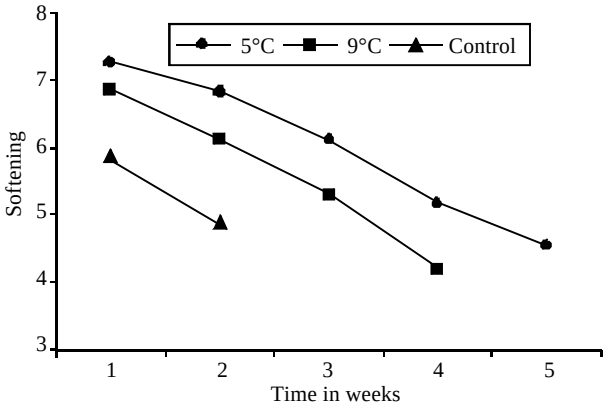

Fig 5: Days to ripe (softening) of cold stored avocado fruit cv. Hass for 5 weeks at 5°C and 4 weeks at 9°C and holded at 20 o C for one week compared to control fruits only kept at 20°C for 2 weeks. 5N represents a characteristic of ripe Hass fruits. (Average of two seasons)

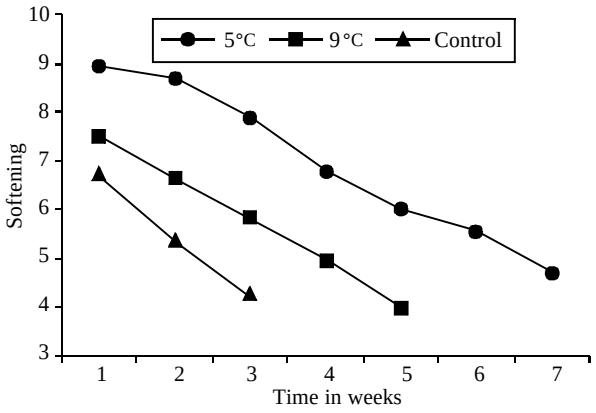

Fig 6: days to ripe (softening) of cold stored avocado Fruit cv. Fuerte for 7weeks at 5°C and 5 weeks at 9°C and holded at 20°C for one week compared to control fruits only kept at 20°C for 2 weeks. 5N represents a characteristic of ripe Fuerte fruits (average of two seasons)

temperature degree and storage duration. At 5°C the fruit began to ripen and were available to eat after 5 and 7 weeks storage period for Hass and Fuerte fruits, meanwhile these periods reduced to 4 and 5 weeks at 9°C for both cultivars under study.

These results were in parallel with[7,15] They reported that long exposure to low storage temperatures significantly increased the time required for ripening at 20°C compared with control fruits.

Table 6: Effect of cold storage treatment on cellulase and pectinase activities after storage and holding at 20°C of Hass and Fuerte avocado fruits unit/9m. F.W.

Varieties	Hass				Fuerte			
Storage temperatures	Cellulase		Pectinasex10^3		Cellulase		Pectinasex10^3	
	Storage	Holding	Storage	Holding	Storage	Holding	Storage	Holding
5°C	23,180	39,820	7,520	4,747	20,180	35,120	10,838	6,152
9°C	32,690	45,160	6,321	2,346	24,770	41,620	10,614	6,028
at harvest	4,320	-	8,326	-	3,380	-	12,779	-

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