JOHP

Journal of Ornamental and Horticultural Plants
Available online on: www.jornamental.com
ISSN (Print): 2251-6433
ISSN (Online): 2251-6441

The Effect of Hot Water Treatments on Gray Mold and Physicochemical Quality of Kiwifruit During Storage

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Received: 7 February 2012 Accepted: 6 June 2012
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Abstract

Decline in postharvest losses of kiwifruit depended to maintain of quality characteristics during storage and transportation. Storage losses caused serious economic losses in kiwifruit. This study was conducted to inhibition of pathogen infection and increasing fruit quality of Kiwifruit. Hayward kiwifruits inoculated by *B.cinerea* conidia through pore wounds which formed by removal of the pedicels. Fruits treated through immersion in hot water (45, 50 and 55 °C) for 2, 4 and 8 minutes after 3 weeks. All fruits stored at 0.5°C and 85-90 RH for 18 weeks. The samples had taken at 6th, 12th and 18th weeks and measured some characters including weight loss, peel and pulp color indices (*L** and chroma), decay numbers, firmness, decay depth, SSC, TA, SSC/TA, pH, EC, Ascorbic acid, compared with the control. Results showed that weight loss rate increased about 2 fold of control but decay depth and losses prevented at 6th and 12th weeks of storage period significantly. Firmness was higher than control at 12th storage week in hot water treatments but had not significant differences with control until end of storage period. Generally, *L** parameter had a positive relationship with firmness. Ascorbic acid increased specially in control treatment during cool storage period. EC, pH, and TA parameters had constant changes during of storage.

Keywords: Color, Cool storage, Gray mold, Hayward, Hot water, Physicochemical.

INTRODUCTION

Kiwifruit with the scientific name of *Actinidia deliciosa* cv. Hayward is most famous fruit in the Iran and other countries. In recent years, there is a trend to increase kiwi cultivation especially in the north of Iran. Globally and in some countries like New Zealand, during seventy decades, the kiwifruit considered as commercial and important products. Therefore, the more researches have studied on various aspects of cultivation, production and protective of Kiwi (Debersaques and Mekers, 2007). Although in the recent years, kiwi product development has been remarkable, but less research done on the problems of harvesting and storage of kiwifruit.

An irreparable damage occurred during storage due to the lack of a specific pattern or methods derived from scientific research. Meanwhile among different storage fungi, gray mold are the main factor limiting of kiwifruit storage life. All new harvested products need to be without from pathogens, insects, and synthetic chemicals and contamination. Not certain fungicides have been registered for controlling corruption agents in the storage while not harmful to human health as well. On the other hand, consumer knowledge has increased about consumption effects of chemical agents to control diseases, pests and physiological damage. Therefore, we need to develop effective materials without any damages to health maintenance of horticulture products.

Kiwifruit had excellent storage properties among other subtropical fruits. Moreover, its quality could maintain more than eight months in controlled conditions. Base on study revealed that high CO_2 atmosphere can slow the growth of *B. cinerea* on apples (Janisiewicz *et al*., 2003). Botrytis diseases are very common and widely distributed on vegetables, ornamentals, fruits, and field crops throughout the world. They commonly appear as blossom blights and fruit rots (Kulakiotu *et al*., 2004).In this case, due to fungus activity, fruit began to watery from the tip and then gradually extends to other fruit parts.

It has reported that spores of this fungus needs to ethylene for germination and followed ethylene produced by defected fruits. Ethylene production by fungi caused fruit softening even in the before maturity and thus can reduce the storage life (Hardan *et al*., 2005). Also recognized that ethylene was produced by *B. cinerea* when grown on PDA medium (Chague *et al*., 2002). According to Wurms *et al*., (1999) report, the more conidia produced in pericarp comparison to stem end of fruit, because of this site contains growth inhibitor agents of gray mold. Fruit age also influenced on contamination levels and the fruits with early harvesting are more sensitive than lasted harvesting fruit.

Using of hot water treatments to control decay occurred for the first time in 1992 on citrus fruit (Fallik, 2004). Paull and Chen (2000) reported the beneficial effect of immersion in hot water to control postharvest diseases for kiwifruit. Some researchers found that by applying a moderate heat treatment, ripening could be delayed and fungal decay reduced without major changes in fruit quality (Kou *et al*., 2007). According to a study on grapes found that 45°C for 8 mm was the best hot water treatments for table grapes (Kou *et al*., 2006).

Application of hot water treatment before short-term storage (few minutes) only is effective on pathogens that exist in the outer layers of fruit peel. This treatments commonly done by several methods such as immersion in hot water, hot steam, hot and dry air, hot shower-brush technique. Among these treatments, hot water method used (short time) commercially (Fallik, 2004).

Various studies showed that the cause of ethylene decline by hot water is due to decreasing of EFE (Ethylen Forming Enzyme) activity. Furthermore, the heat treatments used to prevent chilling injury and peel damage during storage and marketing. In avocado fruits, using of hot water through 38◦C for one hour caused a significant decreasing in peel damages (Fallik, 2004; Lurie, 1998).

In relation to temperature effects on fruit quality properties, Irving *et al*., (1991) reported that fruit firmness, taste, respiration rate and ethylene production not affected during optimum temperature conditions. Ippolito *et al*., (1994) were used another method to reduce storage rot. In their experiments, the kiwi fruit before transferring to cold storage placed at 5-30°C and 95-98 RH for 24-96 hours. Based on their results, the thermal treatment at 15°C and 98-95 RH for 48 hours had the best confirmed of

decay control. Immersion of inoculated, freshly harvested table grapes for 3 min at 30, 40, or 50 °C reduced decay to 20.7, 6.7, and 0.1 berries/kg after 30 days of storage at 1 °C, while decay after immersion in water at these temperatures was 35.9, 17.6, and 1.7 berries/kg, respectively (Karabulut *et al*., 2004). The aim of this experiment was the studying of the effect of different hot water temperatures on physicochemical changes and gray mold control in kiwi fruit during cold storage.

MATERIALS AND METHODS

Fruit materials

Fruits were harvested at commercial maturity stage (TSS=7%) from an experiment orchard at the Iran Citrus Research Institute (Ramsar). Fruits transferred to laboratory subsequently and sorted based on size and the absence of physical injuries or infections.

Treatments

The fungal colonies cultured on PDA medium to produce single-spore. Then these spores used to prepared suspension of solution. Hayward fruits inoculated firstly by applying Botrytis cinerea conidia on wounds formed by removal of the pedicels. Then fruits divided into 12 groups randomly, each group containing 120 fruits in three replicates and immersed into hot distilled water with 45, 50, 55◦C for 2, 4 and 8 min. Fruits were then dried for 24 h and then stored at 0.5oC and 85-90 RH for 18 weeks. After weeks 6, 12 and 18, fruit samples (30 numbers) were obtained from each treatment to measure the fruit quality characteristics.

Physicochemical analysis

Firmness was determined by measuring compression using a hand-held Effegi penetrometer with a 7.9 mm probe after removal of skin to a vertical depth of 1 mm on two sides of the fruit. The firmness considered as an average peak force of 10 fruits and expressed as kg/7.9 mm2. Moreover, three fruits per replicate were weighed at the beginning of storage and throughout storage period to calculate weigh loss percentage.

Titratable acidity (TA) was determined using 5 ml of fruit puree from five fruits mixed with 25 ml of distilled water, with two drops of phenolphthalein (1%) as indicator, titrated with 0.1N NaOH to an endpoint pink (pH 8.2). The results expressed as percent anhydrous citric acid since it is the dominant acid in kiwifruit (Fisk *et al*., 2008).

Soluble solids content (SSC) were then measured using an ATC-1E ATAGO hand-held refractometer on the translucent part of the juice. The pH of the samples were measured by a pH meters (Inolab pH 720, WTW, Germany).

The peel and pulp color was evaluated with a Minolta chromometer CR-400, which provided measurements of Hunters L*, a*, b* and chroma. L* measures lightness and varies from 100 for perfect white to zero for black. a* measures redness when its value is positive, gray when zero, and greenness when negative, and b* measures yellowness when positive, gray when zero, and blueness when negative.

Ascorbic acid was determined using the Dye method (Ranganna, 1977). The kiwifruit puree samples (30 g) homogenized with 30 ml of 3% metaphosphoric acid (HPO3). Five ml of aliquot was titrated with a standard dye solution (2, 6-dichlorophenol-indophenol) to a pink color that persisted for 15 seconds using an autotitrator calibrated using standard ascorbic acid. The ascorbic acid content (Vitamin C) expressed as mg/100g FW.

Statistical analysis

Physicochemical data analyzed with MSTAT–C statistical software (Michigan State University, USA). Treatments arranged in completely randomized design, and Tukey's test ($p< 0.5$) used to reveal any differences.

RESULTS AND DISCUSSION

The results of initial assessment showed that the rate of fruit TSS, firmness and TA were 9-10 %, 2.3-kg.7.9mm-3 and 0.9 % at the time of harvest respectively. Peel color values was measured as L* (41.07), a* (6.63) and b* (21.54). Pulp color values also were recorded as well as L* (54.99), a* (-15.51) and b* (36.01). In fact, these characteristics indicated for better evaluated the fruit quality changes before treatment applying and transfer them to cold storage.

Weight loss

The analysis of data showed that the use of hot water increased weight loss comparison to control. The highest weight loss observed when the fruits immersed in 55°C. The lowest weight loss belongs to control that was nearly half of hot water treatments (Fig. 1). Hayward kiwi fruit placed in cool storage with zero temperature. Weight loss rate decreased from 0.34% (3 days after storage) to 0.93 % (6 weeks storage) and finally achieved to 1.54 % at the end of 12 weeks storage (Bautista-Banos *et al*., 1997). Although storage temperature is higher in this experiment, but the process of fruit weight loss is in accordance with the above report results during storage. Fruit weight loss can be occurs due to increasing of respiration rate during storage (Aghdam *et al*., 2011). Conversely, low temperature decreased fruit respiration. For this reason, hot water treatments increased respiration rate comparison to control. Therefore, it is resulted to enhanced weight loss during storage.

Decay rate

In general, all treatments had most impact to control of gray mold between 6 to 8 weeks. In this case, the amount of contamination is less than one percent. Later on (12 and 18 weeks sampling), it was increased to 2.2 and 3.2 numbers (equal to 10 %) respectively (Fig. 2)., Low temperature storage reduced fungal activity in the storage (Bautista-Banos *et al*., 1997) besides water temperature. In another study, with inoculated the picked wound of four trees by *Botrytis* and then maintained at 0°C, it observed that the extent of pollution in 1 to 4 trees were 21.3, 17.1, 41.6 and 2.1 percent, respectively (Poole and McLeod, 1994). Our results revealed that fruit rot reduction was due to decline of *Botrytis* spores in hot temperatures compared to other reports.

Fruit color changes

The peel color and chroma rate decreased during storage (Fig. 3). This value affected by storage time mostly and water temperature had no significant effect on chroma.

The L* value of peel was maximum (average 55) in fruits which were exposed for 2 minutes in all three temperature and control (Table 1). It is thought that immersion time had more effective on L* value than different water temperatures.

There are not a report about influences of hot water on peel lightness changes but suggested that the L* value was 66.6 at the harvesting time and then decreased during storage (Amodio *et al*., 2007). In this experiment, it was 52.09 at harvesting time but decreased to 44 (45 °C for 8 minutes) at the end of storage. Although, L* value had not significant changes at 50 and 55°C treatments.

Based on the table 1, fruits treated with hot water and control, had high levels of chroma at the primary sampling (6th weeks) from storage. In fact, chroma expressed saturation of green color and associated with fruit firmness. With longer periods of fruit storage, pulp chroma decreased due to pulp color was darker than beginning of storage period. It reported that the chroma value in soft and firm ripened fruits were 15.69 and 36.77, respectively. At this form, pulp had high level of green pigment content (Costa *et al*., 2006). In this experiment, chroma value at all treatments and control decreased because of fruit softening at the end of storage. This phenomenon almost affected by storage period.

Fruit firmness

The firmness of fruit pulp was 2.3 kg.7.9 mm-3 at harvesting time. Fruit firmness was changed between 0.6 (samples taken at 18th week) to 1.6 kg.7.9 mm-3 (weeks 6 and 12) during storage (Table 1). In this experiment, the fruit firmness of control decreased during storage. Fruit softening in control occurred earlier and severity than other treatments. The decreasing of firmness in this study is consistent with results of other researchers. It has reported that Botrytis conidia needs to ethylene for germination or he can produced ethylene itself. Ethylene production by fungi caused fruit softening even before maturity, so can reduce the storage life (Poole and McLeod, 1994; Qadir *et al*., 1997). Application of hot water may be destroyed the conidia that led to prevent of ethylene production by fruit tissue. It can be delayed fruit over ripening and softening.

Depth of contamination

According to table 1, the amount of fruit and depth contamination were zero (mm) in six weeks of cold storage. Most expansion of decay observed in the 12th weeks of storage with 2.11 cm in the control treatment, which had not significant differences with other temperatures. Maximum progress in fruit contamination depth (6.42 cm) was in fruits, which treated by water at 45°C and stored for 12 and 18 weeks. Not only the control treatment has shown the greatest amount of contamination in 12th week but also were occurred the maximum development of Botrytis infection in fruit tissue. The 45 and 50°C treatments decreased development of decay until the 12th week firstly, but increased in the last six weeks of storage. Moreover, hot water (55°C) well prevented botrytis development during storage. Chardonnet *et al*., (2003) used grapes volatile oils to control gray mold and measured contamination depth. They found that the contamination depth in treated fruit was 2.5 mm, which was less than comparison of control (15 mm) during 7-11 days storage.

pH changes

Overall, the range of pH changes was between 3.5 and 3.7 during storage. Only the control treatment had high pH value (3.7) in the sixth weeks of sampling date (Table 1). When kiwifruit kept in storage at 2°C for 70 days, it was found that pH indicator increased gradual and steady from 3.61 to 3.75 (Fisk *et al*., 2008). The results of this experiment were fully consistent with this report. It seems that heat treatments had not effect on pH level significantly.

SSC, TA and SSC/TA changes

Results (Table 1) indicated that the TA levels increased in all treatments to the 12th weeks and then decreased until the end of storage. No significant differences observed about SSC during storage. The amount of TA was 0.85 % at harvesting time and then decreased to 0.69 % after 6 weeks. Therefore, it seems TA had more influence on SSC/TA ratio than SSC percent (Table 1). Similarly, Marsh *et al*, (2004) found that the amount of fruit acid reduced from 1.5 % to 1.37 % but had constant changes until the end of storage. In addition, TA did not influenced by hot water, however increased firstly and then declined during storage. The decreasing trend of TA was similar to the results of Fisk *et al*., (2008), that reported amount of TA reduced from 1.26% to less than 1% during 70 days of kiwifruit storage.

Electrical conductivity (EC) changes

Generally, the amount of EC had a direct relationship with time of cold storage. However, rate of EC has increased between weeks 6 to 12 and then almost was constant in the six weeks before the end of storage (Table 2). It is seems that the heat exogenesis from hot water caused an ionic phase in fruit tissue. In fact, EC of fruit juice represent the amount of passing electricity. Enhancing of EC by hot temperatures depended to nature of ions and ionic concentrations. In contrast, EC decreased with increasing of solid content and particle size, which showed there are non-ionic

parts such oils and sugars in fruit juice. In addition, EC enhanced when the acidity increased during storage (Esteve *et al*., 2007).

Ascorbic acid changes

Ascorbic acid content enhanced during storage and reached to maximum (especially in control) in the end of storage. Generally, hot water treatments and time of exposure had not significant impact on ascorbic acid content (Table 3). Some reports referred to decreasing and others to increasing of ascorbic acid in kiwifruit during storage (Amodio *et al*., 2007). About other acids, Marsh *et al*., (2004) found the amount of citric acid was decreased but it was higher in 0°C. In this experiment, ascorbic acid changes did not match even with the results of citric acid.

CONCLUSION

Based on the results, fruit peel sensed to water loss by applying of hot water. In contrast, it well controlled infection rate of Botrytis between 6 and 8 weeks (less than 1%). Due to the spread of fungi, it is important to control of molds in early weeks. Therefore, hot water treatments well have done this duty. Moreover, it inhibited from early fruit softening via destroyed of Botrytis. On the other hand, SSC/TA ratio decreased because of reducing of ethylene production. Ascorbic acid and EC levels increased with greater slope between 6th to 12th weeks. If kiwi growers monitored suspected trees to Botrytis or other fungus, they can harvest the infected fruits separately and dipped to hot water (50°C) for 4 minutes. After that, dried fruits could place in a cold storage.

ACKNOWLEDGEMENTS

This work is part of the kiwifruit project No. 2-023-240000-14-0000-85002 funded by Iranian Citrus Research Institute. We greatly thank Dr. S. Aghajanzadeh for critical supported.

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Tables

Table 1. Interaction effects of dipping time and water temperature on some quality parameters of kiwifruit.

dipping time (min.)	water temperature (◦C)	*L** value (peel)	*L** value (pulp)	Chroma (pulp)	Firmness	Depth of contamination	pH	TSS/TA
2	45	32.4 bcd*	55.7 a	34.7 a	1.3 a	0.0 b	3.6 b	20.9 b
	50	34.0 abc	55.0 a	34.6 a	1.6 a	0.0 b	3.6 b	21.4 ab
	55	35.0 a	56.0 a	33.6 a	1.4 a	0.0 b	3.6 b	26.5 a
	control	32.0 cd	54.0 a	31.3 b	0.9 a	1.2 b	3.6 b	22.2 ab
4	45	33.4 abcd	44.2 c	19.0 cde	1.6 a	0.4 b	3.6 b	20.5 b
	50	32.8 d	43.3 c	18.0 de	1.0 a	0.7 b	3.6 b	21.0 b
	55	34.1 abc	42.9 c	17.6 e	1.6 a	0.2 b	3.6 b	19.6 b
	control	35.1 a	45.2 bc	18.7 de	0.6 a	2.1 b	3.7 a	20.3 b
8	45	34.5 ab	42.5 c	19.3 cde	0.7 a	3.0 a	3.5 b	22.8 ab
	50	34.2 ab	42.6 c	19.7 cd	0.6 a	1.6 b	3.6 b	22.8 ab
	55	34.2 ab	44.2 c	19.7 cd	0.6 a	0.0 b	3.6 b	22.1 ab
	control	34.2 ab	47.7 b	20.8 c	0.5 a	6.4 b	3.5 b	22.8 ab

*Means followed by a different letter are significantly different ($p < 0.05$)

Table 2. Interaction effects of dipping time, water temperature and storage time on electrical conductivity of kiwifruit juice in cool storage.

Storage time (Week)	Water temperature (◦C)	Dipping time (min.)	EC (ms)	Storage time (Week)	Water temperature (◦C)	Dipping time (min.)	EC (ms)	Storage time (Week)	Water temperature (◦C)	Dipping time (min.)	EC (ms)
6	45	2	3.4 f*	12	45	2	10.84 bcde	18	45	2	12.01 bcd
		4	3.21 f			4	9.86 e			4	12.27 bc
		8	3.36 f			8	10.35 bcde			8	11.5 bcde
	50	2	3.52 f		50	2	10.07 de		50	2	10.81 bcde
		4	3.34 f			4	10.04 de			4	12.34 b
		8	3.14 f			8	10.2 de			8	10.82 bcde
	55	2	3.21 f		55	2	10.24 cde		55	2	10.01 de
		4	3.36 f			4	10.57 bcde			4	11.78 bcde
		8	2.95 f			8	9.91 e			8	14.46 a
	control	2	2.8 f		control	2	8.85 e		control	2	10.8 bcde
		4	3.05 f			4	9.7 e			4	11.25 bcde
		8	3.25 f			8	9.83 e			8	11.4 bcde

*Means followed by a different letter are significantly different ($p < 0.05$)

Table 3. Interaction effects of dipping time, water temperature and storage time on ascorbic acid of kiwifruit juice in cool storage.

Storage time (Week)	Water temper-ature (◦C)	Dipping time (min.)	Ascorbic acid (mg/100g FW)	Storage time (Week)	Water temper-ature (◦C)	Dipping time (min.)	Ascorbic acid (mg/100g FW)	Storage time (Week)	Water tempera-ture (◦C)	Dipping time (min.)	Ascorbic acid (mg/100g FW)
6	45	2	27.95 hij*	12	45	2	33.87 fgh	18	45	2	66.13 a
		4	26.06 ijk			4	27.04 ijk			4	54.43 b
		8	25.18 ijk			8	20.27 kl			8	36.23 def
	50	2	26.8 ijk		50	2	49.09 bc		50	2	18.16 l
		4	24.89 ijkl			4	29.77 fghi			4	42.81 cd
		8	23.32 ijkl			8	25.59 ijk			8	53.44 b
	55	2	28.61 ghij		55	2	35.18 efg		55	2	54.48 b
		4	22.06 jkl			4	34.87 efg			4	48.73 bc
		8	24.4 ijkl			8	35.63 ef			8	54.53 b
	control	2	25.5 ijk		control	2	42.7 de		control	2	52.09 b
		4	26.36 ijk			4	40.72 de			4	52.29 b
		8	25.76 ijk			8	39. 6 de			8	51.69 b

*Means followed by a different letter are significantly different (p <0.05)

Figures

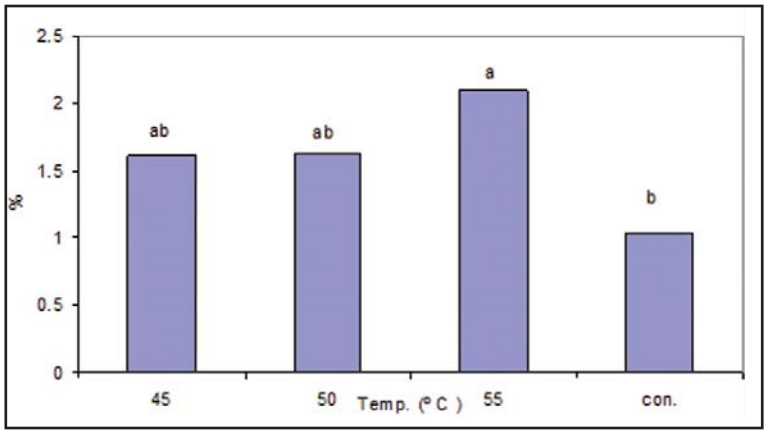

Fig. 1. Effects of different water temperature on weight loss rate.

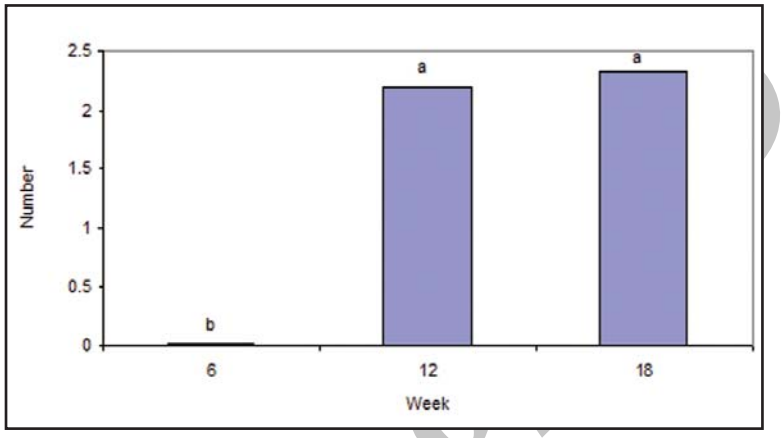

Fig. 2. Effects of different storage time on decay rate.

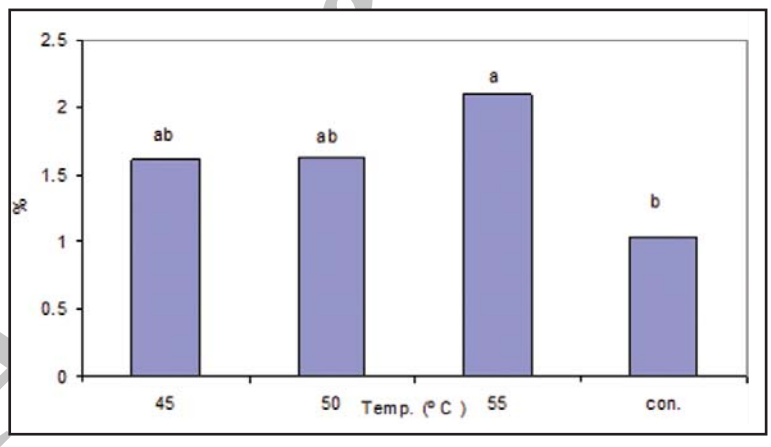

Fig. 3. Effects of different storage time on peel chroma.

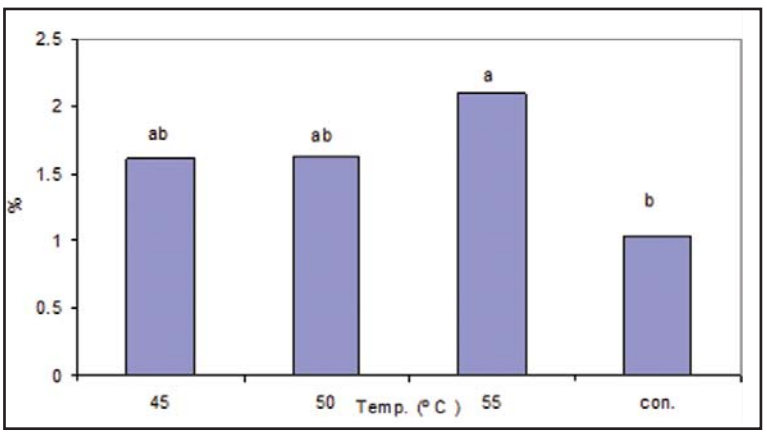

Fig. 4. Effects of different storage time on titratable acidity.