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Master Program in Water and Environmental Sciences

Improving the Quality of Green Bell Peppers Irrigated with Saline Water through the Adoption of Environment Friendly Techniques

تحسين نوعية ثمار الفلفل الأخضر المروي بمياه مالحة من خلال تبني تقنيات صديقة للبيئة

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The findings, interpretations and the conclusions expressed in this study do not express the views of Birzeit University, the views of the individual member of the M Sc. committee or the views of their respective.

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Abstract

Sweet green bell peppers (*Capsicum annum*) cv. 'Vally', were picked from two farms in Jericho, irrigated with different water salinity. The first farm irrigated with fresh water (EC= 0.49 dS m^{-1}), whereas the second irrigated with slightly saline water (EC= 2.535 dS m^{-1}). Within 24 hours from picking, fruits were subjected to the following treatments, either separately or combined: sulphur treatments, modified atmosphere packaging (MAP), ethanol fumigation, hot water treatments, and fumigation with 1-MCP. Fruits were monitored over a period of 30 days, and assessed every 10 days for various quality parameters. Fruit appearance as the major quality parameter was evaluated, among other parameters, by panelist. In this study, it was possible to store fruits for few weeks at 7 °C with good quality and high persuasion for market, using modified atmosphere packaging (MAP) technique, in combination with suitable envelopes type such as GA70 (70 µm in thickness). Moreover, using 1-MCP and hot water treatment (HWT) also gave good results; fruits with proper quality were registered with those irrigated with slightly saline water, and treated with 1-MCP. However, extending the storage period for 30 days seems to be difficult, although 1-MCP treatment is promising upon further optimization of this treatment. On the other hand, treating fruits with either sulphur or ethanol resulted in severe injuries to fruits. Accordingly, it is recommend using the plastic film GA70 for short-term storage period (10 days) at 7 °C, while for longer storage period (20 days), 1-MCP combined with MAP is highly recommended. In conclusion, results of this study show that a storage period of longer than 20 days is not recommended.

ABBREVIATIONS

1-MCP	1-methylcyclopropene
ACO	1-amino-cyclopropane carboxylic acid oxidase
ACS	1-amino-cyclopropane carboxylic acid synthesis
C_2H_4	Ethylene gas
CA	Controlled atmosphere
CI	Chilling injury
dS m^{-1}	Decisiemens per meter
EPA	Environmental Protection Agency
FHAT	Forced hot-air-treatment
GC	Gas Chromatography
HSPs	Heat shock proteins
HWT	Hot water treatment
LC_{50}	"Lethal Concentration" the concentration of the chemical in air that kills 50% of the test animals in a given time.
MA	Modified atmosphere
MCM	Million cubic meter
VHT	Vapor heat-treatment

Chapter One:

Introduction

1. Introduction

In Palestine, the agricultural sector is the largest consumer of water (70%) followed by domestic (27%) and industrial (3%) uses. The cultivated area is irrigated from springs and groundwater wells; 93 million cubic meters (MCM) are used in the West Bank for this purpose. 55% of this quantity comes from springs (Zimmo et al., 2006), while the rest is extracted by wells. Concerning the water quality, it is obvious that the quality is decreasing mainly due to over pumping and to heavy application of fertilizers and pesticides (ARIJ, 2001). The Jordan Valley, which is considered as the main agricultural area in Palestine, constitutes more than 50% of the irrigated area in the West Bank (ARIJ, 1998). Jordan valley is characterized by a low precipitation rate and high potential evaporation.

Concerning the postharvest handling of fruits and vegetables, recent surveys (Harb; personal communication) revealed that the Palestinian agricultural sector is highly underdeveloped in the field of postharvest technology. Consequently, only few farmers have traditional cooling rooms in central markets used to store fruit and vegetable for only few days without any further treatment. Accordingly, postharvest losses are expected in different stages: at harvest time, during storage, transport and marketing, or even after purchase by the consumer. Based on these facts, reducing postharvest food losses is a major agricultural goal in Palestine, as in all countries. That is essential to feed the world's expected 10 billion people within the next 40 to 50 years, and food production efficiency and distribution needs to be improved immensely (Campbell, 1998). In this respect, postharvest losses are estimated to range from 10 to 30% per year despite the use of modern storage facilities and techniques (Harvey, 1978).

Reducing postharvest losses by developing various treatments or techniques aimed generally to increase shelf life, preserve the quality, and control postharvest decay of fruit crops and vegetables. These techniques could include the use of sulfur, fungicide treatments, irradiation for postharvest decay control using low doses of ultraviolet light irradiation, gamma radiation, controlling temperature and relative humidity, and using modified or controlled atmospheres storage techniques by alternating O_2 and CO_2 concentrations around fruit and vegetables.

The aim of this study was is to test various environmental friendly techniques including modified atmosphere packaging (MAP), hot water dipping, and 1-methylcyclopropene (1-MCP), to maintain and preserve the quality of stored sweet bell peppers irrigated with saline water. In addition to that, this study aimed to investigate the combination effect of the above treatments with different water salinity levels.

Chapter Two:

Literature review

2. Literature review:

Pepper (*Capsicum annuum* L.) belongs to the Solanaceae family which is comprised of more than 75 genera with more than 2,000 species, including major economic crops like tomato (*Lycopersicon esculentum*), eggplant (*Solanum melongena* L.), and potato (*Solanum tuberosum* L.). Pepper which has a deep taproot is used for fresh consumption, although fruits can be processed into powders, sauces. Concerning the nutritional value of fruits, sweet peppers are considered as an important source of vitamins and minerals; it is considered as one of the most important source of vitamin C, and one of the highest in its content when compared to other fruits and vegetables; it contains 3 to 4 folders than orange and lemon (Naidu, 2003). Table 2.1 shows the nutritional value of sweet-green- raw peppers (USDA, 2007).

Table 2.1: Nutrient values and weights for 100 gm edible portion of peppers (sweet, green, raw), adapted from (USDA, 2007).

Nutrient	Units	Value per 100 grams
Water	g	93.89
Energy	kcal	20
Protein	g	0.86
Total lipid (fat)	g	0.17
Ash	g	0.43
Carbohydrate,	g	4.64
Fiber, total dietary	g	1.7
Sugars, total	g	2.40
Minerals		
Calcium, Ca	mg	10
Iron, Fe	mg	0.34
Magnesium, Mg	mg	10
Phosphorus, P	mg	20
Potassium, K	mg	175
Sodium, Na	mg	3
Zinc, Zn	mg	0.13
Copper, Cu	mg	0.066
Manganese, Mn	mg	0.122
Fluoride, F	mcg	2.0
Vitamins		
Vitamin C, total ascorbic acid	mg	80.4
Thiamin	mg	0.057
Riboflavin	mg	0.028
Niacin	mg	0.480
Pantothenic acid	mg	0.099
Vitamin B-6	mg	0.224
Folate, total	mcg	10
Betaine	mg	0.1
Vitamin A, IU	IU	370
Vitamin E (alpha-tocopherol)	mg	0.37
Vitamin K (phylloquinone)	mcg	7.4
Other		
Carotene, beta	mcg	208
Carotene, alpha	mcg	21
Cryptoxanthin, beta	mcg	7

Concerning the postharvest behavior of sweet peppers, it is considered as non-climacteric fruits, and the level of ethylene emitted by fruits is from 0.1 and 0.2 μL kg^{-1} h^{-1} at 10 and 20 °C, respectively, with respiration rates of 7-8 and 10-15 mg CO_2 kg^{-1} h^{-1} at 5 °C and 10 °C respectively (FAO, 2004). The major decay organisms for sweet pepper are *Botrytis* (Grey mold), *Alternaria* rot, and Bacterial soft rot, and chilling injury occurs, because of subtropical origin of sweet peppers (FAO, 2004).

2.1. Modified atmosphere packaging (MAP):

The basic concept of storage is to extend the shelf life of products by storing them in appropriate conditions to maintain their availability to consumers and processing industries in their usable form (Tasneem, 2004). One of the widely used techniques is the modified atmosphere packaging (MAP), which is considered as a simple and cheap method to achieve lower O_2 and higher CO_2 atmosphere inside special plastic films, in addition to the creation of a humid atmosphere around the stored fruits that will decrease water loss (AVRDC, 2006). Furthermore, MAP can help extending shelf life by slowing respiration rate, maintaining appearance by slowing color development, maintaining texture by slowing softening, maintaining quality by slowing the growth of some microorganisms, and preserving flavor by slowing the degradation of sugars during respiration (Tasneem, 2004). The films used in MAP include various kinds of plastic polymers, and their unique function is to restrict the movement of O_2 and CO_2 through the bag and allow the establishment of a modified atmosphere.

Plastic films maintain a gradient between the gas concentrations in air and those inside the bag (Zagory, 2000), and the gradient that results is not dependent on the initial gas concentrations inside the bag, but rather on the respiration rate of the product and the gas permeabilities of the bag. This permeability ratio is referred to as ß (P_{CO2}/P_{O2}), and is one of the most useful descriptive parameters of a plastic film. Films with a high ß value will allow CO_2 to escape the package relatively easily, resulting in an atmosphere with low CO_2, whereas films with lower ß values will allow greater buildup of CO_2 in the package (Zagory, 2000). Adopting MAP rely heavily in finding the suitable air composition inside the bags because it affects many processes, mainly respiration. Respiration is the major physiological activity of concern in postharvest storage, since it resulted in the oxidative breakdown of complex materials such as starch, sugar, and other organic compounds into simple molecules such as carbon dioxide, water and energy (Tasneem, 2004). However, exposing fresh produce to very low O_2 levels for extended periodscan lead to abnormal ripening, browning of tissues, and accumulation of ethanol and acetaldehyde (Imahori et al., 2002). During storage, the fruits undergo various physiochemical activities, such as loss in weight, skin color change, acidity, loss in firmness, increase in total solids and sugar concentration. As an important aspect, it is well known that most commodities require a minimum of 1 to 3% O_2 in CA or MA storage to avoid this shift to anaerobic metabolism (Kader, 1986). By elevating carbon dioxide and lowering the oxygen amount surrounding the product as done in these systems, there will be a decrease in respiration and a decrease in the rate of ethylene production. In a closed storage, respiration will simultaneously lead to the build-up of CO_2 and depletion of O_2. Oxygen levels as low as 0.2% in the plant cell may result in anaerobic respiration, which result in fermentation and unwanted by-products that can cause damage to certain products. In aerobic conditions, pyruvate usually follows the aerobic pathway and is completely oxidized to CO_2 and water, while in anaerobic conditions pyruvate is broken down to ethanol and CO_2; this process is called alcoholic fermentation. Approximately 7 % of the total available energy of the glucose molecule –about 52 kilocalories per mole- is released, with about 93 % remaining in the two alcohol molecules. Hence, ethanol is usually the major end-product in low O_2-stressed commodities.

2.2. Heat Treatment:

One of the most interesting aspects of postharvest heat treatments is the beneficial effects in reducing chilling injury in a range of fruits during subsequent low temperature storage (Ferguson et al., 2000). Part of this interest is because there is a growing demand to decrease the postharvest use of chemicals against pathogens and insects (Lurie, 1998). There are three methods that are commonly used to heat commodities: hot water treatment (HWT), vapor heat treatment (VHT) and forced hot air treatment (FHAT). The heat shock response is manifested in most living organisms as induction or enhanced synthesis of heat shock proteins (HSPs) (Ferguson et al., 2000) and subsequently the development of thermotolerance (Vierling, 1991). The synthesis of HSPs is part of the response of all organisms to heat stress, from man to bacteria (Lindiquist, 1986). It has been found that heat stress can condition plants to low temperature. This resistance to low temperature injury was found to be contingent on the presence of HSPs, and this response has been found in numerous commodities including pepper (Mencarelli et al., 1993). Concerning the hot water treatment, it was originally used for fungal pathogen control, especially for *Botrytis* and *Alternaria*.

2.3. 1-methylcyclopropene (1-MCP):

The background work for the discovery of 1-MCP as an ethylene inhibitor came out from the laboratories of Sisler and Blankenship (Blankenship and Dole, 2003). 1-MCP is a potent inhibitor of ethylene action and has been added to the options for extending the shelf life and maintaining the quality of fresh products for which ethylene response limit storability (Nanthachi et al., 2007). 1-MCP is thought to occupy ethylene receptors such that ethylene cannot bind and elicit action (Blankenship and Dole, 2003). Studies showed that 1-MCP impact on ethylene biosynthesis is manifested in reduced activities of 1-amino-cyclopropane carboxylic acid synthesis (ACS) and 1- amino-cyclopropane carboxylic acid oxidase (ACO) enzymes and their respective gene transcription with bananas, tomatoes, and peachs (Khan and Singh, 2007).

1-MCP has a molecular weight of 54 and at standard temperature and pressure, this compound is a gas. The current commercial formulation known as SmartFresh®. It is complexed with α-cyclodextrin to produce a water-soluble powder that is stable as long as it kept dry, and the method of application is to generate 1-MCP gas by mixing the soluble powder with water and then dispersing the 1-MCP into the air around the produce. The LC_{50} of 1-MCP is greater than 2.5 mg L (or 1.126 ppm v/v active ingredient in air), and in tests for acute toxicity, 1-MCP caused no death or clinical signs of systemic toxicology (EPA, 2002).

2.4. Ethanol:

Ethanol is a volatile compound which quickly evaporates from the fruits' surfaces during storage. Ethanol dips and vapors have been reported to control postharvest diseases of peaches, citrus fruit, and table grapes (Karabulut et al., 2005). Ethanol efficacy declines during prolonged storage, because its residues are low and short-lived, which reduces its effectiveness against secondary *Botrytis* infections during storage. Concerning the dosage, it was found that concentrations greater than 30% killed spores of *B. cinerea* rapidly, while 20% or lower are sublethal; the use of higher concentrations of ethanol concentration incurs additional ethanol costs and exacerbates safety hazards and disposal issues that can reduce the feasibility of ethanol use (Karabulut et al., 2005). These issues are disadvantages of postharvest ethanol applications, and can limit the use of ethanol in practice.

2.5. Sulfur:

The most common commercial method to control decay is the use of SO_2 during cold storage, either by fumigation or generators (Arte's et al., 2006). In spite of its excellent responses to control decay and avoiding stem browning, SO_2 application is becoming very restrictive in many countries. The maximum tolerance to sulphite residues in fruit is 10 μL L^{-1}, established by the U.S. Food and Drug Administration (Crisosto and Mitchell, 2002).

2.6. Quality:

Consumers tend to use texture rather than flavor as the primary limiting factor for acceptability when evaluating fresh fruits or vegetables (Shewflt, 1998). In reference to the United States Standards for Grades of Sweet Peppers (USDA, 2005) peppers are classified into three grades: Fancy, U.S. No. 1, and U.S. No. 2. All grades consist of mature green sweet peppers of similar variety characteristics, which are firm, well shaped, and free from sunscald, freezing injury, decay affecting calyxes and/or walls, decay affecting stems, and from injury caused by scars, hail, sunburn, disease, insects, and mechanical damages. Among the quality parameters is the color, which is the function of the light striking the product. Consumers have developed distinct correlations between color and the overall quality of specific products. In fruits and vegetables there are five major pigments; chlorophylls, carotenoids, anthocyannins, anthoxanthins, and betalains. Chlorophyll pigments are found in clusters called photosystems located in the thylakoid membrane contained within the chloroplast (Raven et al., 1992). These pigments give a green color to fruits and vegetables. Changes in chlorophyll content are probably the most dramatic postharvest color alteration, and the loss of chlorophyll is influenced by light, temperature, and humidity, although the influence of these factors is different for different vegetable tissue types. In this qualitative change chlorophyllase catalyzes the cleavage of phytol from chlorophyll to chlorophyllide, in addition to the removal of phytol group from pheophytin to form pheophorbide. This enzyme is activated after harvest by the increased heat produced in postharvest commodities (Ball, 1997), and the activity of chlorophyllase depends upon external factors as presence of ethylene. Furthermore, the photodegradation of chlorophyll leads also to color changes. Moreover, the deterioration of lipid membranes and other pigment molecules like carotenoids during senescence renders chlorophyll molecules vulnerable to degradation, since these components function in the protection of the chlorophyll pigments from degradation.

The second major quality parameter is the firmness. Firmness is directly related to the composition of cell walls. The cellular walls are made up of cellulose fibers which are held together by cement like substance called pectin (Raven et al., 1992). These cells take up water, which generates a hydrostatic pressure, giving rise to the crisp texture. After harvest, turgor pressure changes due to the reduced transpiration rates, since additional water can not move into the plant cells. However, the major chemicals that contribute to the firmness are the pectins. Pectin in immature fruits is in the form of protopectin, and the enzyme protopectinase changes upon ripening the protopectin into pectin. As the fruit begins to senescence and proceed to an overripe stage, the pectin is being changed into pectic acid by the enzyme pectinase; pectic acid imparts the characteristic mushy texture to overripe fruit (Ball, 1997).

Another important quality parameter is the flavor. It is well known that large number of compounds present in vegetables and fruits, and it is usually very hard to distinguish which of these compounds are responsible for providing the characteristic flavors. With green bell pepper, the characteristic flavor is attributed to Methoxy alkyl pyraxine; this flavor is described as having an "earthy-green" flavor and aroma (Ball, 1997).

2.7. Salinity:

Irrigation water contains a mixture of naturally occurring salts. Soils irrigated with this water will contain a similar mix but usually at a higher concentration than in the applied water. The extent to which the salts accumulate in the soil will depend upon the irrigation water quality, irrigation management and the adequacy of drainage. If salts become excessive, as salinity levels increase, plants extract water less easily from soil, aggravating water stress conditions. High soil salinity can also cause nutrient imbalances, result in the accumulation of elements toxic to plants (Kotuby-Amacher et al., 2000) losses in yield will result, and salinity stress occurred. Salinity stress is an important constraint to world agriculture, affecting 7% of the land surface of the earth and over 50% of irrigated land (Halperin1 et al., 2003).

The impact of salinity in greenhouses differs from salinity under field conditions. The most striking difference is the overall much higher concentrations of nutrients in greenhouses in comparison with those in field soils (Sonneveld, 2000). In sweet pepper, it is estimated that when the plant irrigated with water has an electrical conductivity equal to 2.2 dSm^{-1}, the production will decreased by 25% , and more sensitive to the occurrence of blossom-end-rot in fruits (Blom-

Zandstra et al., 1998). Also, as the Jordan Valley has a low precipitation rate and high potential evaporation, with hot summers and warm winters, this will led to increase the effect of salinity, because climatic condition can affect salinity, e.g. high temperature and high transpiration increase salinity effects (Sonneveld, 2000).

Chapter Three:

Materials and Methodology

3. Materials and Methodology:

3.1 Fruits:

Sweet green bell peppers (*Capsicum annum*) type, cv. 'Vally' - (Peto Seeds Company) cultivated in greenhouses were obtained from commercial farms located in Jericho- Palestine. A liquid fertilizer (SHEVER®, 5:3:8; N: P_2O_5: K_2O) was used on both farms. The fertilizer was supplied once a week with water (Fertigation) using a drip irrigation system, with a concentration equal of 1 L m^{-3} water. The duration of each irrigating lasts for 3 hours, using 4 L hr^{-1} drippers. Fruits from the first farm, irrigated with slightly saline water extracted from a well in that farm (EC= 2.535 dS m^{-1}), and from the second irrigated with low salinity water from Ein Sultan spring (EC= 0.49 dS m^{-1}) were used separately as the plant material for the experiments discussed below.

The fruits were picked randomly from all rows in the greenhouse (area= 1000 m^2) early in the morning at three different dates, the first was at the end of February, the second at the beginning of March, while the last at the beginning of May. The electrical conductivity (EC) of the irrigation water from both farms were measured by taking three water samples at each harvest time. The water samples were taken from the lines before the fertilizer injection to ensure that water salinity readings are not affected by the fertilizers. Samples were taken in a 1-L plastic container, and tested using an EC meter at the next day.

The fruits were transported by a pickup that has a closed rear box were the fruits were loaded to avoid environmental effects from the sun and wind, or any physical damage.

At the laboratory fruits that were selected for uniformity in size and color. Fruits that were firm, well shaped, well colored, free from mold, soft rot, worm holes, or other holes, and free from any damage were chosen for the experiment. Subsequently, fruits were grouped randomly for the different treatments required for each stage of the experiment. Six plots were designated for each treatment, with two replicates for each sampling date.

3.2 Experiment stages and treatments:

The experiment was conducted in three stages, and each stage has its own treatments. In general, four types of plastic films (bags) were used for packaging trials. The following are the specifications for the plastic films:

1. CLARUS 110 GG with a thickness of 19 µm.
2. PA140 with a thickness of 35 µm, a polypropylene film.
3. GA70 with a thickness of 70 µm, a jointed films composed from 7 stratifies sheets of Polyamid-6 (PA) 16 µm.
4. NGZ80 with a thickness of 80 µm, 3 stratifies sheets jointed together PE-PA-PE (PE= polyethylene, PA= polyamid-6).

First stage (HWT, sulfur treatment, and MAP technique):

This stage of the experiment started on 01-03-2007 and was completed on 29-03-2007. Four fruits were included in each envelope. Treatments used in this stage are mentioned in table 3.1.

Table 3.1: Treatments used in the first stage of the experiment.

No.	Envelope type	Irrigation water	Treatment	Storage Temp.
1	CLARUS 110 GG	Saline water	HWT* 50 °C for 30 seconds	7 °C
2	CLARUS 110 GG	Saline water	Sulfur pads	7 °C
3	CLARUS 110 GG	Saline water	Sulfur pads	RT
4	CLARUS 110 GG	Saline water	-	7 °C
5	CLARUS 110 GG	Saline water	Perforated envelopes	7 °C
6	CLARUS 110 GG	Saline water	Perforated envelopes	RT.

HWT: Hot water treatment; RT: Room temperature

Second stage (HWT, ethanol treatment,1-MCP, and MAP technique):

This stage of the experiment elapsed the period between 03-04-2007 and 02-05-2007. Four fruits per envelope were used for all treatments except two fruits for envelope type PA140, and three fruits per envelope for treatments with 1-MCP. Treatments used in this stage are mentioned below in Table No. 3.2.

Table 3.2: Treatments used in the second stage of the experiment.

No.	Envelope type	Irrigation water	Treatment	Storage Temp.
1	GA70	Fresh water	-	7 °C
2	GA70	Saline water	-	7 °C
3	PA140	Fresh water	-	7 °C
4	PA140	Saline water	-	7 °C
5	CLARUS 110 GG	Saline water	-	7 °C
6	CLARUS 110 GG	Saline water	-	RT
7	CLARUS 110 GG	Saline water	Opened envelopes	7 °C
8	CLARUS 110 GG	Saline water	HWT 60 °C for 60 seconds	7 °C
9	CLARUS 110 GG	Saline water	HWT 55 °C for 60 seconds	7 °C
10	CLARUS 110 GG	Saline water	HWT 50 °C for 60 seconds	7 °C
11	CLARUS 110 GG	Saline water	0.5 ml ethanol	7 °C
12	CLARUS 110 GG	Saline water	0.5 ml ethanol	RT
13	CLARUS 110 GG	Saline water	1.0 ml ethanol	7 °C
14	CLARUS 110 GG	Saline water	1.0 ml ethanol	RT
15	CLARUS 110 GG	Saline water	1.5 ml ethanol	7 °C
16	CLARUS 110 GG	Saline water	1.5 ml ethanol	RT
17	CLARUS 110 GG	Saline water	40 mg 1-MCP	7 °C
18	CLARUS 110 GG	Saline water	20 mg 1-MCP	7 °C

HWT: Hot water treatment; RT: Room temperature

Third stage (1-MCP treatment and MAP technique):

This stage extended from 03-05-2007 to 29-05-2007. Six to eight fruits were packaged per envelope for treatments using 1-MCP, while three to four fruits per envelope for other treatments as control and envelopes type NGZ80. Treatments used in this stage are mentioned in Table No. 3.3:

Table 3.3: Treatments used in the third stage of the experiment.

No.	Envelope type	Irrigation water	Treatment	Storage Temp.
1	CLARUS 110 GG	Saline water	40 mg 1-MCP	7 °C
2	CLARUS 110 GG	Saline water	20 mg 1-MCP	7 °C
3	CLARUS 110 GG	Saline water	-	7 °C
4	CLARUS 110 GG	Fresh water	40 mg 1-MCP	7 °C
5	CLARUS 110 GG	Fresh water	20 mg 1-MCP	7 °C

6	CLARUS 110 GG	Fresh water	-	7 °C
7	NGZ80	Saline water	-	7 °C
8	NGZ80	Fresh water	-	7 °C
9	CLARUS 110 GG	Fresh water	Opened envelopes	7 °C
10	CLARUS 110 GG	Saline water	Opened envelopes	7 °C

The weights of fruits were recorded prior to packaging by using an analytical balance (±0.01 gram) to estimate the amount of moisture loss from the fruits during the storage period.

3.2.1 Treating fruits by hot water:

Fruits were dipped in water at different temperatures including 50 °C, 55 °C, and 60 °C for different periods ranging from 30 to 60 seconds. Dips were conducted using a temperature-controlled water bath (Figure 3.1).

Figure 3.1: Temperature-controlled water bath used for treating pepper fruits by hot water dipping in different temperature and time.

3.2.3 Treating fruits with ethanol:

Pure ethanol was used for treating fruits. Concentrations used were 0.5 ml, 1.0 ml, and 1.5 ml per envelope. This was done by adding the required amount of ethanol on a quarter filter paper attached by adhering plaster in a 70 mm Petri dish, which was then packaged in the envelopes with fruits and stored at different temperature.

3.2.4 Treating fruits with sulfur:

SO_2 generating pads (OSCK-VID® LV8, manufactured by productos Quimicos y Alimenticios OSKU S.A, each one pad contains 0.4375 gm, consists of active ingredient $Na_2S_2O_5$ 97.5% with inert ingredient 2.5%,.) were used for treating fruits. One pad per envelope was inserted and packaged with fruits during storage.

3.2.5 Treating fruits with 1-MCP:

SmartFreshTM powder (a commercial form of 1-MCP) was used for treating fruits in this experiment; this powder has an active ingredient 0.14% 1-MCP. Fruits treated with 1-MCP were placed in a glass champers (6.6 liter volume), and two concentrations were used in this experiment (20 and 40 mg 1-MCP per chamber). The procedure was done by placing a small glass beaker (50 ml) above the fruits inside the chamber, and the required amount of 1-MCP was weighed previously using an analytical balance and placed in the beaker. 20 ml warm water (40 °C) were added in the beaker to ensure the release of 1-MCP, and the chambers were closed tightly at room temperature for 24 hours in the darkness.

Figure 3.2: Pepper fruits treated with 1-MCP in glass champers for 24 hours.

Figure 3.3: Refrigerator used for pepper fruits storage at 7 °C.

3.3 Fruit assessment:

Before starting the assessment session, fruits were removed from the refrigerator (for those fruits stored at treatments at 7 °C) and left at room temperature for 24 hours to assimilate market conditions, from storage facilities to the market.

3.3.1 Storage fruit samples for further analysis:

Fruit samples were conserved by cutting the fruit samples in to small pieces and were immediately frozen in liquid nitrogen to avoid any losses of the fruits chemical composition. Samples were then deep frozen at - 32 °C.

Figure 3.4: Treating pepper samples with liquid nitrogen.

Figure 3.5: Pepper samples treated with liquid nitrogen.

Figure 3.6: Plastic container used for treating pepper samples with liquid nitrogen for further analysis in the future.

3.3.2 Fruit assessment parameters and scales used:

Many parameters were studied to assess consumer-oriented fruit quality. These parameters include color, firmness, presence of decay on both fruit and stalk, the color of stalk (if it is normal or has some discolorations –e.g. browning) and fruit surface state (free from any pitting or water soaked spots), in addition to another two factors: the fruit weight loss during storage and CO_2 concentrations inside MAP using GC instrument (model TDS 3300) with a TDC detector, N2 was the carrier gas (flow rate 30 ml min^{-1}), temperature program 60-80 °C -increases 5 °C min^{-1}; column: 5 meter glass-packed column with OV 17 on carbowax).

Fruit evaluation factors was conducted using a scale from 1-5; 1 means the best result and 5 means the worst. For color evaluation scale: 1= dark green; 2= green; 3= light green; 4= yellowish or brownish; 5= over ripening. The firmness evaluation scale includes: 1= very firm; 2= firm; 3= slightly firm; 4= starts shriveling, and 5= limp. For the decay; 1= no decay; 2= decay appearing as small spots, 3= decay is present in larger spots; 4= decay is covering more than 50% of the fruit surface; and 5 = decay is covering more than 70% of the fruit surface. For stalk decay; 1= no decay; 2= decay appearing in small spots; 3= decay is covering more than 30 % of the stalk surface; 4= decay is covering more than 50% of the stalk surface; and 5 = (severe) decay is covering more than 70% of the stalk surface. For the stalk browning evaluation scale; 1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe (more than 70% of the stalk is brown). The pitting evaluation scale includes: 1= fruit surface is normal; 2= surface has small pitting spots; 3= more than 30% of the fruit surface is covered with pitting spots; 4= more than 50 % of the fruit surface is covered with water soaked or brown spots; and 5= severe (more than 70% of the fruit surface is covered with water soaked or brown spots).

For each assessment, two replicates were chosen randomly and evaluated at room temperature. For the gas composition inside the packages, packages were removed from the refrigerator and analysis was done by using GC 3300. Air sample were taken using syringes (5 cm volume). The GC instrument gave the results of gas concentrations in area unit (peak area), and a previous calibration of the instrument were done using a known concentration of carbon dioxide gas.

3.4 Experimental design and statistical analysis:

Experiments were laid out using a completely randomized design. Data were analyzed by analysis of variance (ANOVA). Mean comparisons were made using the Duncan Test at $P \leq 0.05$. Statistical analysis was carried out using the SPSS system (SPSS for Windows, Release 12.0.1., SPSS Inc. ®, 2003).

Chapter Four:

Results

4.1 Experiment One (HWT, sulfur treatment, and MAP technique):

4.1.1 Pitting:

Fruits stored in perforated plastic film type CLARUS 110 GG showed the lowest pitting after 10 days of storage at 7 °C (figure 4.1), followed by fruits treated with hot water treatment at 50 °C for 30 seconds and stored in non-perforated CLARUS films at the same temperature. The highest pitting was registered with fruits treated with Sulfur and enclosed in the same film at room temperature.

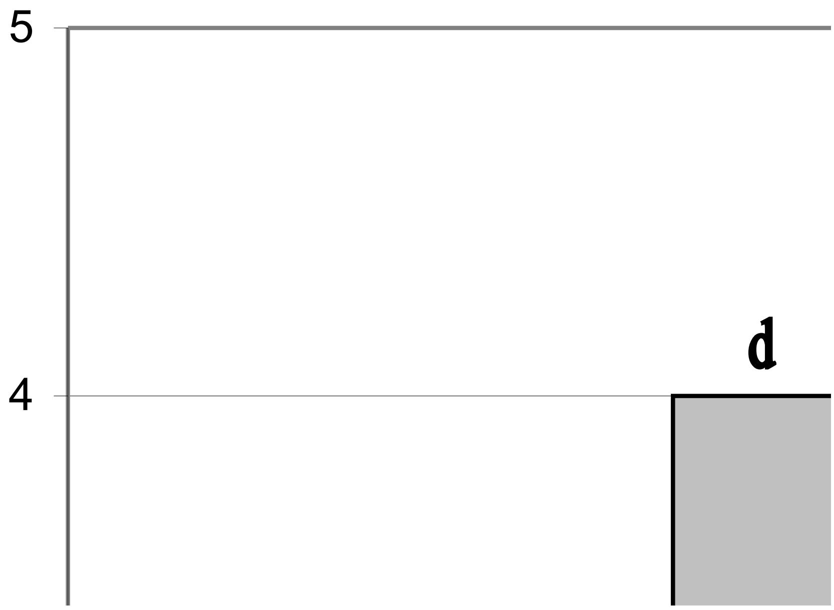


Figure 4.1: Pitting after 10 days of storage, experiment part one. (MAP: modified atmosphere packaged; S: sulfur; 07; storage temperature in °C; RT: room temperature; Per: perforated envelopes; HW: hot water treatment; s: second), scale of fruit surface pitting (1 = normal; 2= small pitting spots; 3= more than 30% of the fruit surface; 4= more than 50% of the fruit surface is pitted; 5= sever -more than 70% of the fruit surface is pitted). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 30 days, the enclosed fruits in CLARUS plastic film without sulfur treatment gave the best results. Consequently, the best treatment that gives the lowest pitting is MAP with CLARUS films at 7 °C without sulfur treatment. The highest pitting appeared with fruits packaged in perforated envelopes and stored at 7 °C (figure 4.2).

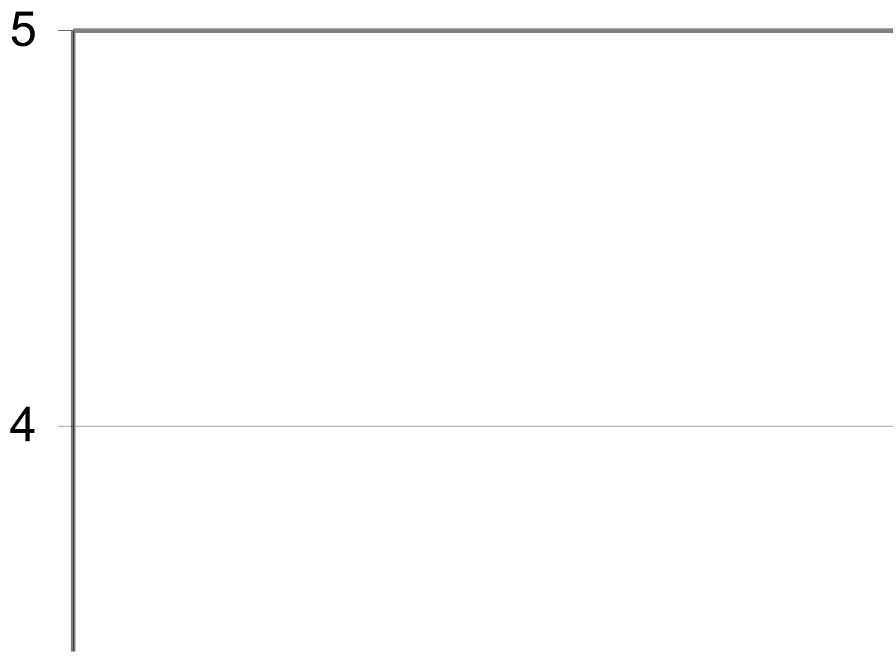


Figure 4.2: Pitting after 30 days of storage, experiment part one. (MAP: modified atmosphere packaged; S: sulfur; 07; storage temperature in °C; RT: room temperature; Per: perforated envelopes; HW: hot water treatment; s: second). Scale of fruit surface pitting (1 = normal; 2= small pitting spots; 3= more than 30% of the fruit surface; 4= more than 50% of the fruit surface is pitted; 5= sever -more than 70% of the fruit surface is pitted).Bars have the same letter are not significantly different. Duncan values ($P \leq 0.05$).

4.1.2 Stalk Browning:

Fruits packaged in CLARUS plastic films with sulfur treatment showed the highest stalk color deterioration and turned to brown color after 10 days of storage at room temperature (figure 4.3).

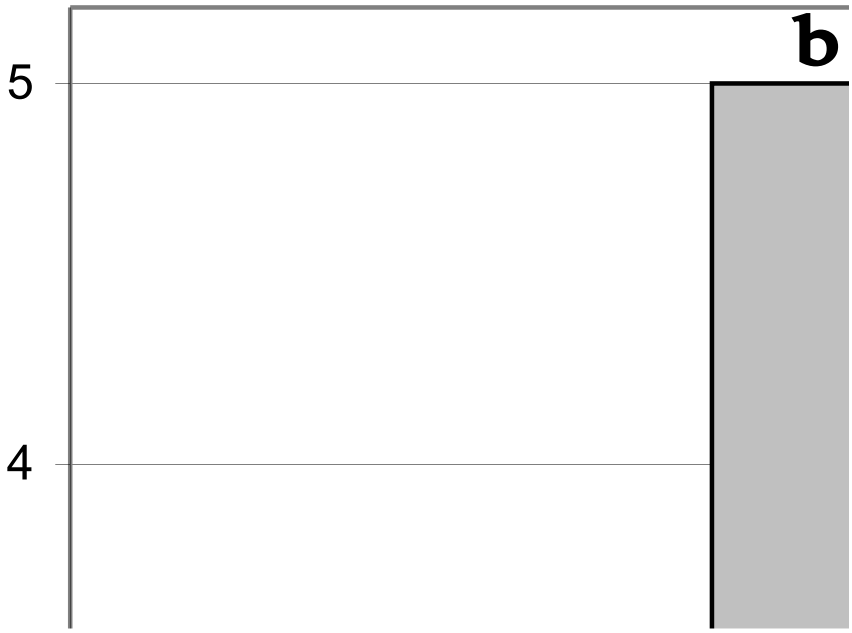


Figure 4.3: Stalk browning after 10 days of storage, experiment part one. (MAP: modified atmosphere packaged; S: sulfur; 07; storage temperature in °C; RT: room temperature; Per: perforated envelopes; HW: hot water treatment; s: second). Scale of stalk browning (1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe (over 70%) browning). Bars have the same letter are not significantly different. Duncan values (*$P<0.05$*).

After 30 days of storage, the highest stalk browning was registered for fruits packaged in CLARUS plastic films combined with sulfur treatment at both temperature storage (RT and at 7 °C), followed by fruits packaged in perforated envelopes and stored at 7 °C (figure 4.4).

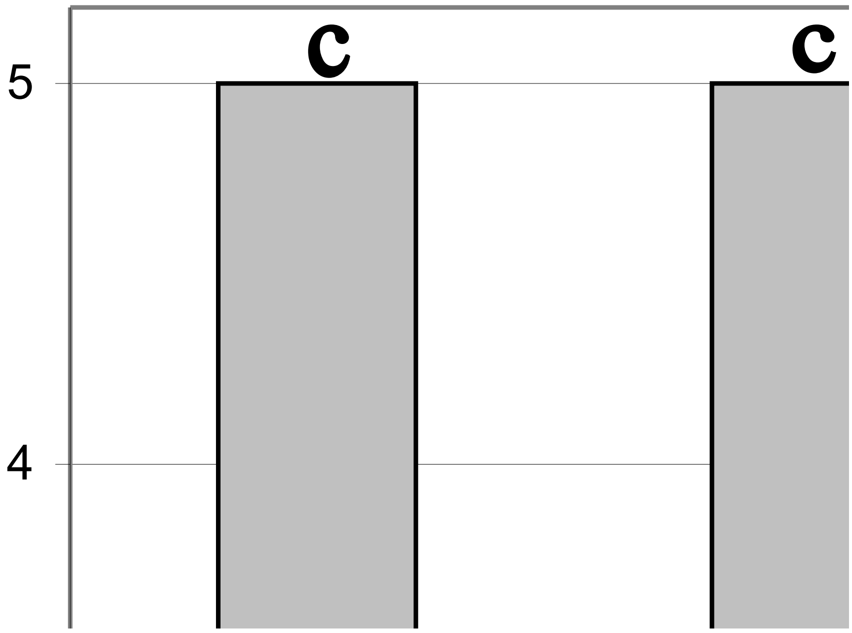


Figure 4.4: Stalk browning after 30 days of storage, experiment part one. (MAP: modified atmosphere packaged; S: sulfur; 07; storage temperature in °C; RT: room temperature; Per: perforated envelopes; HW: hot water treatment; s: second). Scale of stalk browning (1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe (over 70%) browning). Bars have the same letter are not significantly different. Duncan values (*P<0.05*).

4.1.3 Firmness:

Fruits packaged in CLARUS plastic films with sulfur treatment showed the highest fruit firmness deterioration after 10 days of storage at room temperature (figure 4.5)

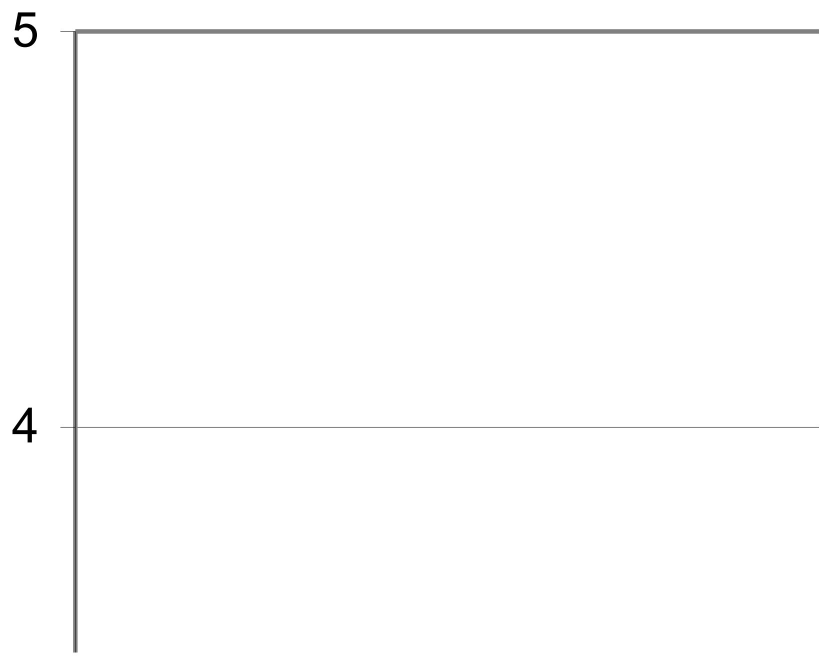


Figure 4.5: Firmness after 10 days of storage, experiment part one. (MAP: modified atmosphere packaged; S: sulfur; 07; storage temperature in °C; RT: room temperature; Per: perforated envelopes; HW: hot water treatment; s: second). Scale of firmness (1= very firm; 2= firm; 3= slight firm; 4= starts shriveling, and 5= limp). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 10 days of storage, the best results were registered with fruits packaged in non-perforated plastic film type CLARUS 110 GG and treated with hot water treatment at 50 °C for 30 seconds. Consequently, showed the lowest firmness deterioration, the same as fruits packaged in perforated envelopes and stored at the same temperature, but for the further storage periods, different treatments did not show significant difference in between.

4.1.4 CO_2 gas after 8 days of storage:

Fruits packaged in perforated envelopes and stored at 7 °C showed the lowest CO_2 gas concentration, followed by fruits packaged in same envelopes but stored at room temperature (Figure 4.6).

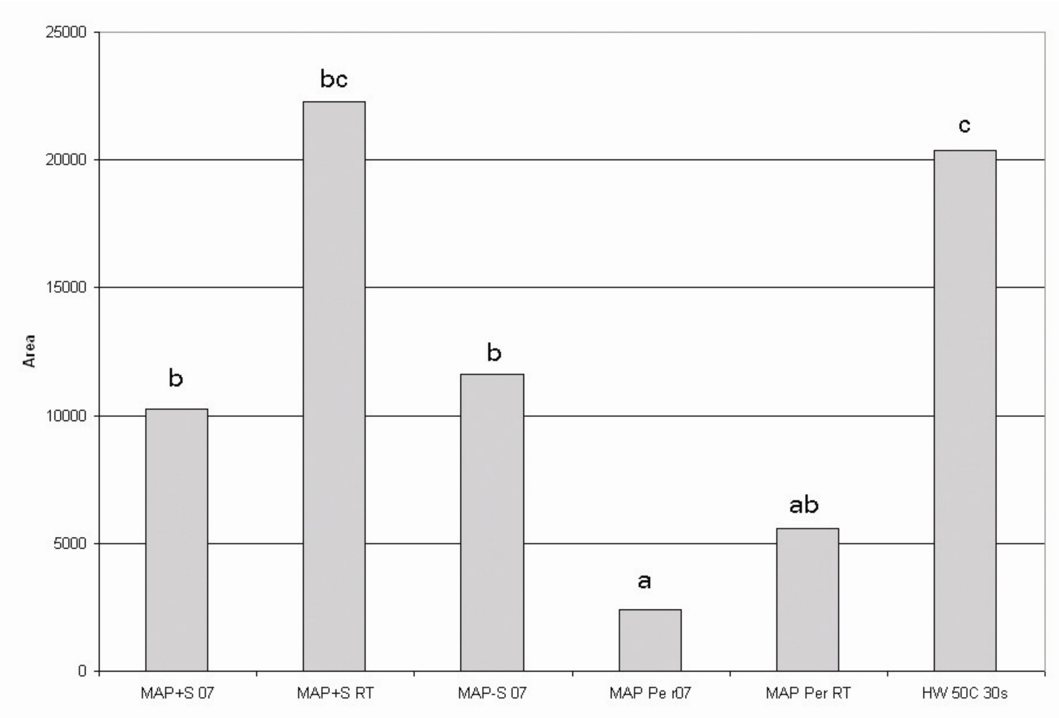


Figure 4.6: Peak area tested on 08-03-2007, experiment part one. (MAP: modified atmosphere packaged; S: sulfur; 07; storage temperature in °C; RT: room temperature; Per: perforated envelopes; HW: hot water treatment; s: second). Bars have the same letter are not significantly different. Duncan values (*$P \leq 0.05$*).

Fruits treated with sulfur and packaged in non-perforated plastic film type CLARUS 110 GG and stored at RT showed the highest gas concentration, while at 7 °C showed lower concentration.

4.2 Experiment Two (HWT, ethanol treatment, 1-MCP treatment, and MAP technique):

4.2.1 Acceptance:

After 10 days of storage at 7 °C (figure 4.7), fruits irrigated with slightly saline water and treated with both 20 mg or 40 mg of 1-MCP and packaged in non-perforated plastic film type CLARUS 110 GG showed the best results. Similar results were obtained with fruits irrigated with fresh water and packaged in PA140 and GA70 and stored in the same conditions, followed by fruits treated received HWT (50 °C for 60 seconds), and also fruits packaged in non-perforated envelopes type CLARUS. The worst results registered with fruits stored at room temperature.

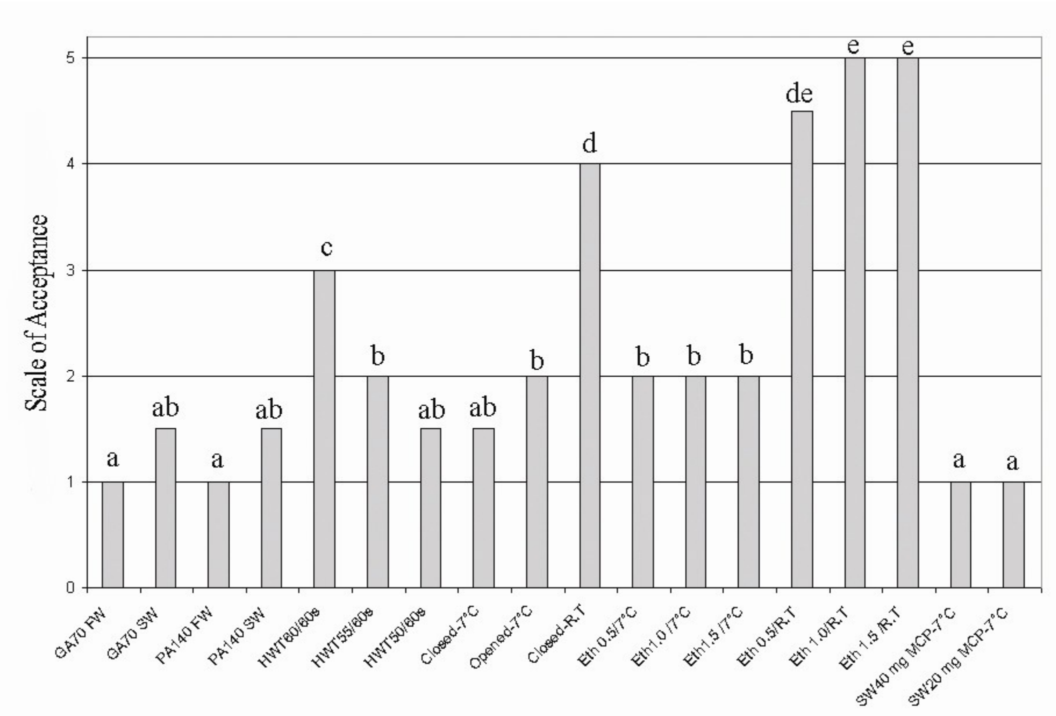


Figure 4.7: Acceptance after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of acceptance (=1very good; 2= good; 3=fair; 4=bad; 5=very bad). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 20 days of storage at 7 °C (figure 4.8), fruits irrigated with slightly saline water and treated with both 20 mg 1-MCP showed the best result with very good acceptance by the consumer, while the worst acceptance was registered with fruits packaged in envelopes type PA140 and those received HWT (60 °C for 60 seconds).

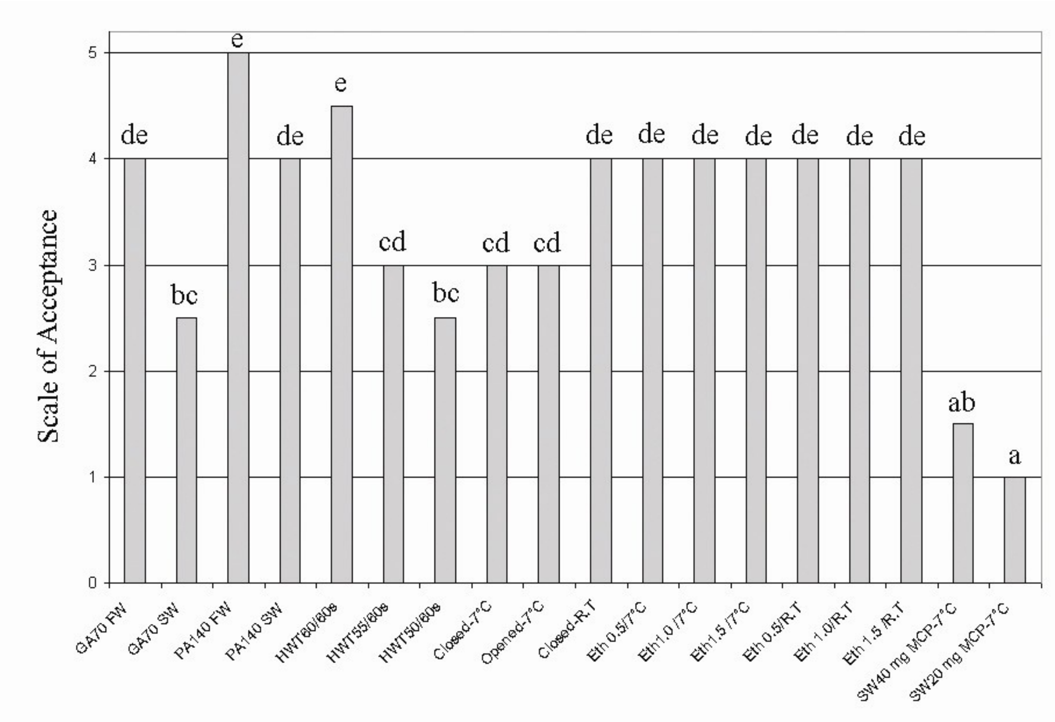


Figure 4.8: Acceptance after 20 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of acceptance (=1very good; 2= good; 3=fair; 4=bad; 5=very bad). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 29 days of storage at 7 °C (figure 4.9), panelist preferred fruits treated with either 20 mg or 40 mg 1-MCP and packaged in non-perforated envelopes type CLARUS. Similarly, fruits irrigated with slightly saline water and packaged in envelop type GA70 received good acceptance.

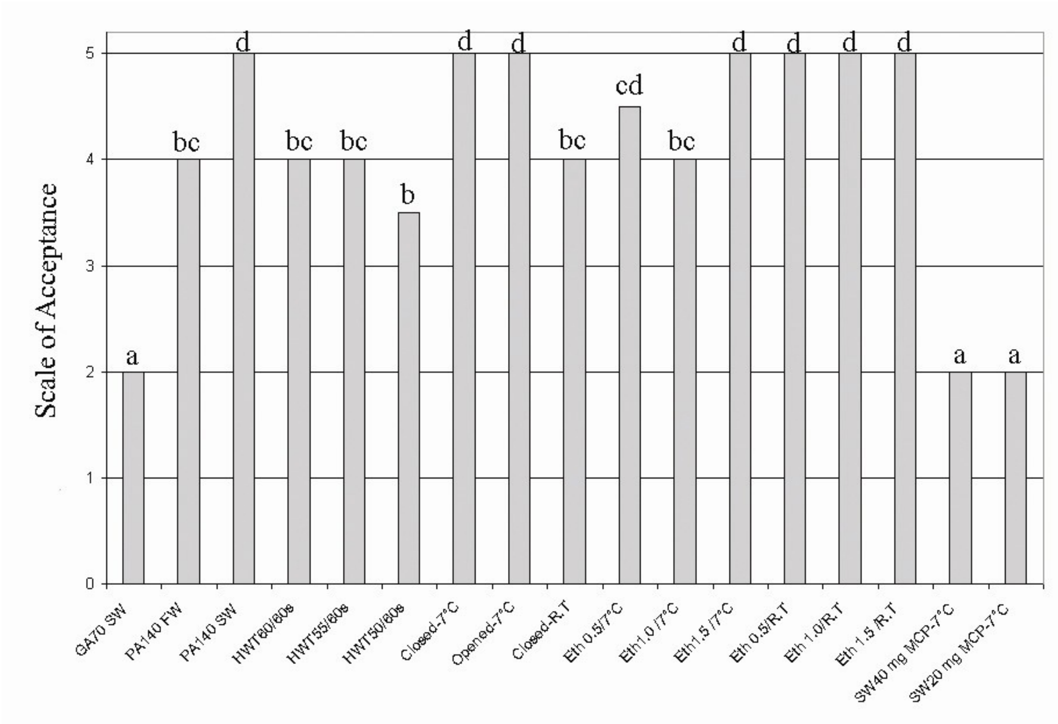


Figure 4.9: Acceptance after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of acceptance (=1very good; 2= good; 3=fair; 4=bad; 5=very bad). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.2 Fruit decay:

Fruits treated with the three concentrations of ethanol showed the worst result after 10 days of storage at room temperature (figure 4.10). It appeared that ethanol led to fruit decay at room temperature, which not appeared with the same treated fruits that were stored at 7 °C.

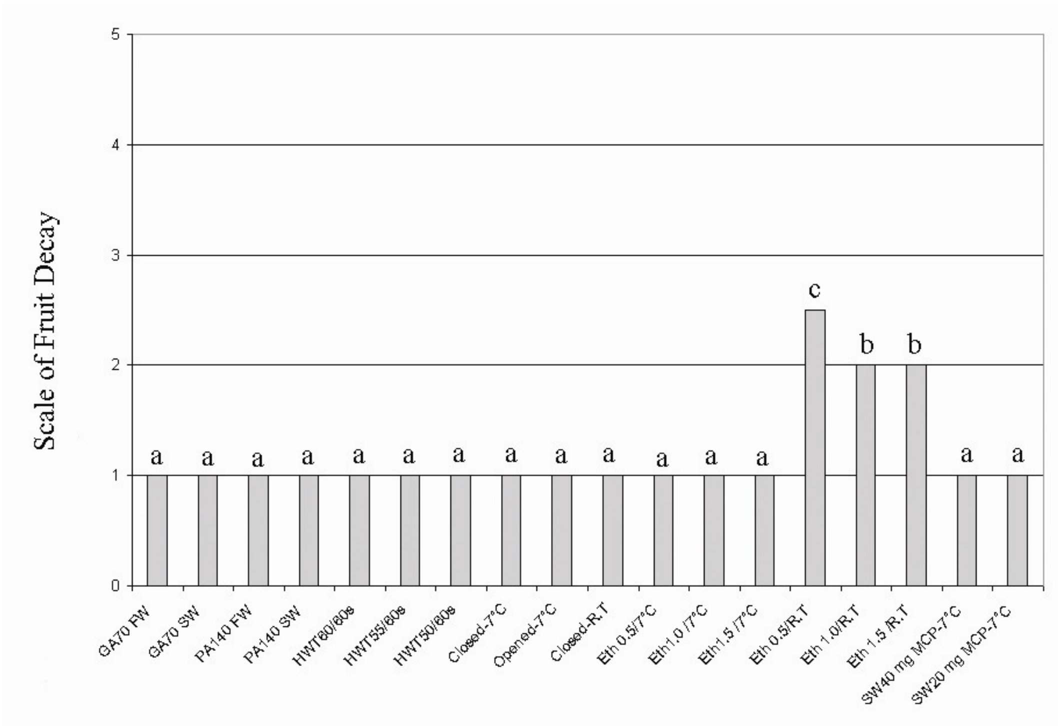


Figure 4.10: Fruit decay after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of fruit decay (1= decay free; 2= starts with small spots, 3= presents in larger spots; 4= covering more than 50% ; 5= covering more than 70%). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 20 days of storage (figure 4.11), the worst results were obtained with fruits irrigated with fresh water and packaged in PA140 envelopes and stored at 7°C, followed by fruits packaged with 0.5 ml ethanol in CLARUS envelopes and stored at room temperature.

After 29 days of storage at 7 °C (figure 4.12), the best results, consequently did not showed any decay infection, were registered with fruits irrigated with slightly saline water and treated with either 20 mg or 40 mg 1-MCP and packaged in CLARUS envelopes, followed by fruits irrigated with slightly saline water and packaged in GA70 envelopes. Similar response was registered by fruits subjected to HWT (55 °C for 60 seconds) and packaged in non-perforated CLARUS envelopes. The worst results were registered with fruits stored at room temperature after treatment with ethanol.

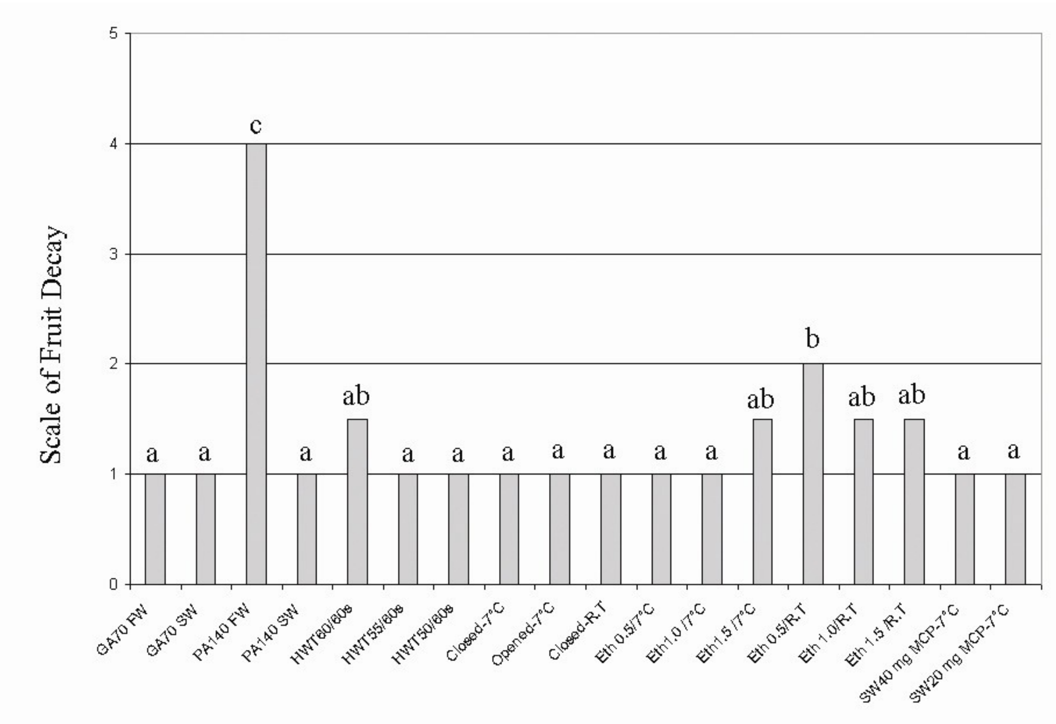


Figure 4.11: Fruit decay after 20 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of fruit decay (1= decay free; 2= starts with small spots; 3= presents in larger spots; 4= covering more than 50%; 5= covering more than 70%). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

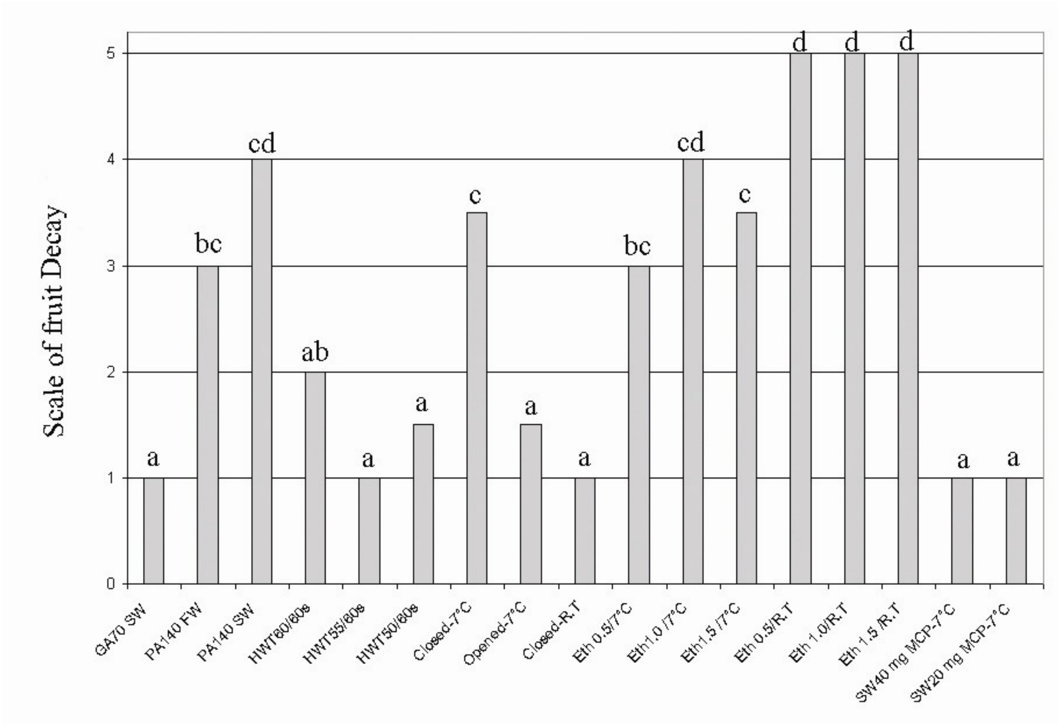


Figure 4.12: Fruit decay after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of fruit decay (1= decay free; 2= starts with small spots, 3= presents in larger spots; 4= covering more than 50%; 5= covering more than 70%). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.3 Stalk decay:

Bad results were recorded with fruits stored at RT, irrespective of treatments (figure 4.13). The worst treatment was ethanol treatments, in particular 1.5 ml ethanol.

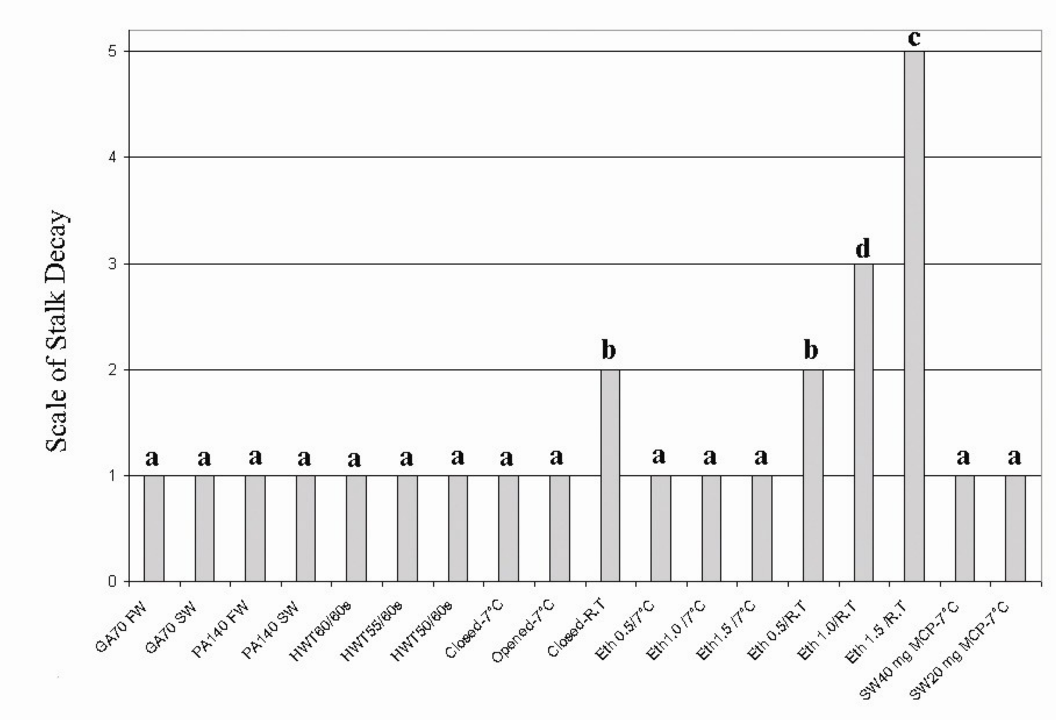


Figure 4.13: Stalk decay after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of Stalk decay (1= not appear; 2= small spots; 3= more than 30 %; 4= more than 50% ; and 5 = (sever) more than 70 %). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 20 days of storage (figure 4.14), the best results appeared with fruits irrigated with slightly saline water and packaged in non-perforated CLARUS envelopes and subjected to 1-MCP treatment. Moreover, fruits packaged in open envelopes without treatment, or packaged in either PA140 or GA70 envelopes at 7 °C were in good condition. Similar results were also recorded with fruits irrigated with fresh water and packaged in GA70 envelopes at the same temperature. The worst results were recorded with fruits treated with 1.5 ml ethanol and stored at room temperature upon packaging in non-perforated CLARUS envelopes.

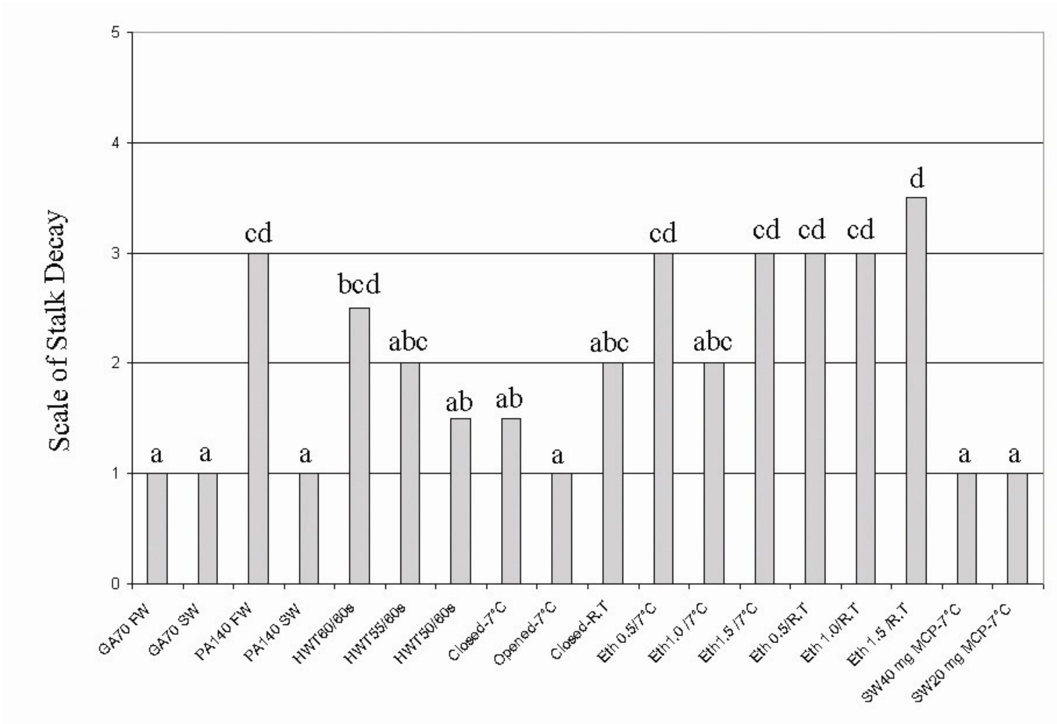


Figure 4.14: Stalk decay after 20 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of Stalk decay (1= not appear; 2= small spots; 3= more than 30 %; 4= more than 50% ; and 5 = (sever) more than 70 %). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 29 days of storage (4.15), fruits irrigated with slightly saline water and packaged in GA70 envelopes at 7 °C showed the best result, followed by fruits treated with either 1-MCP concentrations and packaged in non-perforated CLARUS envelopes at 7 °C. The worst results were recorded with fruits stored at room temperature following treatment with ethanol.

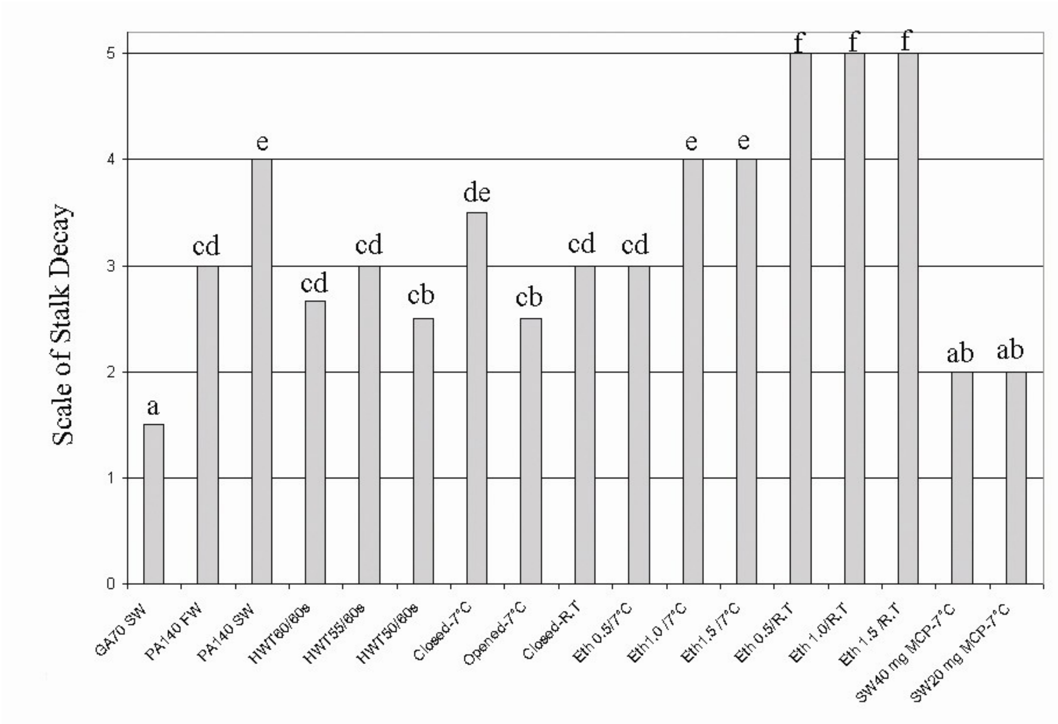


Figure 4.15: Stalk decay after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of Stalk decay (1= not appear; 2= small spots; 3= more than 30 %; 4= more than 50% ; and 5 = (sever) more than 70 %). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.4 Stalk browning:

Several treatments that involved storage at 7 ˚C preserved the freshness of stalks. Among these are 1) fruits irrigated with slightly saline water, packaged in non-perforated envelopes type CLARUS, and subjected to 1-MCP used, 2) fruits packaged in the same envelopes type without any treatment, 3) fruits packaged in open envelopes, 4) fruits packaged in non-perforated envelopes type CLARUS after HWT (50 °C for 60 seconds), and 5) fruits irrigated with slightly saline water or fresh water and packaged in GA70 envelopes. The worst results were recorded with fruits treated with ethanol, in particular with the highest ethanol concentration used (1.5 ml) followed by storage at room temperature (Figure 4.16).

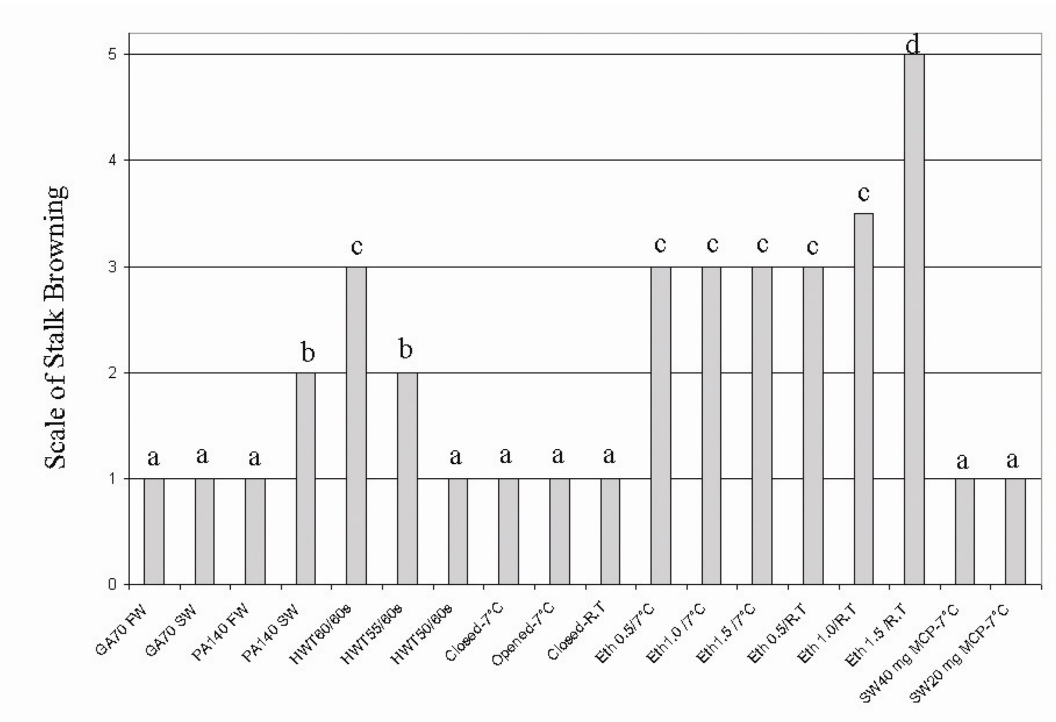


Figure 4.16: Stalk browning after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of stalk browning (1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe (over 70%) browning). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 20 days of storage, the worst results were recorded also with all ethanol treatments, and with fruits irrigated with fresh water and packaged in PA140 envelopes and stored at 7 °C.

After 29 days of storage at 7 °C (figure 4.17), fruits irrigated with slightly saline water and treated with either 1-MCP concentration used (20mg, 40 mg) and packaged in non-perforated envelopes showed the best results. The same results obtained with fruits subjected to HWT (55 °C or 60 °C for 60 seconds) and packaged in the same envelopes, and with fruits irrigated with slightly saline water and packaged in GA70 envelopes. The worst results were recorded with ethanol treatments that were stored at room temperature, followed by the same treatments but stored at 7 °C. Moreover, fruits irrigated with slightly saline water, stored at the same temperature, and packaged in PA140 envelopes showed similar response.

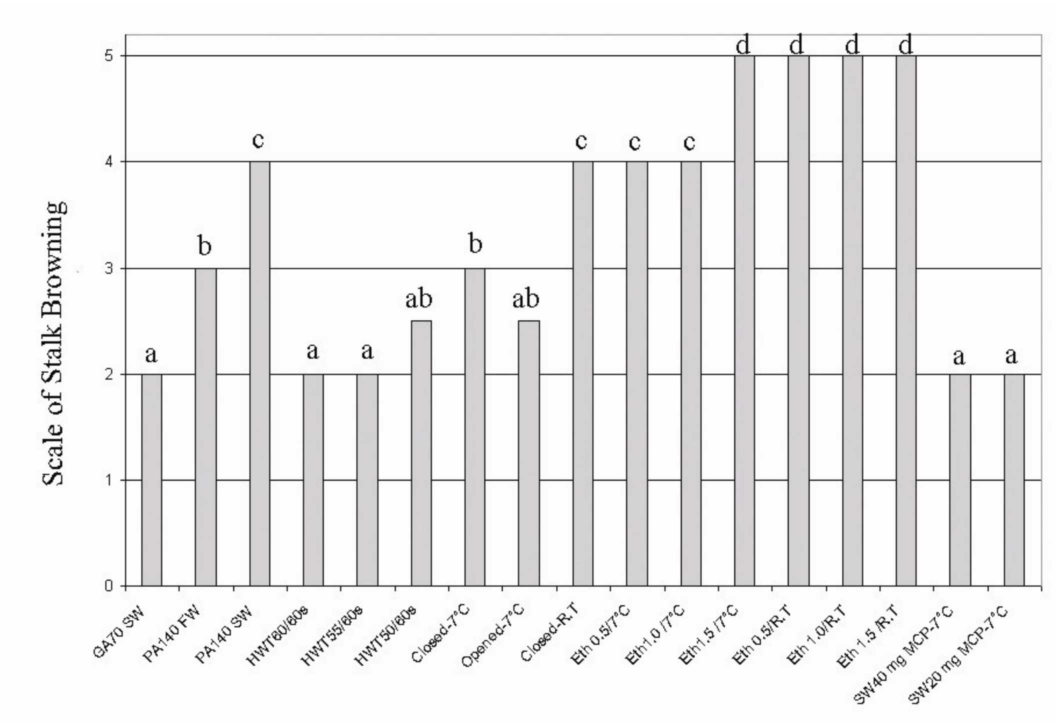


Figure 4.17: Stalk browning after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of stalk browning (1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe (over 70%) browning). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.5 Fruit surface pitting:

After 10 days of storage at 7 °C (figure 4.18), the following treatments show excellent results, consequently gave normal fruit surface: - fruits irrigated with slightly saline and fresh water and packaged in GA70 or PA140 envelopes, - fruits packaged in open envelopes without any treatment, - fruits packaged in non-perforated CLARUS envelopes after treatment with 0.5ml or 1.0 ml ethanol, - fruits treated with 1-MCP used and packaged in non-perforated CLARUS envelops, and - fruits packaged in non-perforated CLARUS envelops after treatment with 0.5 ml ethanol and stored at room temperature.

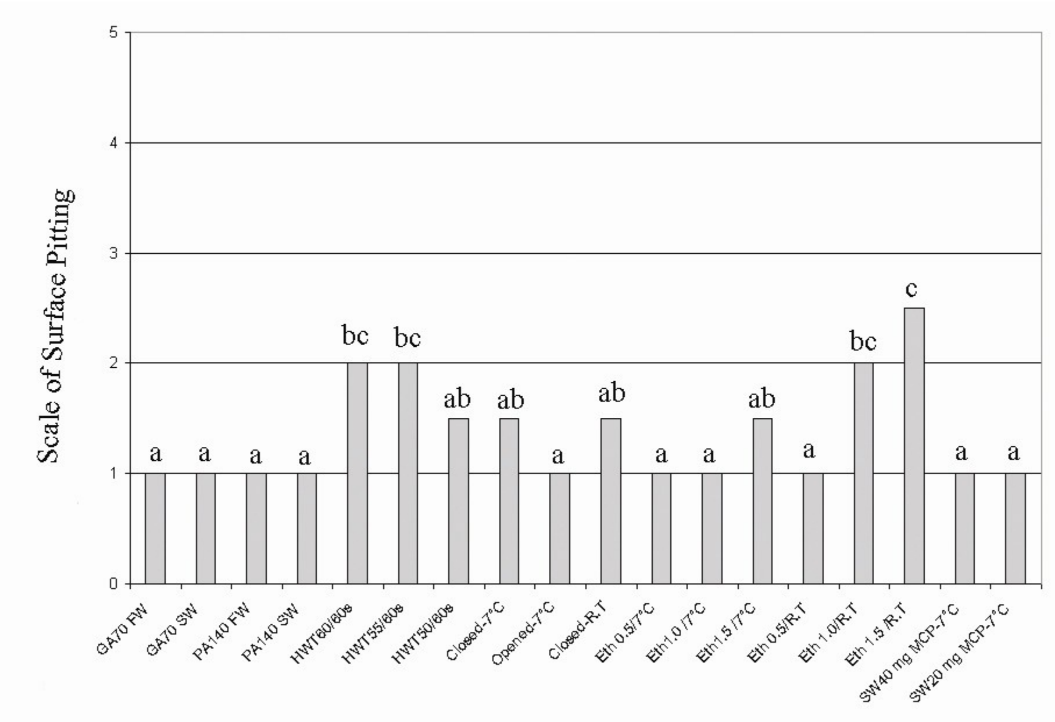


Figure 4.18: Pitting after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of surface pitting (1= normal; 2= small pitting spots; 3= more than 30% of the fruit surface; 4= more than 50% of the fruit surface is pitted; 5= sever -more than 70% of the fruit surface is pitted). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 20 days of storage at 7 °C (figure 4.19), fruits treated with either 20 mg or 40 mg 1-MCP and packaged in non-perforated CLARUS envelopes showed the best results with normal fruit surface, followed by fruits packaged in non-perforated CLARUS envelopes after treated with HW at 55 °C for 60 seconds. The worst results were obtained with fruits irrigated with fresh water and packaged in envelopes type PA140.

After 29 days of storage at 7 °C (figure 4.20), fruits irrigated with slightly saline water and packaged in GA70 envelopes showed the best results with normal fruit surface, followed by fruits packaged in non-perforated CLARUS envelopes after treatment with 1-MCP or HWT, and that fruits stored at room temperature.

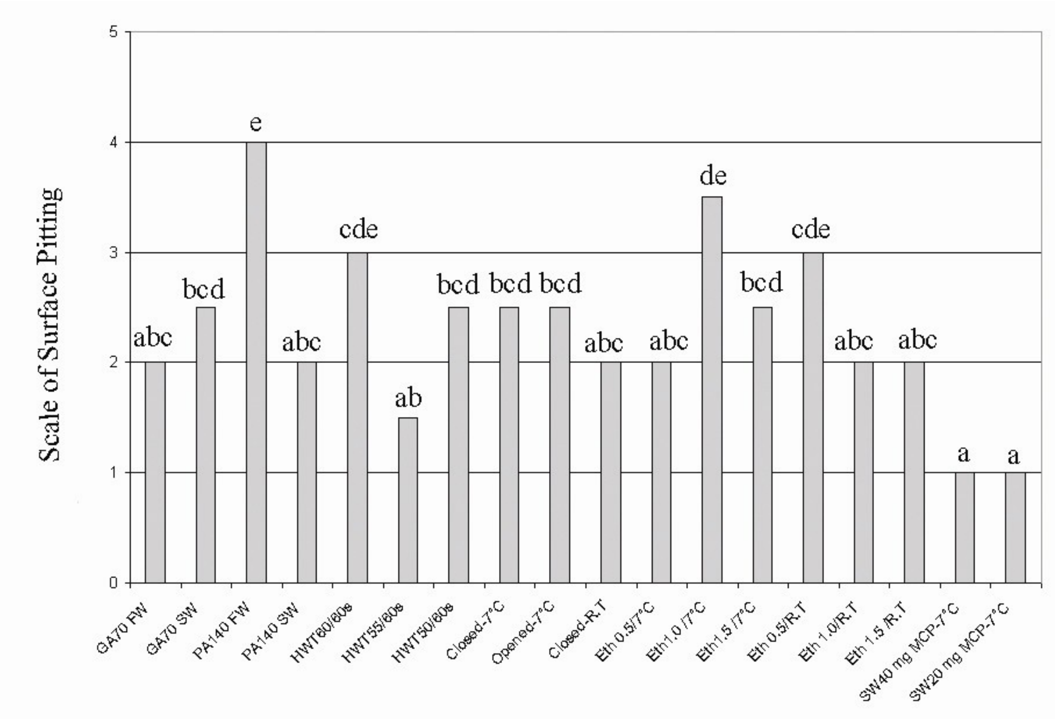


Figure 4.19: Pitting after 20 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of surface pitting (1= normal; 2= small pitting spots; 3= more than 30% of the fruit surface; 4= more than 50% of the fruit surface is pitted; 5= sever -more than 70% of the fruit surface is pitted). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

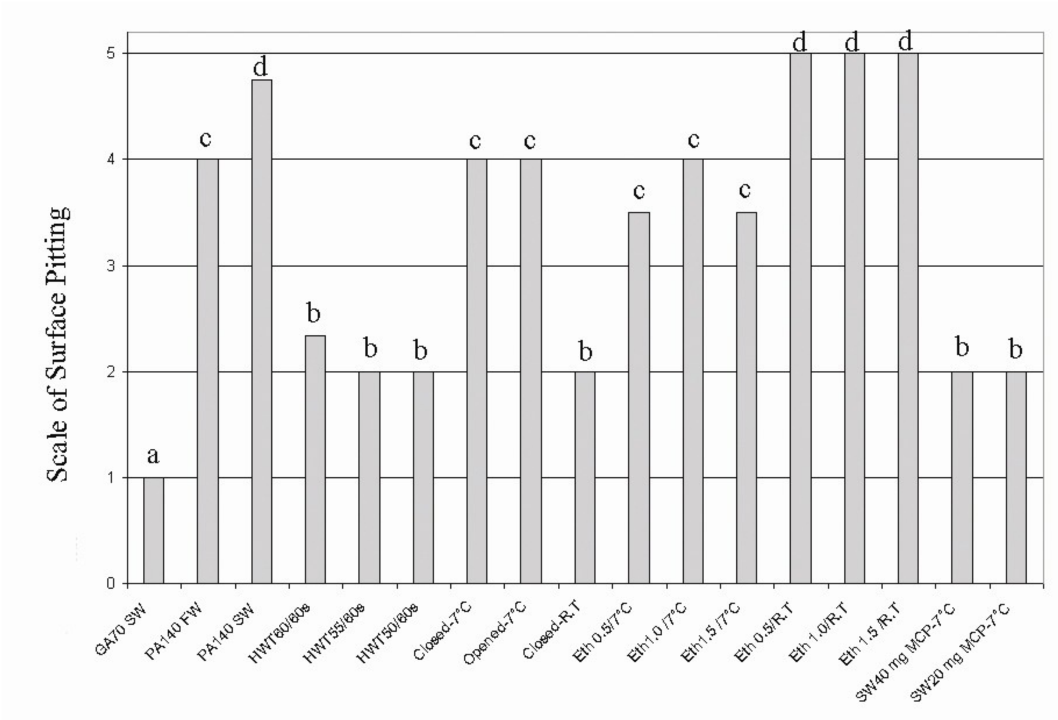


Figure 4.20: Pitting after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of surface pitting (1= normal; 2= small pitting spots; 3= more than 30% of the fruit surface; 4= more than 50% of the fruit surface is pitted; 5= sever -more than 70% of the fruit surface is pitted). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.6 Firmness:

After 10 days of storage (figure 4.21), the best results which gave very firm fruits appeared with many treatments as the following; - fruits packaged in GA70 envelopes, - fruits packaged with CLARUS envelopes after treatment with 1-MCP, - fruits packaged in CLARU envelopes after treatment with one of the three ethanol concentrations used and stored at 7 °C, - fruits packaged without treatment in CLARUS non-perforated envelopes at 7 °C, and - fruits treated with HWT (60 °C for 60 seconds).

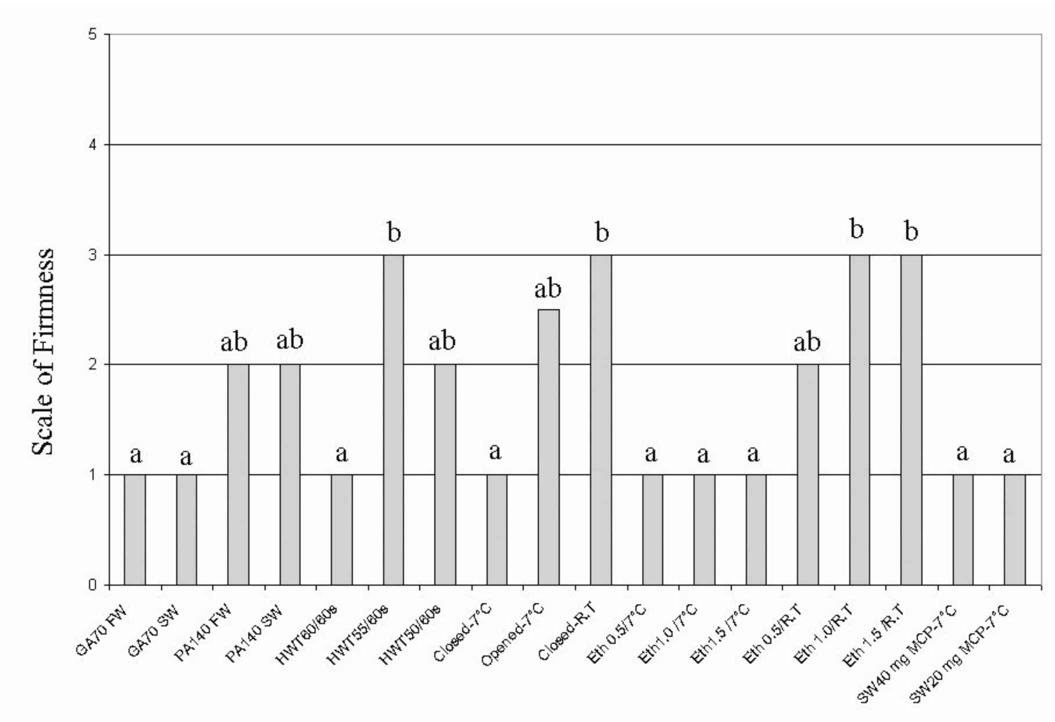


Figure 4.21: Firmness after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of firmness (1= very firm; 2= firm; 3= slight firm; 4= starts shriveling, and 5= limp). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

Also after 20 days of storage at 7 °C (figure 4.22), many treatments showed good results. These treatments are: - fruits irrigated with slightly saline water and packaged in CLARUS non-perforated envelopes after treatment with 40 mg 1-

MCP, - fruits packaged in CLARUS non-perforated envelopes after treatment with one of the three ethanol concentrations used, - fruits packaged without treatment in CLARUS non-perforated envelopes, and - fruits treated with one of HWT used.

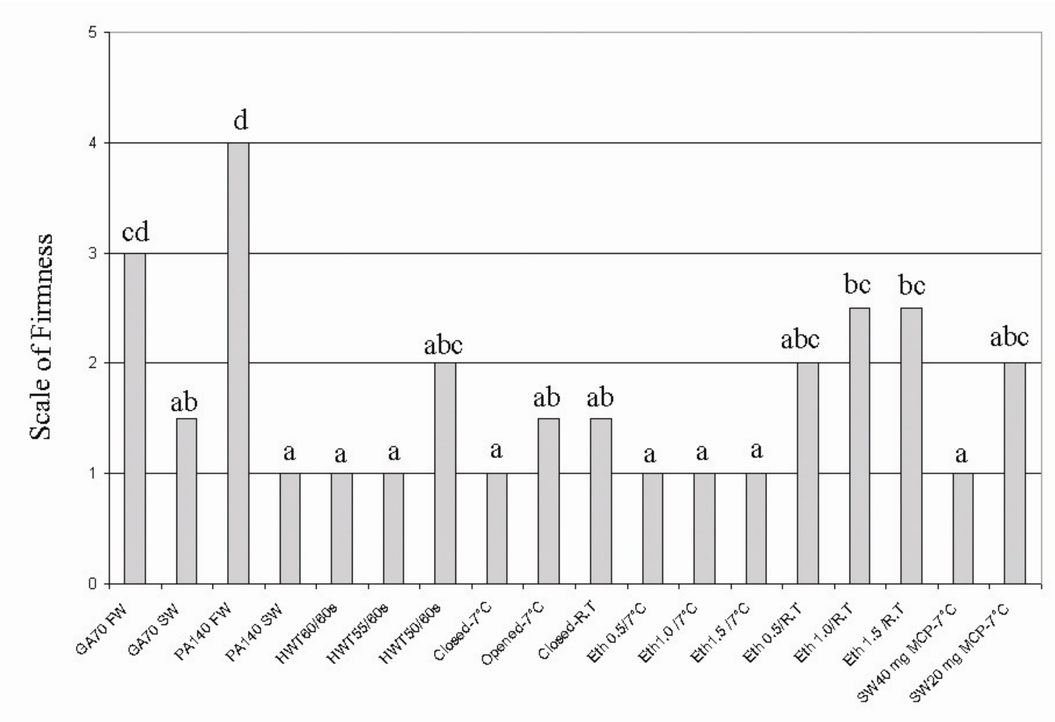


Figure 4.22: Firmness after 20 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of firmness (1= very firm; 2= firm; 3= slight firm; 4= starts shriveling, and 5= limp). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 29 days of storage at 7 °C (figure 4.23), the following treatment showed the very firm fruits: - fruits irrigated with slightly saline water and treated with 1-MCP used after packaging in CLARUS non-perforated envelopes, - fruits treated with any of the three HWT used, and - fruits irrigated with slightly saline water and packaged in GA70 envelopes. The worst results appeared with limp texture fruits for fruits stored at room temperature and packaged with non-perforated CLARUS envelopes after treated with any of the ethanol concentrations used, the same results gave limp texture with fruits packaged in both open and closed CLARUS envelopes and stored at 7 °C.

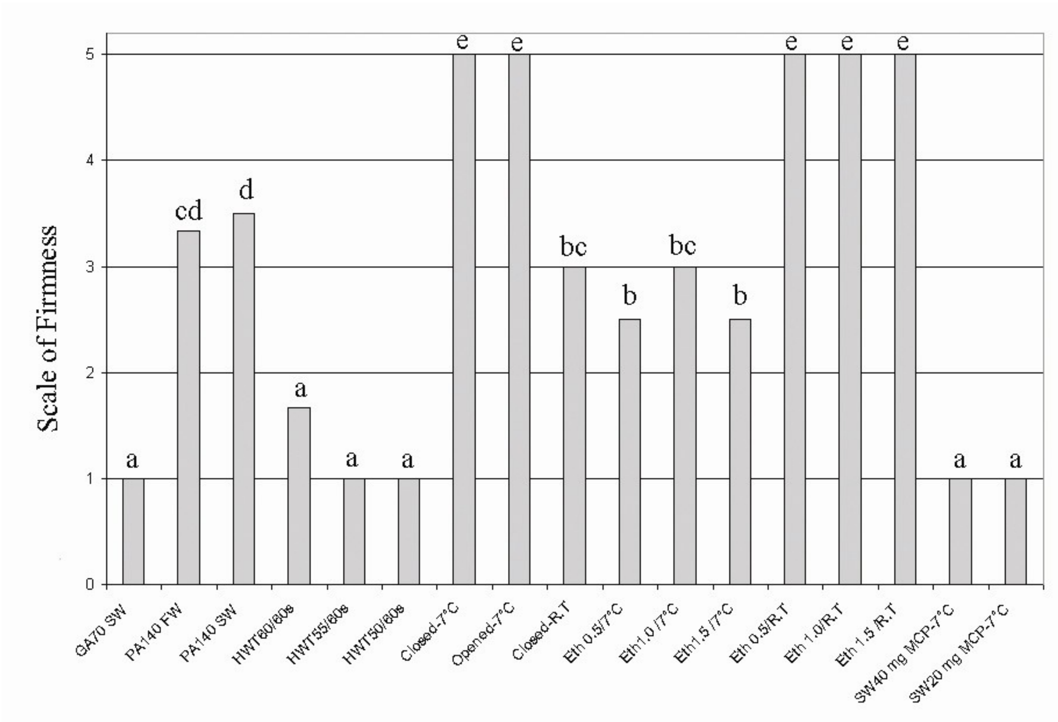


Figure 4.23: Firmness after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of firmness (1= very firm; 2= firm; 3= slight firm; 4= starts shriveling, and 5= limp). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.7 Color:

Fruits irrigated with slightly saline water and packaged in non-perforated plastic film type CLARUS 110 GG after treatment with 20 or 40 mg 1-MCP showed the lowest color deterioration after 10 days of storage at 7 °C (figure 4.24). Also fruits irrigated with fresh water but packaged in envelopes type PA140 and GA70 and stored in the same conditions showed the same results, followed by fruits irrigated with slightly saline water and treated with HWT (50 °C for 60 seconds), in addition to fruits treated with 1.0 ml ethanol, these last two treatments packaged in non-perforated plastic film type CLARUS 110 GG and stored in the same condition. The worst result was recorded with fruits packaged with 1.0 ml ethanol in non-perforated plastic film type CLARUS 110 GG and stored at room temperature.

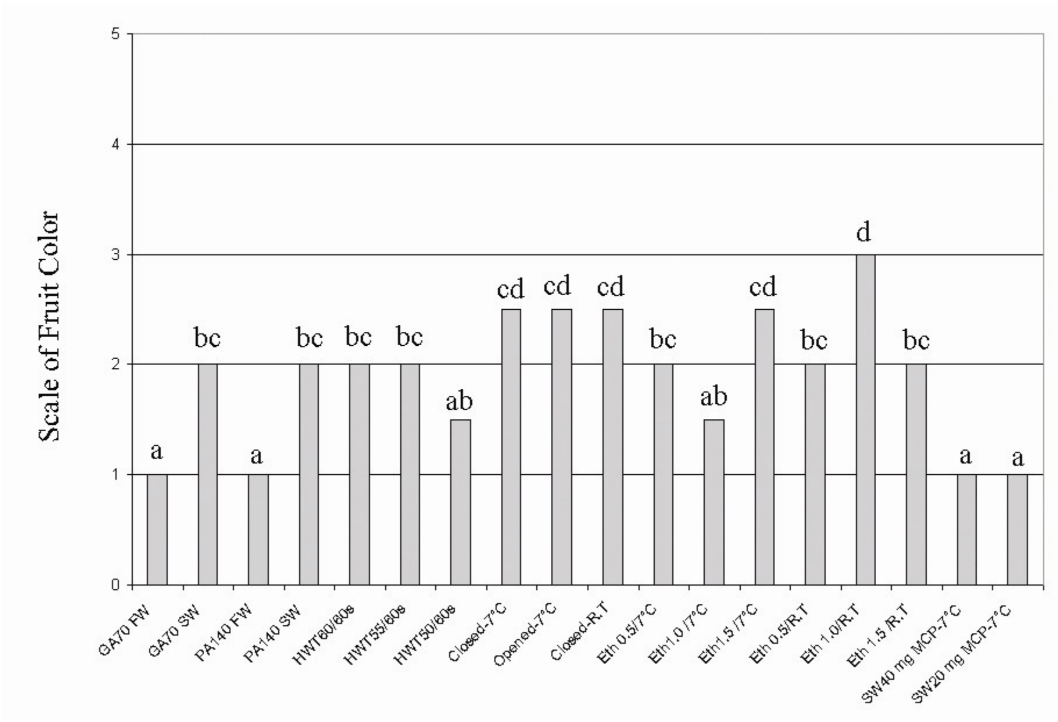


Figure 4.24: Color after 10 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of fruit color (1= dark green; 2= green; 3= light green; 4= yellowish or brownish; 5= over ripening or more than 70% of the fruit is brown). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

After 20 days of storage (figure 4.25), the HWT fruits (50 °C for 60 seconds) and fruits treated with 1.0 ml ethanol, packaged in non-perforated plastic film type CLARUS 110 GG and stored at 7 °C showed the best results, while the worst results were recorded with all treatments stored at room temperature, in addition to fruits irrigated with fresh water and packaged in envelopes type PA140.

After 29 days of storage (figure 4.26), the best results were recorded with fruits irrigated with slightly saline water, packaged at 7 °C in non-perforated plastic film type CLARUS 110 GG, and treated with 20 or 40 mg 1-MCP, followed by fruits subjected to HWT (50 °C or 55 °C for 60 seconds) and packaged and stored in the same conditions. The worst results were recorded with treatments stored at room temperature.

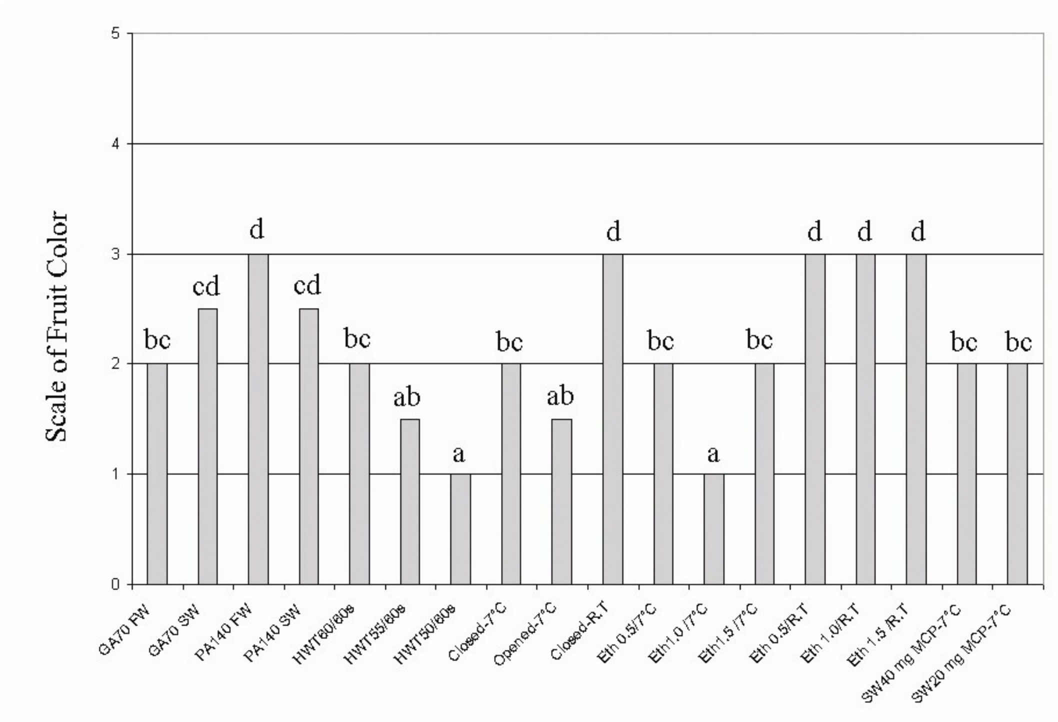


Figure 4.25: Color after20 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of fruit color (1= dark green; 2= green; 3= light green; 4= yellowish or brownish; 5= over ripening or more than 70% of the fruit is brown). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

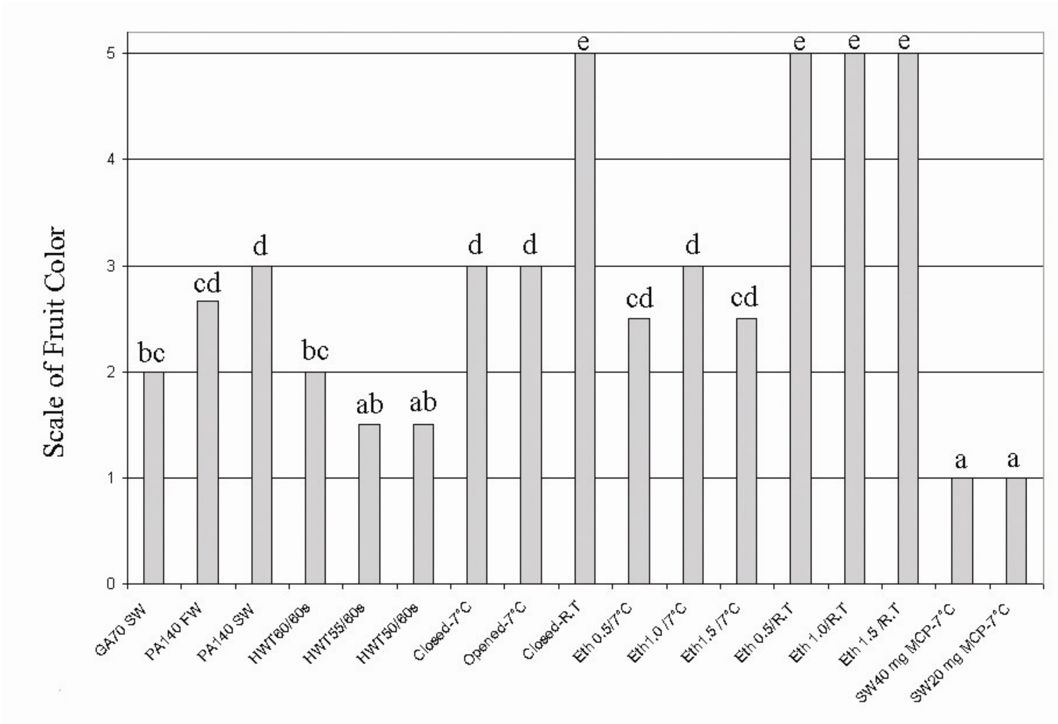


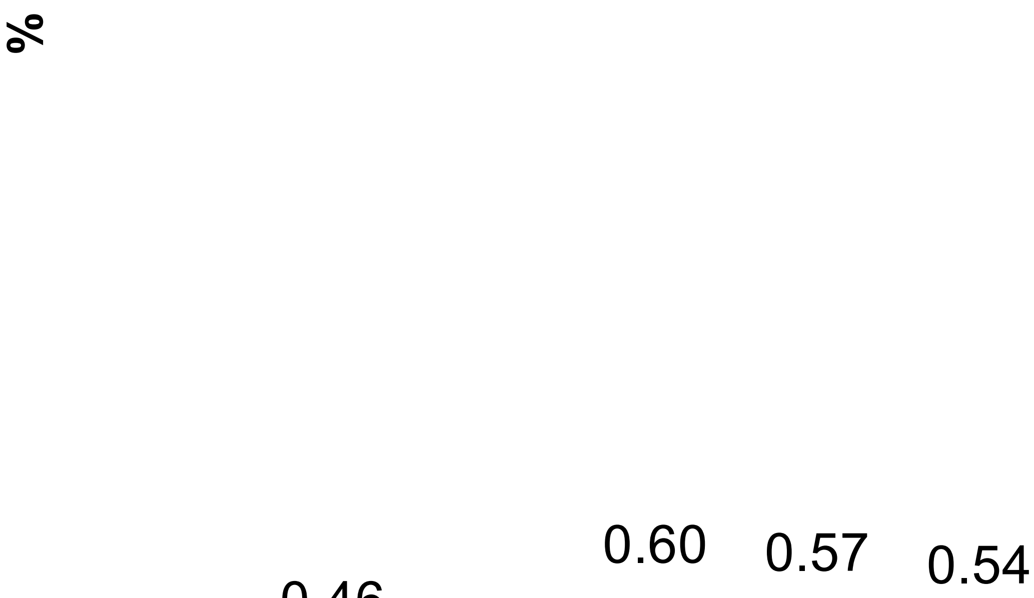
Figure 4.26: Color after 29 days of storage, experiment part two. (FW: fresh water; SW: slightly saline water; HWT: hot water treatment; R.T: room temperature; Eth: ethanol; s: second). Scale of fruit color (1= dark green; 2= green; 3= light green; 4= yellowish or brownish; 5= over ripening or more than 70% of the fruit is brown). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.2.8 Weight losses:

After 10 days of storage (figure 4.27), the highest fruit weight losses were recorded with treatments done with fruits irrigated with slightly saline water, treated with 1.0, 0.5, and 1.5 ml ethanol, and stored at room temperature (3.45%, 2.9%, and 1.76 respectively), while the lowest losses were registered with fruits treated with 0.5 ml ethanol (0.18 %) and 1.5 ml ethanol (0.27%) following packaging in non-perforated envelopes type CLARUS and storage at 7 °C. After 20 days of storage (figure 4.28), the highest weight loss was registered for fruits packaged in open envelopes and stored at 7 °C (1.08%), and the lowest registered with fruits treated with 1.0 ml ethanol and stored at 7°C following packaging in non-perforated envelopes type CLARUS.

After 29 days of storage (figure 4.29), the highest weight loss was registered with fruits stored at room temperature following packaging in non-perforated envelopes type CLARUS (3.54%), while the lowest was with fruits treated with 1.0 ml ethanol and stored at 7 °C following packaging in non-perforated envelopes type CLARUS (0.68%).

Figure 4.27: Weight loss % after 10 days of storage, experiment part two. (HWT: heat water treatment; SW: slightly saline water; FW: fresh water; R.T: room temperature; Eth: ethanol; s: second).



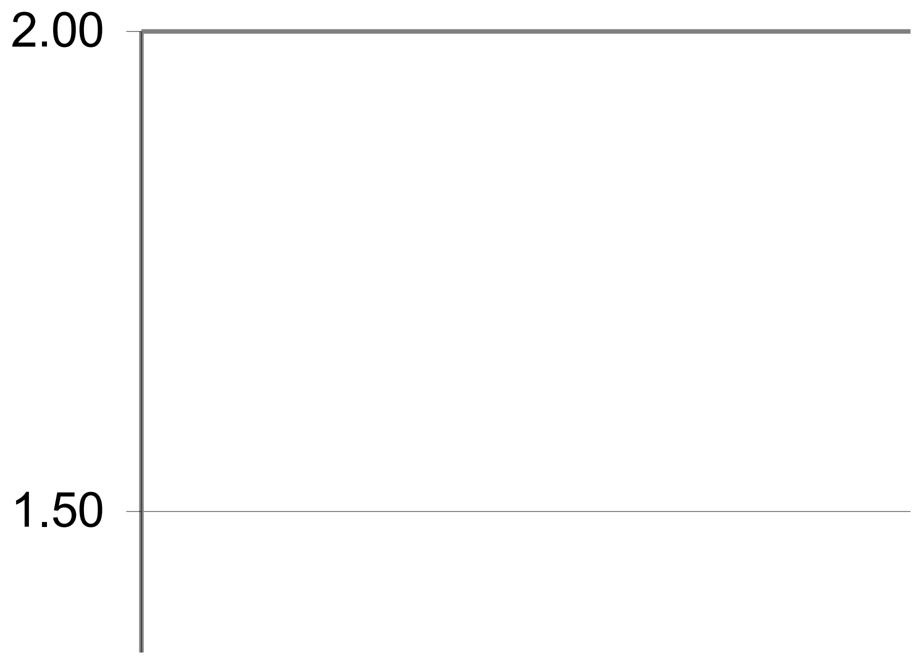


Figure 4.28: Weight loss % after 20 days of storage, experiment part two. (HWT: heat water treatment; SW: slightly saline water; FW: fresh water; Eth: ethanol; s: second).

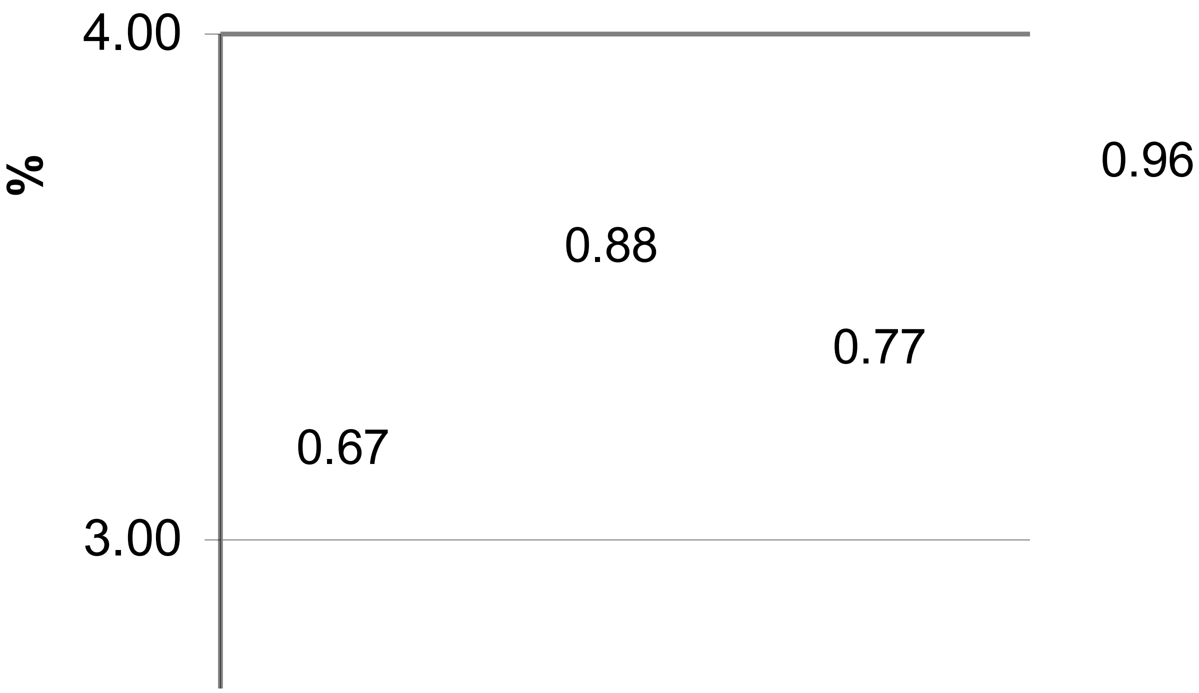


Figure 4.29: Weight loss % after 29 days of storage, experiment part two. (HWT: heat water treatment; SW: slightly saline water; FW: fresh water; R.T: room temperature; Eth: ethanol; s: second).

4.3 Experiment Three (1-MCP treatment and MAP technique):

4.3.1 Acceptance:

After 12 days of storage at 7 °C (figure 4.30), the best results were registered with fruits that were irrigated with slightly saline water, and packaged in non-perforated plastic film type CLARUS 110 GG following treatment with 40 mg of 1-MCP. Panelist appreciated these fruits, followed by the same treatment, but with fruits irrigated with fresh water.

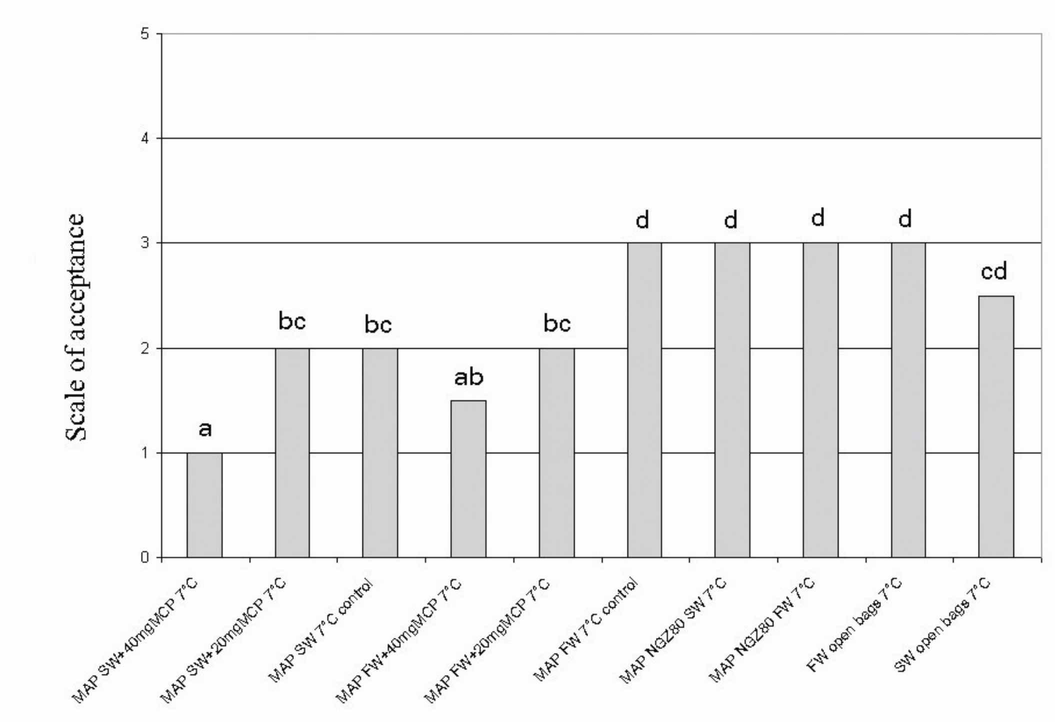


Figure 4.30: Acceptance after 12 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water). Scale of acceptance (1=very good; 2= good; 3=fair; 4=bad; 5=very bad). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

In this part of experiment, the impact of the salinity level of water was clear after 12 days of storage at 7 °C, but this impact disappeared after 26 days storage time. Consequently, fruits irrigated with slightly saline water and treated with 40 mg of 1-MCP shown better results than fruits irrigated with fresh water and treated with either one of the two concentrations of 1-MCP used. Moreover, application of 40 mg of 1-MCP gave better results than using 20 mg for both fruits sources. Furthermore, fruits irrigated with slightly saline water gave better results than fruits irrigated with fresh water following packaging in plastic film type CLARUS 110 GG and storage at 7 °C .

In part two, there were no significant differences between fruits treated with 20 mg or 40 mg 1-MCP in all tested parameters after 10, and 29 days of storage. Only after 20 days of storage there was a difference with the acceptance and the firmness of the fruits, in which 40 mg 1-MCP application gave better results. But in part three and after 12 days of storage, fruits irrigated with slightly saline water and treated with 40 mg 1-MCP showed better results than 20 mg, but after 26 days of storage it gave bad acceptance, and treatment with 20 mg gave better results.

4.3.2 Stalk Browning:

Fruits packaged in non-perforated plastic film type NGZ80 showed the highest stalk color deterioration and turned to brown, followed by fruits packaged in open envelopes after 12 days of storage at 7 °C (figure 4.31); these results are for both fruits irrigated with slightly saline or fresh water. The salinity of irrigation water used in all treatments did not show a significant effect on stalk browning during the first 12 days of storage at 7 °C. Also fruits treated with 1-MCP for both concentrations 20 and 40 mg gave the same results, there were no significant differences between the two 1-MCP concentrations.

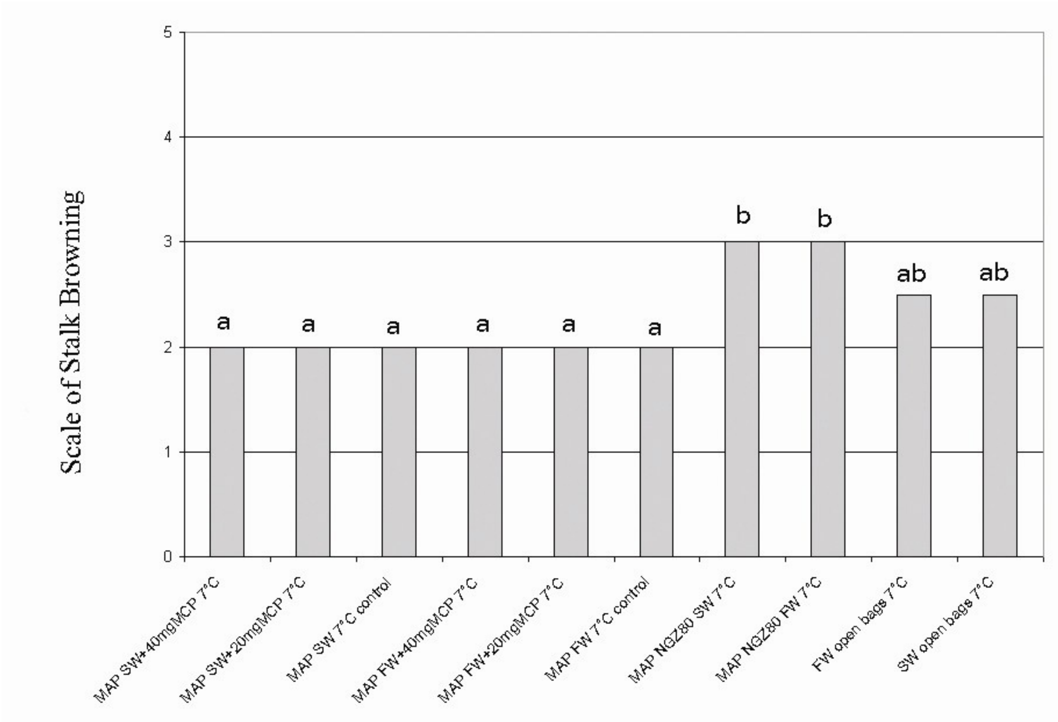


Figure 4.31: Stalk browning after 12 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water). Scale of stalk browning (1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe -over 70%- browning). Bars have the same letter are not significantly different. Duncan values (*$P \leq 0.05$*).

After 26 days of storage at 7 °C (figure 4.32), fruits irrigated with slightly saline water and packaged in open envelopes showed the highest stalk browning, followed by fruits irrigated with fresh water and packaged in open envelopes too. Fruits irrigated with slightly saline water and treated with 20 mg 1-MCP gave better results than 40 mg for the same fruits and for fruits irrigated with fresh water.

Water salinity has a negative effect on stalk browning with fruits packaged in open envelopes, while 1-MCP treatment alleviate this negative impact; these fruits which were irrigated with slightly saline water and treated with 20 mg 1-

MCP were better than fruits irrigated with fresh water and treated with 1-MCP at both concentrations (20 and 40 mg).

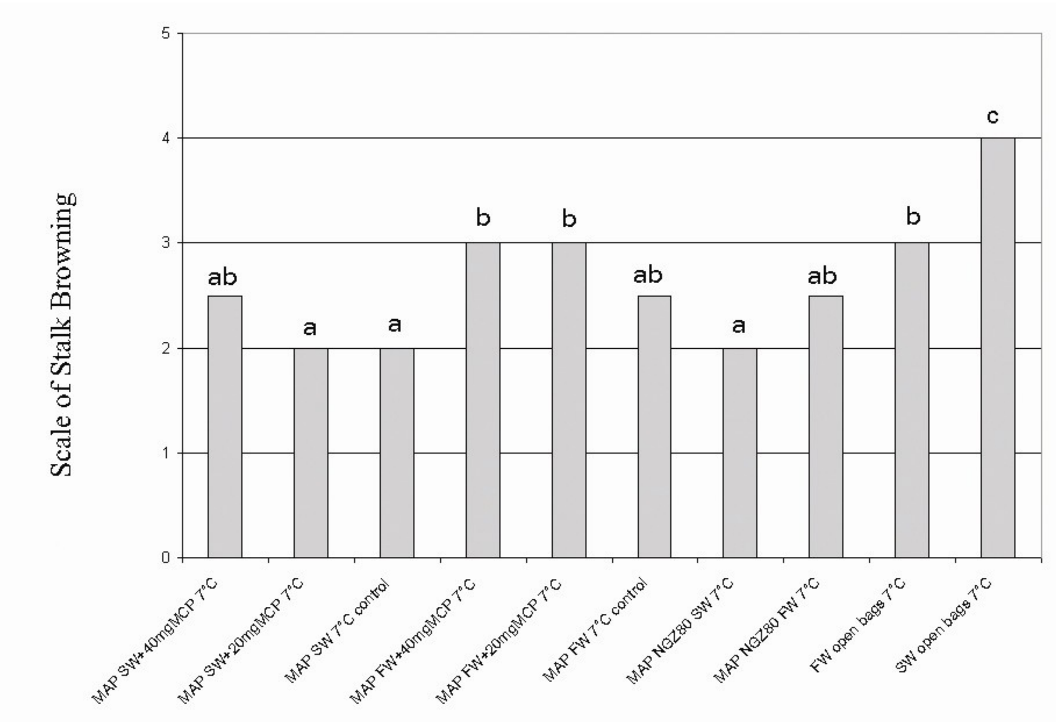


Figure 4.32: Stalk browning after 26 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water). Scale of stalk browning (1= green and normal; 2= slight coloring; 3= 1/3 of the stalk is brown; 4= more than 50% of the stalk is brown; 5= severe -over 70%- browning). Bars have the same letter are not significantly different. Duncan values (*$P \leq 0.05$*).

4.3.3 Weight Losses:

After 12 days of storage at 7 °C (figure 4.33), fruits irrigated with slightly saline water and packaged in open envelopes showed the highest in weight losses (0.98 %), followed by the fruits irrigated with fresh water and packaged in closed envelopes type CLARUS 110 GG (0.90%). The lowest weight losses were registered with fruits irrigated with fresh water, and packaged in non-perforated envelopes type CLARUS following treatment with 40 mg of 1-MCP, followed by fruits irrigated with slightly saline water and treated with 40 mg 1-MCP, and fruits irrigated with fresh water and treated with 20 mg 1-MCP.

Figure 4.33: Weight loss % after 12 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water).

After 26 days of storage at 7 °C (figure 4.34), fruits packaged in open envelopes and irrigated with slightly saline water showed the highest weight losses (3.19 %), followed by fruits irrigated with fresh water and packaged in open envelopes, while the best result that show the lowest in weight looses was registered with fruits irrigated with fresh water, packaged in non-perforated envelopes type CLARUS, and treated with 20 and 40 mg of 1-MCP (0.21 and 0.24 respectively).

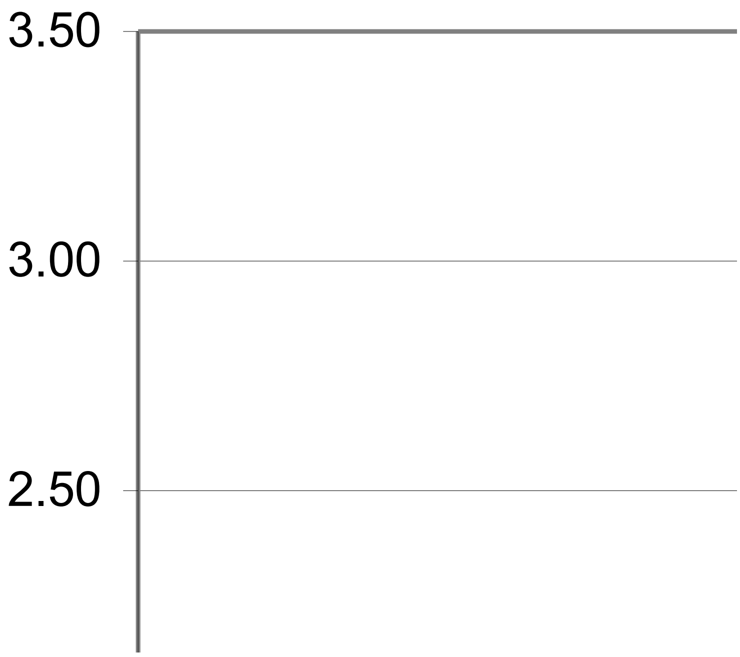


Figure 4.34: Weight loss % after 26 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water). Bars have the same letter are not significantly different. Duncan values ($P\leq 0.05$).

4.3.4 Firmness:

No significant differences were obtained after 12 days of storage at 7 °C, but after 26 days of storage (figure 4.35) significant differences appeared. The best results obtained was for fruits irrigated with slightly saline water and packaged in non-perforated envelopes type CLARUS without any treatment, and for fruits packaged in the same envelopes following treatment with 20 mg 1-MCP. The same results were obtained also with fruits irrigated with fresh water and packaged in non-perforated envelopes type CLARUS following treatment with 40 mg 1-MCP, whereas the worst results was obtained with fruits packaged in open envelopes.

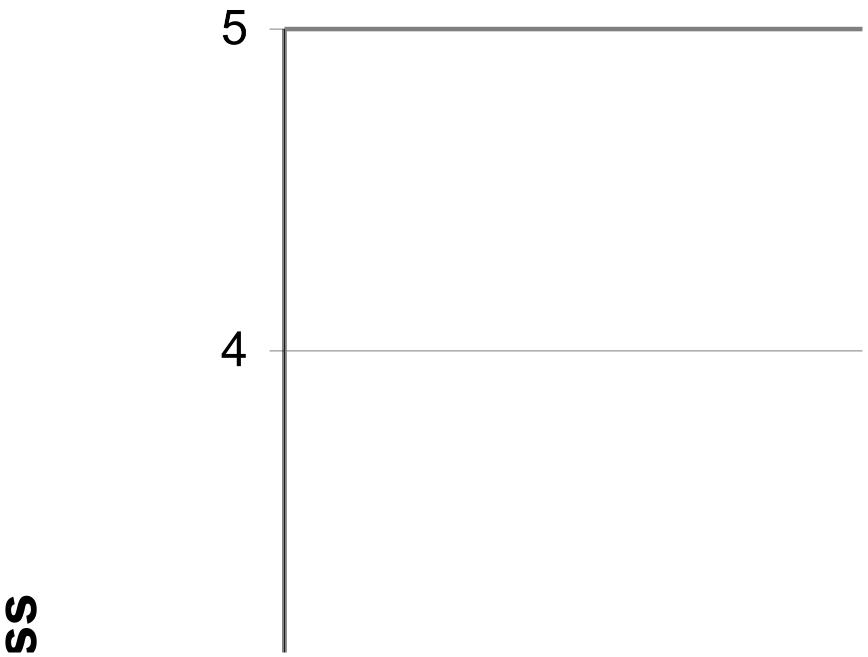


Figure 4.35: Firmness after 26 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water). Scale of firmness (1= very firm; 2= firm; 3= slight firm; 4= starts shriveling, and 5= limp). Bars have the same letter are not significantly different. Duncan values (*P≤0.05*).

4.3.5 Fruit Decay:

After 26 days of storage at 7 °C (figure 4.36), significant differences appeared between treatments, although these differences did not appeared after 12 days; until 12 days no decay was present with all treatments. The best results were recorded for fruits packaged in envelopes type NGZ80, irrespective of water source.

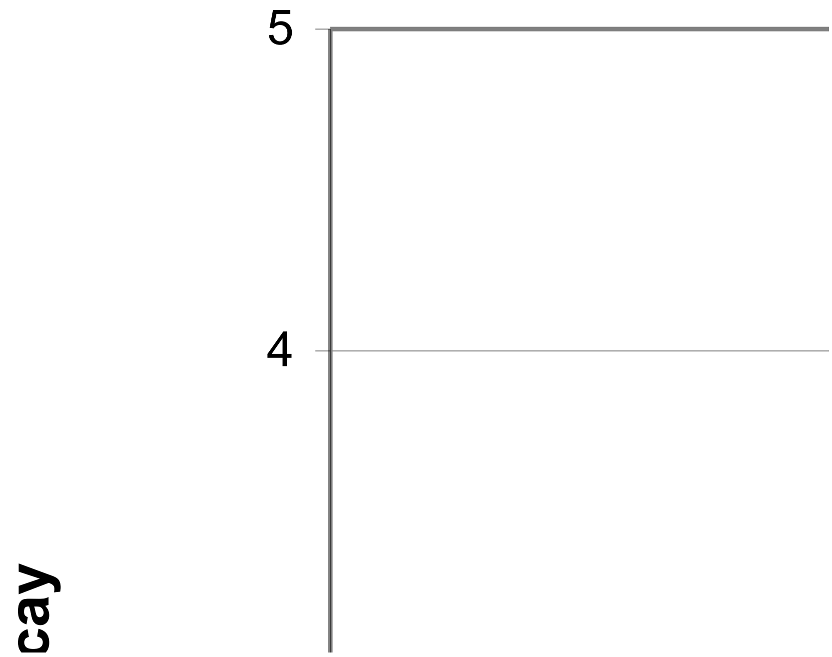


Figure 4.36: Fruit decay after 26 days of storage, experiment part three. (MAP: modified atmosphere packaging; SW: slightly saline water; FW: fresh water). Scale of fruit decay (1= decay free; 2= starts with small spots, 3= presents in larger spots; 4= covering more than 50%; 5= covering more than 70%). Bars have the same letter are not significantly different. Duncan values ($P \leq 0.05$).

Chapter Five:

Discussion

5.1 Sulfur Treatments:

Our results with bell peppers treated with sulfur show clearly that S-treatment gave the worst results and has negative effects on pitting, stalk browning, and fruit firmness in the first 10 days of storage. Furthermore, 30 days after treatment the most susceptible part of the fruit to sulfur injury appeared to be the stalk; it turned to brown color.

Fruits that were treated with sulfur before storage, either at room temperature or at low temperature, showed high sensitivity to sulfur injury, mainly the stalk which turned to yellowish or brown color. These results are in agreement with Zoffoli et al. (2008). Researchers mentioned that sulfur injury can result in bleaching, discoloration, and fruit pitting. In a current study, fruits were affected by sulfur, which was manifested in an increased rate of pitting, in particular with fruits stored at room temperature. Surface pitting was not the only sign of sulfur injury, as stalk browning and fruit firmness were also affected upon S-treatment, in accordance with results recorded with Zoffoli et al. (2008).

Fruits treated with sulfur and packaged in non-perforated plastic film showed the highest gas concentration following storage at room temperature, while fruits stored at 7 °C gave lower gas concentration. The increase in gas accumulation under room temperature storage can be explained by one of the following two illustrations; the first one that this increases resulted from an increased respiration rate due to injuries caused by sulfur treatment, which is accelerated at RT. The second explanation suggested that the increases of CO_2 inside bags under room temperature storage came from the increase in temperature only. This is in agreement with Tasneem (2004) about the accumulation of CO_2, which comes from the increase in fruit respiration that is highly affected by the storage temperature. Furthermore, this trend is in agreement with Ben-Yehoshua et al. (1983) results with pepper fruits. These researchers mentioned that ripening or senescence of detached plant organs is accompanied by the loss of membrane integrity which affected various processes in plants.

5.2 Hot Water Treatment (HWT):

After 10 days of storage, HWT shown the best results in keeping fruit, in particular they were firmer. This is in agreement with Mencarelli et al. (1993), who based this response to the presence of synthesized heat shock proteins (HSPs); in this experiment no analysis for HSPs was done.

5.3 1-MCP treatments:

The results obtained from fruits treated with 1-MCP came in agreement with Nanthachi et al. (2007). It was considered that using 1-MCP represents an option for extending the shelf life and maintaining the quality of fresh produce, which respond to ethylene that limit storability. Results clearly show that fruits irrigated with slightly saline water and picked at the beginning of April, treated with 20 mg or 40 mg 1-MCP, and packaged in CLARUS envelopes at 7 °C were in better condition for 20 days; fruits were of very good quality and highly marketable. Even after 29 days storage period, fruits were of good quality. Similar results were obtained using GA70 envelopes for 10 days or 29 days of storage, in particular with fruits picked from plants irrigated with slightly saline water. Accordingly, 1-MCP proved to be of value when used with bell peppers, as described by Saltveit (1999). This in agreement with Khan and Singh (2007), who demonstrated the impact of 1-MCP on ethylene action on different crops including tomatoes. Fruits picked at the beginning of April, 2007 and treated with both 1-MCP concentrations used (20 and 40 mg) gave better results than the same treatments done with fruits picked at the beginning of May; in both time intervals the water salinity was the same. It is obvious that harvesting time has an influence, and growing temperature may have an effect. Kosiyachinda and Young (1976) and Lipton (1978) mentioned that there are many factors affect fruit postharvest efficiency. Among these factors are: fruit maturity at harvest and degree of ripeness, which are considered important factors in determining chilling sensitivity in sensitive fruits. Blankenship and Dole (2003) reported that 1-MCP effect on *Prunus armeniaca* decreased as fruit development advance; with "Delicious" apples advancing maturity slightly decreased the effect of 1-MCP.

5.4 Packaging in different plastic films:

Using MAP as a tool to increase the shelf life of pepper in this experiment came in agreement with Zagory (2000). MAP is used to maintain a gradient in gas composition between air and headspace inside the package. Results of this study show that the lowest CO_2 level occurred with fruits packaged in perforated envelopes, which means there was no buildup of CO_2 inside the envelopes. From biochemical perspective, it is worth to refer here to the enzyme polyphenol oxidase, which is present in high quantities in certain fruits and vegetables. This enzyme is responsible for the degradative change in color in a process known as enzymatic browning. This enzyme catalyses the reaction of phenolic compounds with oxygen to produce quinones. Quinones undergo further oxidation and polymerize to form brown pigments known as melanins. Since polyphenol oxidase requires oxygen, it is to predict that its exposure to air via tissue injury will cause this reaction to proceed. However, increasing CO_2 inside envelopes decreased stalks browning, probably through reduction in the activity of this enzyme. Smyth et al. (1998) mentioned that low O_2 MAP is used to reduce the browning of cut surfaces, whereas the highest stalk browning was registered with fruits packaged in open or perforated envelopes, in which the level of CO_2 is the lowest. In agreement with these findings, using GA70 envelopes gave good results with accepted fruit quality, since this plastic film thickest was 70 µm, in addition to the fact that it has lower ß value; GA70 is synthesized from 7 layers. In contrast, CLARUS plastic film has a thickness of 19 µm, and PA140 has a thickness of 35 µm. Zagory (2000) recorded that ß value of different plastic film envelopes affect the permeability of these films. Furthermore, the impact of plastic films was manifested in the development of fruit firmness. Fruits packaged in open envelopes, which did not maintain the relative humidity around the fruits, shriveled and loss much of its quality. Ben-yehoshua et al. (1983) mentioned that the pepper firmness is affected by changes of the relative humidity.

When envelopes type NGZ80 was used for MAP, it gave the worst results with highest stalk browning after 12 days of storage at 7 °C, despite it strong thickness (80 µm in three layers). Moreover, this envelope prevented the development of decay organisms, but it has no effect upon the stalk color deterioration. Concerning the water loss, the highest losses were registered with fruits packaged in open envelopes, which is in agreement with AVRDC (2006), who reported that creation of a humid atmosphere around the stored fruits will decrease water loss, and that is one of the benefits when using MAP.

5.5 Water salinity:

Fruits picked from plants irrigated with slightly saline water and treated with 20, or 40 mg 1-MCP, or packaged in GA70 envelopes, gave the best results (good accepted fruits to marketable) after 29 days of storage period. In the third experiment, the best results were also obtained with fruits irrigated with slightly saline water and treated with 40 mg 1-MCP. The consumer acceptance was very high, followed by the same treatment but for fruits irrigated with fresh water. Consequently, fruits obtained from plants irrigated with slightly saline water gave better results than those irrigated with fresh water. The positive impact of mild-moderate salinity stress is an agreement with Mirzahi and Pasternaki (1985), who reported that irrigating plants with moderately saline water improve the quality of fruits; fruits had higher values of the total soluble solids (TSS) and acidity as it appeared with fruits from a processing tomato cultivar after exposure to various degrees of salinity. Kunio et al. (2002) concluded that salinity was essentially a form of water stress that resulted in an improvement of tomato fruit quality. Flores et al. (2003) investigated tomatoes (cv. Daniela), and noticed that increasing the salinity level and NH_4^+ concentration increased fruit quality by increasing the content of sugars and organic acids, although the increase in fruit quality was associated with a decrease in yield. Another important effect of salinity stress is the improvement of fruit tolerance to chilling injury, which may be similar to hot water dipping. It is believed that the synthesis of heat shock proteins (HSPs) has beneficial effects in reducing chilling injury in a range of fruits during subsequent low temperature storage. Anderson et al. (1994), Coca et al. (1994), and Kiyosue et al. (1994) reported that HSPs are also induced by other stresses such as cold, drought, or salinity. Consequently, it is to predict that fruits obtained from plants irrigated with saline water may have more HSPs, with a result of better ability for storage under low temperature compared to fruits irrigated with fresh water only.

5.6 Treating with ethanol:

The ethanol used in treating fruits enhanced decay development for both fruits and stalks under room temperature storage. This negative development is further enhanced by the high relative humidity created inside the packages. Moreover, ethanol-treated fruits showed the highest weight loss, which indicates higher rates of water loss. This is in agreement with Shirazi and Cameron (1992), who noted that high relative humidity aggravates decay development.

Chapter Six:

Recommendations and future prospects

Further research is highly needed to explore the effect of 1-MCP and the reasons why fruits obtained from plants irrigated with slightly saline water gave better results than fruits obtained from plants irrigated with fresh water when using 1-MCP.

Depending on the obtained results, we can recommend that the suitable treatment depends on the period of storage needed, and that appear as the following:

1. For short term storage, up to 10 days, it is clear that modified atmosphere packaging (MAP) alone is sufficient. The most suitable plastic film is GA70.
2. For up to 20 days, 1-MCP treatment, in combination with MAP, prove to be effective. The proper 1-MCP concentration is 20 mg 1-MCP.6.6 L^{-1}.

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ملخص

في هذه التجربة، تم استخدام ثمار الفلفل الأخضر الحلو (*Capsicum annum*) صنف 'Vally' بعد أن تم قطفها من مزرعتين بمدينة أريحا. نوعية مياه الري المستخدمة في المزرعتين تختلف عن بعضهما البعض، ففي المزرعة الأولى يبلغ التوصيل الكهربائي لمياه الري (0.49 $dS\ m^{-1}$) بينما في المزرعة الثانية يبلغ (2.535 $dS\ m^{-1}$)، وخلال 24 ساعة من القطف تم معاملة الثمار بواحدة أو اثنتين معا من المعاملات التالية: المعاملة بالكبريت، استخدام أغلفة مُعَدِّلة جوياً، التعريض لبخار الإيثانول، التعريض لبخار MCP-1، المعاملة بالماء الساخن، وقد تم مراقبة الثمار أثناء التخزين الذي استمر 30 يوماً من خلال عمليات تقييم النوعية للثمار وقابليتها للتسويق بواقع مرة كل 10 أيام، حيث كان المظهر العام للثمار هو العامل الرئيس في اتخاذ الحكم على نوعية الثمار من قبل المقيّمين.

في هذه الدراسة، كان من الممكن تخزين الثمار لعدة أسابيع على 7 درجات مئوية والحصول على ثمار بنوعية جيدة وقدرة تسويقية عالية وذلك بعدة طرق، أولها من خلال تبني أنظمة الأغلفة المعدلة جويا شريطة اختيار أنواع مناسبة من الأغلفة مثل GA70، أيضاً عند استخدام MCP-1، وكذلك المعاملة بالماء الساخن أعطت نتائج جيدة. الثمار التي أعطت النوعية المناسبة كانت من تلك المروية بالمياه المالحة والمعاملة بمادة MCP-1، ومع ذلك فإن النتائج أظهرت صعوبة تمديد فترة التخزين لمدة تصل إلى 30 يوماً. من الناحية الأخرى، فإن معاملة الثمار بالكبريت أو الإيثانول أظهر الإيذاء الشديد عليها. من هذه النتائج نوصي باستخدام أغلفة بلاستيكية نوع GA70 لأنظمة الأغلفة المُعَدِّلة جويا من أجل التخزين لفترات قصيرة (10 أيام) على درجة حرارة 7 مئوي، ومن أجل التخزين لفترات أطول (20 يوماً) وعلى درجة حرارة 7 مئوي يجب استخدام MCP-1، أما التخزين لفترات أطول من هذه فلا يوصى به.