

STUDIES ON THE REMOVAL OF ASTRINGENCY
AND STORAGE OF JAPANESE PERSIMMON
(*Diospyros kaki* L.)

THESIS

By

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D E D I C A T E D

T O M Y

A D O R A B L E

P A R E N T S

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CERTIFICATE - I

This is to certify that the thesis entitled "Studies on the removal of astringency and storage of Japanese persimmon (Diospyros kaki L.)" submitted in partial fulfilment of the requirements for the award of the degree of MASTER OF SCIENCE in Horticulture (Pomology and Fruit Technology) of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan is a faithful record of the bonafide research work carried out by Mr. Sanjay Chadha (Admission No. H-86-14-M) under my guidance and supervision and no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been fully acknowledged.


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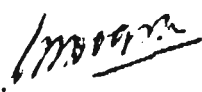
CERTIFICATE - II

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A handwritten signature in cursive script, appearing to read 'Sanjay Chadha', with a horizontal line drawn underneath the name.

(SANJAY CHADHA)

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LIST OF ABBREVIATIONS

A.O.A.C.	Association of Official Analytical Chemists
AgNO ₃	Silver nitrate
CA	Controlled Atmosphere
CaCl ₂	Calcium chloride
cc	cubic centimetre
cm	centimetres
ft	feet
g	grams
HCl	Hydrochloric acid
hl	hundred litres
kg	kilograms
KMnO ₄	Potassium permanganate
m.a.s.l.	metres above sea level
min	minutes
mg	milligrams
ml	millilitres
m	metres
mm	millimetres
NAA	Naphthalene acetic acid
NaOH	Sodium hydroxide
PCA	Pollination constant and astringent
PCNA	Pollination constant and non-astringent
ppm	parts per million
PVA	Pollination variant and astringent
PVNA	Pollination variant and non-astringent
rpm	rotations per minute
TSS	Total soluble solids

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I N T R O D U C T I O N

Chapter 1

INTRODUCTION

The Japanese persimmon, Diospyros kaki L., belongs to the family Ebenaceae and its tree has hard fine wood, oblong leaves and small bell shaped white flowers. It is a deciduous, monoecious tree fairly common in the warm regions of the world, mainly in Asia and South American countries, and is often considered a sub-tropical fruit. Besides D. kaki, three other species, D. lotus L., D. virginiana L., and D. oleifera have been used commercially for the production of fruit. D. kaki, the most important species, has numerous horticultural varieties and is thought to be a native of Japan. However, studies made by Ikegami (1967) suggest that it was introduced from China during the Nara era (A.D. 710 to A.D. 794). Some of the other species related to persimmon and found in India are

D. tomentosa (Tendu), D. discolor, D. embryopteris and D. melanoxylon, which yields Coramendel ebony wood. Many other wild species of Diospyros are found in India (Singh, 1969).

The Japanese persimmon was introduced into India sometime in the early 1920s by European settlers in the Kulu valley of Himachal Pradesh (then of Punjab). During the World War II and after, the import of plant material came to a standstill and so did the extension of area under this fruit.

Mori (1953) has classified the Japanese persimmon into the following four groups:

- (1) Nonstringent and pollination constant varieties (PCNA). They usually have dark tannin spots.
- (2) Nonstringent and pollination variant varieties (PVNA). These have dark tannin spots and may become astringent when seedless.
- (3) Astringent and pollination constant varieties (PCA). They have no dark tannin spots.
- (4) Astringent and pollination variant varieties (PVA). They are astringent when pollinated, and have some dark tannin spots around the seed.

The varieties which undergo no change in the colour of the flesh under the influence of pollination are referred to as 'pollination constant', and those in which the fruit is darkened as a result of pollination are designated 'pollination variant' (Hume, 1914).

The persimmon is a nutritious fruit being a rich source of ascorbic acid, sugars, pectins and tannins. It is a fruit of excellent quality and under favourable conditions produces a heavy crop. The harvesting season of persimmon under Himachal conditions extends from September to December. Fruits are harvested when they attain a yellow to reddish colour but are still firm. The process of ripening in persimmon is fairly slow, and hence the freshly picked fruits have excellent keeping quality making it possible to ship them long distances. However, ripening is not uniform and fruits are astringent (excepting nonastringent varieties) when unripe.

Despite there being great potentials for persimmon cultivation in Himachal Pradesh, its production and trade have remained extremely restricted because of the astringent nature of the

fruit (at harvest) of the predominant varieties grown here; the fruit is edible only after the removal of astringency. Astringency in persimmon is due to water-soluble tannin diospyrin (leuco-delphinidin-3-glucoside) present in the tannin cells (Ito, 1971; Itoo, 1980). These cells increase in size and number during ripening, and it is frequently necessary to apply postharvest treatments to decrease the astringency of the fruit in order to make it acceptable to eat. The soluble tannins are fluid and easily spread over the cut surfaces. The tannin has a strong protein binding capacity and has been used as a deproteinizing agent in the brewing process of sake, the Japanese rice wine. On the other hand, coagulated (polymerised) tannin does not show astringency because of its water insolubility.

The disappearance of astringency with ripening in persimmon fruit is one of the most pronounced ripening changes known. The conventional method of removing astringency is to store persimmon fruits with tomato, mangosteen, pear, passion fruit, cape gooseberry and more slowly with banana. The ethylene gas released by these fruits during their own ripening

helps ripen and remove the astringency of persimmon (Singh, 1969). The practice, unfortunately yields fruits which are too ripe and soft for market and are only fit for immediate consumption, or at the best for local market. There is, therefore, an urgent need to devise methods for scientific removal of astringency of persimmon fruit without undue softening and browning, and without compromising its shipping and marketing quality.

The present study was undertaken to investigate the on-tree and postharvest removal of astringency and its effect on the fruit quality and storage in 'Hachiya' persimmon, an astringent and pollination constant variety - a cultivar of great commercial importance in Himachal Pradesh.

REVIEW OF LITERATURE

Chapter 3

REVIEW OF LITERATURE

Astringency in an immature persimmon fruit is due to the presence of water soluble tannins present in the tannin cells (Ito, 1980). Nakayama and Chichester (1963) suggested that astringency was due to the presence of a delphinidin generating leucoanthocyanin. Studies of its derivatives by Ito and Oshima (1962) proved it to be a leucodelphinidin-3-glucoside. Matsuo and Ito (1978) found that tannin extracted from immature fruit gave delphinidin and cyanidin on acid hydrolysis. Further examination suggested that it consisted of catechin, catechin-3-gallate, gallocatechin, gallocatechin-3-gallate and an unknown terminal residue. Nakabayashi (1971) isolated a polyphenolic compound, β -D-glucogallin (β -1-O-galloyl-D-glucose)

from immature astringent persimmon fruits. A conversion of the astringent tannins from a soluble to an insoluble form occurs as the fruits become non-astringent (Gazit and Levy, 1963).

On-tree and postharvest treatments have been employed in an effort to remove astringency in persimmon fruit. The available literature relevant to the present investigations is reviewed under the following heads:

2.1 On-tree removal of astringency.

2.1.1 Alcohol treatment

2.1.2 Ethylene treatment

2.2 Postharvest removal of astringency.

2.2.1 Warm water treatment

2.2.2 Ethylene treatment

2.2.3 Alcohol treatment

2.2.4 CO₂ treatment

2.2.5 Acetaldehyde treatment

2.2.6 Other treatments

2.3 Storage studies.

2.1 On-tree removal of astringency

2.1.1 Alcohol treatment

Sugiura et al., (1975) developed a method of applying ethanol to remove astringency from the fruit while still on the tree. The astringent fruit was enclosed in polythene bags (0.03 mm thick, 10 x 14.5 cm length) containing 2 to 5 ml of 5 to 20% ethanol and kept on the tree. The ethanol vapours penetrated the flesh of the fruit, primarily through the skin, and successfully removed the astringency. The time required for complete loss of astringency varied with time of treatment, fruit size, concentration and amount of ethanol employed, and the cultivar. Astringency, once removed did not reappear. The flesh of the treated fruits, however, developed brown flecks within 2 weeks and eventually became entirely brown, but fruit with slight remaining astringency did not react thus. Browning was found to be more severe with early or more concentrated ethanol treatments. Sugiura et al. (1985) found that treatment of fruits with ethanol vapour while still on the tree induce darkening of the flesh and reduced the astringency, but had no effect on cold stored fruits.

Sugiura and Tomano (1983) compared the ethanol production in the seeds and its accumulation in the

flesh in relation to their degree of astringency among 47 cultivars. Those which produced relatively high amounts of ethanol and accumulated it in the flesh (PVNA cultivars) lost astringency on the tree, while those producing less ethanol (PVA cultivars) remained astringent. PCNA and PCA cultivars generally produced little ethanol in the seeds and accumulated small amounts or none in the flesh. They suggested that two mechanisms may be involved in loss of astringency - one associated with PVNA, PVA and PCA types and is dependent on the production and accumulation of ethanol and presumably acetaldehyde, whereas the second is associated with PCNA types which do not produce these volatiles.

2.1.2 Ethylene treatment

Japanese persimmon contains little natural ethylene, and ethylene treatment hastens softening, colouring and loss of astringency and causes a sharp increase in CO₂ production in both ripe and unripe fruits (Iwata et al., 1969). Vakamatsu et al., 1973 observed that the ripening of persimmon fruits was advanced by 3 to 9 days by sprays of 15 to 50 ppm ethephon. Fruits from sprayed trees were softer and had less astringency than fruits from unsprayed trees.

Testoni and Sozzi (1979) also found ethephon to be effective in accelerating the ripening process in persimmon. A dose of 10 g/hl gave good results whereas a 20 g/hl treatment gave fruits that were too soft.

2.2 Postharvest removal of astringency

2.2.1 Warm water treatment

The traditional method of removing astringency from persimmon fruit followed in Japan consists of dipping in warm water at 40°C and standing for 15 to 24 hours (Ito, 1980). Kitagawa (1968) noticed an increase in ethyl alcohol, methyl alcohol and acetaldehyde, when immature astringent fruits were immersed in warm water to remove astringency. During the warm water treatment, as the acetaldehyde was formed in the fruit, the astringency disappeared. Kitagawa (1969) found that astringency reappeared after boiling whole persimmon fruits from which astringency had been removed by warm water treatment. This happened because the protoplast of the coagulated tannin cells had gelled. The gel was insoluble in cold water, methanol and ethanol, ether, acetone and formamide, but was soluble in hot water, dilute HCl, methanolic HCl and ethanolic HCl.

2.2.2 Ethylene treatment

The natural ripening process and the respiratory rate of persimmon fruits can be accelerated by treatment by ethylene. Awad and Amenomori (1972) reported that immersing persimmon fruit in 1000 ppm ethephon for one hour followed by storage at room temperature effectively removed the astringency in four days. Rao et al., (1971) observed that mature persimmon fruits ripened within 1 to 3 days after they were dipped in 5000 ppm ethephon before storage at room temperature or kept in air tight chambers in the presence of aqueous ethrel solution at 500 to 5000 ppm and 2 gm sodium hydroxide pellets kept in the centre of the chamber. The ripening time and changes in fruit composition (colour turning red, an increase in TSS, and a marked reduction in phenolic content) were found to be directly proportional to the concentrations of ethephon used. Rouhani et al., (1975) observed a decrease in fruit firmness and pedicel removing force as a result of both ethephon treatment and maturity level of persimmon fruit at harvest.

2.2.3 Alcohol treatment

Eaks (1967) noticed that persimmon fruits

reached the non-astringent condition within 5 days when sealed in a glass chamber with ethyl alcohol. Kato (1984), in a series of experiments, sprayed harvested persimmon fruits with 0 to 50% ethanol on 1, 2, 3 or 4 days of harvest and recorded fruit ethanol concentrations of 0.01 to 1.40% of fresh weight. The higher the ethanol concentration, the shorter was the time taken to decrease tannin concentration and the more rapid was the rate of decrease in astringency. For adequate astringency removal and fruit quality the optimum ethanol concentration in the fruit was 0.1 to 0.2% at 10 to 20°C and about 0.2% at 30°C. Dauriach (1986) reported that spraying boxes (15 kg) of persimmon fruits with a 40% alcohol solution caused the astringency to disappear within 10 days.

Ito (1972) has developed a alcohol vapour method, using specific absorption paper. In this method alcohol is not sprayed on the fruit directly, but rather alcohol vapour evaporates from the absorption paper and causes deastringency of persimmon fruit (packed in polythene bags 0.03 mm thick, within a corrugated cardboard box). After the removal of astringency, the kaki fruit is of good quality.

Kawashima et al., (1984) treated persimmon fruits with 38% ethanol by spraying (control) or by storing with highly absorbent polymer sheets soaked in the solution. It was found that blackening of the pericarp was markedly reduced by the latter method, but astringency removal was slower compared with spraying method.

Consolmagno (1968) describes the construction of curing room to remove the astringency from persimmons. A temperature of 20 to 28°C and a relative humidity of 80% should be maintained. The most common curing method used 0.4-0.6 litres alcohol per cubic metre; the curing time was reduced by pouring the alcohol onto hot bricks.

2.2.4 CO₂ treatment

Firm, crisp non-astringent persimmon fruits can be obtained by sealing them in containers and continuously passing CO₂ or N₂ over the fruits or by periodically flushing sealed chambers of fruit with CO₂ or N₂. After the removal of astringency by CO₂ the fruits remain firm and are easy to handle without damage during normal market periods if refrigerated (Eaks, 1967).

Gazit and Adato (1972) recognised two distinct processes in the disappearance of astringency; that is, an induction process in which exposure of the fruit to CO_2 gas causes chemical reactions related to the deastringency to occur; and a deastringency process, in which the astringency in the fruit gradually disappears and the presence of CO_2 gas is no longer essential. They arrived at this conclusion by treating persimmon fruit for upto 24 hours in a CO_2 atmosphere followed by a period of shelf life. Astringency disappeared only when the fruit had been in a CO_2 atmosphere for at least 6 hours, and the fruits lost their astringency approximately 15 hours after the start of treatment.

Partial softening, a physiological disorder consisting of abnormal softening of the fruit around the blossom end occurs after the removal of astringency by CO_2 treatment (Ito, 1980). The colour of the softening area changes to dark brown in 1 to 2 days. No relationship (Sato et al., 1962) has been found between the degree of partial softening and the stage of ripeness of the fruit. A practical method has not been found for controlling this partial softening but it may be minimised by using the alcohol method for

removing astringency (Sato et al., 1962).

Another disorder of the fruit associated with the removal of astringency by CO₂ is the 'darkening'. Dark speckles appear on the peel with the passage of time (Ito, 1980). The degree of darkening varies with the variety. The varieties Hachiya and Yukono are sensitive, whereas Hiratanenashi and Yotsumizo are immune to this disorder. The mechanism of darkening has not yet been explained, although polyphenoloxidase and peroxidase activities of the peel have been found to increase gradually and reach a maximum with the appearance of darkening (Tsukamoto, 1942).

Matsuo et al. (1976) describe a new Constant Temperature Short Duration (CTSD) method of CO₂ treatment for removal of astringency in persimmon recently developed in Japan. They noted that treatment with CO₂ at 20°C for 18 to 24 hours, followed by storage in air at 30°C for 3 days, produced non-astringent fruits of excellent quality without abnormal softening. Matsuo and Ito (1977) recorded a rapid increase in ethanol content and a gradual one in acetaldehyde content during treatment with CO₂ at 40°C for 6 hours. The soluble tannin content decreased rapidly to two-

third of its initial level after a lag period of 3 hours.

Ito (1986) suggests that dry ice (solid CO_2) may be substituted for the gas by scattering the pieces of dry ice throughout the containers. Sufficient dry ice is added to fill the vessel with gas which is then sealed and left for 3 to 4 days to complete the process.

2.2.5 Acetaldehyde treatment

Kitagawa (1968) observed that mature astringent persimmon fruit, when treated with 20% acetaldehyde solution, became deastringent within 12 hours. Pesis et al., (1986) found the rate of deastringency to be proportional to the acetaldehyde accumulation in the fruit. Pesis and Ben-Arie (1986) have reported that application of malate or pyruvate to pulp discs of astringent fruits causes an immediate increase in acetaldehyde production.

2.2.6 Other treatments

Freezing the persimmon fruit at -25°C for 10 to 90 days causes the soluble tannin content to decrease gradually, but the amount of loss of astringency varies considerably with the variety. This method,

however, does not give complete removal of astringency (Nakamura, 1961).

Attempts have been made to use irradiation of the fruit with 0.15 to 0.26 M rad of gamma rays from a cobalt source as a means of removing astringency, but the fruits become soft (Kitagawa et al., 1964; Ogato et al., 1968).

2.3 Storage studies

A temperature of -1°C (30°F) and relative humidity of 90 to 95% are the recommended conditions for storing persimmon for 3 to 4 months (Lutz and Hardenburg, 1968). Williams (1935) reported 0°C (32°F) as a better temperature than 2° and 5°C (36° and 40°F) because it permitted less ripening. He found that Australian fruit could be held for 6 months. Experiments with California persimmons by Overholser and Hodgson (1922) demonstrated that fruit could be stored for 2 months at 0°C (32°F) and still have 8 days market life after removal. The ranking in keeng quality was Tamopan, Hachiya, Fuyu, and two minor cultivars.

Wardlow (1937) reviewed the literature on the storage of persimmons and cited Dorsett's (1928) observation in China. He saw millions of persimmon stored outdoors where they would be held from harvest

until March. The persimmons were stored 6 fruits deep on a bed of Sorghum stems placed across trenches to give drainage and ventilation. The fruit was covered with a light reed grass matting to protect it from rain. After the fruit became frozen they were then covered with about 0.6 m (2 feet) of dry grass to keep them frozen until spring. Some of the beds were 402 m (1320 ft) long, and in a small valley in the eastern hills about 60 miles north-west of Peking (now Beijing), Dorsett estimated that 2300 tonnes were stored in this fashion. The winters in this area are dry and cold (Ryall and Pentzer, 1982).

El-Wahab et al., (1983) reported the overall storage period of persimmon fruits to be 31 days at room temperature, the main cause of deterioration being shrivelling. Shaybany et al., (1978) observed that regardless of the types of containers used, both astringency and firmness were reduced by increased storage temperatures and duration. However, at 20 days of storage the persimmon fruits kept in open containers were softer and riper than fruits kept in polythene bags. Young et al., (1981) found polythene film 0.1 mm thick to be the best for sealing astringent persimmon cultivars. The weight loss was also reduced

by sealed storage. El-Wahab et al., (1983) reported that persimmon fruit dipped in ethephon had better storability than those immersed in it, and among the various concentrations (100 to 1500 ppm) 100 ppm ethephon resulted in the best shelf life.

Testoni et al., (1981), after storage of 11 cultivars at 0°C for 65 or 85 days, found fruits of the cultivars Hachiya, Lycopersicon, Sakvamiathan, Hana Fuyu and Fuyu to be the most attractive and having the best storage properties. Tovkach (1979) observed that long term storage of different persimmon cultivars was only possible with fruit showing low pectin and ascorbic acid fluctuations.

Controlled Atmosphere (CA) storage is not used commercially for persimmons but Ito (1971) reported that 8% CO₂ and 3 to 5% O₂ at 1°C (34°F) and 90 to 100% relative humidity appeared to be the optimum. Storage in sealed polythene bags of 0.06 mm thickness at 0°C (32°F) produced atmospheres of 5% CO₂ and 5 to 8% O₂ and almost 100% relative humidity, and increased storage life (Tarutani, 1960).

Ben-Arie and Guelfat-Reich (1976), working in Israel, have investigated the possibilities of

removing the natural astringency of unripe persimmon through CA storage. They found that CA storage at -1°C (30°F) or 0°C (32°F) enabled astringency removal if the CO_2 was 12% or more and the O_2 was 3 to 5%. Under these conditions there was a severe pulp injury and off flavour. At 3 to 9% CO_2 , astringency was reduced but not entirely removed. It was necessary to give the fruit 12 or more hours at 90% CO_2 at 17°C (63°F) to make the fruit edible. In a later paper Ben-Arie and Guelfat-Reich (1976) reported that simply using 90% CO_2 at 17°C (63°F) removed the astringency of 'Triumph' persimmon during, before, or after storage at -1°C (30°F).

Pesis et al., (1986) removed astringency of persimmon fruits by wrapping them in polythene bags with evacuated, N_2 or CO_2 atmosphere. The deastringency process was the fastest under CO_2 atmosphere, where acetaldehyde accumulated most rapidly, but the fruits were susceptible to flesh browning. They noticed that fruits stored under vacuum or N_2 atmosphere maintained high quality and firmness for 2 weeks at 20°C and 3 months at -1°C . Little and Taylor (1983) report that treating fruits with 90% CO_2 after controlled atmosphere storage before marketing, removes astringency.

MATERIALS AND METHODS

Chapter 3

MATERIALS AND METHODS

The present investigations on the on-tree and postharvest removal of astringency and its effect on the fruit quality and storage of Hachiya - an astringent type persimmon were carried out in the Department of Pomology and Fruit Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan during the year 1987-88. Plant material from Rajindar Orchards and Nurseries, Kotkhai (1600 m.a.s.l.) in Shimla district was used in these investigations and the biochemical analyses were done in the Postharvest Physiology Laboratory of the erstwhile Department of Pomology and Fruit Technology, and later of the Department of Postharvest Technology, Nauni, Solan.

The investigations were carried out in two experiments, assigned to a block of twelve 18-year

old uniform trees selected and maintained under a strictly uniform schedule of cultural operations. The two experiments comprised of nine and six treatments respectively.

3.1 Experiment I - On tree removal of astringency

- T₁ Spraying the fruit with 30% ethanol and covering it with polythene bag (0.03 mm thick, 10 x 14 cm length).
- T₂ Enclosing fruit in polythene bag (0.03 mm, 10 x 14 cm) containing 3 ml of 15 to 20% ethanol.
- T₃ Spraying the fruit with 5% acetaldehyde and enclosing it in polythene bag (0.03 mm, 10 x 14 cm).
- T₄ Enclosing the fruit in polythene bag (0.03 mm, 10 x 14 cm) containing 5 ml of 5% acetaldehyde.
- T₅ Spraying fruit with Alar 500 ppm, 45 days before harvest.
- T₆ Spraying fruit with ethephon 500 ppm + NAA 10 ppm, 12 days before harvest.
- T₇ Spraying fruit with Alar 500 ppm 45 days before harvest, and with ethephon 500 ppm + NAA 10 ppm 12 days before harvest.
- T₈ Enclosing the fruit in polythene bag (0.03 mm, 10 x 14 cm) without any treatment.
- T₉ Control - no treatment.

3.2 Experiment II - Postharvest removal of astringency

- P₁ Dipping the fruits in warm water (at 40°C) for 3 to 4 minutes and holding them for 15 hours at 20°C before storage in polythene bags.
- P₂ Spraying the fruits with 35% ethanol, enclosing in polythene bags and holding for 5 days at 20°C before storage.
- P₃ Sealing the fruits in a 5 litre plastic container with tight fitting cover together with 10 ml of 35% ethanol and holding for 5 days at 20°C before storage.
- P₄ Spraying the fruits with 5% acetaldehyde, enclosing in polythene bags and holding for 5 days at 20°C before storage.
- P₅ Sealing the fruits in plastic containers with 10 ml of 5% acetaldehyde and holding for 5 days at 20°C before storage.
- P₆ Control - enclosing fruit in polythene bags without treatment, and subsequent storage.

Preharvest sprays for on-tree removal of astringency were given to nine trees on four preselected limbs each and the experiment was laid out in randomised block design with one tree per treatment replicated four times (one limb per replication). Three trees were retained exclusively for providing fruits for postharvest treatments, the experiment being laid out in completely

randomised design with four replications. On-tree treatments were made on September 27th, 1987 except in case of Alar where the spray was given on 25th August, 1987. The fruits for both the experiments were harvested at optimum maturity as assessed by colour change on 9th October, 1987 and brought to the laboratory the same day in tray filled Corrugated Fibre Board cartons. All precautions were taken and care exercised to see that the fruits were not damaged in transit.

In the laboratory blemished, bruised or otherwise damaged and misshapen fruits, if any, were discarded. In all seven hundred twenty fruits representing 72 sample units (a sample unit comprising ten fruits) were selected for Experiment I, and 480 fruits representing 48 sample units for Experiment II were selected for physicochemical analyses and storage.

The physico-chemical analyses of fruit samples were done before and after 60 days storage at $0^{\circ} \pm 1^{\circ}\text{C}$ as per following procedures:

3.3.1 Size, weight, volume and specific gravity

Fruit size, in terms of length and diameter, was recorded with the help of Vernier callipers and

expressed in mm/fruit. Fruit weight was recorded on a spring balance and was expressed in g/fruit. Fruit volume was determined by water displacement method and expressed as cc/fruit. Specific gravity was calculated by dividing the weight of the fruit by its volume.

3.3.2 Total soluble solids (TSS)

The total soluble solids were determined with Atago Digital Refractometer Model RX-1 with automatic temperature control and results expressed as per cent soluble solids.

3.3.3 Total sugars, reducing sugars and non-reducing sugars

Twenty g fruit tissue was macerated and homogenized with distilled water in Vir Tis-45 homogenizer for 5 min at 4500 rpm. The volume of the homogenate was raised to 200 ml with distilled water. The extract was neutralised with 1 N sodium hydroxide. Ten ml of 45 per cent lead acetate was added to this extract and it was allowed to stand for 30 minutes, followed by filtration and addition of 2 ml of 22 per cent potassium oxalate. Extracts were again filtered through Whatman 1 filter paper. From this filtrate 50 ml were drawn and hydrolysed with concentrated hydrochloric acid (HCl)

and left overnight for the analysis of total sugars. The left over extract was used for the analysis of reducing sugars.

Reducing sugars and total sugars were determined by standard A.O.A.C. method (Horwitz, 1980) and results expressed as per cent sugars. The amount of non reducing sugars was calculated by subtracting reducing sugars from total sugars and multiplying the difference by 0.95 and results expressed as per cent non reducing sugars.

3.3.4 Pectins

Pectin was estimated by Carre and Haynes method of 1922 as described by Ruck (1963). Fifty g of blended sample was extracted with 400 ml of 0.05 N HCl for two hours at 80 to 90°C. Water lost by evaporation was replaced and the volume was made to 500 ml by adding distilled water. After filtration, 100 ml of the filtrate was taken to which a drop of phenolphthalein was added and the solution neutralized by 0.05 N NaOH. To this, 20 ml of 0.05 N NaOH was added and kept overnight. Next day, 50 ml of 1 N acetic acid and after 5 minutes, 25 ml of 1 N CaCl₂ solution were added. After allowing it to stand for 1 hour, the solution was filtered through a previously

weighed and prepared Whatman 1 filter paper (wetted in hot water, dried at 102°C for two hours and cooled in a desiccator). The precipitate was washed with almost boiling water a number of times, until it was chloride free. The absence of chloride was tested with AgNO₃ solution. The filter paper together with the precipitate was dried overnight in an oven at 100°C, cooled in a desiccator and weighed. The weight of the precipitate was determined and the pectin as percent calcium pectate was calculated by the use of the following formula:

$$\% \text{ Calcium pectate} = \frac{\text{Weight of precipitate} \times 500 \times 100}{\text{Volume of filtrate taken for estimation} \times \text{Weight of sample}}$$

3.3.5 Soluble tannins,

The tissue extracts for the quantitative analysis of soluble tannins were prepared by hot methanol extraction (Joslyn and Goldstein, 1964). The fruit was halved and portions of tissues from the mesocarp region adjacent to the seed cavity were cut out with a cork borer. Tissue from four segments was obtained and 2.5 g portions of composite sample was weighed out into 25 ml of methanol and heated to boiling for 10 minutes, the tissue being pressed out with a glass

rod to facilitate penetration of solvent and extraction of soluble tannins. The methanol extract was then decanted from the residue and filtered, and the residue returned to the flask and further extracted with absolute methanol. The tissue was extracted five successive times in the same manner and the filtrates were combined and made upto 100 ml. The residual tissue was re-extracted three times with 50% methanol and the filtrates were made upto 50 ml with 50% methanol.

The soluble tannins so extracted were quantitatively estimated by A.O.A.C. procedure by determining their oxidizability by potassium permanganate solution (Horwitz, 1980). To an aliquot of the extract in a porcelain dish, 20 ml of indigo carmine solution and about 500-700 ml of water was added. Potassium permanganate solution (0.04 N) was added 1 ml at a time from a burette with vigorous stirring, until the colour changed to light green. Then it was added dropwise until the colour changed to a faint pink at the rim. The millimetres of potassium permanganate used were noted (A). To 50 ml of the filtered extract in a 250 ml flask, 25 ml of gelatin solution was added and the volume made up with acid sodium chloride

solution. The solution was transferred to a conical flask and after shaking for 15 minutes, was filtered. To 50 ml of the filtrate 20 ml of indigo carmine solution and about 500-700 ml of water were added and titrated as before with potassium permanganate solution (B). The amount in millimetres of potassium permanganate solution used in this case (B) subtracted from (A) gave the quantity of potassium permanganate solution required to oxidise the tannins. Per cent tannins were calculated using the formula:

$$\% \text{ tannins} = \frac{\text{Titre} \times 100 \times \text{g of tannin per ml KMnO}_4 \text{ sol.}}{\text{ml of aliquot taken}}$$

$$(1 \text{ ml of } 0.1 \text{ N KMnO}_4 = 0.0042 \text{ g of tannin})$$

The degree of, astringency was also evaluated by pressing one-half of the fruit against a filter paper previously soaked with a 5% FeCl_3 solution and dried (Eaks, 1967). The astringent soluble tannins react with the FeCl_3 to form a black complex. The amount of black colour is an indication of the astringency level: 3 (high), 2 (medium), 1 (low), 0 (nil).

3.3.6 Ascorbic acid (Vitamin C)

Quantitative determination of ascorbic acid

was done according to A.O.A.C. method (Horwitz, 1980) using 2, 6 - dichlorophenol indophenol.

Reagents

(a) Extracting solution

15 g of metaphosphoric acid pellets were dissolved in 40 ml glacial acetic acid and 200 ml of water and diluted to 500 ml. The solution was filtered rapidly through a filter paper in a glass stoppered bottle and stored in refrigerator.

(b) Ascorbic acid standard solution

50 g analytical grade (Reference standard) ascorbic acid was weighed and transferred to 50 ml volumetric flask. It was diluted to volume immediately before use with metaphosphoric acetic acid solution.

(c) Indophenol standard solution

50 mg, 2, 6-dichlorophenol indophenol sodium salt that had been stored in a desiccator over soda lime was dissolved in 50 ml double distilled water to which had been added 42 mg sodium bicarbonate. It was shaken vigorously and when the dye had dissolved, diluted to 200 ml with distilled water and filtered into an amber coloured glass stoppered bottle and stored in a refrigerator.

Procedure

A known quantity of homogenized fruit extract was taken and an equal volume of extracting solution was added and titrated against indophenol standard solution. A rose pink colour indicated the end point. The titration was repeated with the buffer solution for the blank. The results were expressed as mg ascorbic acid per 100 g fresh weight of fruit tissue.

3.3.7 Organoleptic evaluation

A taste panel of 10 University staff/students were selected for tasting session. The panelists were given coded samples, each sample consisting of a longitudinal section from four persimmon fruits. The panelists were asked to assess the sample for general appearance, astringency, firmness and taste and flavour of the fruit, using a five point hedonic scale for each attribute (Wills et al., 1980)

- 1 = Unacceptable
- 2 = poor
- 3 = satisfactory
- 4 = good
- 5 = excellent

The scores produced by the various panelists

were totalled for each attribute and mean values calculated. When the mean value for overall quality for fruit was 2 (= poor) no further testing was carried out on that fruit as poor quality was regarded as less than acceptable at the market.

3.3.8 Statistical analyses

The observations taken were subjected to analysis of variance appropriate to the design of the experiments. The fruits that were observed to have rotted during the stipulated storage period were designated zero value and the data were Square root transformed, using the formula $\sqrt{x + 1}$. The design of the experiment for on-tree treatment was randomised block design and that for postharvest treatments, completely randomised design.

EXPERIMENTAL RESULTS

Chapter 4

EXPERIMENTAL RESULTS

The present investigations on the on-tree and postharvest removal of astringency and its effects on storageability of Hachiya persimmon - an astringent type cultivar, were carried out in 1987. The results obtained are given below:

4.1 On-tree treatments

4.1.1 Fruit size, weight, volume and specific gravity

The data on size, weight and volume of the fruit at harvest and at the end of stipulated 60 days storage are presented in Table 1.

A perusal of the data reveals that the size of the fruit in terms of length and diameter was not affected by any preharvest treatment except T₅ and T₇. The fruit size was recorded to be the largest in T₈ the values being on a par with T₉, T₃, T₄, T₆, T₁ and

On-tree treatments		FRUIT SIZE						Weight (g)			Volume(cc)			Sp.gravity	
		Length(cm)		Diameter(cm)		L/D ratio									
								D A Y S			I N S T O R A G E				
		0	60	0	60	0	60	0	60	% Loss	0	60	% Loss	0	60
Spraying the fruit with 30% ethanol and covering it with polythene bag.	T ₁	7.46	7.45 (2.90)	6.79	6.78 (2.78)	1.09	1.09	215.75	212.00 (14.58)	1.83	200.75	199.50 (14.15)	0.62	1.07	1.06 (1.42)
Enclosing fruit in polythene bag containing 3ml of 15-20% ethanol.	T ₂	7.39	7.37 (2.89)	6.74	6.73 (2.77)	1.09	1.09	213.75	208.00 (14.45)	2.69	202.00	196.30 (14.04)	2.80	1.06	1.06 (1.42)
Spraying the fruit with 5%acetaldehyde and enclosing in polythene bags.	T ₃	7.51	Rotted (0.16)	6.78	Rotted (0.16)	1.10	Rotted	207.25	Rotted (0.16)	-	195.25	Rotted (0.16)	-	1.06	Rotted (0.16)
Enclosing the fruit in polythene bag containing 5ml of 5% acetaldehyde.	T ₄	7.49	Rotted (0.16)	6.76	Rotted (0.16)	1.10	Rotted	209.25	Rotted (0.16)	-	196.50	Rotted (0.16)	-	1.07	Rotted (0.16)
Spraying fruit with Alar 500ppm 45 days before harvest.	T ₅	7.01	7.05 (2.83)	6.41	6.40 (2.71)	1.10	1.10	176.25	170.00 (13.07)	3.54	166.25	160.25 (12.69)	3.61	1.09	1.09 (1.44)
Spraying fruit with ethephon 500 ppm + NAA 10 ppm, 12days before harvest	T ₆	7.48	7.40 (2.89)	6.81	6.74 (2.77)	1.09	1.09	227.75	211.25 (14.56)	7.58	212.50	197.00 (14.06)	7.29	1.07	1.08 (1.43)
Spraying fruit with Alar 500 ppm 45 days before harvest and with ethaphon + NAA 10 ppm 12 days before harvest.	T ₇	7.04	7.14 (2.85)	6.61	6.58 (2.74)	1.08	1.08	186.25	176.50 (13.31)	5.23	174.25	163.25 (12.81)	6.31	1.07	1.08 (1.43)
Enclosing fruit in polythene bag without any treatment.	T ₈	7.56	7.55 (2.92)	6.81	6.79 (2.78)	1.10	1.10	201.75	196.50 (14.04)	2.60	188.50	187.30 (13.71)	6.63	1.07	1.07 (1.43)
Control - No treatment	T ₉	7.53	7.50 (2.91)	6.80	6.76 (2.78)	1.10	1.10	207.00	199.25 (14.14)	3.74	193.50	184.75 (13.60)	4.39	1.07	1.08 (1.43)
C.D. (0.05)		0.41	0.01	0.29	0.01	NS	NS	15.87	0.40		15.29	0.32		NS	0.01

The values in the parentheses are square root transformed using the formula $\sqrt{x+1}$

T₂ (in descending order). The smallest fruit size and also the lowest weight and volume, on the other hand, were recorded in fruits sprayed with Alar 500 ppm (T₅), the treatment being on a par with T₇ where the fruits had received Alar 500 ppm 45 days before harvest and ethephon 500 ppm + NAA 10 ppm 12 days before harvest. No significant differences in the length to diameter ratio could be observed among different treatments.

The average weight and volume of the fruit was recorded to be the highest in T₆, which though on a par with T₁ and T₂, was significantly superior to the rest. On the other hand, fruits sprayed with Alar 500 ppm (T₅) and those sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇) recorded the lowest average fruit weight and volume, being significantly inferior in this respect to other treatments. The values for fruit weight and volume recorded by other treatments viz., T₃, T₄, T₈ and T₉ were on a par with each other. No significant treatment differences in the specific gravity of fruits were observed at harvest.

After the stipulated 60 days storage, the lowest weight and volume were recorded in fruits sprayed with Alar 500 ppm (T₅) followed by those sprayed with

Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇). Ethanol 30% sprayed fruits (T₁), on the other hand, recorded the highest weight and volume, the values being on a par with fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T₆) and enclosed with 15-20% ethanol (T₂), but superior to those enclosed in polythene bags (T₈), control (T₉), sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇) and Alar 500 ppm (T₅) in descending order. The loss in fruit weight and volume was, however, recorded to be the highest in fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T₆), followed by the ones sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇), control (T₉) and those sprayed with Alar 500 ppm (T₅). The lowest weight loss (less than 1%), on the other hand, was recorded in fruits sprayed with ethanol 30% (T₁), followed in ascending order by the ones enclosed in polythene bags with 15-20% ethanol (T₂) and those covered with polythene bags without treatment (T₈) at the end of 60 days storage.

The specific gravity of fruit after 60 days storage was recorded to be the highest in Alar 500 ppm sprayed (T₅) fruits, the values being on a par with fruits from ethephon 500 ppm + NAA 10 ppm (T₆),

Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T_7), polythene bag (T_8) and control (T_9) but superior to ethanol treatments (T_1 and T_2). No significant differences in length to diameter ratio of fruits after the stipulated storage period were observed among the various treatments.

Almost all the fruits treated with acetaldehyde 5% (T_3 and T_4) were observed to have either rotted or rendered unfit for consumption during storage.

4.1.2 Total soluble solids, total sugars, and reducing and non-reducing sugars

The data on the total soluble solids (TSS), total sugars as well as reducing and non-reducing sugars are presented in Table 2.

The data reveal that TSS, total sugar and reducing sugar contents were the highest in fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T_6) and the lowest, on the other hand, in fruits sprayed with Alar 500 ppm (T_5). The TSS and the reducing sugar contents of fruits sprayed with Alar 500 ppm (T_5) and control (T_9) were on a par with each other but significantly inferior to those under other treatments. However, the total sugar content of fruits in these treatments was on a par with that of other

Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T_7), polythene bag (T_8) and control (T_9) but superior to ethanol treatments (T_1 and T_2). No significant differences in length to diameter ratio of fruits after the stipulated storage period were observed among the various treatments.

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Table 2 - Effect of the on-tree treatments on the TSS, total sugar, reducing and non-reducing sugar contents at harvest and after 60 days storage.

On-tree treatments	TSS (%)			Total Sugar (%)			Reducing sugar (%)			Non-reducing sugar (%)		
				D A Y S			I N			S T O R A G E		
	0	60	% Loss	0	60	% Loss	0	60	% Loss	0	60	% loss
T ₁	18.15	16.25 (4.14)	10.47	14.97	13.51 (3.81)	9.75	13.33	12.27 (3.64)	7.9	1.56	0.95 (1.39)	39.10
T ₂	18.30	16.42 (4.17)	10.27	15.02	13.81 (3.85)	8.06	13.20	12.54 (3.68)	5.0	1.73	1.16 (1.46)	32.95
T ₃	18.12	Rotted (0.16)	-	15.21	Rotted (0.16)	-	13.32	Rotted (0.16)	-	1.80	Rotted (0.16)	-
T ₄	18.25	Rotted (0.16)	-	15.30	Rotted (0.16)	-	13.31	Rotted (0.16)	-	1.80	Rotted (0.16)	-
T ₅	16.85	14.70 (3.95)	12.76	14.72	11.36 (3.52)	22.82	11.98	11.15 (3.48)	6.93	1.65	0.88 (1.36)	46.66
T ₆	19.26	14.61 (3.94)	22.32	16.10	10.66 (3.41)	33.79	14.26	9.78 (3.28)	31.42	1.75	0.69 (1.29)	60.57
T ₇	19.15	15.02 (4.00)	21.57	15.37	10.23 (3.35)	33.44	14.17	11.03 (3.47)	21.94	1.80	0.87 (1.36)	51.66
T ₈	18.03	15.93 (4.10)	11.64	15.01	13.69 (3.84)	8.79	13.40	12.47 (3.67)	6.94	1.53	0.93 (1.37)	39.21
T ₉	16.97	13.99 (3.86)	17.56	14.81	9.91 (3.30)	33.09	12.41	10.43 (3.38)	15.95	1.33	0.67 (1.28)	49.62
C.D. (0.05)	0.86	0.01		0.58	0.09		0.77	0.03		NS	0.08	

The values in the parentheses are square root transformed using the formula $\sqrt{x+1}$

treatments except those sprayed with ethephon 500 ppm + NAA 10 ppm (T_6), which recorded the highest total sugar content. No significant treatment differences in non-reducing sugars could be observed at harvest.

After 60 days storage at $0 \pm 1^\circ\text{C}$ the highest TSS, total sugar, reducing and non-reducing sugar contents were observed in fruits enclosed in polythene bags with 15-20% ethanol (T_2) and the lowest in control fruits (T_9). The TSS content of fruits sprayed with Alar 500 ppm (T_5), and ethephon 500 ppm + NAA 10 ppm (T_6) was on a par but inferior to other treatments except control (T_9). The total sugar and reducing as well as non-reducing sugar contents of fruits sprayed with ethanol 30% (T_1) was on a par with the ones enclosed in polythene bags (T_8), but superior to other treatments. The TSS content of fruits sprayed with Alar 500 ppm (T_5) was on a par with ethephon 500 ppm + NAA 10 ppm (T_6) but inferior to other treatments except control (T_9). The reducing sugar contents of fruits sprayed with Alar 500 ppm (T_5) and Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T_7) were on a par with each other but inferior to other treatments except control (T_9). No significant differences in

non-reducing sugars were observed in fruits under T_5 , T_6 , T_7 and T_9 , which were on a par but were significantly superior to other treatments in this respect. The percent loss in TSS, total sugar, reducing as well as non-reducing sugar contents was recorded to be the lowest in fruits enclosed with ethanol 15-20% (T_2), followed by those sprayed with ethanol 30% (T_1), enclosed in polythene bags (T_8), and those sprayed with Alar 500 ppm (T_5) in ascending order. The highest loss, on the other hand, was observed in fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T_6). The fruits sprayed with Alar 500 ppm followed by ethephon 500 ppm + NAA 10 ppm (T_7) and untreated control (T_9) also recorded fairly high losses in these attributes. The fruits treated with acetaldehyde 5% (T_3 and T_4) rotted during storage.

4.1.3 Soluble tannins

The data on soluble tannins as affected by various on-tree treatments are given in Table 3.

It is evident that all the treatments except Alar 500 ppm (T_5) were effective in sharply lowering the soluble tannin content of fruits. The lowest soluble tannin contents were recorded with ethephon treatment (T_6) the values being on a par with T_7 , T_1 .

Table 3 - Effect of the on-tree treatments on the soluble tannin, pectin and ascorbic acid contents of the fruit at harvest and after 60 days storage.

On-tree treatments	Astringency level (FeCl ₃ test)		Soluble tannins (%)		Pectins (%)			Ascorbic acid (mg/100 g f.w.)		
					D A Y S I N S T O R A G E					
	0	60	0	60	0	60	% loss	0	60	% loss
T ₁	1	0	0.18	0	0.95	0.78 (1.33)	17.89	13.1	8.1 (3.01)	38.16
T ₂	2	0	0.24	0	0.92	0.69 (1.29)	25.00	14.2	9.3 (3.20)	34.51
T ₃	2	Rotted	0.19	Rotted	0.60	Rotted (0.16)	-	11.7	Rotted (0.16)	-
T ₄	2	Rotted	0.22	Rotted	0.57	Rotted (0.16)	-	10.8	Rotted (0.16)	-
T ₅	3	0	1.63	0.08	1.01	0.83 (1.34)	17.82	19.2	13.3 (3.77)	30.70
T ₆	0	0	0.08	0	0.54	0.24 (1.10)	55.56	11.3	6.2 (2.68)	49.59
T ₇	0	0	0.10	0	0.68	0.31 (1.14)	54.41	12.3	7.1 (2.84)	37.17
T ₈	3	0	0.78	0	0.91	0.71 (1.30)	21.97	13.8	8.9 (3.14)	35.51
T ₉	3	0	1.68	0	0.89	0.56 (1.24)	37.08	12.3	6.3 (2.69)	48.78
C.D. (0.05)			0.09		0.08	0.02		1.99	0.05	

The values in the parentheses are square root transformed using the formula $\sqrt{x+1}$

T₃ and T₄. Alar 500 ppm treated fruits (T₅) and the ones from untreated control (T₀), on the other hand, recorded the highest soluble tannin contents both being on a par with each other. On the basis of FeCl₃ test for determining the degree of astringency, the fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T₆) and Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇) had no astringency while the fruit sprayed with ethanol 30% (T₁) were slightly astringent. The fruits enclosed with ethanol 15-20% (T₂) and given acetaldehyde treatments (T₃ and T₄) had medium degree of astringency while those under other treatments were highly astringent.

After 60 days storage at $0 \pm 1^{\circ}\text{C}$ the soluble tannin completely disappeared in all the treatments including control and only negligible amounts were recorded in Alar treated (T₅) fruits. The fruits treated with 5% acetaldehyde (T₃ and T₄) rotted during storage.

4.1.4 Total pectin

The data on total pectin content of fruits as affected by various on-tree treatments at harvest and after 60 days storage are presented in Table 3.

It is seen that the highest pectin content was

recorded from fruits sprayed with Alar 500 ppm (T_5), the values being on a par with those sprayed with ethanol 30% (T_1) but superior to fruits from other treatments. The pectin content of fruits sprayed with ethanol 30% (T_1) was, however, on a par with those enclosed with 15-20% ethanol (T_2), covered with polythene bag (T_8) and control (T_9). The pectin content of fruits sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T_7) while being on a par with that of acetaldehyde 5% sprayed fruits (T_3) was superior to fruits enclosed with acetaldehyde 5% (T_4), and ethephon 500 ppm + NAA 10 ppm (T_6), the latter having the lowest pectin content.

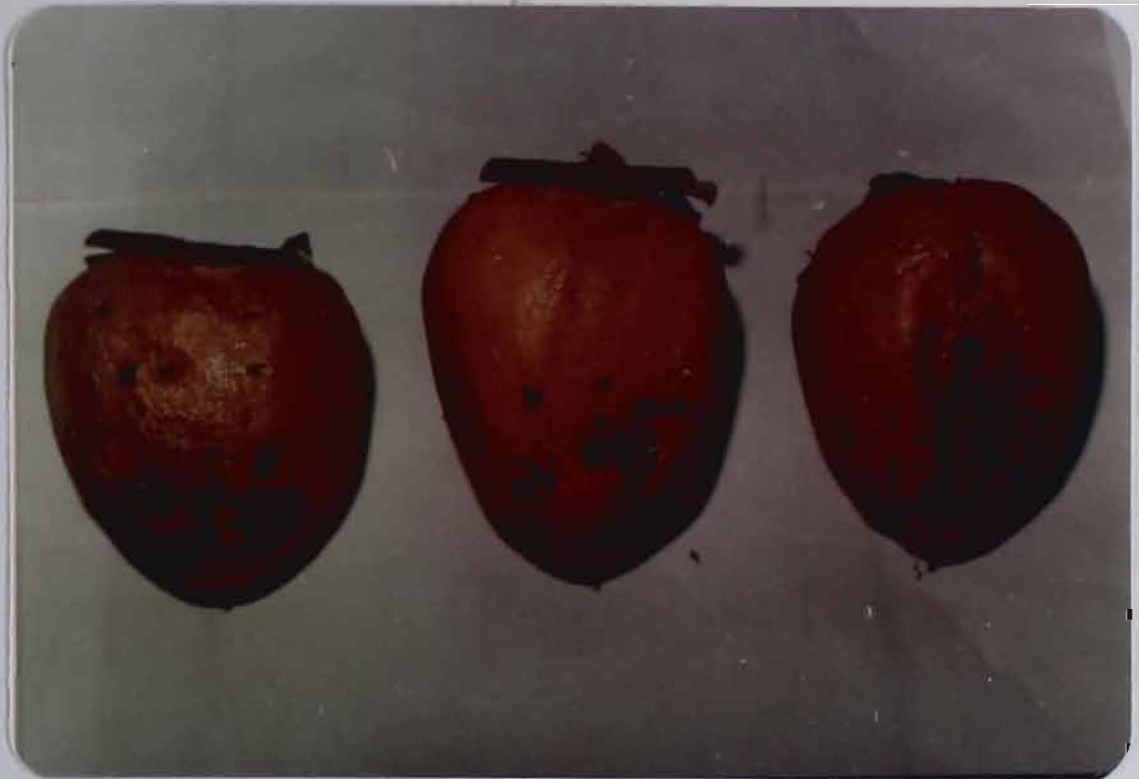
The minimum per cent loss in pectin content at the end of 60 days storage was recorded in fruits sprayed with Alar 500 ppm (T_5), followed closely by those sprayed with ethanol 30% (T_2). Maximum loss, on the other hand, was observed in fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T_6). The fruits enclosed in polythene bags (T_8) and the ones enclosed with ethanol 15-20% (T_2) exhibited considerably lower loss in pectin content as compared to fruits from T_6 , T_7 and T_9 . The fruits treated with acetaldehyde 5% (T_3 and T_4) were observed to have rotted during storage.

4.1.5 Ascorbic acid

The ascorbic acid content of the fruits at harvest and after 60 day storage are presented in Table 3.

The fruits sprayed with Alar 500 ppm (T_5) had significantly higher ascorbic acid content at harvest than the fruits under other treatments. The ascorbic acid content of fruits treated with ethanol (T_1 and T_2) sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T_7), those enclosed in polythene bags (T_8), and control (T_9) fruits were on a par with each other at harvest and were superior in this respect to fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T_6), acetaldehyde 5% (T_3), and enclosed with acetaldehyde 5% (T_4), the latter recording the lowest ascorbic acid content.

After 60 days storage at $0 \pm 1^\circ\text{C}$, the fruits sprayed with Alar 500 ppm (T_5) recorded the highest ascorbic acid content being significantly superior to other treatments in this respect. The lowest ascorbic acid contents, on the other hand was recorded in fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T_6) and control (T_9). The percent loss in ascorbic acid content was recorded to be minimum in fruits sprayed with Alar



Fruits given on-tree acetaldehyde 5%
spray (T_3), at harvest



Fruits enclosed on-tree with
acetaldehyde 5% (T_4), at harvest

500 ppm (T₅) followed by those enclosed with ethanol 15-20% (T₂), in polythene bags (T₈) sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇), ethanol 30% (T₁) and control (T₉) in ascending order. The loss was recorded to be the highest in fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T₆). The fruits treated with acetaldehyde 5% (T₃ and T₄) were observed to have rotted during storage.

4.1.6 Organoleptic evaluation

The organoleptic score based on general appearance, astringency, taste and flavour and firmness are presented in Table 4.

The fruits sprayed with ethephon 500 ppm + NAA 10 ppm (T₆) and those sprayed with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇) had excellent general appearance, taste and flavour at harvest, but the former were soft and slightly shrivelled. The fruits given ethanol 30% spray (T₁) and those enclosed with ethanol 15-20% (T₂) had good general appearance, taste and flavour and were firm with no shrivelling, but were slightly astringent. The fruits treated with acetaldehyde 5% (T₃ and T₄) ranked poor in general appearance, taste and flavour and fair in firmness. The fruits sprayed with Alar 500 ppm (T₅), those

Table 4 - Quality of fruits based on organoleptic evaluation given on-tree treatments, at harvest and after 60 days storage.

On-tree treatments	Organoleptic rating	
	DAYS	IN STORAGE
	0	60
T ₁	2.7	4.1
T ₂	2.8	3.9
T ₃	2.1	1.0
T ₄	1.9	1.0
T ₅	3.1	3.8
T ₆	4.2	1.5
T ₇	4.2	2.8
T ₈	2.8	4.1
T ₉	2.7	1.9

enclosed in polythene bags (T_8) and control (T_9) had a good general appearance and were very firm but highly astringent and unacceptable for immediate consumption at harvest.

The fruits sprayed with ethanol 30% (T_1), enclosed with ethanol 15-20% (T_2), and those covered with polythene bag (T_8) had good general appearance, taste and flavour and exhibited no astringency after the stipulated 60 days storage period. The fruits from these treatments scored the highest on organoleptic rating. The fruits sprayed with Alar 500 ppm (T_5) and with Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T_7) had a fair general appearance, taste and flavour, no astringency and were quite firm but the fruits under the latter treatment showed a high amount of shrivelling. The fruits under other treatments were not acceptable for consumption after the stipulated storage period.

4.2 Postharvest treatments

4.2.1 Weight, volume and specific gravity

The effect of various postharvest treatments on the weight, volume and specific gravity before and after storage are presented in Table 5.

Table 5 - Effect of postharvest treatments on the weight, volume and specific gravity of the fruits stored.

Postharvest treatments		Weight (g)			Volume (cc)			Specific gravity	
		0	60	% loss	D A Y S I N S T O R A G E			0	60
					0	60	% loss		
Dipping the fruits in warm water (at 40°C) for 3 to 4 minutes and holding them for 15 hours at 20°C before storage in polythene bags.	P ₁	156.75	Rotted (0.16)	-	146.25	Rotted (0.16)	-	1.07	Rotted (0.16)
Spraying the fruits with 35% ethanol enclosing in polythene bags and holding for 5 days at 20°C before storage.	P ₂	176.75	175.25 (13.22)	0.58	165.25	164.50 (12.83)	0.45	1.06	1.06 (1.43)
Sealing the fruits in a 5 litre plastic container with tight fitting cover together with 10 ml of 35% ethanol and holding for 5 days at 20°C before storage.	P ₃	194.25	193.50 (13.93)	0.38	181.50	180.50 (13.46)	0.58	1.07	1.07 (1.44)
Spraying the fruits with 5% acetaldehyde enclosing in polythene bags and holding for 5 days at 20°C before storage.	P ₄	167.25	Rotted (0.16)	-	156.25	Rotted (0.16)	-	1.07	Rotted (0.16)
Sealing of fruits in plastic containers with 10 ml of 5% acetaldehyde and holding for 5 days at 20°C before storage.	P ₅	169.00	Rotted (0.16)	-	159.25	Rotted (0.16)	-	1.06	Rotted (0.16)
Control - enclosing fruit in polythene bag without treatment, holding for 5 days at 20°C, and subsequent storage.	P ₆	192.75	186.00 (13.67)	3.40	180.00	179.00 (13.39)	0.55	1.07	1.05 (1.43)
C.D. (0.05)		30.69	0.92		27.46	1.04		NS	0.01

The values in the parentheses are square root transformed during using the formula $\sqrt{x + 1}$

Table 5 - Effect of postharvest treatments on the weight, volume and specific gravity of the fruits stored.

Postharvest treatments		Weight (g)			Volume (cc)			Specific gravity	
				% loss	D A Y S		% loss	S T O R A G E	
		0	60		0	60		0	60
Dipping the fruits in warm water (at 40°C) for 3 to 4 minutes and holding them for 15 hours at 20°C before storage in polythene bags.	P ₁	156.75	Rotted (0.16)	-	146.25	Rotted (0.16)	-	1.07	Rotted (0.16)
Spraying the fruits with 35% ethanol enclosing in polythene bags and holding for 5 days at 20°C before storage.	P ₂	176.75	175.25 (13.22)	0.58	165.25	164.50 (12.83)	0.45	1.06	1.06 (1.43)
Sealing the fruits in a 5 litre plastic container with tight fitting cover together with 10 ml of 35% ethanol and holding for 5 days at 20°C before storage.	P ₃	194.25	193.50 (13.93)	0.38	181.50	180.50 (13.46)	0.58	1.07	1.07 (1.44)
Spraying the fruits with 5% acetaldehyde enclosing in polythene bags and holding for 5 days at 20°C before storage.	P ₄	167.25	Rotted (0.16)	-	156.25	Rotted (0.16)	-	1.07	Rotted (0.16)
Sealing of fruits in plastic containers with 10 ml of 5% acetaldehyde and holding for 5 days at 20°C before storage.	P ₅	169.00	Rotted (0.16)	-	159.25	Rotted (0.16)	-	1.06	Rotted (0.16)
Control - enclosing fruit in polythene bag without treatment, holding for 5 days at 20°C, and subsequent storage.	P ₆	192.75	186.00 (13.67)	3.40	180.00	179.00 (13.39)	0.55	1.07	1.05 (1.43)
C.D. (0.05)		30.69	0.92		27.46	1.04		NS	0.01

The values in the parentheses are square root transformed during using the formula $\sqrt{x + 1}$

The highest weight and volume, before storage were recorded in fruits sealed with ethanol 35% (P₃), the values being on a par with control (P₆) fruits. On the other hand, fruits dipped in warm water (P₁) recorded the lowest weight and volume, the treatment being on a par with P₂, P₅ and P₄.

After the stipulated storage period, the lowest loss in weight was observed in fruits sealed with ethanol 35% (P₃) followed in ascending order by the ones sprayed with ethanol 35% (P₂) and control (P₆). The lowest loss in volume, however, was recorded in fruits sprayed with ethanol 35% (P₂) followed by the ones enclosed with ethanol 35% (P₃) and control (P₆), in ascending order. However, no significant difference in the weight, volume and specific gravity was recorded in fruits under P₂, P₃ and P₆ treatments. The fruits given warm water (P₁) and acetaldehyde (P₃ and P₄) treatments were observed to have rotted during storage.

4.2.2 Total soluble solids, total sugars and reducing and non-reducing sugars

The total soluble solids (TSS), total sugar, reducing and non-reducing sugar contents before and after storage are presented in Table 6.

Although the TSS content of fruits given

Table 6 - Effect of the postharvest treatments on the TSS, total sugar, reducing and non-reducing sugar contents of the fruit before and after 60 days storage.

Postharvest treatments	TSS (%)			Total sugar (%)			Reducing sugar (%)			Non-reducing sugar (%)		
	D A Y S I N S T O R A G E											
	0	60	% Loss	0	60	% Loss	0	60	% Loss	0	60	% Loss
P ₁	17.8	Rotted (0.16)	-	14.60	Rotted (0.16)	-	13.04	Rotted (0.16)	-	1.48	Rotted (0.16)	-
P ₂	17.9	15.20 (4.02)	15.08	14.75	14.10 (3.89)	4:41	13.61	13.15 (3.76)	3.37	1.08	0.82 (1.35)	24.07
P ₃	18.58	16.47 (4.18)	11.36	15.05	14.50 (3.94)	3.65	13.96	13.55 (3.82)	2.94	1.03	0.87 (1.36)	15.53
P ₄	19.25	Rotted (0.16)	-	13.60	Rotted (0.16)	-	12.04	Rotted (0.16)	-	1.20	Rotted (0.16)	-
P ₅	19.22	Rotted (0.16)	-	13.07	Rotted (0.16)	-	11.96	Rotted (0.16)	-	1.53	Rotted (0.16)	-
P ₆	18.41	16.52 (4.18)	10.26	15.10	14.52 (3.94)	3.84	13.96	13.54 (3.81)	3.01	1.08	0.90 (1.39)	16.66
C.D. (0.05)	0.63	0.05		0.53	0.07		0.12	0.10		0.35	0.38	

The values in the parentheses are square root transformed using the formula $\sqrt{x+1}$

acetaldehyde treatments (P_4 and P_5) was observed to be the highest, they recorded the lowest total and reducing sugar contents before storage. The highest total and reducing sugar contents, on the other hand, were recorded in fruits under control (P_6), the values being on a par with the ones sealed with ethanol 35% (P_3) and in case of total sugars also with those sprayed with ethanol 35% (P_2) and dipped in warm water (P_1). The non-reducing sugar content of the fruits sealed with acetaldehyde 5% (P_5), dipped in warm water (P_1) and sprayed with acetaldehyde 5% (P_4) was on a par and superior than that of other treatments.

After the stipulated storage period, the lowest loss in total sugar, reducing and non-reducing sugar content was recorded in fruits sealed with 35% ethanol (P_3) followed by control (P_6) and the ones sprayed with ethanol 35% (P_2), in ascending order. The lowest loss in TSS was, however, recorded in fruits under control (P_6). The fruits given warm water (P_1) and acetaldehyde (P_4 and P_5) treatments rotted during storage.

4.2.3 Soluble tannins

Data regarding the soluble tannin content of

Table 7 - Effect of the postharvest treatments on the soluble tannin, pectin and ascorbic acid contents of the fruit before and after 60 days storage.

Postharvest treatments	Astringency level (FeCl ₃ test)		Soluble tannins (%)		Pectins (%)			Ascorbic acid (mg/100g f.w.) *		
			D A Y S		I N S T O R A G E					
	0	60	0	60	0	60	% loss	0	60	% loss
P ₁	3	Rotted	0.46	Rotted	0.89	Rotted (0.16)	-	12.8	Rotted (0.16)	-
P ₂	3	0	0.54	0	0.91	0.78 (1.32)	14.28	12.5	9.1 (3.17)	27.78
P ₃	3	0	0.63	0	0.91	0.71 (1.30)	21.98	12.3	9.1 (3.18)	26.02
P ₄	3	Rotted	0.59	Rotted	0.82	Rotted (0.16)	-	12.4	Rotted (0.16)	-
P ₅	3	Rotted	0.65	Rotted	0.85	Rotted (0.16)	-	12.6	Rotted (0.16)	-
P ₆	3	0	0.81	0	0.92	0.60 (1.25)	34.78	12.6	9.6 (3.26)	27.82
C.D. (0.05)			0.05		0.04	0.01		NS	0.03	

The values in the parentheses are square root transformed using the formula $\sqrt{x+1}$

the fruits subjected to various postharvest treatments before and after storage are presented in Table 7.

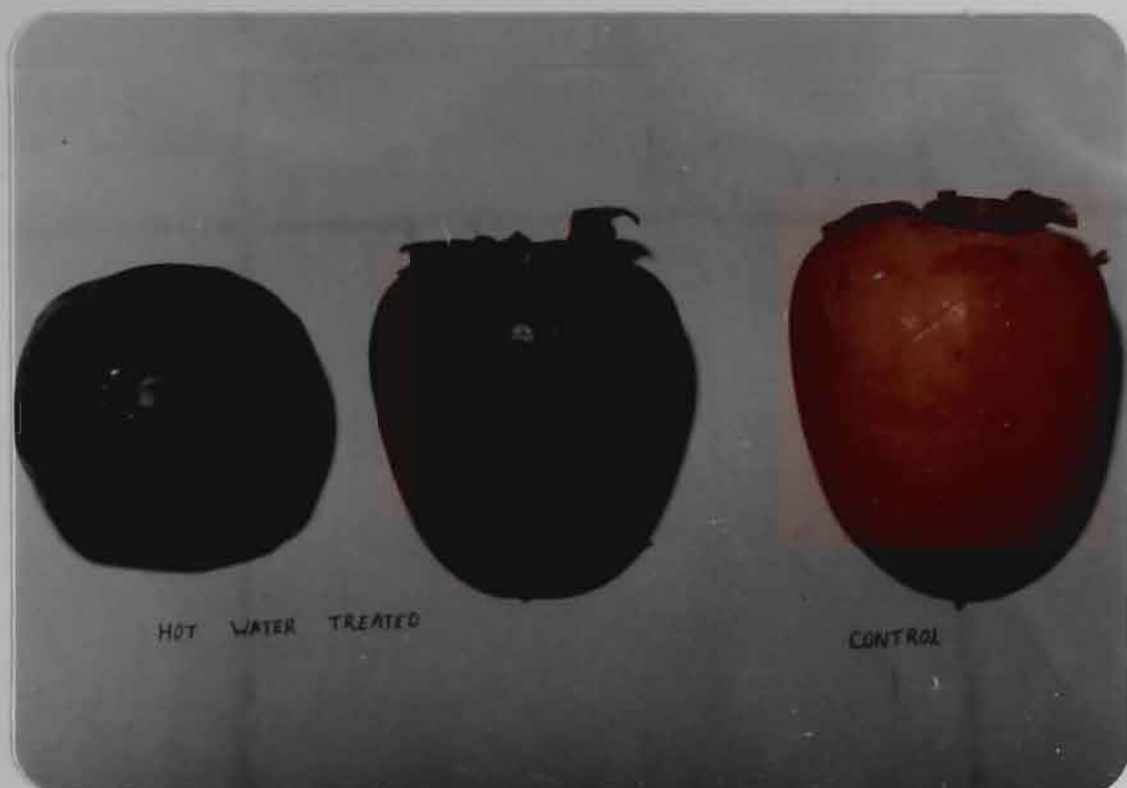
The lowest soluble tannin content was recorded in fruits dipped in warm water (P_1) followed, in ascending order, by the ones sprayed with ethanol 35% (P_2) and acetaldehyde 5% (P_4), which were on a par with each other. Control fruits (P_6), on the other hand, recorded the highest soluble tannin content before the commencement of storage. All the treatments were, however, observed to be highly astringent by $FeCl_3$ test.

After the stipulated storage period, the soluble tannin content was recorded to be zero and the astringency nil in fruits given ethanol treatments (P_2 and P_3) and control (P_6). The fruits under warm water (P_1) and acetaldehyde (P_4 and P_5) rotted during storage.

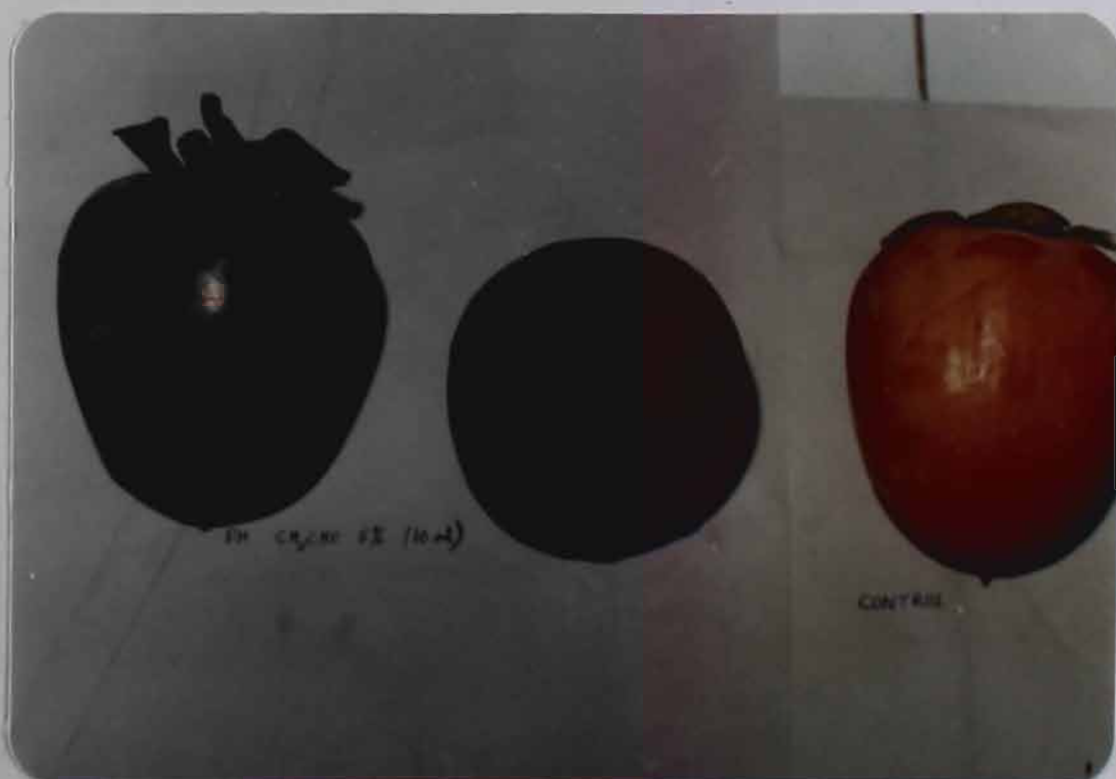
4.2.4 Pectins

The pectin content of the fruits given postharvest treatments are presented in Table 7.

At the commencement of storage, the highest pectin content was observed in control fruits (P_6), the value being on a par with the ones treated with ethanol



Fruits given warm water treatment (P_1) and control (P_6) on the right, before storage



Fruits sealed with acetaldehyde 5% (P_5) and control (P_6) on the right, before storage

(P₂ and P₃) and warm water (P₁).

After 60 days storage at 0 ± 1°C, the lowest loss in pectin content was observed in fruits sprayed with ethanol 35% (P₂) followed, in ascending order, by the ones sealed with ethanol 35% (P₃) and control (P₆). The fruits under P₁, P₄ and P₅ treatments were observed to have rotted during storage.

4.2.5 Ascorbic acid

The effect of the postharvest treatments on the ascorbic acid content of the fruits presented in Table 7.

The ascorbic acid contents of the fruits given various postharvest treatments showed no significant differences before commencement of storage.

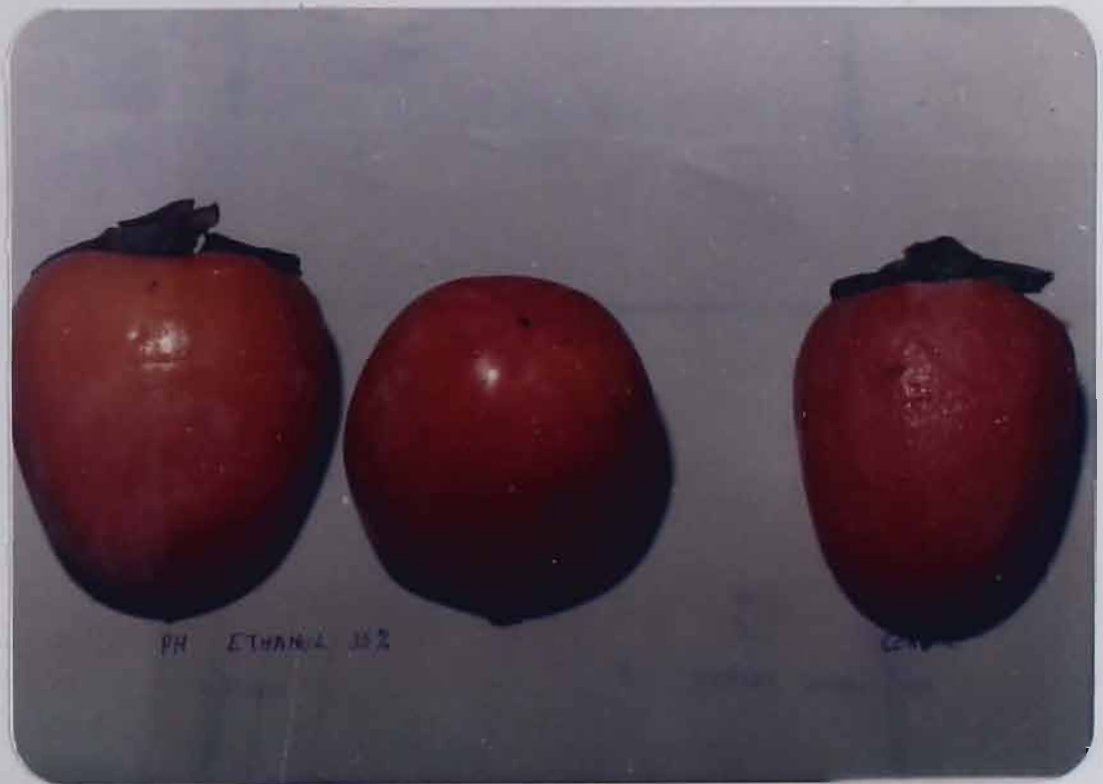
After the stipulated storage period, the lowest loss in ascorbic acid content was observed in fruits sealed with ethanol 35% (P₃) followed, in ascending order, by those sprayed with ethanol 35% (P₂) and control (P₆). The fruits given warm water dip (P₁) and acetaldehyde treatments (P₄ and P₅) rotted during storage.

4.2.6 Organoleptic evaluation

The general appearance, astringency, taste and

Table 8 - Quality of fruits based on organoleptic tests given postharvest treatments before and after 60 days storage.

Postharvest treatments	Organoleptic rating	
	DAYS IN STORAGE	
	0	60
P ₁	3.2	1.2
P ₂	3.4	3.8
P ₃	3.4	3.8
P ₄	2.6	1.2
P ₅	2.6	1.0
P ₆	3.6	3.8



Fruits treated with ethanol 35% (P_2 and P_3)
and control (P_6) on the right, after storage

flavour, and firmness of the fruits was studied by conducting organoleptic tests with the help of a panel of 10 judges. The results obtained are presented in Table 8.

The fruits which were treated with ethanol 35% (P_2 and P_3) and control (P_6) showed good general appearance, were very firm and showed no shrivelling before storage. Warm water treated fruits (P_1) ranked fair in general appearance whereas those treated with acetaldehyde (P_4 and P_5) developed blotches on their surface. The fruits under various postharvest treatments were, however, highly astringent before the commencement of storage.

After 60 days storage, the fruits given ethanol treatments (P_2 and P_3) and control (P_6) had a good general appearance, no astringency, good taste and flavour and were quite firm. Ethanol treated fruits (P_2 and P_3) did not shrivel, however, control (P_6) fruits showed a slight amount of shrivelling. The fruits given warm water (P_1) and acetaldehyde (P_4 and P_5) treatments were observed to rot during storage and were ranked unacceptable.

D I S C U S S I O N

Chapter 5

DISCUSSION

The Japanese persimmon, a very nutritive and delicious fruit, has a great commercial potential in Himachal Pradesh. Hachiya, is by far the most popular cultivar grown here. It is a large oblong conical shaped fruit with the apex rounded and having a black-coloured point. The skin is shiny, deep orange red and the flesh dark yellow. However, the fruits are highly astringent when unripe, and by the time they ripen and lose astringency, they are rendered too soft for handling and marketing, and are only fit for immediate consumption or at the best for local market. The astringent nature of the fruit is probably the major constraint that has thus far restricted the production and trade in persimmon despite there being great potentials for its cultivation in the State. Any means of scientific removal of

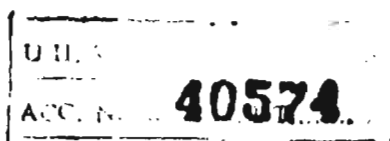
astringency without undue softening and browning of flesh, and without compromising its shipping and marketing quality will go a long way in popularising persimmon and increasing its production in the State. The present investigations were, therefore, undertaken to study the on-tree and postharvest removal of astringency in Hachiya persimmon fruit and its effect on storage quality. The findings from these investigations are discussed in the light of the available literature. The parameters of study and results of the two experiments, being more or less identical, have been grouped together for discussion for the sake of brevity and continuity.

5.1 Removal of astringency

Astringency in immature persimmon fruits is due to water-soluble tannins present in the tannin cells. The soluble tannins are fluid and easily spread over cut surfaces (Ito, 1980, 1986). The tannin called "kaki-tannin" has a strong protein binding capacity and is strongly positive in ferric chloride showing indigo coloration. Nakayama and Chichester (1963) suggested that the astringency was because of the presence of a delphinidin generating leucoanthocyanin. Ito and Joslyn (1964) showed that kaki-tannin was a type of conjugated tannin; the major component was

leucodelphinidin, to which gallic acid, gallactocatechin, and gallactocatechin gallate were conjugated in this molecule. Coagulated (polymerized) tannin, on the other hand, does not show astringency because of its insolubility in water. Conversion of the astringent tannins from a soluble to an insoluble form occurs as the fruits become non-astringent (Gazit and Levy, 1963). Kato (1984) reported that fruits containing about 0.2% soluble tannins were slightly astringent and those containing less than 0.1% were almost non-astringent. Ripening to a mushy condition and the removal of astringency in persimmon fruits can occur simultaneously, or the fruits can be treated to remove astringency without normal ripening and softening (Eaks, 1967).

In the present study ethephon 500 ppm spray given 12 days before harvest (T_6) proved to be the most effective treatment for the on-tree removal of astringency in Hachiya persimmon. The treated fruits recorded the lowest content of soluble tannins at harvest (0.08%) and also scored the lowest value when evaluated by ferric chloride test. However, these fruits were very soft at harvest and at the end of 60-day storage at $0 \pm 1^\circ\text{C}$ were found to be either rotted or too



soft to handle. The loss of astringency in ethephon treated fruits may be attributed to the accelerated rate of ripening and the attendant ripening associated metabolic changes including softening. The advancement of ripening by ethephon in persimmon has also been reported by a number of workers (Eaks, 1967; Iwata et al., 1971; Vakamatsu et al., 1973; Testoni and Sozzi, 1979). Iwata et al., (1969) observed that Japanese persimmon contained little natural ethylene and as such ethylene treatment hastened softening, colouring and loss of astringency. Rao et al., (1971) observed that persimmon fruits treated with 5000 ppm ethrel solution were completely ripe within 1-3 days, but were too soft to handle and did not last long.

Application of Alar 500 ppm before ethephon treatment (T₇), however, tended to counter the softening effect of the latter and yielded fruits with significant reduction in astringency as compared to untreated control without compromising their organoleptic rating at harvest, and at the end of 60 days refrigerated storage. Fruits that had received application of Alar only (T₅), on the other hand, recorded soluble tannin content comparable to

control fruits at harvest, but lent themselves well to storage, scoring high on the organoleptic test. Pre- or post-harvest application of ethanol or acetaldehyde also proved very effective in removing the astringency of the fruit. The treated fruits recorded very low soluble tannin content and were quite comparable in this respect to ethephon treatment. However, whereas ethanol treated fruits lent themselves exceedingly well to 2-month storage at $0 \pm 1^{\circ}\text{C}$, the acetaldehyde treated ones performed dismally, being either rotted/unfit for consumption or too soft to handle or market.

The mechanism of ethanol induced removal of astringency in persimmon is not very clear. Sugiura and Tomana (1983) have reported that the cultivars which produce relatively high amounts of ethanol and accumulate it in the flesh, lose astringency or soluble tannins while still on the tree. Sugiura et al., (1975) found that enclosing astringent fruits on the tree in polythene bags containing 2-5 ml of 5 to 20% ethanol removed astringency in 2 days to over a week, but the time varied with ethanol concentration and fruit size. Itoo (1980) has reported that about the time that deastringency is completed, large amounts

of acetaldehyde and ethanol are found with all destringency treatments, including those of carbon dioxide (Tarutani and Manabe, 1957; Nakamura, 1973); ethanol (Araki et al., 1975), and warm water (Kitagawa, 1969).

Again, the mechanism of removal of astringency by acetaldehyde is not very clear. Kitagawa (1969) showed that acetaldehyde gas alone could remove astringency over a relatively short period. Ito (1962) observed that the isolated and partially purified tannin precipitates upon acetaldehyde addition (in vitro) within 1 day at room temperature. Komazawa and Uchida (1956) found the alcohol dehydrogenase enzyme in kaki fruit to produce acetaldehyde from the alcohol existing in the flesh of persimmon.

The present study also showed that the efficacy of warm water (at 40°C) - the traditional method used in Japan - to remove astringency from persimmon fruit was suspect. Though the treatment was fairly effective in removing the astringency, it yielded a product of very poor quality. The treated fruits exhibited undue softening when held at 20°C for 5 days and deteriorated during subsequent storage. At the end of 60 day storage at 0 ± 1°C, the fruits were rotted and unfit for human consumption. Kitagawa (1969) has

suggested that the removal of astringency during warm water treatment is not due to chemical change in the tannins, such as polymerization or condensation, but rather is due to the gelling of the protoplasm in the tannin cells.

Simply enclosing the fruit in unvented polythene bag either on tree (T_8) or postharvest (P_6) was also found to be fairly effective in removing astringency without undue softening. The soluble tannin content of fruits under these treatments was significantly lower than untreated unbagged control (T_9) and the fruits lent themselves well to 2-month storage at $0 \pm 1^\circ\text{C}$. This may be attributed to the modification of the atmosphere around the fruit, which though brought about unwittingly, was conducive to better storage. Tarutani (1960) reported that fruits packed in polythene bags (0.06 mm thick) and stored at 0°C afforded a slight modification of controlled atmosphere (CA) storage conditions; that is, a combination of 5% carbon dioxide with 5 to 8% oxygen, and almost 100% relative humidity. Gazit and Adato (1972) recognized two distinct processes in the disappearance of astringency by CO_2 treatment:

an induction process in which exposure of the fruit to CO₂ gas causes chemical reactions related to deastringency to occur (formation of an "astringency - removing factor"), and a deastringency process, in which astringency in the fruit disappears gradually and the presence of CO₂ gas is no longer essential.

5.2 Changes in physicochemical characteristics

5.2.1 Fruit size, weight, volume and specific gravity

The size, weight and volume of the fruit was not affected by any pre- or post-harvest treatment except where the fruits had received on-tree spray of Alar 500 ppm (T₅) or Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm (T₇). The size in terms of length and diameter and volume of the fruits in these treatments were found to be smaller than in fruits from other treatments. Reduction in fruit size with the application of Alar has been reported by a number of workers (Batjer et al., 1964; Edgerton and Hoffman, 1965; Sullivan, 1968; Sullivan and Wildmeyer, 1970, and Naquash, 1986) in a number of fruits including apple, but the present is probably the first report on persimmon. Controlling fruit size and delaying fruit ripening by decreasing the softening rates are among the best known physiological manifestation of Alar

(Edgerton and Hoffman, 1965; Sullivan and Wildmeyer, 1970). In fact, the objective of using Alar in the present study was to offset the softening effect of ethephon which otherwise is very effective in reducing the astringency of the fruit. In this respect, Alar seems to have justified its expected role as will be seen in subsequent discussion.

The specific gravity of the fruits treated with Alar was also found to be higher than those from other treatments though the differences within the treatments were non-significant. Zika (1979) reported that Alar increased the storage quality of apples by increasing their specific gravity.

At the end of 60 days stipulated storage at $0 \pm 1^{\circ}\text{C}$ the per cent loss in fruit weight was recorded to be considerably lower in fruits receiving alcohol treatments for removal of astringency (T_1 and T_2 in Experiment I and P_2 and P_3 in Experiment II) and the ones enclosed in polythene bags without any treatment (T_8), than in fruits from other treatments. The role of alcohol in the regulation of physiological loss in weight of the fruit is, however, not clear. The mechanism of water loss from the fruit which primarily accounts for the weight loss is essentially the same

as the evaporation of water. The driving force is the vapour pressure of the moisture in the fruit (ASHRAE, 1972). Wilkinson (1965) reported that some of the water accounting for fruit weight, may be lost by evaporation and respiration but major portion is lost by transpiration. No change in the length to diameter ratio and in specific gravity of the fruit was recorded in any treatment during storage.

Surprisingly and quite unexpectedly, the fruits treated with acetaldehyde 5% (T_3 , T_4 and P_4 , P_5) for the on-tree and postharvest removal of astringency, and those given the hot water treatment (P_1) for post-harvest removal of astringency, were found to be completely rotten at the end of 60 day storage. This observation is quite at variance with that of Kitagawa (1969) who showed that acetaldehyde gas alone could remove astringency over a relatively short period. It has also been reported by a number of workers (Tazaki and Matsuoka, 1924; Tarutani and Manabe, 1957; Nakamura, 1973; Araki et al., 1975) that about the time the deastringency is completed large amounts of acetaldehyde and ethanol are found with all deastringency treatments, including carbon

dioxide, ethanol and warm water. In all likelihood, it is possible that acetaldehyde can remove astringency over a relatively short period, but the treated fruits have an extremely short storage life. More studies will need be taken up to substantiate the potentials of acetaldehyde in the removal of astringency without sacrificing the normal storage life of the fruit.

5.2.2 Total soluble solids (TSS), total sugar and reducing and non reducing sugars

The main sugars in the flesh of the mature persimmon fruit are fructose and glucose, the total amount of which is more than 90% of the total sugars. The amount of fructose is always slightly higher than that of glucose. Sucrose is present as a minor component (Ito, 1962).

In the present study the TSS, total sugar and reducing sugar contents were recorded to be the highest in fruits that had received pre-harvest spray of ethephon (T_6). This may be due to the ethylene induced acceleration of ripening and the consequent transformation in the metabolic rates. Ripening is a series of parallel and sequential metabolic events including changes in juvenility hormones, pigmentation, texture, aroma, carbohydrates, organic acids, respiration and production of ethylene (Grierson et al., 1985). However, the direct effect of ethylene on

photosynthetic biochemistry is not yet known (Abeles, 1987). Rao et al., (1971) and Testoni and Sozzi (1979) also found ethephon treated persimmon fruits to have higher TSS and sugar contents at harvest, as compared to untreated fruits.

At the end of two-month storage at $0 \pm 1^{\circ}\text{C}$ the per cent loss in TSS, total sugars, and reducing and non-reducing sugar were recorded to be the lowest in fruits given ethanol (T_1 and T_2), Alar (T_5) treatments or enclosed in polythene bags (T_8). Sugiura et al., (1975, 1977) also recorded higher reducing sugar content in fruits treated with ethanol as compared with the untreated ones.

5.2.3 Pectins, soluble tannins and ascorbic acid

In the present study the highest pectin content was recorded in fruits sprayed with Alar 500 ppm (T_5) and the lowest in ethephon treated fruits (T_6). Similarly the loss of pectin in fruits at the end of 60 days storage at $0 \pm 1^{\circ}\text{C}$ was recorded to be the lowest with Alar treatment and the highest with ethephon.

Alar (Succinic acid, 2, 2-dimethylhydrazide) a growth retardant, is known to have a pronounced effect

on fruit physiology and quality. Preharvest applications of Alar to apple trees have been shown to delay ripening (Looney, 1967) and improve flesh firmness by reducing soluble pectin levels (Cummins et al., 1982) and decrease softening rate (Sullivan, 1968). The accelerated rate of ripening in ethephon treated fruits, explains the rapid loss of pectins in persimmon fruits observed in the present study. The advancement of ripening by ethephon in persimmon fruits has also been reported by a number of other workers (Eaks, 1967; Iwata et al., 1971; Vakamatsu et al., 1975; Testoni and Sozzi, 1980).

The soluble tannins which are responsible for the astringency in persimmon were recorded to be the lowest in ethephon treated fruits (T_6). This may be attributed to the accelerated rate of ripening and the attendant metabolic changes including softening. Iwata et al., (1971) observed that Japanese persimmon contained little natural ethylene and as such ethylene treatment hastened softening, colouring, and loss of astringency.

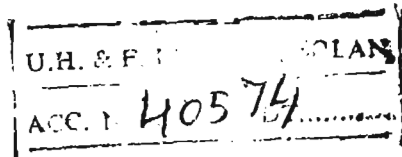
Alar treated fruits, on the other hand, recorded soluble tannin content comparable to control fruits at harvest and lent themselves well to storage. Slower polymerization of tannins in Alar treated fruits

can be explained in the light of the general role of Alar on the postharvest physiology and quality of fruits. Retardation of ripening, reduced rate of respiration, retardation of chlorophyll breakdown and better firmness are some of the best known effects of Alar application to fruits. Berard and Loughheed (1982) have conclusively shown that Alar (daminozide) favours a reduction in membrane permeability.

The ascorbic acid (Vitamin C) content of fruits given various on-tree treatments was recorded to be the highest in Alar treated fruits (T_5) at harvest. These fruits also recorded the lowest per cent loss in vitamin C at the end of 60 day storage at $0 \pm 1^\circ\text{C}$. The retention of vitamin C during storage was also observed to be fairly good in fruits which had received ethanol treatment (T_1 and T_2) or were enclosed in polythene bags (T_8). In fruits given postharvest treatments for removal of astringency, no treatment differences in ascorbic acid contents were noticed.

The effect of Alar on ascorbic acid metabolism is not clear. Zielenski (1948) in one of the earlier studies had concluded that the production of vitamin C

was under genetic control and that the environmental factors had only a modifying effect. Itoo (1980) reported that the immature persimmon fruit and nonedible peel of the mature fruit contained considerably more ascorbic acid than the pulp of the mature fruit. There is a greater concentration of ascorbic acid in the outer portion of the fruit than in the core.



S U M M A R Y

Chapter 6

SUMMARY

The present study on the on-tree and postharvest removal of astringency and its effect on the fruit quality and storage of Japanese persimmon cultivar Hachiya was carried out in the Department of Pomology and Fruit Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan during the year 1987-88.

1. Ethephon 500 ppm spray given 12 days before harvest proved to be the most effective on-tree treatment for the removal of astringency. However, the fruits were very soft at harvest and at the end of 60 day storage at $0 \pm 1^{\circ}\text{C}$ were either rotted or too soft to handle.
2. Application of Alar 500 ppm before ethephon treatment tended to counter the softening effect of

the latter and yielded fruits with significant reduction in astringency. Fruits treated with Alar only, on the other hand, had soluble tannin content comparable to control fruit at harvest, but were better suited for storage.

3. Pre- or post-harvest application of ethanol or acetaldehyde also proved effective in removing the astringency of the fruit. However, while ethanol treated fruits were well suited for storage, the acetaldehyde treated ones either rotted or became too soft to handle.

4. The present study showed that though the warm water treatment was fairly effective in removing the astringency, it yielded a product of very poor quality and not fit for storage.

5. Simply sealing the fruit in polythene bag either on-tree or postharvest was also found to be fairly effective in removing astringency without undue softening and these fruits lent themselves well to storage.

6. The size, weight and volume of the fruit was not affected by any pre- or post-harvest treatment except in Experiment I, where the fruits had received on-tree treatment of Alar 500 ppm and Alar 500 ppm and ethephon 500 ppm + NAA 10 ppm. The size, weight and volume of

fruits under these treatments were found to be smaller than other treatments. The specific gravity of the fruits treated with Alar was higher than those of other treatments though there was no significant difference within the treatments in this respect.

7. At the end of the stipulated storage period, per cent loss in fruit weight was recorded to be considerably low in fruits receiving alcohol treatments and the ones enclosed in polythene bags without any treatment.

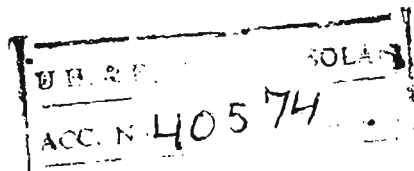
8. The TSS, total sugar and reducing sugar contents were recorded to be the highest in fruits treated with ethephon. However, at the end of two month storage, the per cent loss in TSS, total sugars and reducing and non-reducing sugars was recorded to be the lowest in fruits given ethanol or Alar treatments or covered with polythene bags.

9. The highest pectin content was recorded in fruits sprayed with Alar and the lowest in ethephon treated fruits at harvest and at the end of 60 days storage.

10. The ascorbic acid content of the fruits given

various on-tree treatments was recorded to be the highest in Alar treated fruits at harvest. These fruits also recorded the lowest per cent loss in vitamin C during storage. The retention of vitamin C during storage was fairly good in fruits given alcohol treatments or enclosed in polythene bags without any treatment.

11. The fruits treated with acetaldehyde 5% and those given warm water treatment were found to be completely rotten at the end of 60 day storage.



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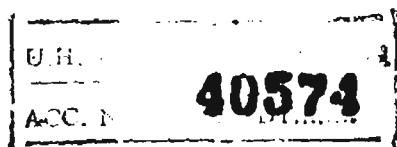
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