Postharvest Management Practices in Papaya (*Carica papaya* L.) for Improving Shelf Life

by

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THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"Postharvest Management Practices in Papaya (*Carica papaya* L.) for Improving Shelf Life"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Postharvest Management Practices in Papaya (*Carica papaya* L.) for Improving Shelf Life"** is a record of research work done independently by Mr. Jayasheela D.S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

%	per cent
ATP	Adenosine triphosphate
°B	degree Brix
°C	Degree Celsius
CD	Critical difference
cm	Centimetre
cm^2	square centimetre
CO_2	Carbon dioxide
cfu	colony forming units
cv	Cultivar
DFFB	Days from full bloom
et al	And others
EDTA	Ethylene Diamine Tetra Acetic acid
Fig.	Figure
g	Gram
hr	Hour
H	Hydrogen
Kg	Kilogram
$KMnO_4$	Potassium permanganate
K	Potassium
L	Litre
1-MCP	1-Methylcyclopropene
µl	micro litre
mg	milligram
ml	millilitre
MgO	Magnesium oxide
NAA	1-Napthlene Acetic Acid
NaClO	sodium hypochlorite

nm	nanometer
NS	Non Significant
O_2	Oxygen
PLW	Physiological Loss in Weight
ppm	parts per million
SE	Standard Error
TSS	Total soluble solids
Sl	Serial
Viz.,	Namely
Rs	Rupees

Introduction

1. INTRODUCTION

Papaya (*Carica papaya* L.) is a delicious fruit widely cultivated in tropical and subtropical areas. The cultivated papaya belongs to the family Caricaceae and is the most important economic species in Caricaceae (Paull and Duarte, 2011).

Papaya with a world production of 12.6 million tons in 2012- 2013 is a major economic crop in tropical countries. India stands first among papaya producing countries in the world with a production of 5.2 million tons of papaya during 2012-2013 (NHB, 2014).

Papaya fruits are highly perishable and need to be handled with extreme care from the time they are harvested until they reach the consumer. Desiccation of fruits and the perishable nature of papaya make heavy losses while storing and transport during glut in the market. The estimated postharvest losses of papaya fruits had been 30-60 per cent in South East Asian region (FAO, 2006).

The high content of water, the softness of the fruit on ripening and the vulnerability of the fruit to many postharvest diseases altogether contribute to the substantial increase in postharvest losses. Thus an integrated approach controlling postharvest disease, mechanical damage and fruit ripening should be considered to extend the shelf life. The development of the technology for the postharvest management of papaya will thus definitely be a help in decreasing the postharvest losses in papaya.

Thus an investigation entitled "Postharvest management practices in papaya (*Carica papaya* L.) for improving shelf life" was carried out in the Department of Processing Technology, College of Agriculture, Vellayani, during with the following objectives:

1. To determine the stage of harvest maturity of papaya for local and distant market.
2. To standardize postharvest practices for improved shelf life with minimum nutritional loss.

2.1 POSTHARVEST LOSSES IN PAPAYA

Papaya (*Carica papaya* L.) fruits are highly perishable and need to be handled with extreme care from the time they are harvested until they reach the consumer. Desiccation of fruits and the perishable nature of papaya make heavy losses while storing and transport during glut in the market. The postharvest losses of up to 75 per cent have been reported in papaya fruits by Hawaii shippers to mainland USA wholesalers and retailers (Paull *et al.*, 1997). The estimated postharvest losses of papaya fruits had been 30-60 per cent in South East Asian region (FAO, 2006). A study conducted on papaya variety Taiwan 786 grown in the major producing state of Andhra Pradesh and marketed in Bangalore revealed a total postharvest loss of 25.49 per cent consisting of 1.66 per cent at field level, 4.12 per cent of transit loss and 8.22 per cent of ripening loss at market level and 11.49 per cent loss at the retail level (Gajanana *et al.*, 2010). According to Gamage and Ranawana (2011) the highest percentage of postharvest loss was found in papaya (46 per cent) compared to banana and pineapple (20-30 per cent).

Survey carried out by Paull *et al.* (1997) revealed that in 73.3 per cent of the inspected cartons, moulds and rots were found, while mechanical injuries such as 'sunken areas on skin', 'scarring on the skin' and 'bruising of flesh' were also responsible for a high percentage of losses of papaya fruit. According to Ventura *et al.* (2004) postharvest rots may be divided into three types: superficial, peduncular and internal rots accounting in some cases for 100 per cent of the total losses. Other postharvest losses were due to over-ripeness (47.4 per cent), soft fruit (16.7 per cent) and bruise damage (14.8 per cent). However, Singh *et al.* (2010) reported that postharvest diseases caused by fungi are the most important problem during handling and storage of papaya fruit.

2.2 STAGE OF HARVEST

Harvesting of fruits at proper stage of maturity is of paramount importance for attaining desirable quality. The level of maturity actually helps in selection of storage methods, estimation of shelf life and selection of processing operations for value addition. Maturation is the developmental process by which the fruit attains maturity. It is the transient phase of development from near completion of physical growth to attainment of physiological maturity (Dhatt and Mahajan, 2007).

Harvest date, a parameter going along with maturity of fruit, contributes to quality and maturity of fruit. Fruits harvested at an immature stage may not achieve normal ripening characteristics (Lechaudel and Joas, 2006). On the other hand, an over ripe fruit may deteriorate quickly after harvest (Tefera *et al.*, 2007). Normally, several harvest indices are used to determine picking times such as size, skin and pulp colour, acidity, sugar content, flesh firmness and calendar day from bloom to harvest (Crane *et al.*, 2009).

Various destructive and non-destructive indices can be used to determine the harvest maturity of papaya. The non-destructive index includes the number of days from flowering, fruit size, and external colour. It is important to harvest papaya fruit at the proper maturity stage, because they do not increase in sugar content after picking. Hawaiian papayas normally require about 3 months from flowering until fruit maturity. The most obvious index of fruit maturity is external skin colour. As the fruit matures, the skin colour will change from green to yellow or orange (New GMC, 2004).

Destructive indices used for determining harvest maturity include internal pulp colour and per cent soluble solids content (sugar content). These indices are used to test randomly selected fruits in order to correlate fruit size with maturity. The internal pulp colour of mature papaya fruit changes from cream to yellow orange as the external skin colour changes from green to yellow-orange during ripening. The soluble solids content of Hawaiian mature fruits should be at least 11.5 per cent, and can be determined by placing several drops of juice on a hand-held refractometer. Experienced growers use a combination of external and internal maturity indices to determine when to harvest (New GMC, 2004). According to Paull and Durate (2011) green immature fruit do not ripen well and have a total soluble solids value that is frequently less than 10 per cent, giving a bland taste.

According to Basulto *et al.* (2009) fruit colour in papaya is a good maturity index, and Cielab colour, TSS and firmness values can be used as quality standards. Skin colour is an appropriate maturity index, while $b*$ values representing yellow are good indicators for early maturity stages, and $a*$ value green or red for late stages.

Rimberia (1998) reported that papaya *cv.* Solo fruits harvested at one third ripe had higher mean flesh firmness than those harvested at colour break. They also had higher means for total soluble solids, total titratable acidity, total solids, total sugars and reduced ascorbic acid.

New Guyana Marketing Co-operation published the postharvest care and market preparation for papaya. According to them domesticated market fruits should be harvested when the skin colour is between one quarter to one half yellow while for export it should be harvested between the one stripe yellow stage and the quarter ripe stage (New GMC, 2003).

The effect of stage of maturity at harvest on the quality of ripe papaya var. Rathna revealed harvesting at trace yellow stage, did not result in the development of attractive yellow skin colour, in addition, shrivelling of fruits, excessive weight loss and high incidence of diseases in fruits reduced visual quality rating. The results of the study concluded that papaya var. Rathna must be harvested at 50 per cent yellow stage to maintain best postharvest quality (Sarananda *et al.*, 2004).

Bron and Jacomino (2006) studied the effect of harvest at different maturity stages on the physiology of ripening and quality of Golden papaya. The four maturity stages studied included harvest at totally green skin colour, 15 per cent yellow skin, 16-25 per cent yellow skin and 26-50 per cent yellow skin. Harvesting at early stages does decrease fruit quality but did not make the fruit unacceptable for consumption. The maturity stage at harvest affected the respiratory activity and ethylene production during postharvest of Golden papaya.

Harvesting at correct stage is very important in papaya. Many people harvest papaya at the immature stage to avoid physiological damages, but those fruits do not ripe correctly and give off flavours. The peel colour and flesh colour also do not develop well and skin gets damaged due to high latex exudation in immature fruits during harvesting. Those damages cause negative consumer preference in the market place. Uneven ripening caused poor quality peel colour

Review of Literature

2. REVIEW OF LITERATURE

Papaya (*Carica papaya* L.) belongs to family *Caricaceae*, is one of the economically important fruit crops in many tropical and subtropical countries.

The commercial varieties of *Carica papaya* grown in India are Coorg Honeydew, Washington, Honey dew, Pusa delicious, Pusa nanha, Taiwan 786, Taiwan 785, Sunrise, Solo, CO-1, CO-7 and CO-3 respectively. Because of the high superior quality, nutritional as well as medicinal value of the fruit, Indian papaya has a great demand in African countries, Middle East and European market (Malabadi *et al.*, 2011). The postharvest losses of papaya fruit is one of the highest among various horticultural crops. The high content of water, the softness of the fruit on ripening and the vulnerability of the fruit to many postharvest diseases altogether contribute to the substantial increase in postharvest losses. Being a crop of high export potential and due to the heavy postharvest loss noticed in papaya, a study was carried out at the Department of Processing Technology, College of Agriculture, Vellayani, to find out ways to extend the shelf life through postharvest management. Efforts have been made by many workers to reduce the extent of postharvest losses and to extend the storage shelf life of harvested fruits through application of various methods to improve storage life. In the present project effort has been taken up to study the stage of harvest, use of sanitising agents, waxing and ethylene absorbent on preventing the postharvest loss of papaya. The present chapter reviews the literature on maturity stages, sanitising agents, hot water treatment, waxing and ethylene absorbents in papaya and related fruit crops.

Coorg Honeydew is one of the earliest gynodioecious selections made in the country (Aiyappa and Nanjappa, 1959). The variety yields big sized fruits of about 1.5-2.0 kg, pulp is yellow in colour and fruits are sweet to taste with a TSS of 12°B (Karunakaran *et al.*, 2010) and is popularly cultivated for table as well as for processing purpose. It fetches good market value due to the excellent fruit quality (NHB, 2012).

and flesh colour in Red Lady papaya. Dark yellow peel colour and the thick red colour flesh in ripe fruits attracted the consumer (Sarananda and Wijesundara, 2009).

The degree of ripeness for harvesting of papaya depends upon distance to markets. Fruits may be one-quarter to one-half ripe for local markets. Fruits to be transported long distances or exported are harvested at colour break to one quarter ripe, depending upon the cultivar's ripening characteristics and season (Paull and Duarte, 2011).

Syaefullah *et al.* (2013) determined quality and level of maturity in papaya using non-destructive method of image processing, an artificial neural network (ANN) and near infrared (NIR) spectroscopy. The ANN model was able to determine level of maturity of papaya with accuracy of close to 100 per cent. Near infrared spectroscopy at a wavelength band of 900-1400 nm could be used to measure total soluble solids (TSS) and firmness of papaya fruit.

2.3 SURFACE STERILIZATION

2.3.1 Hot Water Treatment

The use of heat treatments in postharvest management is applied to many kinds of fruits to prevent fungal and insect eradication (Paull, 1994; Lurie, 1998). Heat treatments (hot water, hot air, vapour heat) may be used for disease control (such as anthracnose on mango and crown rot on banana) and for insect control to meet quarantine requirements for some commodities, such as mango and papaya (Kader, 2013).

A significant benefit of heat treatment is that no chemical residues remain on the fruits. Commercially applied heat treatments are hot water, vapour heat and hot air. Hot water was originally used for fungal control, but has been extended to disinfestation of insects. Vapour heat was developed specifically for insect control, and hot air has been used for both fungal and insect control and to study the response of commodities to high temperature (Lurie, 1998).

Methods of heat treatment may influence the response of the commodity as well as the length of exposure to achieve a desired effect. Hot water is a heat transfer medium, which is more efficient than hot air (Shellie and Mangan, 1994). Furthermore, hot water dip effectively controls fungal pathogens (Paull, 1994).

Effects of heat treatments on the physiology of fruit after harvest are various, including slower rates of flesh softening and pectin solubilisation (Klein *et al.*, 1990), reduced ethylene production (Klein and Lurie, 1990; Paull and Donald, 1994) and delaying processes of ripening (Wolf *et al.*, 1995). According to Lurie (1998) and Jacobi *et al.*, (2001) postharvest heat disinfestation treatments can cause injury and thus it may cause reduction in the quality of fresh fruits.

Many kinds of fruits can tolerate temperatures of 50 - 60°C for up to 10 minutes (Golan and Phillips, 1991) but it takes 60 minutes or more if temperatures are below 50°C (Lurie, 1998) for heat treated disinfestation. Recommended temperature for heat treatment of mango ranges between 22 - 48°C for up to 110 minutes (Jacobi *et al.*, 1995, 2000).

Pre-treatment of heat can also reduce the incidence of heat injury symptoms in fruits due to too low or too high temperature (Wild, 1993; Jacobi *et al.*, 2001). Sometimes, pre-treatment with heat is necessary to reduce injury and maintain better postharvest quality. Hot water pre-treated mango at 55°C for 5 minutes stored under controlled atmosphere at 8°C for 45 days displayed no symptoms of morphological chilling injury and ripened normally at ambient conditions (Niranjana *et al.*, 2009).

Pajaro strawberry fruit were treated at 45° C by hot air or hot water prior to storage at 3° C for 10 days. Treatment with hot water improved fruit resistance to fungal infection, but caused external damage, which rendered fruit commercially unacceptable. Hot air treatment did not affect external appearance, improved resistance to fungal infection and preserved firmness (Lara *et al.*, 2006).

Efficacy of hot water treatment is alternative to chemical treatment. Hot water treatment becomes a feasible method for controlling postharvest decay in freshly harvested banana. Immersion of Gros Mischel and Namwa in 42°C hot water for 15 minutes delayed peel blackening during cold storage (Promyou *et al.*, 2008). Banana cv. Bungulan was selected to hot water treatment at 50°C for 20 minutes, as an alternative to chemical treatment, to control crown rot and maintain postharvest quality. Hot water treatment delayed ripening and prolonged the green-life of fruit (Alvindia, 2012). Shelf-life of bananas increased and post-harvest losses of fruits reduced significantly through hot water treatment at 53° C for 9 minutes or 55°C for 7 minutes (Amin and Hossain, 2012). Dipping of Berangan banana fruit in hot water at 50°C for 20 minutes was more effective in suppressing anthracnose disease (Mirshekari *et al.*, 2012).

Arina *et al.* (2010) reported effects of postharvest hot water treatment on the Eksotika papaya fruit quality during ripening. Hot water treatment is a method for fruit fly disinfestation which is a quarantine requirement for the papaya exportation industries. Postharvest hot water treatment at the selected temperature can maintain postharvest quality of Eksotika papaya fruit and at the same time prevent it from insect infestation.

Martins *et al.* (2010) reported that treatment of papaya fruit with hot water at 48-50° C for 20 minutes controlled the *Colletrotrichum gleosporioides* and *Phoma caricae.*

Kechinski *et al.* (2012) applied heat treatments with a hot water brushing system at temperatures of 45, 55 and 65° C in papaya fruits. No mould was observed under the wax film of fruits treated with hot water, ozonated water and wax, indicating that the combined treatment effectively disinfected the papaya fruits.

Hot water treatment at 54°C for 4 minutes effectively slowed fruit ripening and reduced postharvest decay of papaya fruit by 43.7 per cent after 9 days for the fruits kept at 25°C. Hot water treated papaya fruits remained firmer by slowing down the fruit ripening, with a better colour improvement than control, which increased its economic value. The appropriate hot water treatment reduced respiration rate and ethylene production of fruit, and inhibited activity of polygalacturonase and pectin methylesterase enzymes associated with cell wall degradation and enhanced poly galacturonase inhibiting protein gene expression (Zaho *et al.*, 2013).

NHB (2012) recommends hot water treatment for papaya fruits meant for export for the control of anthracnose.

According to Sanchez *et al.* (2013) anti-fungal hot water treatment of 55 °C for 3 minutes did not affect negatively the quality parameters of pulp and skin of papaya at their colour-break stage of ripeness. So, this treatment can be applied in order to delay decay development during the papaya marketing at non-refrigerated temperatures (25 °C).

2.3.2 Sodium Hypochlorite

Efficacy of the sanitizers used to reduce microbial population is usually dependent upon the type of treatment, type and physiology of the target microorganisms, characteristics of produce surfaces (cracks, crevices texture, and hydrophobic tendency), exposure tissue and concentration of sanitizer, pH and temperature.

Chlorinated compounds, particularly hypochlorites, are widely used in microbial control and have a long history of application in the food processing industry (Wei *et al.*, 1985). In addition to their economic benefits, hypochlorites are effective in inactivating micro-organisms suspended in water and on nonporous surfaces (Brackett, 1987).

According to Nishijima (1994) sodium hydroxide, sodium carbonate, sodium hypochlorite (Clorox), EDTA, and calcium hypochlorite were found to be safe to use in a five- minute dip at 8,000 ppm for papaya fruits instead of mancozeb for the prevention of major postharvest diseases as well as blight caused by *Phytophthora palmivora.*

The wash water containing a mild detergent like hypochlorous acid at concentration of 150 ppm and water at pH of 6.5 along with thiobendazole 50 ppm was reported to control postharvest disease of papaya (New GMC, 2003).

Whole fresh fruits before processing are washed with water containing chemical sanitizing agents such as chlorine, chlorine dioxide, tri sodium phosphate, hydrogen peroxide, organic acids and ozone to decontaminate the surface of the fruit and chlorine being the more effective chemical additives in reducing pathogenic or naturally occurring microorganisms, by the order of 10 to 100 fold (Balla and Farkas, 2006).

Several studies demonstrated that the application of chlorine dioxide, hydrogen peroxide and sodium hypochlorite can reduce populations of total aerobic bacteria, yeasts and moulds on strawberry (Kim *et al.*, 2010)

2.4 WAXING

Fruits are dipped or sprayed with a range of materials to improve their appearance or delay deterioration. Conventionally grown fruits and vegetables are often waxed to prevent moisture loss, protect them from bruising during shipping, and to increase their shelf life. Different kinds of wax are used which includes carnauba wax (from the carnauba palm tree), beeswax, and shellac (from the lac beetle), petroleum-based waxes, which contain solvent residues or wood resins. Often other compounds are added to which includes ethyl alcohol for consistency, milk casein (a protein linked to milk allergy) as a film former or soap as a flowing agent (WHF, 2014).

Carnauba wax is obtained from the leaves of carnauba palm, which is native to Brazil. The leaves produce wax in such abundance that heating in a little water can yield 5-10 grams of wax from each leaf. Carnauba is a moderate glossy wax. It imparts a much better shine to the product than paraffin, but less than shellac. A carnauba wax finish is more permeable than shellac and does not whiten (New GMC, 2004).

Waxing of fruits and vegetables reduces water loss from the commodity and thus reducing shrivelling, weight loss, improve the appearance of fruit, protects from minor infections and increase the shelf life of the commodity (Sharma, 2010).

Banana cv. Rasthali fruits dipped in 8 per cent wax have high TSS and ascorbic acid. The loss of firmness in wax coated fruits was very slow and minimum (Devi and Arumugam, 2008). Maqbool *et al.* (2010) showed the possibility of using 10 per cent arabic gum incorporated with 1.0 per cent chitosan as a bio fungicide for controlling postharvest anthracnose in banana. Banana cv. Robusta dipped with six per cent wax gave shelf life of 13 days in room storage, 19 days in Zero energy cool chamber and 24 days in cold storage (Doshi and Sutar, 2010). Dipping of banana fruits in 1.5 per cent or 2.5 per cent Tal-prolong solution delayed yellow colour development by 4-8 days (NHB, 2012). According to Saravanan, *et al.* (2013) six per cent wax coating in Dwarf Cavendish increased the green life by 40 days.

Hu *et al.* (2011) reported the effects of two types of waxing treatment (Sta-Fresh 2952 wax and Sta-Fresh 7055 wax) in pineapple fruits of cultivar Paris. The results suggested that waxing is an useful technique to alleviate chilling injury and maintain fruit quality during cold storage. Lin *et al.* (2013) treated pineapple fruits with fruit wax 2952 (Sta-Fresh, FMC) of different concentrations and reported that coating was effective in decreasing titratable acidity, loss of weight and respiration rate, delaying the colour change of pineapple peel and pulp, and extending the storage life .

The potential efficacy of a combination of the bio control agent *Candida oleophila* with two per cent sodium bicarbonate incorporated wax coating represented a commercially acceptable alternative to chemicals for postharvest control of anthracnose of papaya during storage (Gamagae *et al.*, 2004). Hewajulige *et al.* (2007) concluded that effect of chitosan coating at a concentration of 1 per cent in vivo significantly reduced both disease incidence and severity on papaya fruit, showed improved fruit firmness after ripening, protected the fruit from decay and kept the fruit quality at an acceptable level throughout the storage period. According to Issar *et al.* (2010) the reduced spoilage in waxed fruits was probably due to the covering of bruised points with wax and restricting the entry of microorganisms into the fruit.

Dikki *et al.* (2010) reported pre harvest treatment with 6 per cent wax coating and 250 ppm NAA resulted in better retaining of the physicochemical characteristics and also in extending the shelf life of papaya up to 15 days at room temperature as against the 7 days of shelf life of untreated fruits.

Geetha and Thirumaran (2010) observed one week and four week increase in shelf life in waxed vacuum packed papaya fruits kept under room temperature and refrigeration respectively. The effect of chitosan on the physicochemical characteristics of Eksotika II papaya fruit stored at 12 ± 1°C and 85–90 per cent relative humidity was investigated. Chitosan provided an effective control in reducing weight loss, maintained firmness, delayed changes in the peel colour and soluble solids concentration during 5 weeks of storage (Ali *et al.*, 2011). Marpudi *et al.* (2011) observed enhanced storage life of papaya fruits using *Aloe vera* based antimicrobial coating. Maqbool *et al.* (2011) used 10 per cent gum arabic combined with 0.4 per cent cinnamon oil as a bio fungicide for controlling postharvest anthracnose in major tropical fruits such as banana and papaya.

2.5 ETHYLENE ABSORBENT

An exciting new strategy for controlling ethylene production and thus ripening and senescence of fruit, especially climacteric ones, as well as senescence of vegetative tissues, has emerged with the discovery and commercialization of ethylene absorbents or inhibiters.

Ethylene is one of the several plant growth regulators that affect growth and developmental process including ripening and senescence. Ethylene can profoundly affect quality of harvested products. These affects can be beneficial or deleterious depending on the product, its ripening stage and its desired use (Salveit, 1999).

Potassium permanganate is a stable purple solid that is a strong oxidizing agent and readily oxidizes ethylene concentration in the atmosphere around horticultural produce and this was first demonstrated by Forsyth *et al.* (1967) on apples. The reduction in ethylene effected by addition of potassium permanganate was subsequently found to delay the ripening of many climacteric fruits (Wills and Warton, 2004)

Aluminum oxide and potassium permanganate (sachets), activated hydrocarbon (squalane, apiezon) with metal catalyst (sachets), builder- clay powders (films), zeolite films, japanese oya stone (films) and other compound like silicones (phenyl- methyl silicone) are used as ethylene absorbers for prevention of fast ripening and softening in banana fruits (Mangaraj and Goswami, 2009).

Ripening in bananas can be delayed by using an ethylene scrubber. There are several compounds that can be used as inhibitors of ethylene, for example amino ethoxy vinylglycine (AVG), an inhibitor of ethylene synthesis; 1-

Methylcyclopropene (1-MCP), an inhibitor of ethylene action and potassium permanganate ($KMnO_4$), an oxidising agent (Sen *et al.*, 2012).

Fleshy fruit such as papaya during ripening exhibit a climacteric rise in respiration and ethylene production. Ethylene is involved in the initiation and coordination of ripening-process such as internal and skin colour development, softening, flavour and aroma production (Manenoi *et al.*, 2007).

The ethylene inhibitor, 1-methylcyclopropene (MCP) is a nontoxic gas that acts as a non-competitive inhibitor of ethylene action (Sisler and Serek, 1997). 1-MCP is often used as a tool to extend postharvest life and improve quality. Mature Solo papaya treated with 1-MCP a day after harvest is reported to increase the days to reach the ripe stage by 32 per cent, from 5 to 20 days (Hofman *et al.*, 2001). When 'Sunrise' Solo papayas were treated with MCP fruit ripening was delayed (Jacomino *et al.*, 2002). Sunrise Solo papaya treated with 1-MCP at the 10–20 per cent skin yellow and 70–80 per cent skin yellow stage had a delay of 4–6 days while the non-treated control softened in 5 days from 10 to 20 per cent yellow stage and 2 days from the 70 to 80 per cent yellow stage (Ergun and Huber, 2004). Papaya (cvs. Gold and Rainbow) fruit treated with 1-MCP when more than 25 per cent ripe had a delay in softening. The onset of ethylene production and the rise in the respiration rate was also delayed and suppressed in 1-MCP-treated fruit (Manenoi and Paull, 2007). Razali *et al.* (2013) reported in sekaki papaya that combination of heat treatment and 1-MCP was found to be effective in inhibiting the ethylene biosynthesis and reduced percentage of weight loss for four weeks at 10°C.

Manenoi *et al.*.(2007) reported that Rainbow papaya colour break fruit treated with 100 µl/l of 1-MCP for 12 hours and stored at 21 to 22°C delayed the onset of ethylene production and the rise in the respiration rate. 1-MCP-treated fruit had a significant delay of about 7 days in softening and skin colour development. Ruth *et al.* (2010) determined the postharvest responses of two fruit maturity stages (mature green, 5 to15 per cent yellow) of newly harvested *Carica papaya* var Kapoho to various holding times (0, 1, 2 days) in ambient prior to treatment with 1-methylcyclopropene in an air tight chamber. Total soluble solid

(TSS) at the end of shelf life was higher in 5 to 15 per cent yellow fruit treated with 100 μl L^{-1} of 1-MCP. In the 5 to 15 per cent yellow lot peel yellowing was lower in fruit held for 2 days suggesting slower peel colour change at six days after treatment but not at nine days after treatment. Krongyut *et al.* (2011) in Kaek Dum and Red Maradol papaya fruits reported a significant reduction in ethylene production when treated with 1-MCP at 10 per cent yellow peel colour. Papaya treated with 1-MCP experienced a significant delay in skin colour development, weight loss and reduced firmness loss compared with the fruit without 1-MCP treatment. 1-MCP treatment might have delayed softening-related process and thereby extended the postharvest life and maintained the quality of the 'Sekaki' papaya fruit (Ahmad *et al.*, 2013).

Papaya is a climacteric fruit, whose transformations resulting from the ripening occur rapidly after harvesting the physiologically mature fruit, triggered by elevation of ethylene evolution and increase in respiratory rate. To enhance the postharvest life of papaya, it is necessary to use technologies that reduce or remove the ethylene of the storage environment, and this can be achieved by using products such as $KMnO_4$. This product oxidizes the ethylene produced by the fruit during ripening, extending the pre-climacteric period and the post-harvest life (Resende *et al.,* 2001).

According to Correa *et al.*, (2005) the use of $KMnO_4$ as an ethylene absorber reduces the autocatalytic process of ethylene during papaya fruit ripening. Effects of $KMnO_4$ on the extension of postharvest life of 'Sunrise Golden' papaya, stored under modified atmosphere and refrigeration was reported by Silva *et al.* (2009). The potassium permanganate used was effective in maintaining the fruit at the pre-climacteric stage during the 25^{th} day storage, and did not interfere with normal ripening after bag removal.

The use of ethylene absorber to retard the process of ripening, keeping the fruits firmer and with less intensity of colour changes after nine days of storage without affecting the fresh matter loss in papaya had been reported (Correa *et al.*, 2010).

The effectiveness of magnesium oxide (MgO) and potassium permanganate in modifying the in-package gaseous atmosphere to extend the postharvest life of papaya *cv* Rathna was studied. Potassium permanganate was effective as an ethylene scavenger (Jayathunge *et al.*, 2011). The oxidation of ethylene by $KMnO_4$ leads to the formation of water and CO_2 (Saraswathi *et al.*, 2012).

2.6 PHYSIOLOGICAL PARAMETERS

2.6.1 Physiological Loss in Weight

Hot water treatment of Eksotika' papaya fruit left to ripen at ambient temperature (25°C) and about 80 per cent relative humidity experienced almost 12 per cent fresh weight loss during the ripening period (Arina *et al.*, 2010).

Fruits treated with six per cent waxol and NAA 250 ppm showed minimum weight loss while the highest loss was recorded with control. Reduction in weight loss in treated fruits might be due to the retardation of transpiration and respiration (Dikki *et al.*, 2010).

The 1-MCP treated Sekaki papaya fruit experienced slower rate loss as compared with control fruit during the storage. The control fruit experienced maximum water (fresh weight) loss on fifth day while 1-MCP treated fruit showed lower percentage of loss on the same day of ripening (Ahmad *et al.*, 2013) .

The weight loss percentage of 'Sekaki' papaya stored at 10°C followed by transferring to ambient temperature was studied. The percentages of weight loss of Sekaki papaya of all treatments during storage at 10°C were very low. The weight loss increased at faster rates after the fruits were transferred to ambient temperature (Razali, *et al.*, 2013).

2.6.2 Membrane Integrity

Percentage ion leakage is an indicator of loss of membrane integrity resulting from membrane damage. The increase in leakage of intracellular content (electrolyte leakage) is usually due to an increase in membrane permeability as a consequence of injuries caused for example by water (Pimentel *et al.*, 2002) or by salt stress (Amor *et al.*, 2006) ripening or senescence of detached plant organs due to cell collapse (Azevedo *et al.*, 2008).

Electrolyte leakage has also been used as an effective and early indicator of chilling injury. The association of chilling injury and changes in membrane permeability were reported during the storage of plum (Taylor *et al.*, 1993) and guava (Tiwari *et al.*, 2006).

Ion leakage from sunrise solo papaya mesocarp tissue was relatively low and remained nearly constant in slices derived from intact control and intact 1-MCP treated. Electrolyte loss is considered an indirect measure of cell membrane dysfunction associated with both senescence and chilling injury in papaya and other fruit (Ergun *et al.*, 2006).

Azevedo *et al.* (2008) observed that the increase in electrolyte leakage in papaya fruit may be an expression of the fruit ripening and senescence program and may represent a starting point for additional studies on a putative hormonally regulated programmed cell death process during fruit maturation.

The inhibitory effect on ATPase activity may be related to the reduction of membrane integrity as measured by cell electrolyte leakage. Inhibition of the H+ -ATPase implies an abrupt decrease of plasmalemma energization, which could induce cell collapse. However, since a significant H+ gradient was observed at late ripening stages, it seems likely that the ethylene peak could elicit plasmalemma deenergization of only a specific group of cells (Azevedo *et al.*, 2008).

The effect of calcium in tissue firmness is generally explained by complexing cell wall and middle lamella polygalacturonic acid residues imparting improvement of structural integrity. The de-esterified pectin chains may crosslink with either endogenous calcium or added (exogenous) calcium to form a tighter, firmer structure. However, calcium ions may also impact tissue firmness by contributing to increase membrane integrity and the consequent maintenance or increase of cell turgor pressure (Mahmud *et al.*, 2008).

Pereira *et al.* (2009) reported that golden papaya fruit at different maturity stages showed no significant change in absolute membrane integrity percentage for both control and treated fruit during early maturity stages. The values reflected that profound changes in cell membranes had not yet occurred in that period of ripening. After maturity stage 2, fruits not exposed to the gas sulphur hexafluoride (SF_6), (control) showed a great decrease in absolute membrane integrity percentage. Physical integrity of the cellular membranes was reduced leading to a loss of compartmentation as a consequence of ripening. The degree of leakage in control fruit at stage 5 was twice as high as that in green fruit.

2.6.3 Respiration Rate

Papaya fruit demonstrates a climacteric burst in CO_2 production during ripening. There is a gradual increase in CO_2 evolution to peak at as the fruit ripens and the respiratory climacteric appears to peak at a relatively advanced stage of ripeness. The pattern of respiration in ripening fruit varies, depending on maturity at harvest and the holding temperature (Yon, 1994).

The respiration rate at the climacteric peak for different cultivars of papaya at 20 or 25°C typically ranges between 40 and 100 mg CO_2 /kg/hr (Paull and Chen, 1983). During ripening CO_2 accumulates in the cavity. In Solo papaya, the ranges of CO_2 are between 3 to 6 per cent in the cavity. The increase in internal CO_2 concentration to a steady state level on the other hand occurs much, that is, when the fruit is less than 25 per cent yellow (Yon, 1994).

The fruits harvested at different maturity showed a similar variation in respiration rate. The respiratory activity decreased during the first day of storage but after the third day a trend for increase in respiration rate was observed (Bron and Jacomino, 2006).

In cultivars Kaek Dum and Red Maradol treated with 1-MCP retarded respiration rate and delayed the onset of the climacteric peak (Krongyut, *et al.*, 2011).

Carbon dioxide concentration increased in the bags without $KMnO_4$ and accumulated more CO_2. The bags with 1.5 g of $KMnO_4$ maintained a lower concentration of CO_2 during most part of the experimental period. It was observed that CO_2 concentration inside the bags ranged between 5 and 10 per cent in $KMnO_4$ treated fruit, which, however, in treatments without $KMnO_4$, it was above 10 per cent (Silva *et al.*, 2009).

2.7 QUALITY PARAMETERS

Papaya is regarded as an excellent source of vitamin C (ascorbic acid); a good source of carotene, riboflavin, a fair source of iron, calcium, thiamine, niacin, pantothenic acid, vitamin B-6 and vitamin K (Bari *et al.*, 2006; Adetuyi *et al.*, 2008; Saxholt *et al.*, 2008; Saran and Choudhary 2013).

2.7.1 Carotenoids

Carotenoids are responsible for the flesh colour of papaya fruit mesocarp. Red-fleshed papaya fruits contain five carotenoids, *viz.* beta-carotene, betacryptoxanthin, beta-carotene-5-6-epoxide, lycopene and zeta-carotene. Yellow-fleshed papaya contains only three carotenoids, *viz.* beta-carotene, beta-cryptoxanthin and zeta-carotene (Chandrika *et al.*, 2003). Sancho *et al.* (2011) found total carotenoids in papaya pulp (*C. papaya*, *cv.* Maradol) at different ripeness stages, highest being in fruit of 75-100 per cent ripeness (3.27 mg/100 g fresh weight), while the lowest was for 0-25per cent ripeness (0.92 mg/100 g fresh weight).

Carotenoid content (13.80 mg/100 g dry pulp) of papaya was low compared to mango (50 to 260 mg/100 g dry pulp), carrot and tomato (Saran, 2010). Jeyakumar *et al.* (2010) reported 3.46mg/100 g fresh weight of carotenoids in CO-7 variety of papaya.

2.7.2 Total Sugar, Reducing Sugar and Non-Reducing Sugar

Sweet taste is an important quality parameter for fruits. It is usually associated with sucrose, glucose, and fructose contents, which are often used as an index of ripening. Some climacteric fruits, such as kiwi fruit (Rae *et al.*, 1992), and green bananas (Cordenunsi and Lajolo, 1995) have a high starch content which is metabolized to sucrose after harvesting, leading to the fruit sweetness.

In bananas, starch metabolizing enzymes, mainly alpha-amylase and starch phosphorylase along with enzymes related to sucrose synthesis, contribute to this process (Garcia and Lajolo, 1988). The accumulation of sucrose seems to be related to sucrose-phosphate synthase (SPS) and sucrose synthase (SuSy) activities. The former increases during banana ripening, while the latter decreases sharply after harvesting (Cordenunsi and Lajolo, 1995; Nascimento *et al.*, 1997).

Papayas do not accumulate starch during development (Paull 1996; Gomez *et al.*, 1999).

After harvesting and during fruit ripening, sugar changes and sweetness development in papayas are not yet well established, although sweet taste is a possible quality index. Changes in texture, peel, and pulp colour, organic acid levels, and synthesis of volatile compounds normally occur during detached papaya ripening, concomitantly with the climacteric period. There are many contradictions concerning soluble sugar synthesis and accumulation during ripening. Results from investigations done with papayas that ripened attached to the tree, received a constant supply of sucrose that originate from photosynthesis in the leaf, were quite different from those obtained in detached fruit. At the initial stages of papaya development, glucose is prevalent among the soluble sugars (Paull, 1996).

Because papayas have a low starch content at harvest time (about 0.1 per cent), it would not be a sufficient carbon source for the increase in sucrose content and for post-harvest sweetening (Gomez *et al.*, 1999).

The largest change in the cell wall's composition, related to the ripening of many fruits, is the loss of significant amounts of neutral sugars, especially galactose and rabinose (Pressey 1983). The carbon for the sucrose synthesis in papayas may come from the cell wall, which contains about 30 per cent cellulose, 30 per cent hemicelullose, 35 per cent pectin, and 5 per cent proteins (Brett and Waldron, 1996).

According Gomez *et al.*, (1999) the carbon source for the sucrose synthesis after papaya harvest could be derived from galactose, whose levels in the cell wall decreased during fruit ripening. Not sucrose synthase, but sucrose-phosphate synthase activity was highly correlated to sucrose content and seemed to participate in the continuous synthesis of sucrose. The fact that ripe and intermediate papayas are classified as sweeter than green ones, despite the same total soluble sugar content, could be associated to changes in texture, which would result in different sugar liberation from the papaya cells in the mouth during mastication.

The major components of papaya dry matter are carbohydrates (USDA, 2009). There are two main types of carbohydrates in papaya fruits, the cell wall polysaccharides and soluble sugars. During an early stage of fruit development, glucose is the main sugar. The sucrose content increases during the ripening process and can reach levels up to 80 per cent of total sugars (Paull, 1993). Among the major soluble sugars in ripe fruits (glucose, fructose and sucrose), sucrose is most prevalent. During fruit ripening, the sucrose content was shown to increase from 13.9 ± 5.0 mg/g fresh weight in green fruit to 29.8 ± 4.0 mg/g fresh weight in ripe fruits (Gomez *et al.*, 2002).

2.7.3 Total Soluble Solids (TSS)

According to Arina *et al.* (2010) Eksotika papaya fruits harvested at different maturity index treated with hot water showed that the total soluble solids remained more or less unchanged as ripening progressed from Index 2 to Index 5 and no significant changes between the treated and untreated fruits. Dikki *et al.*, (2010) reported, papaya fruits treated with 6 per cent wax coating with 250 ppm NAA recorded highest total soluble solids compared to control.

Kore and Kabir (n.d) reported that in fully mature green guava fruits higher TSS content was maintained in most of the carnauba wax treated and polyethylene packed fruits in later stages of storage (9^{th} day).

2.7.4 Acidity

Golden papaya fruits harvested at different maturity stages did not show any significant change in acidity of the fruit (Iiana and Jacomino, 2006). Papaya fruits treated with ethylene absorbent had no significant effects on titratable acidity. (Osman *et al.*, 2013).

2.7.5 pH

Papaya var. Eksotika fruits treated with hot water showed weakly acidic pH. The pH value did not change throughout the ripening process. A value of about 5.6–5.7 was obtained in treated and untreated fruit at three ripening indices (Arina *et al.*, 2010). Sancho *et al.*, (2010) reported that Maradol papaya harvested at different maturity stages did not show a significant effect on pH values. Papaya fruits treated with ethylene absorbent had no significant effects on pH (Osman *et al.*, 2013).

2.7.6 Nutritional Parameters

Table: 1 Nutritional value of papaya per 100 g (USDA, 2014)

Water	88.06 g
Energy	43 kJ
Protein	0.47 g
Total lipid (Fat)	0.26 g
Carbohydrate, by difference	10.82 g
Fibre, total dietary	1.7 g
Sugars, total	7.82 g
Minerals	
Calcium	24 mg
Iron	0.25 mg
Magnesium	21mg
Phosphorous	10 mg
Potassium	182 mg
Sodium	8 mg
Zinc	0.08 mg
Vitamins	
Vitamin C	60.9 mg
Thiamine (vit B_1)	0.023 mg
Riboflavin (vit B_2)	0.027 mg
Niacin (vit B_3)	0.357 mg
Vitamin B_6	0.038 mg
Folate (vit B_9)	37 μg
Vitamin B_{12}	0.00 μg
Vitamin A, RAE	47 μg
Vitamin A IU	950
Vitamin E (alpha tocopherol)	0.30 mg
Vitamin D ($D_2 + D_3$)	0 μg
Vitamin K (phylloquinone)	2.6 μg
Lipids	
Fatty acids, total saturated	0.081g
Fatty acids, total monounsaturated	0.72 g
Fatty acids, total polyunsaturated	0.058 g
Cholesterol	0 mg

2.8 DISEASE INDEX

There are several important postharvest fungi, with *Colletotrichum gloeosporioides*, causing anthracnose, being the most common and widespread papaya pathogen worldwide (Yon, 1994; Carrillo *et al.*, 2002; Aires *et al.*, 2004). Papaya anthracnose is a major limiting factor in storage and transit, and its importance lies in its influence throughout many other tropical regions where papaya is grown. There are other postharvest fungi associated with papaya that occur on a local level such as *Fusarium* spp, (fusarium fruit rot disease), *Alternaria solani* (alternaria fruit spot), *Rhizopus stolonifer* (rhizopus soft rot), *Penicillium digitatum* (penicillium rot), *Guignardia* spp. (guignardia spot), cercospora papaya (cercospora black spot) and stem-end rot disease that may be caused by various fungi such as *Botryodiplodia theobromae*, *Phomopsis caricae-papayae*, *Mycosphaerella* spp. and *Phytophthora palmivora* (Hewajulige and Wijeratnam, 2010).

Papaya is vulnerable to a large number of diseases and pests with anthracnose being the cosmopolitan and devastating of them during storage (Kader, 2002; Banos *et al.*, 2003). Due to the latency of the pathogen in early ontogeny of the fruits, the symptoms normally only become apparent during ripening (Snowdon, 1990).

Pajaro strawberry fruit were treated at 45° C by hot air or hot water prior to storage treatment with hot water improved fruit resistance to fungal infection, but caused external damage, which rendered fruit commercially unacceptable. Hot air treatment did not affect external appearance, improved resistance to fungal infection and preserved firmness. Heat treatments did not affect cell wall but caused alterations in solubility of the different cell wall polysaccharide fractions (Lara *et al.*, 2006).

Hewajulige *et al.*, (2007) showed that papaya fruits treated with chitosan had low disease severity and maintained 80 per cent of total marketability after 14 days of cold storage followed by two days at ambient temperature (28 ±2°C). Since chitosan is natural product and biodegradable, it will be a biologically sound alternative for exporters faced with bans against fungicides. Chitosan shows the effectiveness in controlling postharvest anthracnose of papaya in laboratory conditions.

In the fruits treated with hot water, ozonated water and wax, no mould under the wax film was observed, indicating that the thermal treatment combined with the ozonization prevented the inner rot of the papaya fruits. (Kechinski *et al.*, 2012).

2.9 MECHANICAL DAMAGE

Bollen *et al.*, (1995) described two different types of mechanical damage during postharvest fruit handling which includes impacts during fruit harvest, selection, manipulation, transport and compression loads during packing lines or storage.

Mechanical damage is considered as a type of stress that occurs during the postharvest manipulation of fruits. This stress is accompanied by physiological and morphological changes that affected the fruit commodity. Apart from the mechanical stress, there are other types of stress due to biological and environmental factors, which also cause quality reduction (Shewfelt, 1998).

Quintana and Paull, (1993) reported mechanical injury to papaya fruit taken randomly from different points along the handling system and ripened at 25° C manifested as green sunken areas on the skin of yellow ripe fruit. Incidence of skin injury increased significantly as the fruit moved through the handling system. The greatest increase in skin injury was seen between and after culling and after packing, with skin injury severity increasing nearly four-fold.

Fresh fruits are very susceptible to mechanical damage during harvesting, packaging and transport, which can result in a substantial reduction in quality. Ideal, such damage would be minimized through improved understanding of the mechanisms. If damage occurs, economic losses might be minimized by grading affected fruits, based on the severity of damage, into those that need more than minimal further processing and those that do not. The main challenge in evaluating mechanical damage to fresh fruit objectively is to develop a method to assess accurately the extent of internal damage to fruits caused by excessive external forces. However, this is still far from being realized and remains an important challenge of past and proposed research in food safety (Li and Thomas, 2014).

2.10 MICROBIAL LOAD

According to Addai *et al.* (2013) papaya fruit of untreated sample revealed an increase in the quantity of colony after seven days of storage. Papaya fruit coated with 10 per cent gum arabic decreased micro-organisms of the fruit when stored at 13° C for 15 days of storage. However, papaya fruit treated with 5 per cent gum arabic and 10 per cent, illustrated a decrease in the number of moulds and yeast. Thus it was found that antimicrobial effect of gum arabic resulted in a decrease the number of colonies in papaya fruit.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Postharvest management practices in papaya (*Carica papaya* L.) for improving shelf life" was under taken at the Department of Processing Technology, College of Agriculture, Vellayani, during 2012-2014, with the objective to determine the stage of harvest maturity of papaya for local and distant market and to standardize postharvest practices for improved shelf life with minimum nutritional loss.

The experiment consisted of three parts. The first part consisted of standardization of stage of harvest for local and distant market. After standardization of stage of harvest for local and distant market the experiment was continued using surface sterilization. The fruits harvested at the standardised stage of harvest for local and distant market were treated with two best sanitizing agents and the effect of waxing and the ethylene absorbent on these treatments were studied (Plate. 1).

3.1 STAGE OF HARVEST

Papaya var. Coorg Honeydew was raised in the field, flowers were tagged at the day of opening and the fruit maturity was worked out (Plate. 2). Fruits were harvested at different maturity stages for local and distant market.

3.1.1 Stage of Harvest for Local Market

For local market, fruits were harvested at ¼ to ½ yellow (Plate. 3). Fruits with ¼ yellow were those with 25 per cent of the surface showing yellowing, surrounded by light green colour. Fruits with ½ yellow were those with 50 per cent of the surface showing yellowing surrounded by light green colour (Pereira *et al.*, 2009).

For local market (Stage I)

T_1- ¼ Yellow

T_2 – ½ Yellow

3.1.2 Stage of Harvest for Distant Market

For distant market fruits were harvested at one stripe yellow and fully mature green stage (Plate. 4). Fruits with one stripe yellow were fruits which did

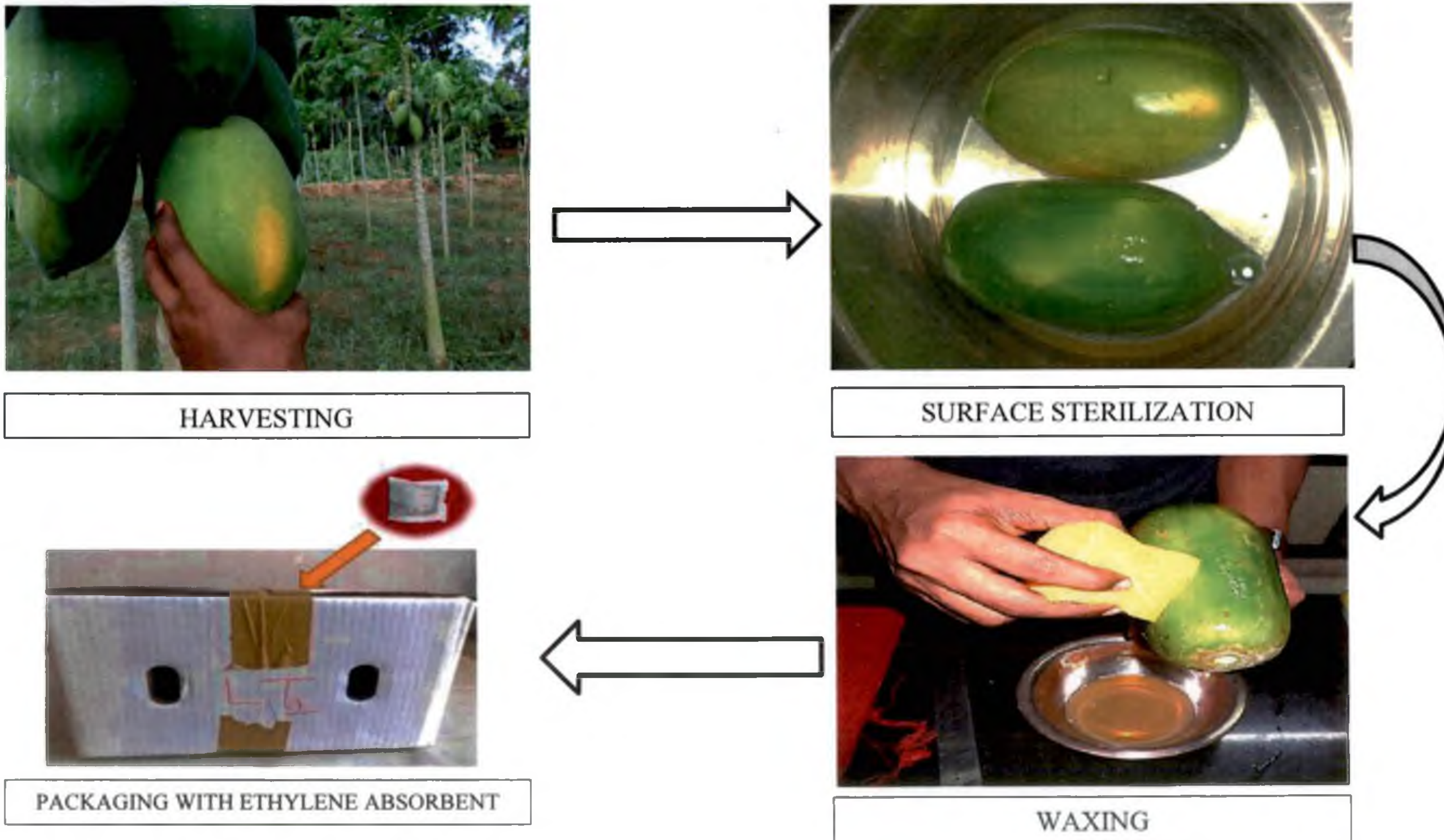

Plate 1: Flow chart of postharvest management in papaya

Plate 2: General view of experimental plot

Plate 3: Treament showing different maturity stages for local market T_1 - ¼ yellow (144.37 DFFB) and T_2 - ½ yellow (146.12 DFFB).

Plate 4: Treatment showing different maturity stages for distant market T_1 - one stripe yellow (142.00 DFFB) and T_2 - fully mature green(139.38 DFFB).

not have more than 15 per cent of the fruit surface yellow and fully mature green fruit were those fruits which were completely matured with 100 per cent green skin colour (Pereira *et al.*, 2009).

For distant market (Stage II)

T_1- One stripe yellow

T_2- Fully mature green

3.2. SURFACE STERILIZATION

3.2.1 Preliminary screening of sanitizing agents

For standardizing sanitizing agent, harvested fruits were washed with running water followed by subjecting to treatments. Hot water (40-50^0 C at different duration), sodium hypochlorite (60 – 150 ppm) and warm sodium hypochlorite (60 -150 ppm) for 10 minutes were applied.

Treatments

Hot water treatment

T_1- 40° C for 20 minutes

T_2- 45° C for 20 minutes

T_3-50° C for 15 minutes

T_4-50° C for 20 minutes

Sodium Hypochlorite

T_1- 60 ppm for 10 minutes

T_2- 90 ppm for 10 minutes

T_3-120 ppm for 10 minutes

T_4-150 ppm for 10 minutes

Warm sodium Hypochlorite

T_1- 60 ppm for 10 minutes

T_2- 90 ppm for 10 minutes

T_3-120 ppm for 10 minutes

T_4-150 ppm for 10 minutes

After hot water treatment fruits were cooled. From this, two best treatments each from hot water, sodium hypochlorite, and warm sodium hypochlorite were selected for further studies, based on microbial load on the last day of edible ripened stage.

The fruits harvested at selected maturity stage for local and distant market were washed in tap water and treated with the sanitizing solutions furnished below for surface decontamination of whole fruit. Each fruit was immersed in different sanitizing solutions in such a way that the whole fruit gets immersed in solution for specified duration (Plate. 5).

Treatments

For local and distant market (Stage I and Stage II)

W_1 - hot water 1 (hot water treatment at 50° C for 15 minutes)

W_2 - hot water 2 (hot water treatment at 50° C for 20 minutes)

W_3 - sodium hypochlorite 1 (sodium hypochlorite 120 ppm for 10 minutes)

W_4 - sodium hypochlorite 2 (sodium hypochlorite 150 ppm for 10 minutes)

W_5 - warm sodium hypochlorite 1 (warm sodium hypochlorite 120 ppm for 10 minutes)

W_6- warm sodium hypochlorite 2 (warm sodium hypochlorite 150 ppm for 10 minutes)

W_7- Control (washing with tap water)

The two best treatments under each stage were selected for further studies and expressed as W_a as first best and W_b as second best.

3.3 WAXING AND ETHYLENE ABSORBENT

The fruits harvested at selected maturity stage for both local market and distant market were sanitized with two best sanitizing agents, and combined with waxing and ethylene absorbents and without these in different combinations.

The fruits at each stage of harvest maturity for local market and distant market were sanitized with two best sanitising agents and waxed and kept in corrugated fibre board boxes with ethylene absorbent and kept under ambient temperature were studied. A control was also kept for local and distant market without sanitizing, waxing and ethylene absorbents in corrugated fibre board boxes packages.

Plate 5: Surface sanitization of whole fruits

Plate 6 : Carnauba wax

The wax used was carnauba wax applied by hand with a sponge, and the papaya fruits were air-dried under the fan as previously described by Kechinski *et al.*, (2012) (Plate. 6 and Plate. 7).

The ethylene absorbent used was $KMnO_4$ pallets taken in muslin cloth sachet of 1.5 cm^2 at the rate of 8.0 g/ kg of fruit. These sachet were kept in corrugated fibre board packages containing papaya fruits for local and distant market (Plate.8).

Treatments

Stage I (For Local market)

The fruits selected as the best stage of harvest for local market was subjected to the following treatments.

T_1 - $W_a + X_1 + E_1$ (1^{st} best sanitizer + waxing+ ethylene absorbent)

T_2 - $W_a + X_1 + E_2$ (1^{st} best sanitizer + waxing +without ethylene absorbent)

T_3 - $W_a + X_2 + E_1$ (1^{st} best sanitizer +without waxing+ ethylene absorbent)

T_4 - $W_a + X_2 + E_1$ (1^{st} best sanitizer +without waxing+ without ethylene absorbent)

T_5 -$W_b + X_1 + E_1$ (2^{nd} best sanitizer + waxing+ ethylene absorbent)

T_6 -$W_b + X_1 + E_2$ (2^{nd} best sanitizer + waxing+ without ethylene absorbent)

T_7 -$W_b + X_2 + E_1$ (2^{nd} best sanitizer + without waxing+ ethylene absorbent)

T_8 -$W_b + X_2 + E_2$ (2^{nd} best sanitizer + without waxing+ without ethylene absorbent)

T_9 - Control

Stage II (For Distant market)

The fruits selected for stage of harvest for distant market was subjected to the following treatments.

T_1 - $W_a + X_1 + E_1$ (1^{st} best sanitizer + waxing+ ethylene absorbent)

T_2 - $W_a + X_1 + E_2$ (1^{st} best sanitizer + waxing +without ethylene absorbent)

T_3 - $W_a + X_2 + E_1$ (1^{st} best sanitizer +without waxing+ ethylene absorbent)

T_4 - $W_a + X_2 + E_1$ (1^{st} best sanitizer +without waxing+ without ethylene absorbent)

T_5 -$W_b + X_1 + E_1$ (2^{nd} best sanitizer + waxing+ ethylene absorbent)

T_6 -$W_b + X_1 + E_2$ (2^{nd} best sanitizer + waxing+ without ethylene absorbent)

T_7 -$W_b + X_2 + E_1$ (2^{nd} best sanitizer + without waxing+ ethylene absorbent)

Plate 7: Waxing of fruit

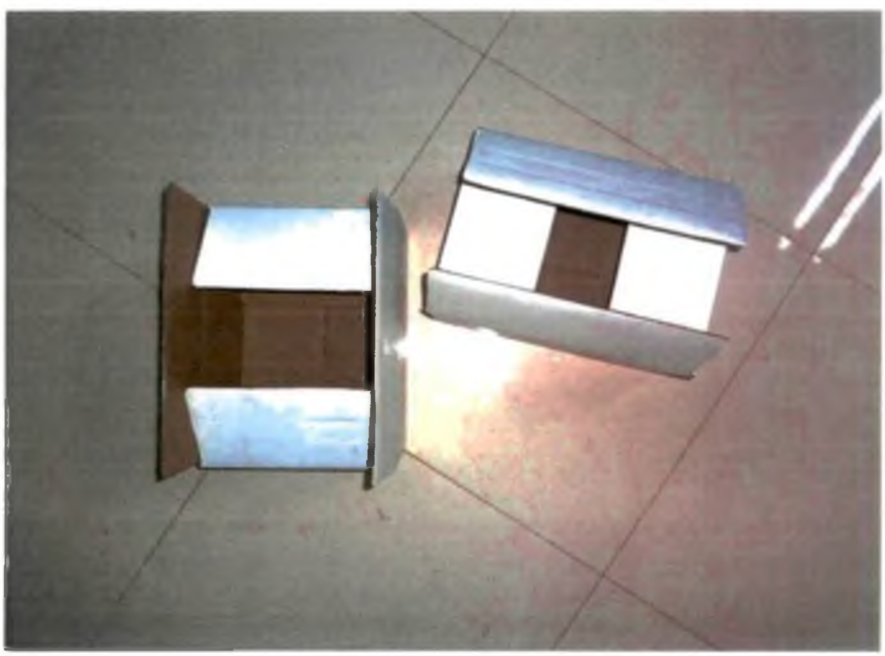

Plate 8: Corrugated fibre board boxes for packing fruits

T_8 -W_b + X_2 + E_2 (2nd best sanitizer + without waxing+ without ethylene absorbent)

T_9 - Control

The papaya fruits for local market and distant market from the above treatments were selected based on the physical, physiological and quality parameters.

3.4 OBSERVATIONS

3.4.1. Physical Parameters

3.4.1.1 Shelf Life

In each treatment, fruit at fully ripe stage was considered as the end of the shelf life in that particular treatment and expressed in days.

3.4.1.2 Sensory Parameters

The physical parameters like colour, texture, appearance, flavour, taste and overall acceptability were examined by conducting a sensory evaluation performed by a 10 member semi trained panel. The panel were asked to evaluate these sensory attributes by organoleptic scoring using a nine point hedonic scale (Appendix I).

3.4.2 Physiological Parameters

3.4.2.1 Physiological Loss in Weight (PLW)

During the storage period, per cent weight loss (physiological loss in weight) was determined on initial weight basis by weighing the fruit samples on the first day of harvest and final weight on the end of shelf life, using the following formula and expressed as percentage (Koraddi and Devendrappa, 2011) :

$$PLW = \frac{\text{Initial weight (g/kg)} - \text{Final weight (g/kg)}}{\text{Initial weight (g/kg)}} \times 100$$

3.4.2.2 Respiration Rate

The changes in the concentration of O_2 and CO_2 over a certain period of time were measured and used to estimate respiration rates. Respiration rate was measured by using Extech Easy view- 80 CO_2 analyser (Plate. 9 and Plate. 10) and expressed in CO_2 mg/kg/hr (Bhande *et al.*, 2008).

Plate 9: Extech Easy view- 80 CO_2 analyser

Plate 10: Meassuring of CO_2 by using CO_2 analyser equipment

3.4.2.3 Membrane Integrity

The uniform sized fruit pieces were made into thin slices, immersed in 20 ml distilled water for three hours and absorbance was read in UV spectrophotometer at 273 nm. The immersed slices were heated in water bath at 100° C for 20 minutes, filtered, filtrate was made upto 20 ml and the absorbance was read in UV spectrophotometer at 273 nm. The loss of membrane integrity was expressed in per cent ion leakage. Percent leakage was calculated using the formula and expressed as percentage (Amith, 2012) :

$$\text{Percent leakage} = \frac{\text{Initial absorbance of bathing medium}}{\text{Final absorbance of bathing medium}} \times \text{Dilution factor}$$

3.5 Quality Parameters

Following parameters were recorded during last day of edible ripening stage.

3.5.1 Carotenoid

Carotenoids were estimated as per the procedure of Saini *et al.*, (2001) and expressed as mg/ 100g of treated fruit.

3.5.2 Total Sugars

The total sugars were determined as per the method described by Ranganna (1977). The results were expressed as per cent on fresh weight basis.

3.5.3 Reducing Sugars

The reducing sugars of the samples were determined as per the method described by Ranganna (1977) as per cent on fresh weight basis.

3.5.4 Non Reducing Sugars

The observation under total sugars and reducing sugars were used for calculating non reducing sugars based on the procedure suggested by Ranganna (1977) and expressed as per cent on fresh weight basis.

Non reducing sugars = Total sugars – Reducing sugars

3.5.5 Total Soluble Solids

Total Soluble Solids (TSS) was recorded directly using Erma Hand refractometer (range 0 -32° brix) and expressed in degree Brix (°B).

3.5.6 Acidity

The titratable acidity was estimated as per the procedure described by Ranganna (1991) and expressed as per cent anhydrous citric acid.

3.5.7 pH

The pH was recorded using electronic pH meter (Saini *et al.*, 2001).

3.5.8 Nutritional Parameters

3.5.8.1 Calcium

The calcium content was estimated by Ethylene Diamine Tetra Acetic Acid (EDTA) titration method (Hesse, 1971) and expressed as mg/100g on fresh weight basis after wet digestion of sample using di -acid mixture.

3.5.8.2 Potassium

The potassium content was estimated by Neutral normal Ammonium Acetate by flame photometry (Jackson, 1973) and expressed as mg/100g on fresh weight basis.

3.5.8.3 Phosphorous

The phosphorous content was estimated from Bray No.1 extractable phosphorus using spectrophotometry (Jackson, 1973) and expressed as mg/100g on fresh weight basis.

3.6 Disease Index

Disease incidence was recorded by the percentage of fruit with any disease. Disease severity of each individual papaya fruit was recorded according to the area affected, using a 1-5 visual rating scale (Maharaj and Sankat, 1990).

1- Zero percent (no disease symptoms)
2- Trace, 1-10 per cent disease symptoms (spot first appearing)
3- Slight, 11-25 per cent disease symptoms (spots increasing in size and number)

4- Moderate, 26-50 per cent disease symptoms (small to large brownish sunken spots with slight to moderate mycelium growth)

5- Severe, 51 per cent to more than 75 per cent disease symptoms (large spots with wide spread mycelium growth fruit is partially or completely rotten)

3.7 Mechanical Damage

Skin injury was expressed as percent of fruit surface area affected. Severity of injury was estimated subjectively on a scale from zero to three (Quintana and Paull, 1993).

0 - None

1 - Light green impact area

2 - Medium green

3 - Dark green

3.8 Microbial Load

The enumeration of microbial load in pre and post treated samples was carried out by serial dilution technique. Nutrient agar and Sabourd Dextrose agar medium were used for the enumeration of bacterial and fungal population of the fruit surfaces respectively.

The fruit was washed with 100 ml sterile distilled water and shaken thoroughly for two minutes. One ml of supernatant was accurately pipetted out into eppendroff tube containing 900 µl of sterile distilled water to get 10^{-3} dilution. This procedure was repeated to get 10^{-5} dilution. 100 µl each of 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were used for enumeration of total bacterial and fungal count. Bacterial count was enumerated for three days continuously from the next day of inoculation whereas fungal count was taken from three days after inoculation and the count just before the damage of the treatment was represented. Number of microorganisms (bacteria and fungi) per cm^2 of post treated sample was calculated as per the following formula (Amith, 2012).

$$\text{No. of colony forming units (cfu) / ml of the sample} = \frac{\text{Total number of colony formed X Dilution factor}}{\text{Aliquot plated}}$$

3.9 Economics of Postharvest Treatments

The economics of postharvest treatment of 1 kg papaya fruit using standardized protocol was calculated as per current market rate (Appendix II and III).

3.10 Statistical analysis

The observations were analyzed statistically in a Completely Randomized Design (CRD) and significance was tested using analysis of variance technique (Gomez and Gomez, 1984). The organoleptic analysis, the different preferences given by the 10 judges as indicated by scores was evaluated by Friedman two-way analysis of variance by ranking.

Results

4. RESULTS

The experimental data collected from the investigation on "Postharvest management practices in papaya (*Carica papaya* L.) for improving shelf life" were analysed and the results are presented in this chapter under the following headings:

4.1 Stage of harvest

4.2 Surface sterilization

4.3 Waxing and Ethylene absorbent

4.1 STANDARDIZATION OF STAGE OF HARVEST

Papaya fruits were harvested at different maturity stages for local and distant market and the physical, physiological and quality parameters were recorded to find out the best stage for local and distant market.

4.1.1 Stage of Harvest for Local Market

4.1.1.1 Physical Parameters

4.1.1.1.1 Shelf Life

The effect of stage of harvest for local market on shelf life of papaya var. Coorg Honeydew is shown in Table 2. There was significant difference in shelf life between papaya fruits harvested at ¼ yellow (T_1) and ½ yellow (T_2). The papaya fruits harvested at ¼ yellow showed a significantly high shelf life of 4.25 days compared to ½ yellow, which had only 2.87 days of shelf life.

4.1.1.1.2 Sensory Parameters

The effect of stage of harvest for local market on sensory parameters of papaya var. Coorg Honeydew is shown in Table 3. Papaya fruits harvested for local market showed no significant difference in sensory parameters between ¼ yellow (T_1) and ½ yellow (T_2).

4.1.1.2 Physiological Parameters

The effect of stage of harvest for local market on physiological parameter is presented in Table 4.

4.1.1.2.1 Physiological Loss in Weight

No significant difference in physiological loss in weight was observed in fruits harvested for local market, at ¼ yellow stage (T_1) and ½ yellow stage (T_2).

Table: 2. Effect of stage of harvest on shelf life of papaya var. Coorg Honeydew for local market

Treatments	Shelf life (days)
T_1	4.25
T_2	2.87
SE	0.3043
CD (0.05)	0.9233

Table: 3. Effect of stage of harvest on sensory parameters of papaya var. Coorg Honeydew for local market

Treatments	Mean sensory scores					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	7.57	7.68	6.77	6.78	7.39	7.23
T_2	7.46	7.72	6.73	6.82	7.41	7.23
SE	0.084	0.120	0.173	0.115	0.137	0.109
CD (0.05)	NS	NS	NS	NS	NS	NS

Table: 4. Effect of stage of harvest on physiological parameters of papaya var. Coorg Honeydew for local market

Treatments	Physiological loss in weight (%)	Membrane integrity (percent leakage)	Respiration rate (mg CO_2/kg/hr)
T_1	1.14	76.15	38.87
T_2	0.71	79.93	36.62
SE	0.353	2.850	1.003
CD (0.05)	NS	NS	NS

4.1.1.2.2 Membrane Integrity

No significant difference in membrane integrity was recorded in fruits harvested at ¼ yellow (T_1) and ½ yellow stages (T_2).

4.1.1.2.3 Respiration Rate

The fruits harvested at ¼ yellow (T_1) and ½ yellow stages (T_2) did not show any significant difference in respiration rate.

4.1.1.3 Quality Parameters

The effect of different maturity stages on quality parameters of papaya var, Coorg Honeydew for local market is shown in Table 5.

4.1.1.3.1 Carotenoids

No significant difference was observed in carotenoids in the fruits harvested at ¼ yellow and ½ yellow stages.

4.1.1.3.2 Reducing Sugars

No significant difference in reducing sugars was observed in fruits harvested at ¼ yellow and ½ yellow stages.

4.1.1.3.3 Non-reducing Sugars

The non-reducing sugars for fruits harvested at ¼ yellow (T_1) and ½ yellow (T_2) stage did not show any significant difference.

4.1.1.3.4 Total Sugars

There was no significant difference in total sugars between fruits harvested at ¼ yellow and ½ yellow stages.

4.1.1.3.5 Total Soluble Solids (TSS)

No significant difference was observed in fruits harvested at ¼ yellow (T_1) and ½ yellow (T_2) stages for total soluble solids.

4.1.1.3.6 Acidity

No significant difference was observed in fruits harvested at ¼ yellow and ½ yellow stages.

4.1.1.3.7 pH

There was no significant difference in the pH of fruits harvested at ¼ yellow (T_1) and ½ yellow (T_2) stages.

Table: 5. Effect of stage of harvest on quality parameters of papaya var. Coorg Honeydew for local market

Treatments	Carotenoids (mg/100 g)	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)	TSS (°Brix)	Acidity (%)	pH
T_1	2.38	6.81	1.53	8.33	10.75	0.24	5.7
T_2	2.40	7.01	1.57	8.59	11.12	0.25	5.5
SE	0.037	0.274	0.101	0.369	0.358	0.016	0.098
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

Table: 6. Effect of stage of harvest on shelf life of papaya var. Coorg Honeydew for distant market

Treatments	Shelf life (days)
T_1	4.71
T_2	5.85
SE	0.225
CD (0.05)	0.788

Table: 7. Effect of stage of harvest on sensory parameters of papaya var. Coorg Honeydew for distant market

Treatments	Mean sensory scores					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	7.13	6.9	6.06	6.23	6.65	6.60
T_2	6.02	5.56	4.78	4.98	5.03	5.25
SE	0.238	0.246	0.372	0.355	0.355	0.285
CD (0.05)	NS	NS	NS	NS	NS	NS

The above described results indicate that the fruits harvested for local market at ¼ yellow (T_1) and ½ yellow (T_2) stages had no significant difference in the physical, physiological and quality parameters. The fruits harvested for local market at ¼ yellow stage had more shelf life (4.25 days) with no significant difference in sensory, physiological and quality parameters compared to fruits harvested at ½ yellow stage. Hence ¼ yellow stage (T_1) was selected as best treatment for further studies for local market.

4.1.2 Stage of Harvest for Distant Market

4.1.2.1 Physical Parameters

4.1.2.1.1 Shelf Life

The effect of stage of harvest for distant market on shelf life of papaya var. Coorg Honeydew is shown in Table 6. The shelf life was found to be significantly higher in fruits harvested at fully mature green, T_2 (5.85 days) and lowest in one stripe yellow, T_1 (4.71 days).

4.1.2.1.2 Sensory Parameters

The effect of stage of harvest for distant market on sensory parameters of papaya var. Coorg Honeydew is shown in Table 7. The papaya fruits harvested for distant market showed no significant difference in sensory parameters between one stripe yellow (T_1) and fully mature green (T_2).

4.1.2.2 Physiological Parameters

The effect of stage of harvest on physiological parameters of papaya var. Coorg Honeydew for distant market is shown in Table 8.

4.1.2.2.1 Physiological Loss in Weight

The physiological loss in weight did not show any significant difference between fruits harvested for distant market at one stripe yellow stage (T_1) and fully mature green stage (T_2).

4.1.2.2.2 Membrane Integrity

There was no significant difference in percent leakage between fruits harvested at one stripe yellow (T_1) and fully mature green stage (T_2).

4.1.2.2.3 Respiration Rate

The respiration rate did not show any significant difference between fruits harvested at one stripe yellow (T_1) and fully mature green stage (T_2).

4.1.2.3 Quality Parameters

The effect of different maturity stages on quality parameters of papaya var, Coorg Honeydew for distant market is shown in Table 9.

4.1.2.3.1 Carotenoids

The fruits harvested at one stripe yellow and fully mature green stage did not show any significant difference in carotenoid content.

4.1.2.3.2 Reducing Sugars

There was no significant difference in reducing sugars between fruits harvested at one stripe yellow (T_1) and fully mature green stages (T_2).

4.1.2.3.3 Non-reducing Sugars

Non reducing sugars did not show any significant difference in fruits harvested at one stripe yellow (T_1) and fully mature green stages (T_2).

4.1.2.3.4 Total Sugars

No significant difference was observed in fruits harvested at one stripe yellow and fully mature green stages with regard to total sugars.

4.1.2.3.5 Total Soluble Solids

The fruits harvested at one stripe yellow (T_1) did not differ significantly from fully mature green stage (T_2) with respect to total soluble solids.

4.1.2.3.6 Acidity

The acidity of fruits harvested at one stripe yellow (T_1) did not differ significantly from fully mature green stage (T_2).

4.1.2.3.7 pH

No significant difference was observed in fruits harvested at one stripe yellow (T_1) and fully mature green (T_2) for distant market with regard to pH.

The above mentioned results indicate that the fruits harvested at one stripe yellow and fully mature green for distant market showed no significant difference in sensory, physiological and quality parameters. However based on higher shelf

Table: 8. Effect of stage of harvest on physiological parameters of papaya var. Coorg Honeydew for distant market

Treatments	Physiological loss in weight (%)	Membrane integrity (Percent leakage)	Respiration rate (mg CO_2 /kg/hr)
T_1	0.96	73.07	40.50
T_2	1.29	72.78	41.87
SE	0.314	4.436	0.471
CD (0.05)	NS	NS	NS

Table: 9. Effect of stage of harvest on quality parameters of papaya var. Coorg Honeydew for distant market

Treatments	Carotenoids (mg/100 g)	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)	TSS (°Brix)	Acidity (%)	pH
T_1	1.75	6.75	1.41	8.16	10.87	0.28	5.43
T_2	1.61	6.53	1.41	8.07	10.5	0.26	5.63
SE	0.048	0.222	0.099	0.355	0.247	0.018	0.073
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

life for fully mature green fruits (T_2), fruits harvested at this stage was selected as the best treatment for further studies.

4. 2 SURFACE STERILIZATION

4.2.1 Preliminary Experiment for Screening of Sanitizing Agents for Local Market

4.2.1.1 Hot Water Treatment

The results of preliminary experiment for screening of hot water treatment at different temperature and duration on papaya var. Coorg Honeydew for local market are presented in Table 10.

Hot water at 50° C for 20 minutes (T_4) registered the highest shelf life (6 days), lowest bacterial (45.50 x 10^6) and fungal (4.00 x 10^3) count, which was on par with T_3 (50° C for 15 minutes). These two treatments were selected as best in the hot water treatment and designated as treatment 50° C for 15 minutes as hot water 1(W_1) and treatment 50° C for 20 minutes as hot water 2 (W_2).

4.2.1.2 Sodium Hypochlorite

The results of preliminary experiment for screening of sodium hypochlorite at different concentration on papaya var. Coorg Honeydew for local market immersed for 10 minutes are presented in Table 11.

Sodium hypochlorite 150 ppm for 10 minutes (T_4) had highest shelf life (6 days), lowest bacterial (70.00 x 10^6) and fungal (6.50 x 10^3) count, which was on par with T_3 (120 ppm for 10 minutes). These two treatments were selected as best among sodium hypochlorite and treatment 120 ppm for 10 minutes was designated as sodium hypochlorite 1(W_3) and treatment 150 ppm 10 minutes as sodium hypochlorite 2 (W_4).

4.2.1.3 Warm Sodium Hypochlorite

The results of preliminary experiment for screening of warm sodium hypochlorite at different concentration on papaya var. Coorg Honeydew for local market immersed for 10 minutes are presented in Table 12.

Warm sodium hypochlorite 150 ppm for 10 minutes (T_4) had highest shelf life (6 days), lowest bacterial (49.50 x 10^6) and fungal (5.50 x 10^3) count, which

Table: 10. Effect of hot water treatment on papaya var. Coorg Honeydew for local market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	4.00	5.08	80.50	10.00
T_2	4.00	4.16	62.50	8.50
T_3	4.67	4.15	56.50	7.50
T_4	6.00	3.77	45.50	4.00
SE	0.440	0.707	1.5	0.612
CD (0.05)	1.438044	NS	5.888785	2.40

Table: 11. Effect of sodium hypochlorite treatment on papaya var. Coorg Honeydew for local market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	4.00	6.64	92.00	10.00
T_2	4.00	5.01	81.50	9.50
T_3	5.00	4.22	75.00	7.50
T_4	6.00	4.07	70.00	6.50
SE	0.288	0.926	3.436	0.661
CD (0.05)	0.941	NS	13.492	2.596

was on par with 120 ppm for 10 minutes (T_3). These two treatments in warm sodium hypochlorite were selected and the treatment warm sodium hypochlorite 120 ppm for 10 minutes was designated as warm sodium hypochlorite (W_5) and treatment warm sodium hypochlorite 150 ppm for 10 minutes as (W_6) for further continuation of the experiment.

4.2.2 Preliminary Experiment for Screening of Sanitizing Agents for Distant Market

4.2.2.1 Hot Water Treatment

The results of preliminary experiment for screening of hot water treatment at different temperature and duration on papaya var. Coorg Honeydew for distant market are presented in Table 13.

The hot water at 50° C for 20 minutes (T_4) had highest shelf life (7.00 days), lowest bacterial (45.50 x 10^6) and fungal (4.00 x 10^3) count, which was on par with 50° C for 15 minutes (T_3). Hence these two treatments were selected as best in the hot water treatment and designated as treatment 50° C for 15 minutes as hot water 1(W_1) and treatment 50° C for 20 minutes as hot water 2 (W_2).

4.2.2.2 Sodium Hypochlorite

The results of preliminary experiment for screening of sodium hypochlorite at different concentration on papaya var. Coorg Honeydew for distant market immersed for 10 minutes are presented in Table 14.

Sodium hypochlorite 150 ppm for 10 minutes (T_4) had highest shelf life (5.33 days), lowest bacterial (89.50 x 10^6) and fungal (7.50 x 10^3) count, which was on par with 120 ppm for 10 minutes (T_3). These two treatments were selected as best among sodium hypochlorite and treatment 120 ppm for 10 minutes was designated as sodium hypochlorite 1(W_3) and treatment 150 ppm 10 minutes as sodium hypochlorite 2 (W_4).

4.2.2.3 Warm Sodium Hypochlorite

The results of preliminary experiment for screening of warm sodium hypochlorite at different concentration on papaya var. Coorg Honeydew for distant market immersed for 10 minutes are presented in Table 15.

Table: 12. Effect of warm sodium hypochlorite treatment on papaya var. Coorg Honeydew for local market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	4.00	4.11	83.00	9.50
T_2	5.00	5.16	62.50	7.50
T_3	5.33	3.85	58.00	6.50
T_4	6.00	2.79	49.50	5.50
SE	0.333	0.870	2.207	0.5
CD (0.05)	1.087	NS	8.668	1.962

Table: 13. Effect of hot water treatment on papaya var. Coorg Honeydew for distant market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	4.33	3.37	91.00	10.50
T_2	6.00	4.04	74.00	8.00
T_3	6.67	4.51	65.50	5.50
T_4	7.00	3.90	45.50	4.00
SE	0.235	1.183	2.031	0.353
CD (0.05)	0.768	NS	7.973	1.388

Table: 14. Effect of sodium hypochlorite treatment on papaya var. Coorg Honeydew for distant market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	3.33	2.48	127.50	12.50
T_2	3.67	2.30	120.50	10.50
T_3	5.00	3.24	116.00	8.50
T_4	5.33	2.06	89.50	7.50
SE	0.408	0.603	5.494	0.5
CD (0.05)	1.331	NS	21.569	1.962

Table: 15. Effect of warm sodium hypochlorite treatment on papaya var. Coorg Honeydew for distant market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	4.00	3.56	131.00	17.00
T_2	4.00	3.83	112.50	12.50
T_3	5.33	3.54	90.00	7.00
T_4	5.67	3.19	65.50	6.50
SE	0.235	0.435	3.446	0.223
CD (0.05)	0.768	NS	13.528	3.103

Warm sodium hypochlorite 150 ppm for 10 minutes (T_4) had highest shelf life (5.67 days), lowest bacterial (65.50 x 10^6) and fungal (6.50 x 10^3) count, which was on par with 120 ppm for 10 minutes (T_3). The treatment sodium hypochlorite 120 ppm for 10 minutes and 150 ppm for 10 minutes are found to be as best treatments and redesignated as W_5 and W_6 and further research was carried out using these selected treatments.

4.2.3 Evaluation of Different Sanitizing Agents for Local Market

The most effective two sanitizing agents having maximum efficiency in controlling the microbial organisms was determined based on microbial count.

4.2.3.1. Shelf Life

The effect of different sanitizing agents on shelf life of papaya var. Coorg Honeydew for local market is shown in Table 16. Significant difference was noted among the papaya fruits treated with different sanitizing agents.

The papaya fruits harvested at ¼ yellow stage treated with hot water at 50° C for 20 minutes (W_2) and warm sodium hypochlorite 150 ppm for 10 minutes (W_6) had highest shelf life (6.00 days), which was on par with sodium hypochlorite 150 ppm (W_4) 5.67 days, hot water at 50° C for 15 minutes W_1 (5.33 days) and warm sodium hypochlorite 120 ppm W_5 (5.33 days). The control sample (W_7) showed lowest shelf life (3.67 days), which was on par with sodium hypochlorite 120 ppm,W_3 (4.67 days).

4.2.3.2 Physiological Loss in Weight

The effect of different sanitizing agents on physiological loss in weight of papaya var. Coorg Honeydew for local market showed significant variation among different treatments and is shown in Table 16. Papaya fruits treated with hot water treatment at 50° C for 20 minutes (W_2) had lowest PLW (2.98 %) which was on par with all the treatments except the control. The control sample (W_7) had the highest PLW (5.18%).

4.2.3.3 Microbial Load

The effect of different sanitizing agents on microbial load of papaya var. Coorg Honeydew harvested at ¼ yellow for local market showed significant variation between treatments and is shown in Table 16. Papaya fruits sanitized

Table: 16. Effect of different sanitizing agents on papaya var. Coorg Honeydew for local market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
W_1	5.33	3.69	59.50	5.00
W_2	6.00	2.98	35.00	3.00
W_3	4.67	3.76	102.00	8.00
W_4	5.67	3.49	74.50	6.50
W_5	5.33	3.30	80.00	5.00
W_6	6.00	3.23	57.50	4.00
W_7	3.67	5.18	122.00	11.50
SE	0.356	0.395	10.370	0.308
CD (0.05)	1.081	1.199	34.683	`0.729

Table: 17. Effect of different sanitizing agents on papaya var. Coorg Honeydew for distant market

Treatments	Shelf life (days)	Physiological loss in weight (%)	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
W_1	5.6	4.51	56.50	5.00
W_2	7.0	4.13	35.00	3.00
W_3	4.6	5.99	69.50	6.50
W_4	5.0	3.65	65.00	5.50
W_5	5.2	3.54	56.50	5.50
W_6	6.3	3.19	49.50	3.50
W_7	4.3	4.74	106.00	12.50
SE	0.398	0.786	4.675	0.597
CD (0.05)	1.208	NS	15.63	1.433

with hot water at 50° C for 20 minutes (W_2) had lowest count of bacterial population (35.00×10^{6}), which was on par with the fruits sanitized with warm sodium hypochlorite, 150 ppm for 10 minutes W_6 (57.50×10^6) and hot water treatment at 50° C for 15 minutes W_1 (59.50×10^6). The control sample (W_7) had maximum count of bacterial population (122.00×10^6) which was on par with sodium hypochlorite 120 ppm for 10 minutes W_3 (102.00×10^6). The papaya fruits treated with warm sodium hypochlorite 120 ppm for 10 minutes (W_5) had a bacterial count of (80.00×10^6) and for sodium hypochlorite 150 ppm for 10 minutes (W_4) the count was 74.50×10^6 and these treatments were on par with each other.

Hot water treatment at 50° C for 20 minutes (W_2) had lowest count of fungal population (3.00×10^3), followed by fruits sanitized with warm sodium hypochlorite 150 ppm for 10 minutes W_6 (4.00×10^3). Hot water treatment at 50° C for 15 minutes W_1 (5.00×10^3) and warm sodium hypochlorite 120 ppm for 10 minutes (W_5) showed the same count (5.00×10^3). The control sample (W_7) had maximum count of fungal population (11.50×10^3). The fruits treated with sodium hypochlorite 120 ppm for 10 minutes (W_3) and sodium hypochlorite 150 ppm for 10 minutes (W_4) showed 8.00×10^3 and 6.50×10^3 fungal counts respectively.

From this experiment, it was observed that sanitization with hot water treatment at 50°C for 20 minutes (W_2) and warm sodium hypochlorite 150 ppm for 10 minutes (W_6) had the lowest count of bacterial and fungal population and hence these treatments were selected for further experiment for local market.

4. 2.4. Evaluation of Different Sanitizing Agents for Distant Market

For distant market papaya var. Coorg Honeydew fruits harvested at fully mature green stage treated with different sanitizing agents were evaluated for shelf life, physiological loss in weight and microbial count.

4.2.4.1 Shelf Life

The effect of different sanitizing agents on shelf life of papaya var. Coorg Honeydew for distant market is shown in Table 17. Papaya fruits treated with hot water at 50° C for 20 minutes (W_2) had highest shelf life (7.00 days), which was on par with warm sodium hypochlorite, 150 ppm for 10 minutes W_6 (6.33 days). The control sample (W_7) had recorded lowest shelf life (4.3 days), which was on par with sodium hypochlorite, 120 ppm for 10 minutes W_3 (4.6 days), sodium hypochlorite, 150 ppm for 10 minutes W_4 (5.00 days) and warm sodium hypochlorite, 120 ppm for 10 minutes W_5 (5.2 days).

4.2.4.2 Physiological Loss in Weight

The effect of different sanitizing agents on physiological loss in weight of papaya var. Coorg Honeydew for distant market is shown in Table 17. No siginificant difference in physiological loss in weight was found in all the treatments of distant market.

4.2.4.3 Microbial Load

The effect of different sanitizing agents on microbial load of papaya var. Coorg Honeydew for distant market is shown in Table 17. Papaya fruits sanitized with hot water treatment at 50° C for 20 minutes (W_2) had lowest count of bacterial population (35.00 x 10^6), which was on par with the fruits sanitized with warm sodium hypochlorite, 150 ppm for 10 minutes (W_6) (49.50 x10^6). The control sample (W_7) had maximum count of bacterial population (106.00 x 10^6). The papaya fruits sanitized with sodium hypochlorite 120 ppm for 10 minutes (W_3) showed a count of 69.50 x 10^6, while that for sodium hypochlorite 150 ppm for 10 minutes W_4 (65.50 x 10^6), warm sodium hypochlorite, 120 ppm for 10 minutes (W_5) and hot water treatment at 50° C for 15 minutes (W_1) were (56.50 x 10^6) on par.

Hot water treatment at 50° C for 20 minutes (W_2) had lowest count of fungal population (3.00 x 10^3), which was on par with the fruits sanitized with warm sodium hypochlorite, 150 ppm for 10 minutes (W_6) (3.50 x10^3). The control (W_7) sample showed maximum count of fungal population of 12.50 x 10^3. The papaya fruit treated with sodium hypochlorite 120 ppm for 10 minutes (W_3) showed a count of 6.50 x 10^3. The treatment sodium hypochlorite, 150 ppm for 10 minutes (W_4) and warm sodium hypochlorite, 120 ppm for 10 minutes (W_5) showed almost the same count of 5.5 x 10^3 while that for, hot water treatment at 50° C for 15 minutes (W_1) was 5.00 x 10^3.

4. 3. WAXING AND ETHYLENE ABSORBENT

4. 3.1. Waxing and Ethylene Absorbent Treatments for Local Market

4.3.1.1 Physical Parameters

4.3.1.1.1 Shelf Life

The effect of pre storage treatments on shelf life of papaya var. Coorg Honeydew for local market is shown in Table 18. Fruits treated with hot water 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) recorded highest shelf life (11.00 days), which was on par with warm sodium hypochlorite 150 ppm for 10 minutes with waxing and ethylene absorbent (T_5) and warm sodium hypochlorite 150 ppm with waxing and without ethylene absorbent (T_6) treatments. (10.33 days). The control sample (T_9) had lowest shelf life (4.00 days). The treatments which was on par with warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (5.67 days), was on par with hot water treatment at 50° C for 20 minutes without wax and without ethylene absorbent (T_4) (6.67 days). The hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent (T_3) (9.33 days) and hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (9.67 days) and warm sodium hypochlorite 150 ppm for 10 minutes without waxing and with ethylene absorbent, T_7 (9.67 days) were on par.

4.3.1.1.2 Sensory Parameter

The effect of prestorage treatments on sensory parameters of papaya var. Coorg Honeydew for local market is shown in Table 19. No significant difference was found in appearance, colour, flavour, texture, taste and overall acceptability among all treatments.

4.3.1.2.1 Physiological Parameters

The effect of prestorage treatments on physiological parameters of papaya var. Coorg Honeydew for local market is shown in Table 20.

4.3.1.2.1 Physiological Loss in Weight

The physiological loss in weight (PLW) was least for the sample treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) (1.84 per cent), which was on par with hot water treatment at 50° C

Table: 18. Effect of pre storage treatments on shelf life of papaya var. Coorg Honeydew for local market

Treatments	Shelf life (days)
T_1	11.00
T_2	9.67
T_3	9.33
T_4	6.67
T_5	10.33
T_6	10.33
T_7	9.67
T_8	5.67
T_9	4.00
SE	0.351
CD (0.05)	1.043

Table: 19. Effect of prestorage treatments on sensory parameters of papaya var. Coorg Honeydew for local market

Treatments	Mean sensory scores					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	5.7	6.5	5.6	5.0	6.0	6.3
T_2	5.6	6.0	4.4	5.0	5.8	5.1
T_3	5.4	4.3	4.8	3.6	4.3	5.2
T_4	4.2	4.8	4.8	6.4	5.3	5.2
T_5	4.3	5.1	5.2	6.4	4.7	4.8
T_6	5.5	4.5	6.3	4.4	4.9	4.6
T_7	4.3	4.2	3.6	5.3	5.2	4.9
T_8	5.1	4.2	4.8	4.3	5.2	4.6
T_9	5.5	5.2	5.2	4.5	4.3	4.1
	NS	NS	NS	NS	NS	NS

for 20 minutes with waxing and without ethylene absorbent, T_2 (1.99 per cent), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (2.10 per cent) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (2.19 per cent). Highest PLW was recorded in control sample, T_9 (3.70 per cent). The treatment warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (2.85 per cent) was on par with warm sodium hypochlorite 150 ppm for 10 minutes without waxing and with ethylene absorbent (T_7) (2.62 per cent). The treatments hot water at 50° C for 20 minutes without waxing and without ethylene absorbent, T_4 (2.44 per cent) and hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (2.38%) were on par.

4.3.1.2.2. Membrane Integrity

Fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) had least percent leakage (58.18 percent), which was on par with warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent T_5 (59.05 percent). The control sample (T_9) had highest percent leakage (96.52 percent).

4.3.1.2.3 Respiration Rate

Significant difference was observed in respiration rate of treated fruits compared with untreated (control). The lowest respiration rate was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent T_1 (30.33 mg CO_2/kg/hr). The control sample (T_9) recorded highest respiration rate (39.00 mg CO_2/kg/hr).

4.3.1.3 Quality Parameters

The effect of prestorage treatments on quality parameters of papaya var. Coorg Honeydew for local market is shown in Table 21.

4.3.1.3.1 Carotenoids

Significant difference was noticed in carotenoid content between different treatments. Highest carotenoid content was exhibited by hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent, T_4 (2.71 mg/100g), which was on par with the hot water treatment at 50° C for 20 minutes

Table: 20. Effect of prestorage treatments on physiological parameters of papaya var. Coorg Honeydew for local market

Treatments	Physiological loss in weight (%)	Membrane integrity (Percent leakage)	Respiration rate (mg CO_2/ kg/hr)
T_1	1.84	58.18	30.33
T_2	1.99	73.28	34.33
T_3	2.38	74.87	35.33
T_4	2.44	95.95	37.33
T_5	2.10	59.05	32.33
T_6	2.19	71.14	33.33
T_7	2.62	73.11	35.67
T_8	2.85	95.77	36.67
T_9	3.70	96.52	39.00
SE	0.127	2.519	0.532
CD (0.05)	0.379	7.485	1.583

Table: 21. Effect of prestorage treatments on quality parameters of papaya var. Coorg Honeydew for local market

Treatments	Carotenoids (mg/100g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	TSS (°Brix)	Acidity (%)	pH	Calcium (mg/100 g)	Potassium (mg/100 g)	Phosphorous (mg/100 g)
T_1	2.68	7.27	1.55	8.82	12.66	0.15	5.56	36.49	196.67	13.09
T_2	2.50	6.90	1.77	8.67	11.66	0.16	5.56	32.28	199.47	13.32
T_3	2.54	7.05	1.73	8.78	12.00	0.11	5.40	34.14	197.60	13.70
T_4	2.71	6.90	1.51	8.41	11.00	0.13	5.26	26.20	137.17	14.00
T_5	2.35	7.14	1.68	8.82	12.00	0.10	5.20	31.57	152.63	11.27
T_6	2.34	6.28	1.81	8.09	10.66	0.11	6.03	29.22	146.66	11.80
T_7	2.30	6.57	1.59	8.15	11.00	0.16	5.70	32.33	159.49	13.83
T_8	2.28	6.85	1.76	8.61	11.33	0.18	5.80	27.39	153.83	10.76
T_9	2.35	6.63	1.55	8.18	10.33	0.11	5.63	26.48	179.45	9.40
SE	0.101	0.299	0.145	0.314	0.415	0.031	0.142	0.749	4.931	0.556
CD (0.05)	0.302	NS	NS	NS	1.2352	NS	0.4227	2.2264	14.651	1.653

with waxing and with ethylene absorbent, T_1 (2.68 mg/100 g), hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (2.54 mg/100 g), hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (2.50 mg/100 g). Warm sodium hypochlorite, 150 ppm for 10 minutes without waxing and without ethylene absorbent (T_8) had recorded lowest carotenoid (2.28 mg/100 g), which was on par with the warm sodium hypochlorite, 150 ppm for 10 minutes without waxing and with ethylene absorbent, T_7 (2.30 mg/100 g), warm sodium hypochlorite, 150 ppm for 10 minutes with waxing with ethylene absorbent, T_6 (2.34 mg/100 g) and control sample, T_9 (2.35 mg/ 100 g).

4.3.1.3.2 Reducing Sugars

No significant difference in reducing sugars was observed in all the treatments, highest reducing sugars being recorded in hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (7.27 per cent) and lowest in the control sample, T_9 (6.63 per cent).

4.3.1.3.3 Non-reducing Sugars

There was no significant difference in non-reducing sugars in all the treatments, however highest non-reducing sugars was recorded in warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (1.81 per cent).

4.3.1.3.4 Total Sugars

The total sugars did not differ significantly between treatments. The hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent (T_5) showed highest total sugars (8.82 per cent). The lowest total sugars were recorded in treatment of warm sodium hypochlorite, 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (8.09 per cent).

4.3.1.3.5 Total Soluble Solids (TSS)

There was significant difference between treatments with regard to total soluble solids. Highest total soluble solids was recorded in fruits treated with the hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (12.66° B), which was on par with the hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (12.00° B), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (12.00° B),the hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (11.66 °B). Lowest TSS was found in the control sample, T_9 (10.33° B).

4.3.1.3.6 Acidity

There was no significant difference between the treatments with respect to acidity. Lowest acidity was recorded in warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (0.10 per cent) and highest was observed in warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (0.18 per cent).

4.3.1.3.7 pH

A significant difference in pH was noted between treatments. The highest pH was observed in warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (6.03) which is on par with warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (5.80), warm sodium hypochlorite 150 ppm for 10 minutes without waxing and with ethylene absorbent, T_7 (5.70). Lowest pH was recorded in warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (5.20).

4.3.1.3.8 Calcium

The calcium content showed significant difference in between treatments. The highest calcium was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (36.49 mg /100 g). Except this treatment all the treatments were on par with the control, T_9 (26.48 mg/ 100 g).

4.3.1.3.9 Potassium

Significant difference in potassium content was noted between treatments. Highest potassium was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent T_2 (199.47 mg /100 g), which was on par with the fruits treated with hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent T_3 (197.60 mg /100 g), fruits treated with hot water treatment at 50° C for 20 minutes waxing and with ethylene absorbent T_1 (196.67 mg /100 g). Fruits treated with hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent (T_4) recorded lowest potassium (137.17 mg/ 100g) content.

4.3.1.3.10 Phosphorous

The phosphorous content of fruits differed significantly between the treatments. The fruits treated with hot water at 50° C for 20 minutes without waxing and without ethylene absorbent (T_4) recorded highest phosphorous content (14.00 mg/100 g), which was on par with the hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (13.70 mg /100 g), fruits treated with hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (13.32 mg /100 g). Lowest phosphorous was recorded in control sample, T_9 (9.40 mg/ 100 g).

4.3.1.4 Disease Index

All the papaya fruits samples whether treated or untreated did not differ significantly with respect to disease index (Table 22).

4.3.1.5 Mechanical Damage

The mechanical damage noted at harvest was practically nil. The effect of prestorage treatments on mechanical damage of papaya due to transport in papaya var. Coorg Honeydew for local market is shown in Table 22.

The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1), hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent (T_2), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent (T_5) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent (T_6) showed lowest score for mechanical damage (0.33). Control sample (T_9) recorded highest score for mechanical damage (1.67).

Table: 22. Effect of prestorage treatments on disease index and mechanical damage of papaya var. Coorg Honeydew for local market

Treatments	Disease index	Mechanical damage
T_1	1.67	0.33
T_2	1.67	0.33
T_3	2.00	1.33
T_4	2.00	1.33
T_5	2.00	0.33
T_6	1.67	0.33
T_7	2.00	1.33
T_8	2.00	1.33
T_9	2.00	1.67
SE	0.192	0.333
CD (0.05)	NS	0.990

4.3.1.6 Microbial Load

The effect of prestorage treatments on microbial load of papaya var, Coorg Honeydew for local market is shown in Table 23. Significant variation in bacterial and fungal count was noticed between treatments. Papaya fruits sanitized with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent had lowest bacterial population, T_1 (25.00×10^6), which was on par with the fruits sanitized with the hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (25.00×10^6), hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent, T_4 (32.00×10^6), hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (32.50×10^6), and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (39.00×10^6). The control sample had maximum bacterial population, T_9 (107.50×10^6). The treatments warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (85.50×10^6), and warm sodium hypochlorite 150 ppm for 10 minutes without waxing and with ethylene absorbent, T_7 (70.00×10^6) were on par.

The papaya fruits sanitized with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent had lowest of fungal population, T_1 (1.50×10^3), which was on par with all the treatments except with control (T_9) and warm sodium hypochlorite 150 ppm for 10 minutes (T_8). The control sample (T_9) had highest of fungal population (11.00×10^3).

4.3.1.7 Economics of Postharvest Treatments for Local Market

The cost of production of postharvest treatments was calculated and details are shown in Appendix II. Highest benefit cost ratio (1.76) was observed in fruits (Table 24) treated with hot water at 50° C for 20 minutes without waxing and without ethylene absorbent (T_4) but these fruits had less shelf life. The fruits treated with hot water at 50° C for 20 minutes followed by waxing and ethylene absorbent (T_1) had more shelf life and benefit cost ratio of 1.04.

Table: 23. Effect of prestorage treatments on microbial load of papaya var, Coorg Honeydew for local market

Treatments	Bacteria (cfu/ml x 10^{6})	Fungi (cfu/ml x 10^{3})
T_1	25.0	1.5
T_2	25.0	2.5
T_3	32.5	2.0
T_4	32.0	2.0
T_5	39.0	2.5
T_6	46.0	2.5
T_7	70.0	2.0
T_8	85.5	4.5
T_9	107.5	11
SE	7.845	0.833
CD (0.05)	17.747	2.665

Table: 24. Economics of postharvest treatments of papaya var. Coorg Honeydew for local market

Treatments	Cost of production (Rs/kg)	Profit (Rs/kg)	Benefit cost ratio
T_1	19.22	0.77	1.04
T_2	13.46	6.53	1.48
T_3	17.56	2.44	1.13
T_4	11.30	8.70	1.76
T_5	21.22	-1.22	0.94
T_6	15.46	4.53	1.29
T_7	19.56	0.44	1.02
T_8	13.30	6.70	1.50

4. 3.2. Waxing and Ethylene Absorbent Treatments for Distant Market

4.3.2.1 Physical Parameters

4.3.2.1.1 Shelf Life

The shelf life of the papaya fruits showed significant variation among treatments. The effect of pre storage treatments on shelf life of papaya var. Coorg Honeydew for distant market is shown in Table 25. The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent showed highest shelf life, T_1 (12.33 days). The control sample, T_9 had lowest shelf life (5.33 days).

4.3.2.1.2 Sensory Parameter

The effect of prestorage treatments on sensory parameters of papaya var. Coorg Honeydew for distant market is shown in Table 26. No significant difference was found in appearance, colour, flavour, texture, taste and overall acceptability in all the treatments of distant market.

4.3.2.2.1 Physiological Parameters

The effect of prestorage treatments on physiological parameters of papaya var. Coorg Honeydew for distant market is shown in Table 27.

4.3.2.2.1 Physiological Loss in Weight

There was significant difference in physiological loss in weight between treatments. The physiological loss in weight was lowest for the sample treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (2.98 per cent), which was on par with hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (3.46 per cent), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (3.72 per cent), hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (3.86 per cent) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (3.91 per cent).

Highest physiological loss in weight was recorded in control sample, T_9 (6.85 per cent), which was on par with warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (5.53 per cent), hot

Table: 25. Effect of prestorage treatments on shelf life of papaya var. Coorg Honeydew for distant market

Treatments	Shelf life (days)
T_1	12.33
T_2	10.33
T_3	9.00
T_4	7.33
T_5	11.00
T_6	9.66
T_7	8.00
T_8	6.66
T_9	5.33
SE	0.430
CD (0.05)	1.278

Table: 26. Effect of prestorage treatments sensory parameters of papaya var. Coorg Honeydew for distant market

Treatments	Mean sensory scores					
	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	6.0	6.2	5.0	6.2	5.9	5.7
T_2	5.8	5.1	5.4	4.4	6.3	6.0
T_3	4.3	4.7	5.2	3.4	6.7	4.6
T_4	5.3	4.9	5.4	4.9	4.2	5.5
T_5	4.7	5.1	4.8	5.5	4.7	3.7
T_6	4.9	4.8	5.0	5.2	3.9	5.4
T_7	5.2	4.0	4.5	5.5	4.5	4.6
T_8	5.2	4.9	4.9	4.1	4.4	4.2
T_9	3.2	4.9	4.6	5.2	4.2	5.1
	NS	NS	NS	NS	NS	NS

Table: 27. Effect of prestorage treatments on physiological parameters of papaya var. Coorg Honeydew for distant market

Treatments	Physiological loss in weight (%)	Membrane integrity (percent leakage)	Respiration rate (CO_2 mg/kg/hr)
T_1	2.98	57.82	35.00
T_2	3.46	72.55	37.67
T_3	3.86	76.32	38.33
T_4	5.06	90.87	40.00
T_5	3.91	69.18	37.00
T_6	3.72	75.17	38.00
T_7	4.81	74.28	39.33
T_8	5.53	93.69	40.33
T_9	6.85	97.48	42.33
SE	0.456	2.0460	0.5665
CD (0.05)	1.355	6.079	1.683

water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_4 (5.06 per cent), warm sodium hypochlorite 150 ppm for 10 minutes without waxing and with ethylene absorbent, T_7 (4.81 per cent).

4.3.2.2.2 Membrane Integrity

A significant difference was observed in membrane integrity between the treatments. Fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) showed least percent leakage (57.82 per cent). The control sample (T_9) had highest percent leakage (97.48 per cent), which was on par with all the treatments except with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1).

4.3.2.2.3 Respiration Rate

The respiration rate recorded showed significant difference between treatments. The lowest respiration rate was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (35.00 mg CO_2/kg/hr). The control sample (T_9) recorded the highest respiration rate (42.33 mg CO_2/kg/hr).

4.3.2.3 Quality Parameters

The effect of different prestorage treatments on quality parameters of papaya var. Coorg Honeydew for distant market is shown in Table 28.

4.3.2.3.1 Carotenoids

No significant difference was found between the treatments.

4.3.2.3.2 Reducing Sugars

There was no significant difference in reducing sugars between the treatments.

4.3.2.3.3 Non-reducing Sugars

No significant difference in non-reducing sugars was observed in all the treatments.

4.3.2.3.4 Total Sugars

Total sugars did not show any significant difference between the treatments.

Table: 28. Effect of prestorage treatments on quality parameters of papaya var. Coorg Honeydew for distant market

Treatments	Carotenoids (mg/100g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	TSS (°Brix)	Acidity (%)	pH	Calcium (mg/100g)	Potassium (mg/100g)	Phosphorous (mg/100g)
T_1	1.80	6.87	1.77	8.63	11.33	0.13	5.43	36.23	176.54	10.80
T_2	1.67	6.47	1.67	8.13	10.66	0.15	5.46	35.21	187.14	11.73
T_3	1.53	6.53	1.73	8.27	10.66	0.15	5.63	32.28	184.00	11.70
T_4	1.59	6.42	1.72	8.13	10.33	0.15	5.90	30.04	146.15	13.50
T_5	1.70	6.38	1.75	8.13	11.66	0.18	5.56	36.52	170.76	9.27
T_6	1.74	6.35	1.85	8.20	10.66	0.15	5.60	32.10	132.4	9.80
T_7	1.67	6.33	1.75	8.08	11.00	0.20	5.70	30.89	127.63	11.83
T_8	1.65	6.00	1.75	7.75	10.33	0.13	5.63	30.64	127.63	8.76
T_9	1.63	6.10	1.58	7.68	10.00	0.11	5.76	28.08	139.43	8.21
SE	0.139	0.388	0.091	0.379	0.293	0.040	0.115	1.258	5.051	0.577
CD (0.05)	NS	NS	NS	NS	0.8734	NS	NS	3.739	15.008	1.715

4.3.2.3.5 Total Soluble Solids (TSS)

Total soluble solids recorded a significant difference between treatments. The highest total soluble solids was recorded in fruits treated with the warm sodium hypochlorite, 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (11.66° B), which was on par with the hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (11.33° B), warm sodium hypochlorite, 150 ppm for 10 minutes without waxing and with ethylene absorbent, T_7 (11.00° B). The lowest TSS was found in control sample, T_9 (10.00° B).

4.3.2.3.6 Acidity

There is no significant difference in acidity among different treatments.

4.3.2.3.7 pH

No significant difference was observed in pH between the treatments.

4.3.2.3.8 Calcium

The calcium content of fruits differed significantly with respect to different treatments. The highest calcium content was recorded in fruits treated with warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (36.52 mg/100 g), which is on par with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (36.23 mg /100 g) and hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (35.21 mg/100 g). The lowest calcium content was recorded in the control sample, T_9 (28.08 mg/ 100 g).

4.3.2.3.9 Potassium

The potassium content recorded significant difference among different treatments. The highest potassium content was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (187.14 mg /100 g), which was on par with the fruits treated with hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent T_3 (184.00 mg /100 g), and hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (176.54 mg /100 g). The fruits treated with warm sodium hypochlorite 150 ppm for 10 minutes without waxing and with ethylene absorbent (T_7) and warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent, T_8 (127.63 mg/100 g) recorded lowest potassium content.

4.3.2.3.10 Phosphorous

A significant difference was noted among various treatments with respect to phosphorous content. The fruits treated with hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent recorded highest phosphorous, T_4 (13.50 mg/100 g), which was on par with the warm sodium hypochlorite 150 ppm for 10 minutes without waxing and without ethylene absorbent T_7 (11.83 mg /100 g). The lowest phosphorous content was in control sample, T_9 (8.21 mg /100 g).

4.3.2.4 Disease Index

All the papaya fruits samples whether treated or untreated had similar disease index (Table 29) and the data was not statistically significant.

4.3.2.5. Mechanical Damage

The mechanical damage during harvest was practically nil. However during transport the mechanical damage recorded showed significant difference between treatments shown in Table 29. For the fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1), hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent (T_2), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent (T_5) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent (T_6) lowest score was noted in mechanical damage (0.33). The control sample (T_9) recorded highest score for mechanical damage (1.67) due to bruises.

4.3.2.6 Microbial Load

Significant difference was noticed in the bacterial and fungal load among various treatments. The effect of prestorage treatments on microbial load of papaya var, Coorg Honeydew for distant market is shown in Table 30. The papaya fruits sanitized with hot water treatment at 50° C for 20 minutes with

Table: 29. Effect of prestorage treatments on disease index and mechanical damage of papaya var. Coorg Honeydew for local market

Treatments	Disease index	Mechanical damage
T_1	1.67	0.33
T_2	1.67	0.33
T_3	2.00	1.33
T_4	2.00	1.33
T_5	2.00	0.33
T_6	1.67	0.33
T_7	2.00	1.33
T_8	2.00	1.33
T_9	2.00	1.67
SE	0.192	0.333
CD (0.05)	NS	0.9904

Table: 30. Effect of prestorage treatments on microbial load of papaya var, Coorg Honeydew for distant market

Treatments	Bacteria (cfu/ml x 10^6)	Fungi (cfu/ml x 10^3)
T_1	94.50	4.50
T_2	118.20	4.50
T_3	126.38	5.00
T_4	127.83	5.50
T_5	122.16	4.50
T_6	132.50	4.50
T_7	137.50	4.50
T_8	139.50	5.00
T_9	235.50	12.50
SE	11.936	2.607
CD (0.05)	38.366	8.340

waxing and with ethylene absorbent (T_1) showed lowest count of bacterial population (94.50×10^6), which was on par with the fruits sanitized with the hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent, T_2 (118.20×10^6), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (122.16×10^6), hot water treatment at 50° C for 20 minutes without waxing and with ethylene absorbent, T_3 (126.38×10^6), hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent, T_4 (127.83×10^6), and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (132.50×10^6). The control sample (T_9) showed maximum of bacterial population (235.50×10^6).

The papaya fruits sanitized with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent showed lowest count of fungal population T_1 (4.50×10^3), which is on par with all the treatments except control. The control sample (T_9) had highest count of fungal population (12.50×10^3).

4.3.2.7 Economics of Postharvest Treatments for Distant Market

The cost of production of postharvest treatments was calculated and details are shown in Appendix III. Highest benefit cost ratio (2.12) was observed in fruits (Table 31) treated with hot water at 50° C for 20 minutes without waxing and without ethylene absorbent (T_4) but these fruits had comparatively less shelf life. The fruits treated with hot water at 50° C for 20 minutes followed by waxing and ethylene absorbent (T_1) had more shelf life with benefit cost ratio of 1.24.

Table: 31. Economics of postharvest treatments of papaya var. Coorg Honeydew for distant market

Treatments	Cost of production (Rs/kg)	Profit (Rs/ kg)	Benefit cost ratio
T_1	19.22	4.77	1.24
T_2	13.46	10.53	1.78
T_3	17.56	6.44	1.36
T_4	11.30	12.70	2.12
T_5	21.22	2.77	1.13
T_6	15.46	8.55	1.55
T_7	19.56	4.44	1.22
T_8	13.30	10.70	1.80

Discussion

5. DISCUSSION

Papaya (*Carica papaya* L.) is a highly perishable fruit and need to be handled with extreme care from the time it is harvested until it reaches the consumer. The estimated postharvest loss of papaya was one of the highest, the main loss being at the ripening stage, at the market and the retail level together contributing to 19.7 per cent (Gajanana *et al.*, 2010).

An experiment was conducted at the Department of Processing Technology, College of Agriculture, Vellayani, to reduce the postharvest loss through postharvest management practices. The investigation was carried out for standardising stage of harvest, surface sterilization and to study the effect of waxing and ethylene absorbent on papaya fruits for local and distant markets. The results of this experiment are discussed in this chapter.

5. 1. STAGE OF HARVEST

5.1.1 Stage of Harvest for Local Market

5.1.1.2 Physical Parameters

5.1.1.2.1 Shelf Life

The papaya fruits harvested at ¼ yellow stage and ½ yellow stage showed significant variation in shelf life. The shelf life for ¼ yellow stage was 4.25 days compared to 2.87 days in ½ yellow stage (Fig.1).

Dhatt and Mahajan (2007) reported that the level of maturity actually helps in selection of storage methods, estimation of shelf life and selection of processing operations for value addition.

New GMC (2003) reported that domesticated market fruits of papaya should be harvested when the skin colour is between one quarter to one half yellow. The degree of ripeness for harvesting of papaya depends upon distance to markets, fruits may be harvested at one quarter to one half for local markets (Paull and Durate, 2011)

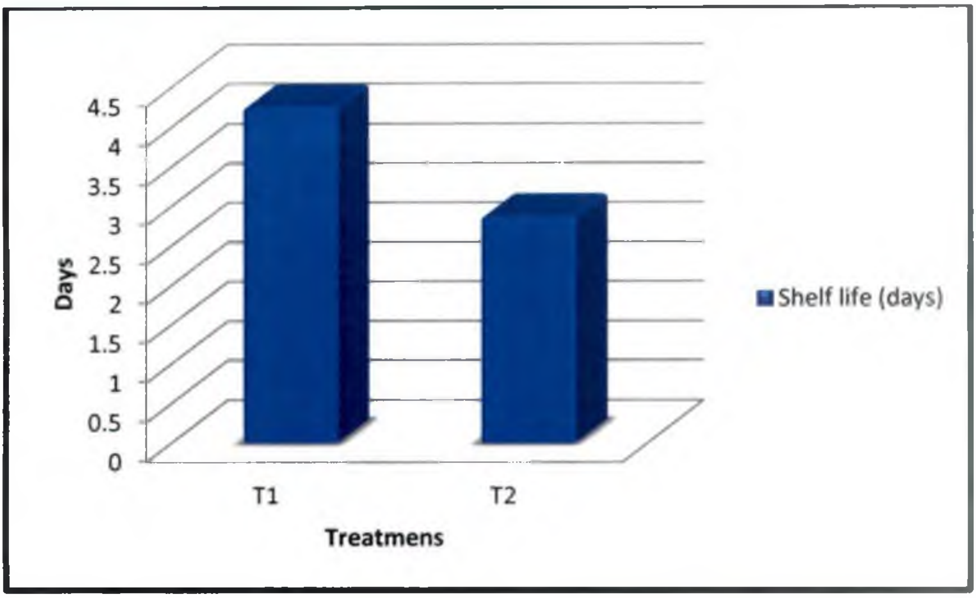

Fig. 1. Effect of stage of harvest on shelf life of papaya var. Coorg Honeydew for local market

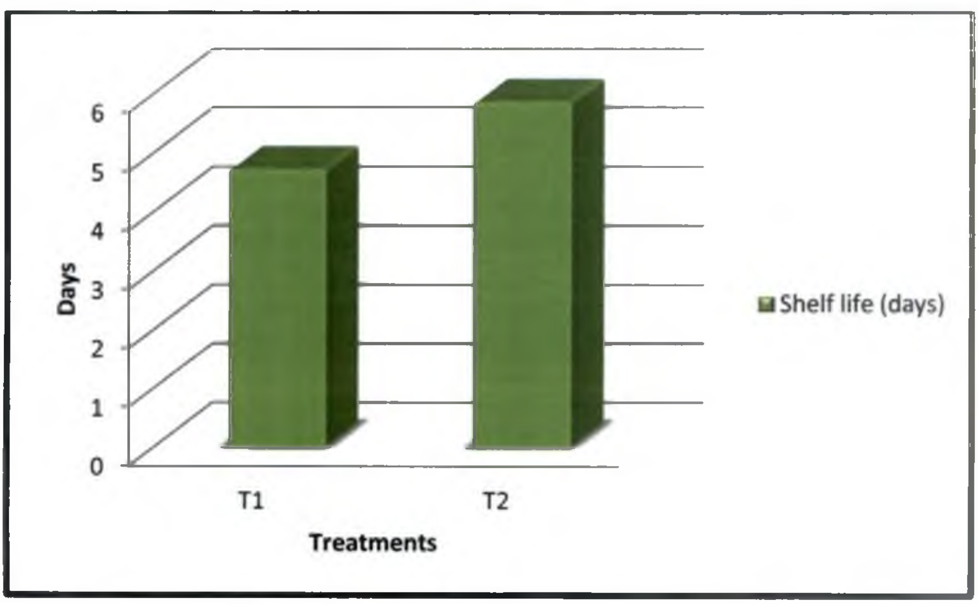

Fig: 2. Effect of stage of harvest on shelf life of papaya var. Coorg Honeydew for distant market

In the present experiment a higher shelf life was recorded in fruits harvested at ¼ yellow and a higher shelf life of 4.25 days indicates the right stage for local market compared ½ yellow stage which remained only for 2.87 days.

5.1.1.2.1 Sensory Parameters

The sensory parameters recorded at edible ripening stage did not show any significant difference between fruits harvested at ¼ yellow stage and ½ yellow stage. The sensory parameter of both stage of harvest were taken at edible ripened stage and no difference in appearance, colour, flavour, texture, taste and overall acceptability was noticed between ¼ yellow and ½ yellow. There is no difference in sensory parameter between ¼ yellow and ½ yellow, it is better to choose ¼ yellow as stage of harvest for local market since it has higher shelf life (4.25 days).

5.1.1.2 Physiological Parameters

5.1.1.2.1 Physiological Loss in Weight, Membrane Integrity, Respiration Rate

The results did not show any significant difference in physiological loss in weight, membrane integrity, and respiration rate between the fruits harvested at ¼ yellow stage and ½ yellow stage. At final edible ripened stage whether the fruit was harvested on ¼ yellow or ½ yellow, show similar loss in weight, membrane integrity, and respiration rate which once again suggest that ¼ yellow can be taken as better stage of harvest for local market based on higher shelf life.

5.1.1.2 Quality Parameters

There is no significant difference in quality between papaya fruits harvested at ¼ yellow and ½ yellow stage. According to Paull (1996) in papaya increase in sweetness after harvest does not take place because unlike other crop such as banana, papaya does not accumulate starch during development. According to Gomez *et al.* (1999), papaya only has low starch content at harvest time (colour break) therefore it would not be a sufficient carbon source for the increase in sucrose content and for postharvest sweetening. Sarananda *et al.* (2004) were of the opinion that papaya var. Rathna must be harvested at 50 per cent yellow stage to maintain best postharvest quality. The availability of less starch along with less difference in shelf life might be the reason for the no significant difference in reducing, non-reducing and total sugars between the treatments.

There was no significant difference in carotenoids between fruits of ¼ yellow and ½ yellow stages. According to Sancho *et al.* (2011) during ripening, chlorophyll began to degrade, coinciding with carotenoid synthesis and resulting in a significant increase of yellow orange colour. The chlorophyll might have degraded and coincided with carotenoid synthesis taking more time in ¼ yellow and less time in ½ yellow but remained the same at the edible fully ripened stage when we recorded the carotenoids.

The maturity stage of papaya did not show any significant effect on pH values, which represents the presence of acidic groups, including organic acids, phenols and amino acids. The pH tends to change, depending on the variety and the degree of ripeness of the fruit (Iiana and Jacomino, 2006; Barajas *et al.*, 2008; *Laura et al.*, 2010 and Sancho *et al.*, 2010).

Many researchers reported that the acidity values did not show any significant change in the different maturity stages of papaya fruit. (Iiana and Jacomino, 2006; Aguayo *et al.*, 2008; Barajas *et al.*, 2008; *Laura et al.*, 2010 and Sancho *et al.*, 2010).

The higher shelf life (4.25 days) in papaya fruits harvested at ¼ yellow stage (T_1) and no significant difference in physiological, sensory and quality parameters compared to ½ yellow stage (T_2) indicate that at ¼ yellow stage can be considered as right maturity for local market for further continuation of the experiment.

5.1.2. Stage of Harvest for Distant Market

5.1.2.1 Physical Parameters

5.1.2.1.1 Shelf Life

The papaya fruits harvested at one stripe yellow (T_1) differed significantly in shelf life from the fruit harvested at fully mature green stage T_2 (Fig.2). The degree of ripeness for harvesting of papaya depends upon distance to markets. New Guyana Marketing cooperation reported that for export, papaya should be harvested between one stripe yellow and quarter ripe stage (New GMC, 2003).

Paull and Durate (2011) were of the opinion that fruits to be transported long distances or export should be harvested at colour break to one quarter ripe, depending upon the cultivars, ripening characteristics and season.

In the present investigation higher shelf life 5.85 days was reported in fully mature green stage compared to one stripe yellow (4.71 days). Which might be because of the more time taken for ripening of fully mature green fruits.

5.1.2.1.1.2 Sensory Parameters

The sensory parameters recorded at edible ripening stage did not show any significant difference between fruits harvested at one stripe yellow stage and fully mature green stage.

5.1.2.2 Physiological Parameters

5.1.1.2.1 Physiological Loss in Weight, Membrane Integrity, Respiration Rate

The physiological parameters especially the physiological loss in weight, membrane integrity and respiration rate of papaya fruits harvested at one stripe yellow and fully mature green did not show any significant variation. The similarity in physiological parameters explains the similar characteristics in the papaya fruits harvested at one stripe yellow and fully mature green stage.

5.1.2.3 Quality Parameters

The papaya fruits harvested at one stripe yellow and fully mature green stage for distant market did not show significant difference in quality parameters like carotenoids, reducing sugars, non-reducing sugars, total sugars, TSS, acidity and pH. Paull (1996) reported that papaya does not increase in sweetness after harvest because unlike other crop such as banana, papaya does not accumulate starch during development. According to Gomez *et al.* (1999), papaya only has low starch content at harvest time (colour break), therefore it would not be a sufficient carbon source for the increase in sucrose content and for postharvest sweetening.

The above results suggest that the papaya fruits harvested at fully mature green stage can be selected for distant market since the shelf life was significantly higher (5.85 days) with not much difference in physiological, sensory and quality attributes compared to fruits harvested at one stripe yellow.

5.2 SURFACE STERILIZATION

5.2.1 Sanitizing Agents for Local Market

5.2.1.1 Shelf Life

Significant difference was noticed between different sanitising agents with respect to shelf life (Fig.3). A higher shelf life was noticed in papaya fruits treated with sanitising agent hot water treatment at 50° C for 20 minutes (W_2) and warm sodium hypochlorite 150 ppm for 10 minutes (W_6) compared to untreated ones (control) .

According to Alvindia (2012) hot water treatment delayed ripening and prolonged green life of fruit. Zaho *et al.* (2013) observed that hot water treatment at 54° C for 4 minutes effectively slowed fruit ripening in papaya.

The higher shelf life in the W_2 and W_6 treatments might be due to lesser microbial load as well as delayed ripening in these treatments compared to control.

5.2.1.2 Physiological Loss in Weight

The physiological loss in weight recorded for papaya fruits harvested at ¼ yellow stage sanitised with different sanitising agents showed significant difference (Fig. 4). The physiological loss in weight was lowest for hot water treatment at 50° C for 20 minutes (W_2) compared to control (W_7).

Arina *et al.* (2010) reported that hot water treatment of Eksotika papaya fruit left to ripen at ambient temperature (25° C) and about 80 per cent relative humidity experienced about almost 12 per cent fresh weight loss during the ripening period.

The less physiological loss in weight in W_2 treatment might be due to the less loss in membrane integrity. The membrane being intact, the loss of water will be less.

5.2.1.3 Microbial Load

The microbial load in papaya fruits harvested at ¼ yellow for local market and treated with different sanitising agents showed significant variation (Fig. 5 and Fig.6). Higher bacterial and fungal load were noticed in untreated papaya fruits (control). The treatments with hot water at 50°C for 20 minutes (W_2) and

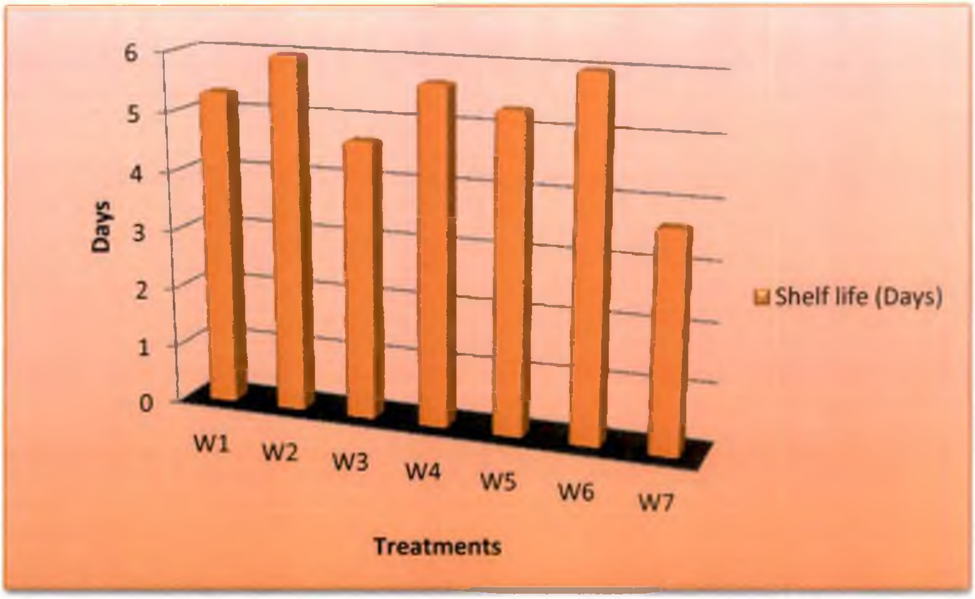

Fig. 3. Effect of different sanitizing agents on shelf life of papaya var. Coorg Honeydew for local market

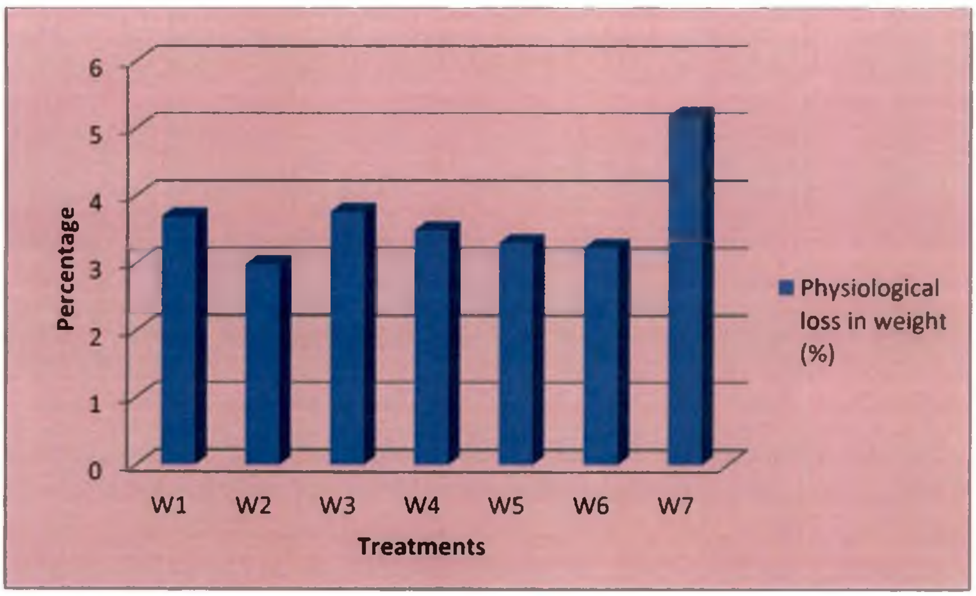

Fig. 4. Effect of different sanitizing agents on physiological loss in weight of papaya var. Coorg Honeydew for local market

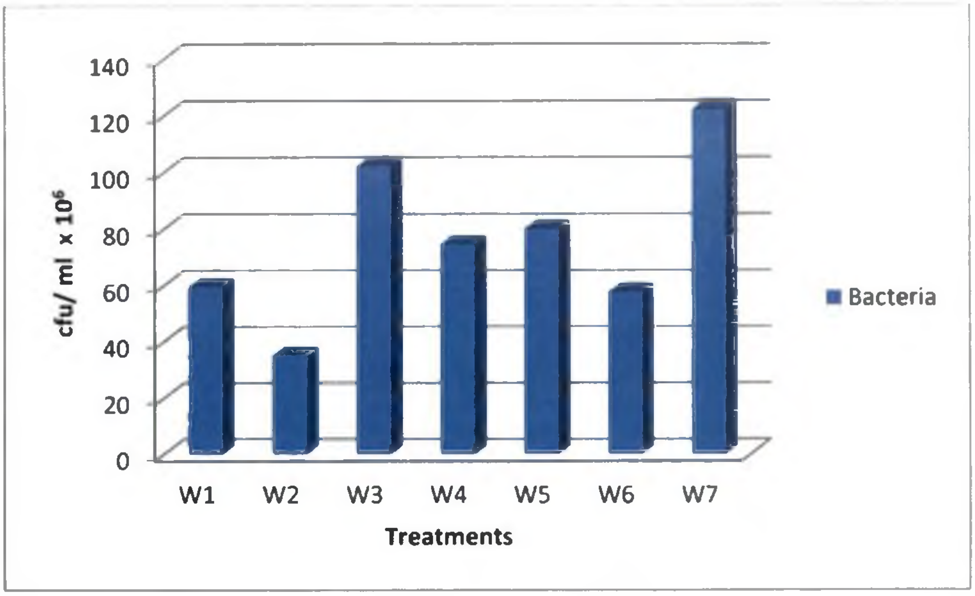

Fig. 5. Effect of different sanitizing agents on bacterial count of papaya var. Coorg Honeydew for local market

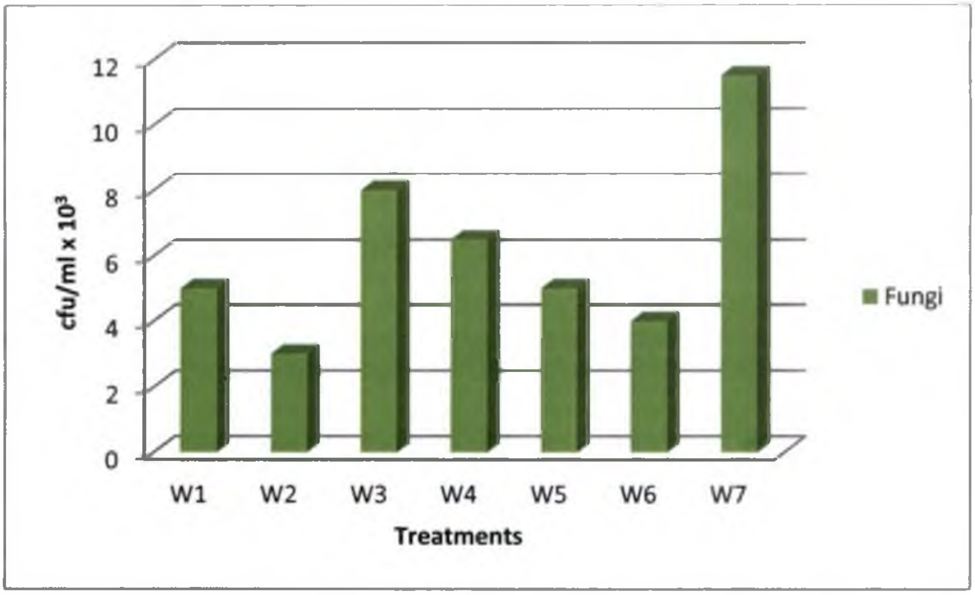

Fig. 6. Effect of different sanitizing agents on fungal count of papaya var. Coorg Honeydew for local market

warm sodium hypochlorite, 150 ppm for 10 minutes (W_6) recorded lowest microbial population. Hot water treatment is suggested as a method for fruit fly disinfestation which is a quarantine requirement for the papaya exporting industries. The hot water treatment at 47 ±1 °C could maintain postharvest quality of 'Eksotika' papaya fruit and at the same time prevented it from insect infestation (Arina *et al.* 2010). Martins *et al.* (2010) reported that treatments of papaya fruit with hot water at 48- 50° C for 20 minutes controlled the *Colletrotrichum gleosporoides* and *Phoma caricae.*

Nishijima (1994) was of the opinion that sodium hydroxide, sodium carbonate, sodium hypochlorite (Clorox), EDTA and calcium hypochlorite were found to be safe to use in five minute dip at 8000 ppm for papaya fruits instead of mancozeb for the prevention of major postharvest diseases as well as blight caused by *Phytophthora palmivora.*

New Guyana Marketing cooperation reported that wash water containing a mild detergent like hypochlorous acid at concentration of 150 ppm in water at pH of 6.5 along with thiabendazole 50 ppm was effective to control postharvest disease of papaya (New GMC, 2004).

The above results on the use of different sanitizing agents suggest that hot water treatment at 50° C for 20 minutes and warm sodium hypochlorite 150 ppm for 10 minutes were the best treatments based on the improved shelf life, less physiological loss in weight and less microbial load. The lesser microbial load in these treatments might have improved the shelf life. Hence these treatments are selected as the two best sanitising agents for continuing the experiment.

5.2.2 Sanitizing Agents for Distant Market

5.2.2.1 Shelf Life

The papaya fruits harvested at fully mature green stage for distant market were sanitised with different sanitising agents and was compared with the untreated one (control). The treatments, hot water at 50° C for 20 minutes (W_2) and warm sodium hypochlorite 150 ppm for 10 minutes (W_6) recorded significantly superior shelf life of 7 days and 6.3 days respectively compared to 4.3 days in the case of control (Fig.7).

Zaho *et al.* (2013) observed that hot water treatment at 54° C for 4 minutes effectively slowed fruit ripening in papaya.

The improved shelf life might be due to the delay in ripening process accompanied by less microbial load in these treatments

5.2.2.2 Physiological Loss in Weight

Papaya fruits harvested at fully mature green stage sanitized with different sanitising agents showed no significant difference in physiological loss in weight. The result was similar to those reported by Lazan *et al.* (1990) and Arina *et al.* (2010).

The less loss in membrane integrity combined with delay in ripening process might have resulted in less physiological loss in weight in the above treated papaya fruits.

5.2.2.3 Microbial Load

The microbial load in papaya harvested at fully mature green stage and sanitised with different sanitising agents showed significant variation with respect to bacterial and fungal count (Fig. 8 and Fig. 9). Higher bacterial and fungal population observed in the control (W_7) and lowest in hot water treatment at 50° C for 20 minutes (W_2) and warm sodium hypochlorite at 150 ppm for 10 minutes W_6.

Martins *et al.* (2010) reported that papaya fruits treated with hot water at 48-50° C for 20 minutes controlled *Colletotrichum gleosporoides* and *Phoma caricae*. NHB (2012) also recommends hot water treatment for papaya fruits meant for export for the control of anthracnose. Sanchez *et al.* (2013) reported that antifungal hot water treatment of 55° C for 3 minutes did not affect negatively the quality parameter of pulp and skin of papaya at their colour break stage of ripeness. The hot water at 50° C for 20 minutes (W_2) and warm sodium hypochlorite 150 ppm at 10 minutes (W_6) appears to be good bacterial and fungal disinfectants.

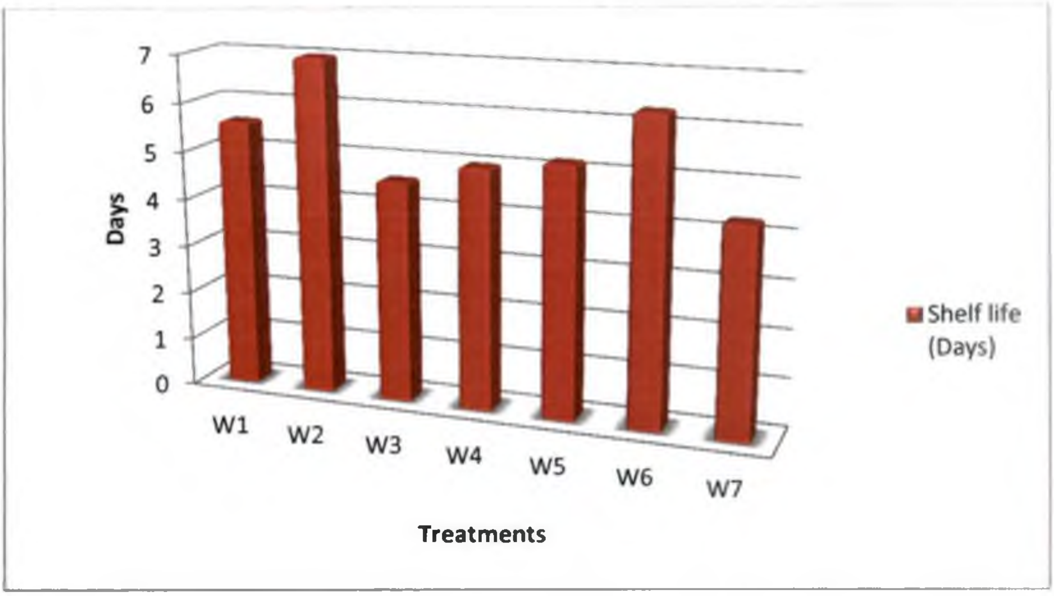

Fig. 7. Effect of different sanitizing agents on shelf life of papaya var. Coorg Honeydew for distant market

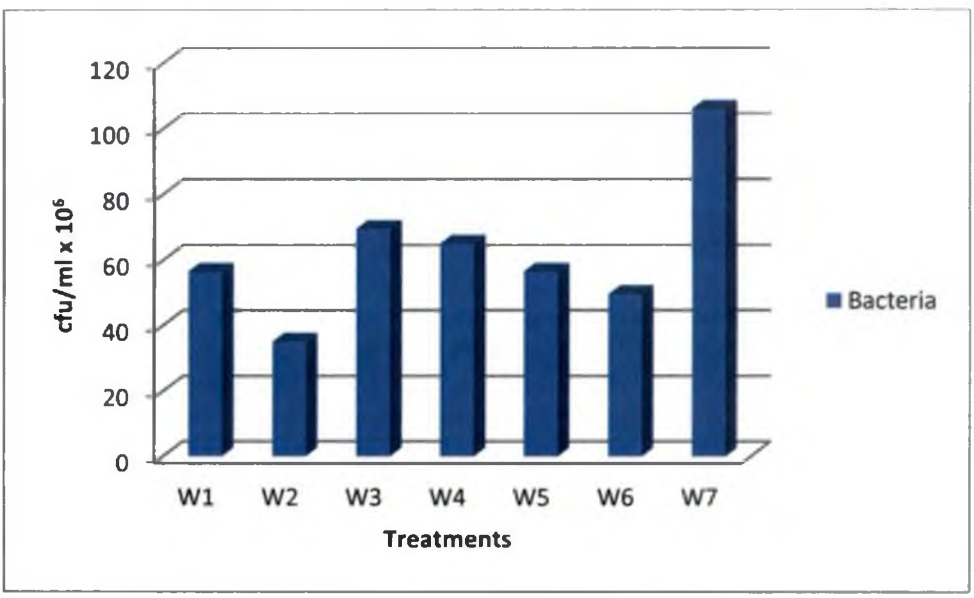

Fig: 8. Effect of different sanitizing agents on bacterial count of papaya var. Coorg Honeydew for distant market

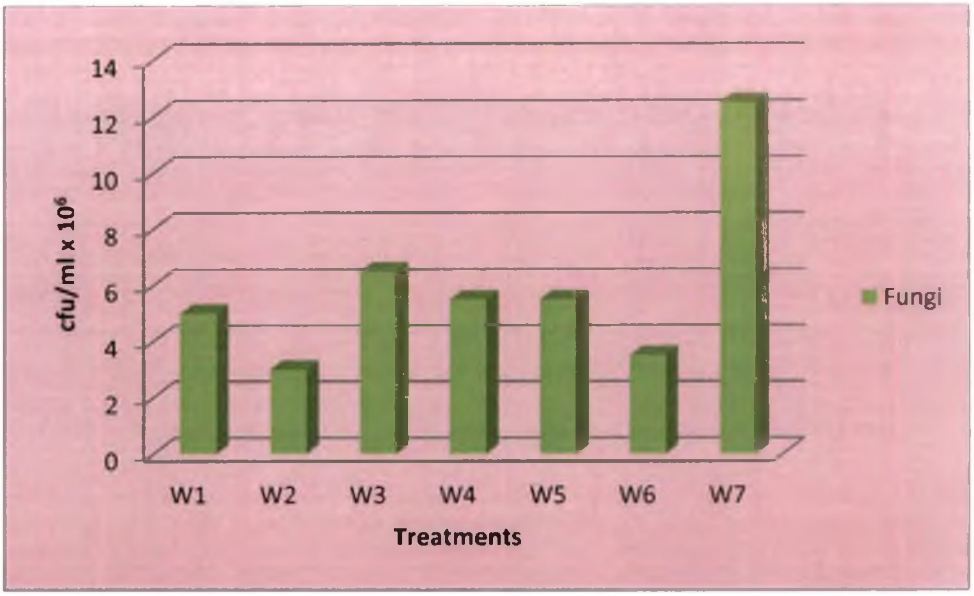

Fig: 9. Effect of different sanitizing agents on fungal count of papaya var. Coorg Honeydew for distant market

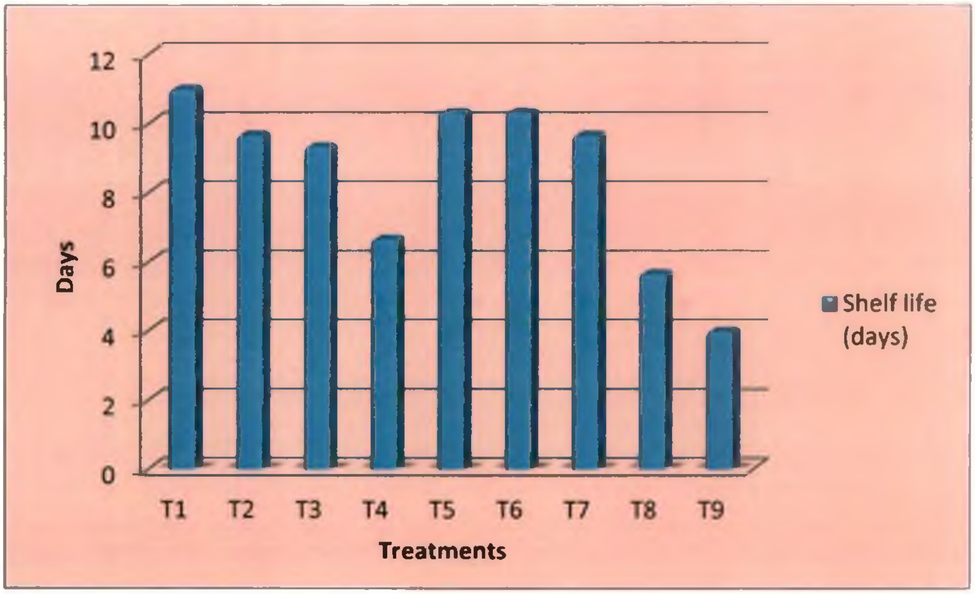

Fig. 10. Effect of pre storage treatments on shelf life of papaya var. Coorg Honeydew for local market

The result of the above study substantiate the improvement of shelf life in papaya fruits treated with hot water treatment 50° C for 20 minutes and warm sodium hypochlorite, 150 ppm for 10 minutes in terms of less microbial load. These two treatments act as best sanitising agents for distant market.

5. 3. WAXING AND ETHYLENE ABSORBENT

The need for suitable alternatives of fungicides to control postharvest decay has prompted research aimed at combining various alternatives to design a control strategy that equals the effectiveness of synthetic chemicals. Hence in the present experiment the effect of waxing and ethylene absorbent were also studied.

5. 3.1. Waxing and Ethylene Absorbent for Local Market

5.3.1.1 Physical Parameters

5.3.1.1 Shelf Life

The papaya fruits harvested at ¼ maturity sanitised with two agents followed by waxing or without waxing and ethylene absorbent or without ethylene absorbent recorded significant difference in shelf life (Fig. 10). Treatments T_1 (hot water 50° C for 20 minutes with wax and with ethylene absorbent) and T_5 (warm sodium hypochlorite 150 ppm for 10 minutes with wax and with ethylene absorbent) and T_6 (warm sodium hypochlorite 150 ppm for 10 minutes with wax and without ethylene absorbent) were on par. The best treatment (T_1) could produce variation in the shelf life from 4 to 11 days. This might be because of the delay in ripening process due to modified atmospheric condition brought about by waxing and ethylene absorbents and the less decay due to less microbial load in these treatments (Plate 11).

Potassium permanganate oxidises the ethylene produced by the fruit during ripening extends the pre-climacteric period and the postharvest life (Resende *et al.* 2001).The reduction in ethylene effected by addition of potassium permanganate subsequently forced to delay the ripening of many climacteric fruits was also reported by Wills and Warton (2004).

Dikki *et al.* (2010) reported that postharvest treatment with 6.0 per cent wax coating and 250 ppm NAA resulted in extending the shelf life of papaya up to 15

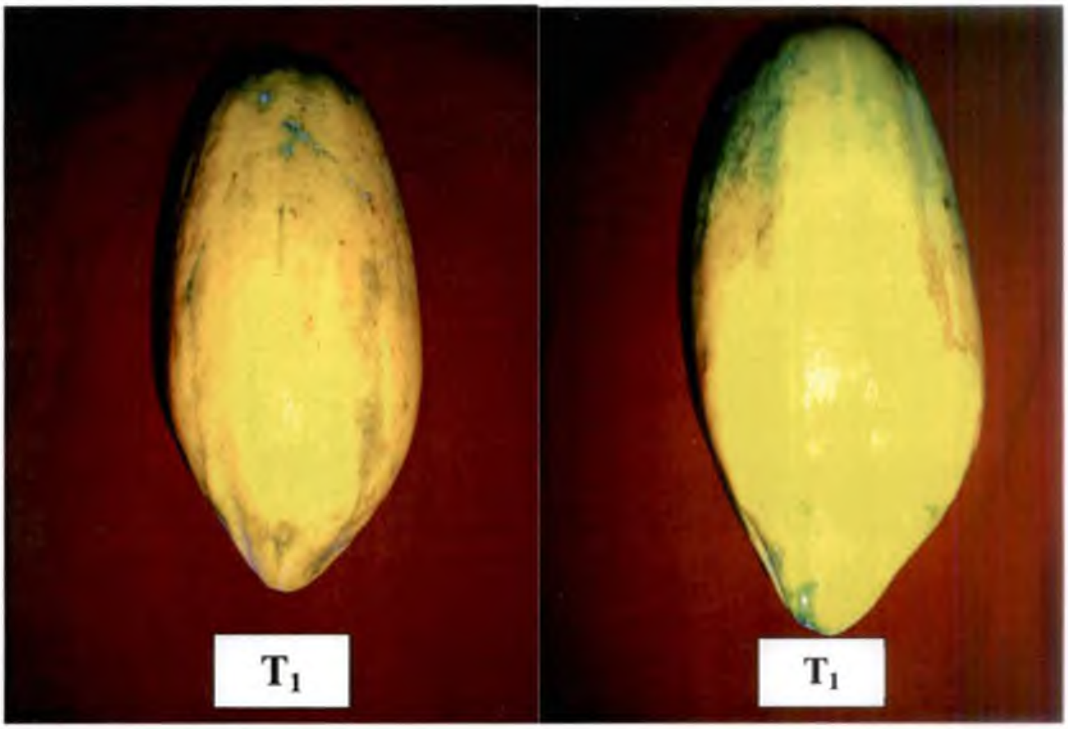

Plate11: Best treatments for local market (T_1) and distant market (T_1) of papaya var. Coorg Honeydew

days at room temperature as against the 7 days of shelf life of untreated fruits. Geetha and Thirumaran (2010) also observed one week and four week increase in shelf life in waxed vacuumed papaya fruits kept under room temperature and refrigeration process.

The effect of $KMnO_4$ on the extension of postharvest life of 'Sunrise Golden' papaya stored under modified atmosphere and refrigeration was reported by Silva *et al.* (2009). The effectiveness of MgO and $KMnO_4$ in modified atmosphere package extended the postharvest life of papaya cv. Rathna (Jayathunge *et al.*, 2011).

It is well established that ripening of climacteric fruit is hastened by autocatalytic production of ethylene, which triggers respiration rate and stimulate the ripening process. By using ethylene absorbent, whatever ethylene that was produced might have been oxidised by $KMnO_4$ thus reducing the autocatalytic process of ethylene during ripening and hence delayed the ripening process.

5.3.1.1.2 Sensory Parameter

No significant difference was found in appearance, colour, flavour, texture, taste and overall acceptability in all the treatments of local market

5.3.1.2.1 Physiological Parameters

5.3.1.2.1 Physiological Loss in Weight

The maximum weight losses were recorded in control, T_9 (3.70 per cent). The least physiological loss in weight (1.84 per cent) was with the fruits treated with hot water at 50° C for 20 minutes in combination with waxing and ethylene absorbent T_1 (Fig. 11). The heat energy produced from the respiration process released from the fruit by evaporation of water caused a weight loss (Dharmasenal and Kumari, 2005; Zewter *et al.*, 2012).

The minimization of weight loss in wax coated fruits might be due to the action of wax as a physical barrier to gas diffusion from fruit stomata through which the gas exchange takes place between tissue and external atmosphere (Islam *et al.*, 2001; Saravanan *et al.*, 2013).

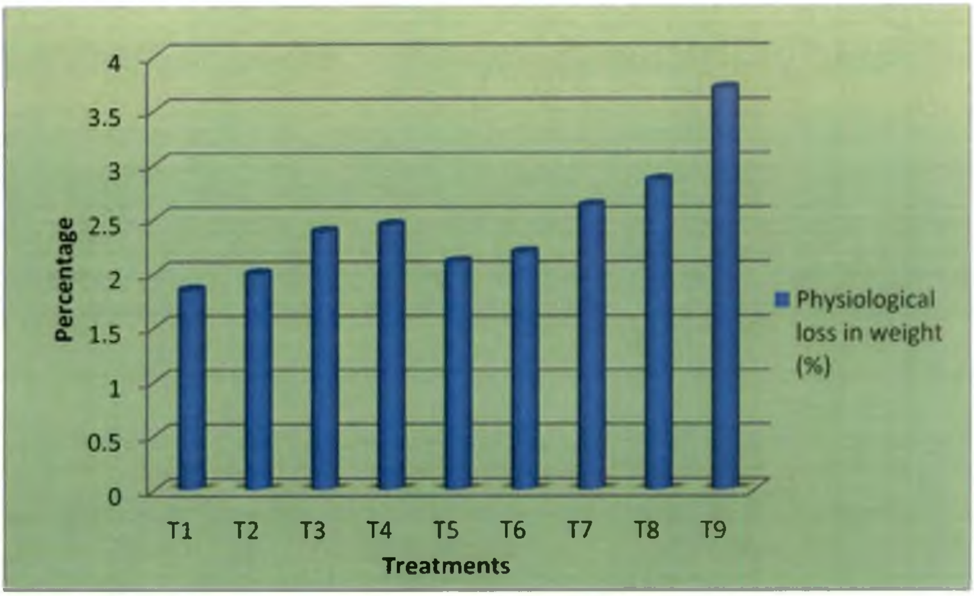

Fig. 11. Effect of prestorage treatments on physiological loss in weight of papaya var. Coorg Honeydew for local market

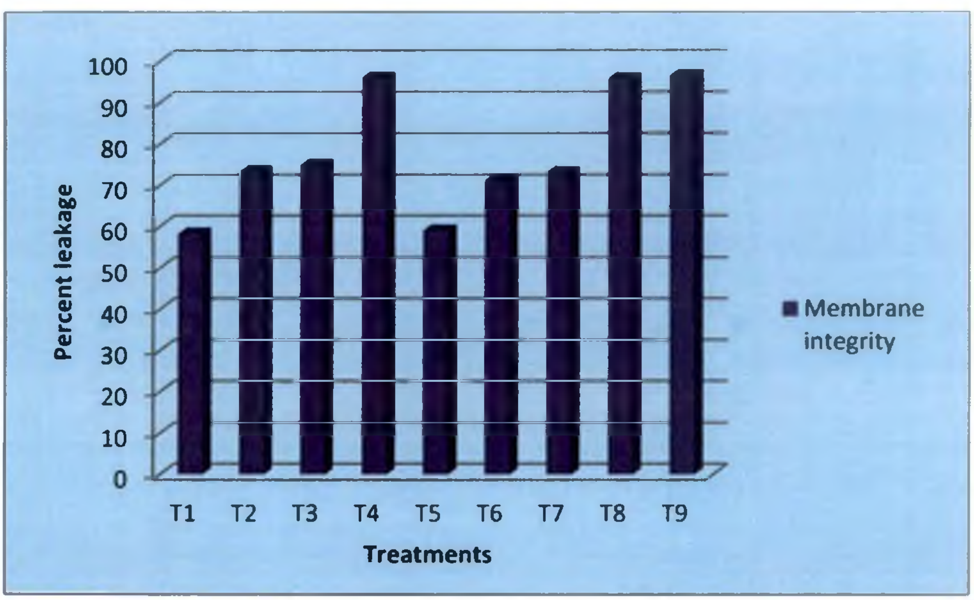

Fig. 12. Effect of prestorage treatments on loss of membrane integrity of papaya var. Coorg Honeydew for local market

The ethylene absorbent treated fruit had reduced weight loss and treated fruit experienced slower loss rate as compared to control fruit during the storage in present study. This was supported by the Ahmad *et al.*, 2013 and Razali *et al.*, 2013.

The less physiological loss in weight in T_1 treatment might be due to the effect of waxing and ethylene absorbents. Wax might have acted as a physiological barrier to gas diffusion thus lessening the gas exchange between tissue and external atmosphere. More over the respiration rate was also lower in that treatment.

5.3.1.2.2. Membrane Integrity

The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) had least percent leakage (58.18) and untreated fruit T_9 had the highest percent leakage 96.52 (Fig. 12). These results suggest a strong association between membrane ion leakage and loss in weight. Walter *et al.*, (1990) found a relationship between increased water loss and increased membrane ion leakage. The loss of cell membrane integrity is known to cause ion leakage and unrestricted movement of fluids within cellular compartments a condition injurious to fruits (Maalekuu *et al.*, 2004). The high water loss rate also showed very high and positive correlation with membrane ion leakage (Parker and Maalekuu, 2013).

The electrolyte leakage in the papaya fruit without $KMnO_4$ treatment was high and in treated fruit electrolyte leakage was low in present study. This is supported by the Silva *et al.*, (2009). The less loss in membrane integrity of treatment T_1 might be due to the intact membrane which resulted from the better treatments like hot water treatment coupled with waxing and ethylene absorbent application. The less loss in membrane integrity resulted in less physiological loss in weight also.

5.3.1.2.3 Respiration Rate

The lowest respiration rate was recorded in fruits treated with hot water at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (30.33 mg CO_2

/kg/hr) and the control sample, T_9 recorded highest respiration rate (39.00 mg CO_2 /kg/hr) (Fig. 13). The fruits respire even after harvest which leads to deterioration. The storage life of fruits is directly related to the rate of respiration (Srivaștava *et al.*, 1961).

Zhao, *et al.*, (2013) reported that 'Havaiian' papaya fruit treated with hot water had a lower respiration rate compared to control. Hot water could reduce respiration rate and ethylene production of fruit, and inhibit activity of certain enzymes associated with cell wall degradation. Hot water treatment has potential to maintain fruit firmness by slowing down fruit ripening.

Papaya cultivars 'Kaek Dum' and 'Red Maradol' treated with 1-MCP retarded respiration rate and delayed the onset of the climacteric peak (Krongyut *et al.*, 2011).

The papaya fruit treated with ethylene absorbent showed reduced respiratory activity than that of non-treated fruits. Research workers in similar field also confirmed a decrease in respiratory activity due to ethylene absorbent application (Jacomino *et al.*, 2002; Argenta *et al.*, 2003; Fabi *et al.*, 2007; Barajas *et al.*, 2009:Bron and Jacomino, 2009; Silva *et al.*, 2009).

The lowest respiration rate in treatment T_1 might be due to the effect of waxing and ethylene absorbent combined with hot water treatment. The waxing of fruit acted as physical barrier, the hot water treatment slowed down fruit ripening, reduced ethylene production and inhibited the activity of certain enzymes associated with cell wall degradation.

5.3.1.3 Quality Parameters

5.3.1.3.1 Carotenoids

The highest carotenoid content was exhibited by hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent, T_4 (2.71 mg/100g) (Fig. 14). The differences in carotenoid could be attributed to agricultural practices, sunlight exposure, production area, stage of ripeness, postharvest handling, and methodology used for analysis (Rosso and Mercadante, 2005; Paz *et al.*, 2008; Andersson *et al.*, 2009; Jeyakumar *et al.*, 2010; Sancho *et al.*, 2011).

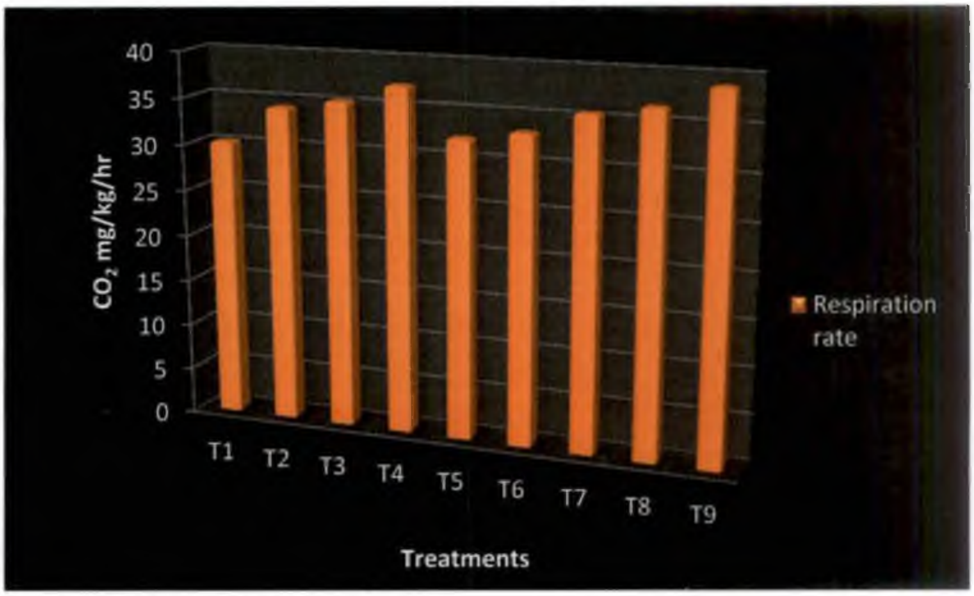

Fig. 13. Effect of prestorage treatments on respiration rate of papaya var. Coorg Honeydew for local market

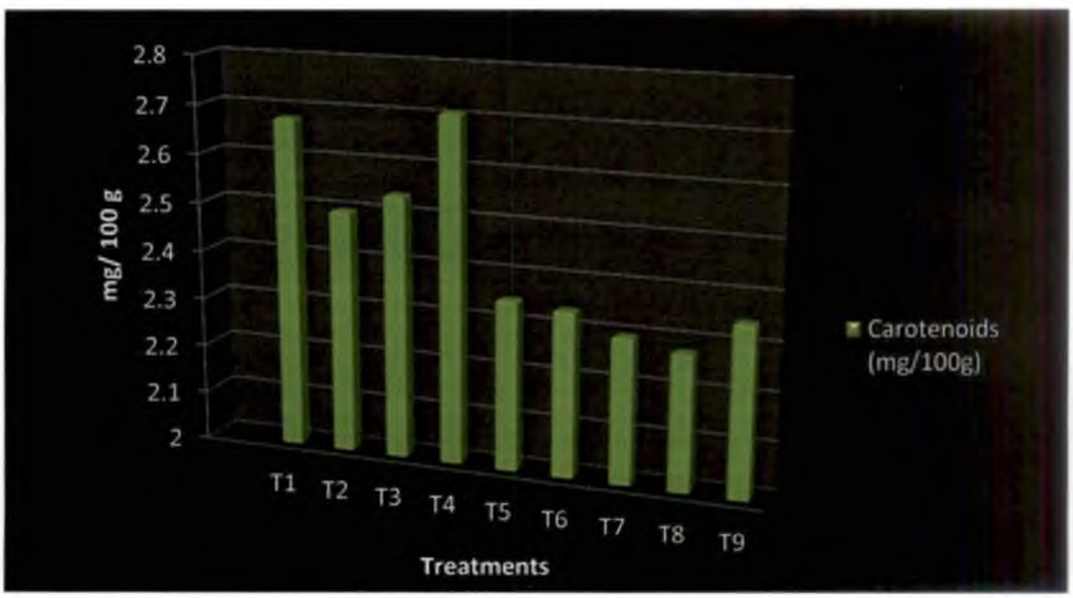

Fig. 14. Effect of prestorage treatments on carotenoids of papaya var. Coorg Honeydew for local market

Leon *et al.* (2004) also observed that 1-MCP treatment inhibited ripening of a mountain papaya variety; thus the inhibition of ethylene production could block normal fruit ripening including the synthesis of carotenoids (Gao *et al.*, 2007). The impairment of carotenoid accumulation in treated papaya fruit could be either by the consumption of their early precursors, such as geranylgeranyl diphosphate (GGDP), or by inhibiting phytoene synthase activity. In fact, a putative acetylCo-A acetyltransferase gene was down regulated after ethylene treatment and during ripening (Fabi *et al.*, 2010).

5.3.1.3.2 Reducing sugars, Non-reducing sugars, Total sugars

There was no significant difference in reducing sugars, non-reducing sugars and total sugars in all the treatments.

According to Gomez *et al.* (1999), papaya only has low starch content at harvest time (colour break) therefore it would not be a sufficient carbon source for the increase in sucrose content and for postharvest sweetening. Sarananda *et al.* (2004) were of the opinion that papaya var. Rathna must be harvested at 50 per cent yellow stage to maintain best postharvest quality.

Not much difference in reducing, non-reducing and total sugars suggested that the treatments could not enhance the sugar contents in the fruits.

5.3.1.3.3 Total Soluble Solids (TSS)

The effect of different storage treatments on papaya fruits on total soluble solids was investigated (Fig. 15). The highest total soluble solids were recorded in fruits treated with the hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent , T_1 (12.66° B). TSS was found to be significantly highest in the waxed fruit; the result was in close confirmation with the finding of Dikki *et al.*, (2010).

5.3.1.3.6 Acidity

There was no significant difference between the treatments with respect to acidity. This shows that the treatments could not make any significant change in the acidity of the fruits.

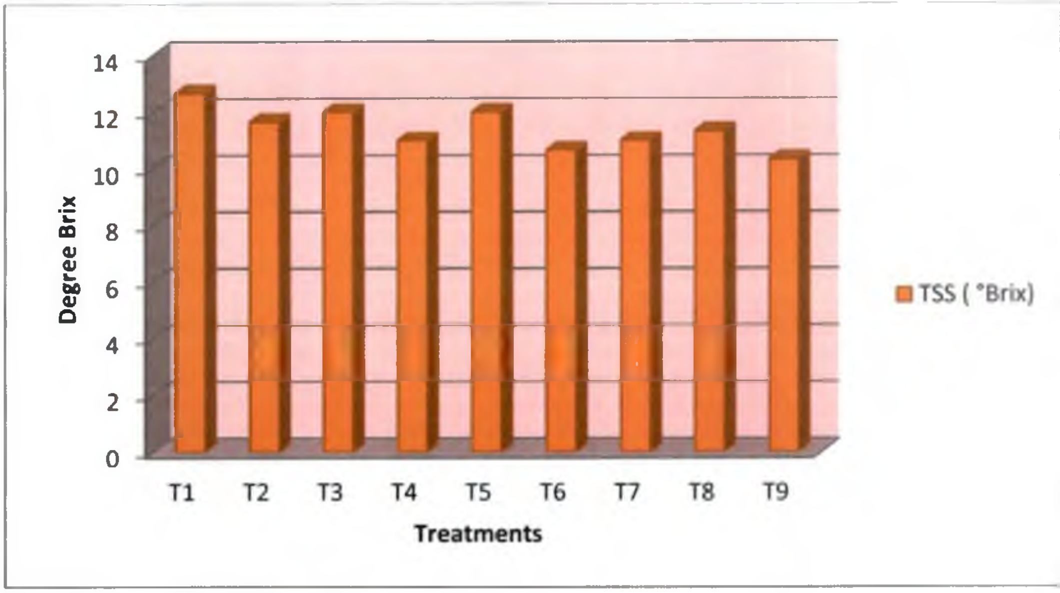

Fig. 15. Effect of prestorage treatments on TSS of papaya var. Coorg Honeydew for local market

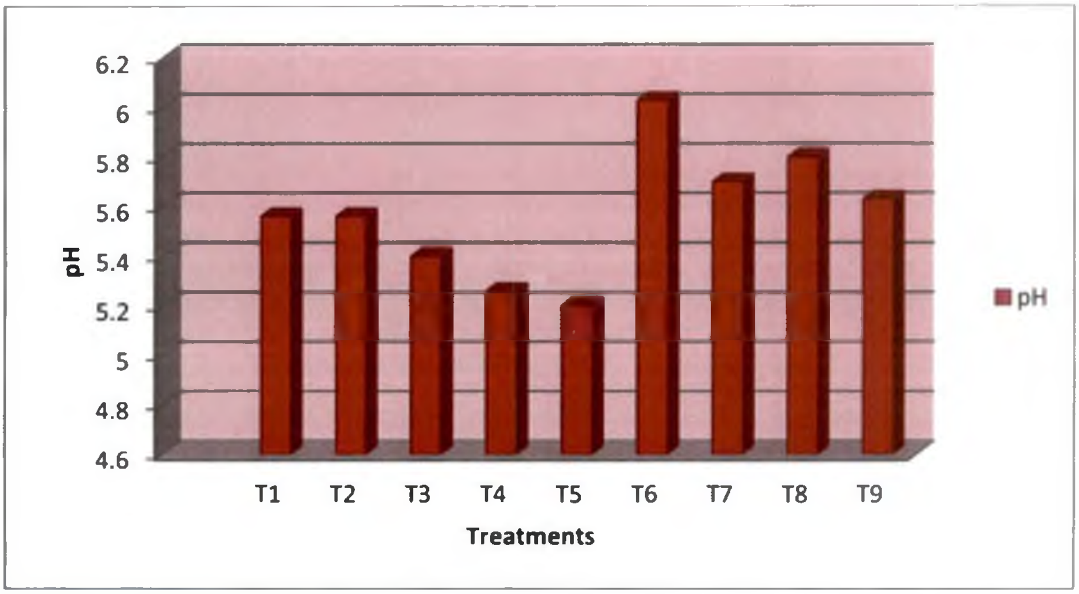

Fig. 16. Effect of prestorage treatments on pH of papaya var. Coorg Honeydew for local market

5.3.1.3.7 pH

A significant difference in pH was noted between treatments (Fig. 16). The highest pH was observed in warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent, T_6 (6.03) and lowest pH was recorded in warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_5 (5.20).

Shahid and Abbasi (2011) reported that in sweet orange *cv.* Blood Red treated with wax coating, change in pH during storage period might be due to number of reasons; firstly, the alteration of biochemical condition of fruit due to treatments secondly, due to lower rate of respiration and metabolic activity. pH increase but at a slower rate particularly at the end of storage period, as there might be the saturation of atmosphere inside the pack with water vapours.

5.3.1.3.8 Calcium

The highest calcium content was recorded in fruits treated with hot water at 50° C for 20 minutes with waxing and ethylene absorbent. The higher calcium content in fruits might be due to higher up take from the soil.

5.3.1.3.9 Potassium

The highest potassium content was recorded in fruits treated with hot water at 50° C for 20 minutes with waxing and without ethylene absorbent. The higher potassium content in fruits might be due to higher up take from the soil

4.3.1.3.10 Phosphorous

The fruits treated with hot water at 50° C for 20 minutes without waxing and without ethylene absorbent recorded highest phosphorous content. The higher phosphorous content in fruits might be due to higher up take from the soil

5.3.1.4 Disease Index

All the papaya fruits samples whether treated or untreated had similar disease index. Papaya is vulnerable to a large number of diseases and pests with anthracnose being the devasting of them during storage (Kader, 2002, Banos *et al.*, 2003).

Due to latency of the pathogen in early ontogeny of the fruits, the symptoms normally only become apparent during ripening (Snowdown, 1990). Ammonium carbonate at 3 per cent followed by sodium carbonate at 2 per cent, tested alone or in combination with wax, had a positive effect on reducing *C. gloeosporioides* in naturally and artificially inoculated fruit by up 50 per cent (Sivakumar *et al.*, 2002).

In the fruits treated with hot water, ozonated water and wax, no mould under the wax film was observed, indicating that the thermal treatment combined with ozonisation prevented the inner rot of the papaya fruits (Kechinski *et al.* 2012).

The disease index was similar in all the treatments. This might be because of less incidence of disease inoculum in the field, usually if the fruits are infected in the field only it will be carried to the storage. The pathogen is latent during early ontogeny of the fruits and the symptoms appear only on ripening. The less incidence of the disease in the field resulted in less or not much difference in disease index in the store.

5.3.1.5 Mechanical Damage

The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1), hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent (T_2), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent (T_5) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent (T_6) had less mechanical damage and control one had more mechanical damage. Mechanical damage during harvesting, packaging and transport can result in a substantial reduction in quality. Ideally, such damage would be minimized through improved understanding of the mechanisms (Li and Thomas 2014).

According to Quintana and Paull (1993) waxing reduced the severity of skin injury. New GMC (2004) reported that application of a surface wax on papaya fruit generally with carnauba or shellac based wax reduced shrinkage and gave the fruits a glossy appearance.

In the present experiment all the treatments with waxing resulted in less mechanical damage suggests that waxing might have resulted in reducing the severity of bruises in the skin during the transport.

5.3.1.6 Microbial Load

The papaya fruits sanitized with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) had lowest number of bacterial and fungal populations (Fig. 17 and Fig. 18). Hot water treatment was suggested as a method for fruit fly disinfestation which is a quarantine requirement for the papaya export industries (Kader, 2013).

The hot water treatment of Eksotika papaya at 47 ±1 °C could maintain postharvest quality of fruit and at the same time prevented it from insect infestation (Arina *et al.* 2010). Martins *et al.* (2010) reported that papaya fruit treatments with hot water at 48-50° C for 20 minutes controlled the anthracnose disease in papaya.

Nishijima (1994) was of the opinion that sodium hydroxide, sodium carbonate, sodium hypochlorite (Clorox), EDTA and calcium hypochlorite were found to be safe to use in five minute dip at 8000 ppm for papaya fruits instead of mancozeb for the prevention of major postharvest diseases as well as blight caused by *Phytophthora palmivora*.

The less microbial load in T_1 might be due to the effective hot water treatment combined with waxing acting as the physical barrier.

5.3.2. Waxing and Ethylene Absorbent for Distant Market

5.3.2.1 Physical Parameters

5.3.2.1.1 Shelf Life

The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) had highest shelf life (12.33 days) and untreated fruits (T_9) had lowest shelf life (5.33 days) (Fig.19).

According to Amarante and Banks (2001), wax coating extended shelf-life of fruit by reducing physiological loss in weight, ethylene synthesis and respiration, retarding colour change and delaying biochemical changes and

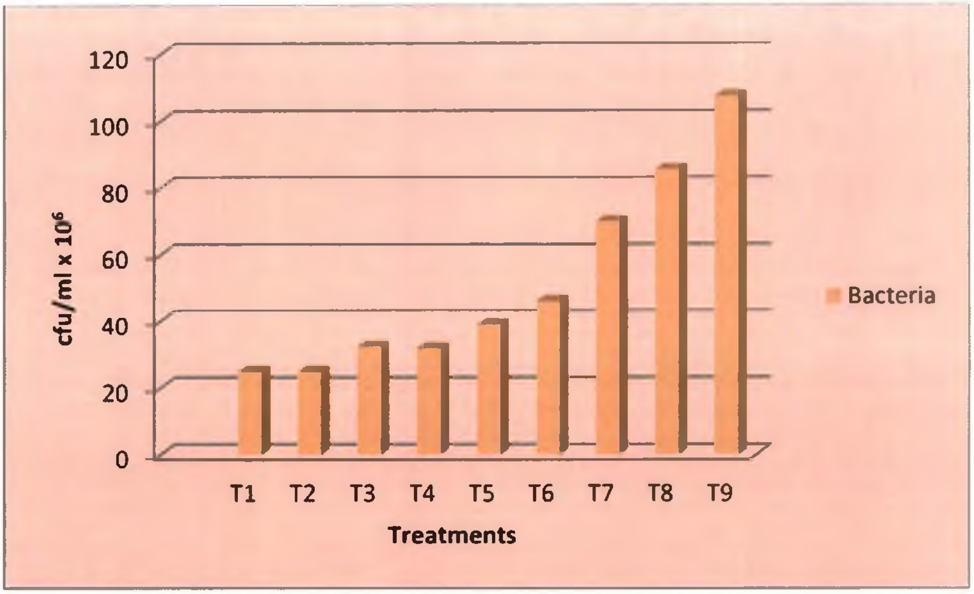

Fig. 17. Effect of prestorage treatments on bacterial count of papaya var. Coorg Honeydew for local market

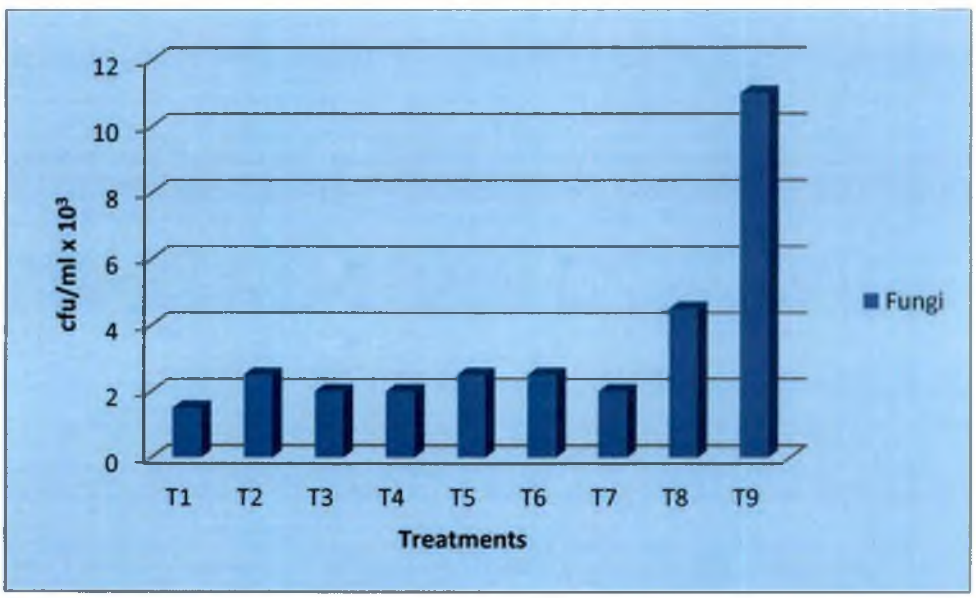

Fig. 18. Effect of prestorage treatments on fungal count of papaya var. Coorg Honeydew for local market

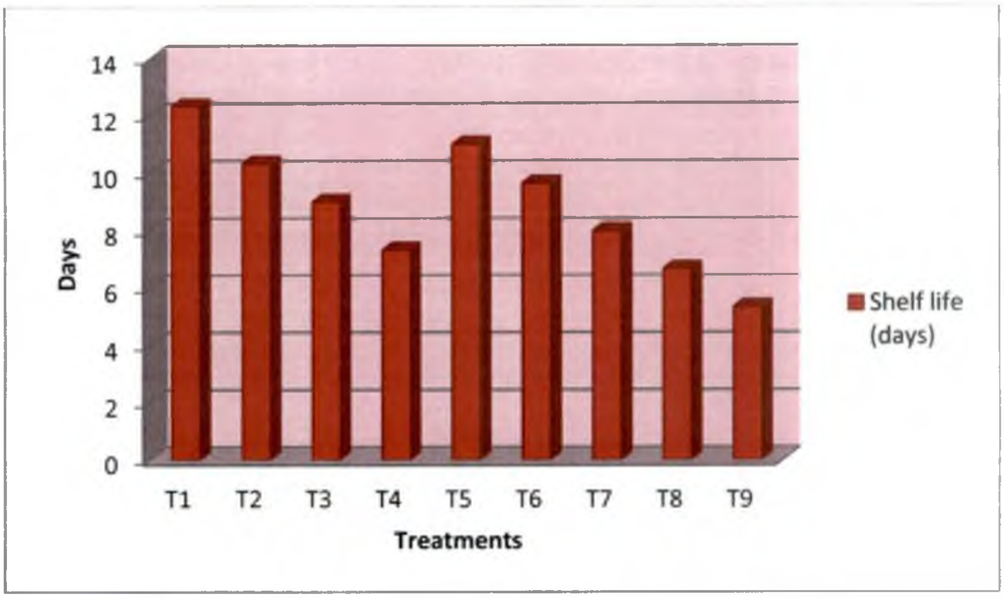

Fig. 19. Effect of prestorage treatments on shelf life of papaya var. Coorg Honeydew for distant market

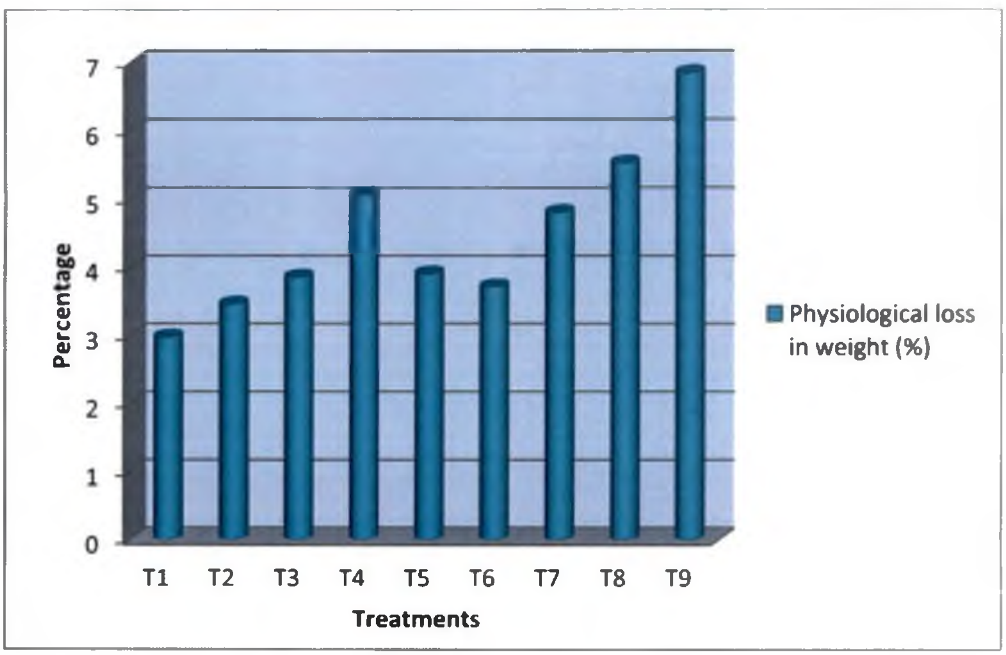

Fig. 20. Effect of prestorage treatments on physiological loss in weight of papaya var. Coorg Honeydew for distant market

extending ripening and senescence of fruit. Wax depositions on fruit surface prevented loss of moisture.

Wax treatment exerted a significant influence on shelf life, indicating that the wax treatment retarded fruit ripening and control sample had least shelf life. Similar results were reported by Doshi and Sutar, (2010); Kechinski *et al.*, (2012). The use of ethylene absorbents, absorb ethylene or block ethylene binding to its receptor, thus preventing build up of ethylene around produce. Use of ethylene absorbents to delay ripening was reported by Hofman *et al.*, 2001; Manenoi *et al.*, (2007); Zewter *et al.*, (2012); Ahmad, *et al.*, (2013); Razali *et al.*, (2013).

The increased shelf life in T_1 might be because of the extended shelf life through wax coating, delay in ripening due to less respiration rate use of ethylene absorbents which prevented the build up of ethylene around the produce, less load of microbes and biochemical changes due to hot water treatment.

5.3.2.1.2 Sensory Parameter

No significant difference was found in appearance, colour, flavour, texture, taste and overall acceptability in all the treatments of distant market.

5.3.2.2. Physiological Parameters

5.3.2.2.1 Physiological Loss in Weight

The physiological loss in weight was lowest for the sample treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (2.98 per cent) and highest physiological loss in weight was recorded in control, T_9 (6.85 per cent) (Fig. 20). The reduction in weight loss in treated fruits might be due to the retardation of transpiration and respiration as substantiated by results of Bhullar and Farmahan, (1980); Manenoi and Paull (2007); Dikki *et al.*, (2010).

The minimization of weight loss in wax coated fruits might be due to the action of wax as a physical barrier to gas diffusion from fruit stomata through which the gas exchange takes place between tissue and external atmosphere (Islam *et al.* 2001; Saravanan *et al.*, 2013). Arumugam and Balamohan (2014) reported that the physiological loss in weight differed during storage and 2 per cent wax treatment had the lowest physiological loss in weight, while the control had the highest physiological loss in weight. Fruit weight decreased as storage time increased. Moisture loss through transpiration might have reduced weight.

The ethylene absorbent treated fruit had reduced weight loss and treated fruit experienced slower rate loss as compared with control fruit during the storage (Ahmad *et al.*, 2013; Razali *et al.*, 2013).

The less physiological loss in weight in the best treatment (T_1) might be due to the effect of wax, hot water and ethylene absorbent.

5.3.2.2.2 Membrane Integrity

The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1) had least percent leakage (57.82 per cent) and untreated sample (T_9) recorded highest percent leakage (97.48 per cent). According to Parker and Maalekuu, (2013) high water loss rate showed very high and positive correlation with membrane ion leakage. The higher percent ion leakage in control might be due to the loss of physical integrity of cellular membrane leading to the loss of ion leakage.

5.3.2.2.3 Respiration Rate

The lowest respiration rate was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent, T_1 (35.00 mg CO_2 /kg/hr). The untreated fruit (T_9) had highest respiration rate (42.33 mg CO_2 / kg /hr) (Fig. 21). The fruits treated with hot water had a lower respiration rate compared with the control (Zhao, *et al.*, 2013).

Wax coating restricted permeation of gases resulting in low level of O_2 and increased CO_2 concentration resulting in modified atmosphere around the fruit. Hence, rate of respiration was reduced, which prolonged the shelf-life of fruit (Arumugam and Balamohan, 2014).

Similar views were expressed by Byung *et al.* (1998) who showed that wax coating in "Tsugaru" apple decreased the rate of respiration and transpiration which in turn resulted in reduced weight loss, shrivel and increased shelf life.

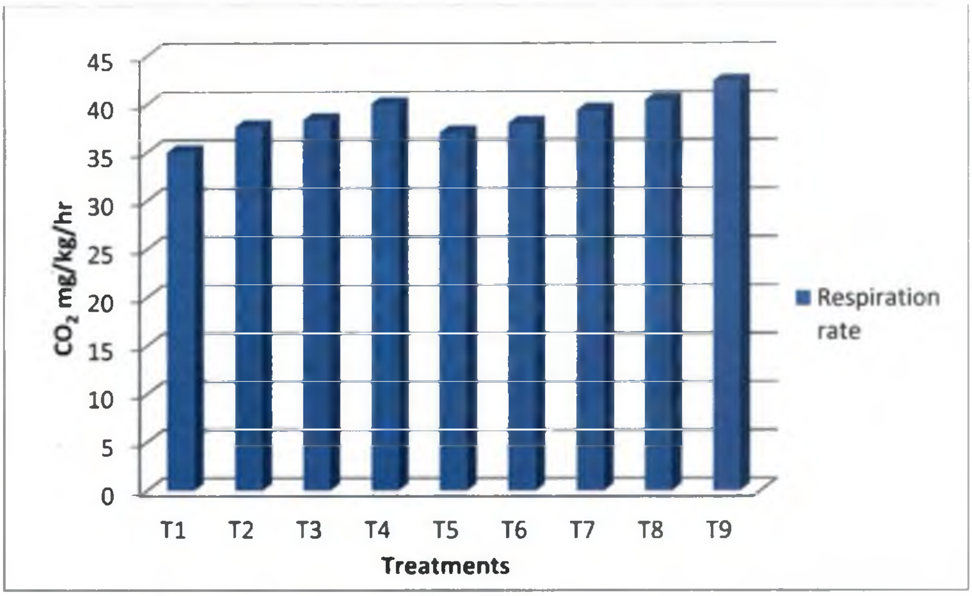

Fig: 21. Effect of prestorage treatments on respiration rate parameters of papaya var. Coorg Honeydew for distant market

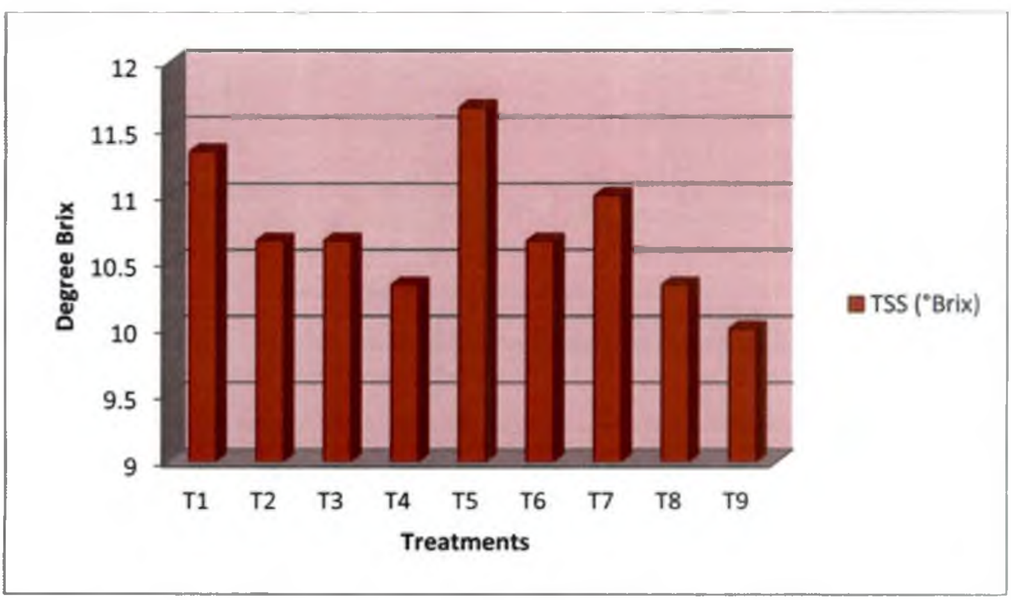

Fig. 22. Effect of different prestorage treatments on TSS of papaya var. Coorg Honeydew for distant market

The papaya fruits treated with ethylene absorbent showed reduced respiratory activity than that of non-treated fruits. Other authors also confirmed a decrease in respiratory activity due to ethylene absorbent application (Jacomino *et al.*, 2002; Argenta *et al.* 2003; Junior *et al.*, 2004; Fabi *et al.*, 2007; Bron and Jacomino, 2009; Barajas *et al.*, 2009; Silva *et al.*, 2009; Krongyut *et al.*, 2011).

5.3.2.3 Quality Parameters

5.3.2.3.1 Carotenoids

No significant difference was found in all the samples whether treated with prestorage treatments or untreated.

5.3.1.3.2 Reducing sugars, Non-reducing sugars, Total sugars

There was no significant difference in reducing sugars, non-reducing sugars and total sugars in all the treatments. According to Gomez *et al.* (1999), papaya only had low starch content at harvest time (colour break) therefore it would not be having sufficient carbon source for the increase in sucrose content and for postharvest sweetening. Sarananda *et al.* (2004) were of the opinion that papaya var. Rathna must be harvested at 50 per cent yellow stage to maintain best postharvest quality.

There was no significant difference in total reducing and non-reducing sugar content between the treated and untreated fruits. The treatment might not have influenced the biochemical pathway of sugar synthesis in papaya.

5.3.2.3.5 Total Soluble Solids (TSS)

The highest total soluble solids were recorded in fruits treated with the warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent, T_1 (11.66° B) and control (T_9) recorded lowest (10.00° B) (Fig. 22). Total soluble solid was found to be significantly highest in waxed fruit. The result was in close confirmation with the finding of Dikki *et al.*, (2010).

Kore and Kabir (n.d) reported fully mature green guava fruits treated with carnauba wax recorded higher total soluble solids.

5.3.2.3.6. Acidity

There is no significant difference between the treatments for acidity. It has been reported that ethylene absorbent treatment had no significant effects on titratable acidity (Osman *et al.*, 2013).

5.3.2.3.7 pH

No significant difference was observed in pH for all the treatments. The pH of the fruit juice showed that it was weakly acidic. The pH value did not change throughout the ripening process.

The Eksotika papaya fruits harvested at different harvest maturity, treated with hot water at 47±1°C for 10 minutes and another group was untreated. The pH value did not change throughout the ripening process. A value of about 5.6–5.7 was obtained in treated and untreated fruit (Arina *et al.*, 2010).

5.3.2.3.8 Calcium

The highest calcium content was recorded in fruits treated with warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent. The higher calcium content in fruits might be due to higher up take from the soil.

5.3.2.3.9 Potassium

The highest potassium content was recorded in fruits treated with hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent. The higher potassium content in fruits might be due to higher up take from the soil.

5.3.2.3.10 Phosphorous

The fruits treated with hot water treatment at 50° C for 20 minutes without waxing and without ethylene absorbent were recorded highest phosphorous content. The higher phosphorous content in fruits might be due to higher up take from the soil.

5.3.2.4 Disease Index

All the papaya fruits samples whether treated or untreated had similar disease index. This might be due to the less disease inoculum carried from the field to store.

5.3.2.5. Mechanical Damage

The fruits treated with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent (T_1), hot water treatment at 50° C for 20 minutes with waxing and without ethylene absorbent (T_2), warm sodium hypochlorite 150 ppm for 10 minutes with waxing and with ethylene absorbent (T_5) and warm sodium hypochlorite 150 ppm for 10 minutes with waxing and without ethylene absorbent (T_6) had lowest score of mechanical damage during transport. Mechanical damage during harvesting, packaging and transport, could result in a substantial reduction in quality. Ideally, such damage would be minimized through improved understanding of the mechanisms (Li and Thomas, 2014).

Waxing reduced the severity of skin injury in papaya fruits (Quintana and Paull, 1993). New GMC (2004) reported that application of a surface wax on papaya fruit generally with carnauba or shellac based wax reduced shrinkage and gave the fruits a glossy appearance. The less mechanical damage in the above treatments might be due to the less bruises brought about by the protective coating of wax.

5.3.2.6 Microbial Load

The papaya fruits sanitized with hot water treatment at 50° C for 20 minutes with waxing and with ethylene absorbent had lowest bacterial and fungal populations (Fig. 23 and Fig. 24). The beneficial effect of prestorage hot water treatment to prevent rot development has been shown in numerous temperate, subtropical and tropical fruits, vegetables and flowers (Schirra *et al.*, 2000).

Martins *et al.* (2010) reported that papaya fruit treated with hot water at 48-50° C for 20 minutes controlled *Colletotrichum gleosporoides* and *Phoma caricae*. NHB (2012) recommended hot water treatment for papaya fruits meant for export for the control of anthracnose. Sanchez *et al.* (2013) reported that antifungal hot water treatment of 55° C for 3 minutes did not affect negatively the quality parameter of pulp and skin of papaya at their colour break stage of ripeness.

Nishijima (1994) was of the opinion that sodium hydroxide, sodium carbonate, sodium hypochlorite (Clorox), EDTA and calcium hypochlorite were found to be safe to use in five minute dip at 8000 ppm for papaya fruits instead of mancozeb for the prevention of major postharvest diseases as well as blight caused by *Phytophthora palmivora*.

New Guyana Marketing cooperation reported that wash water containing a mild detergent like hypochlorous acid at concentration of 150 ppm in water at pH of 6.5 along with thiabendazole 50 ppm was reported to control postharvest disease of papaya (New GMC, 2004).

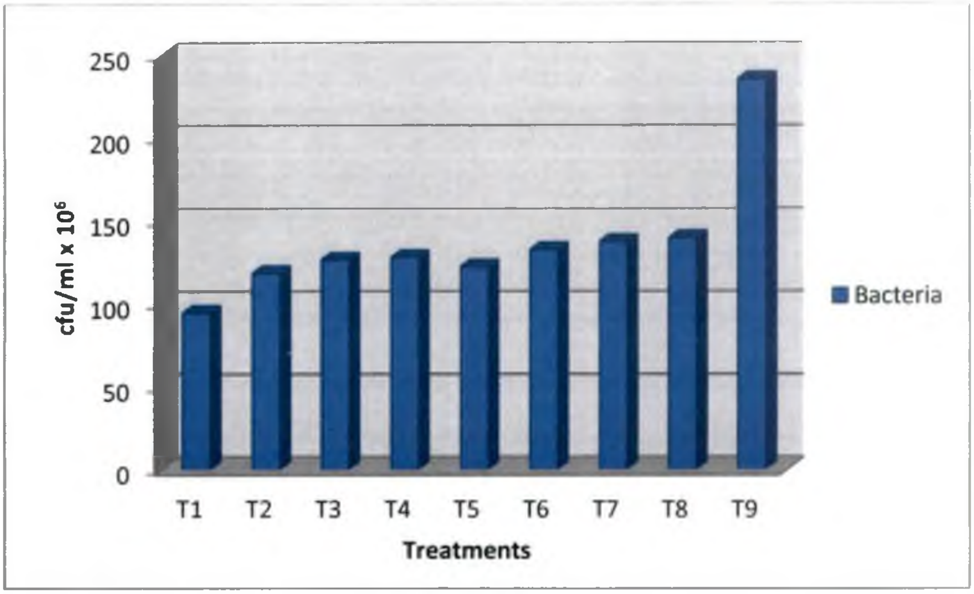

Fig. 23. Effect of different prestorage treatments on bacterial count of papaya var. Coorg Honeydew for distant market

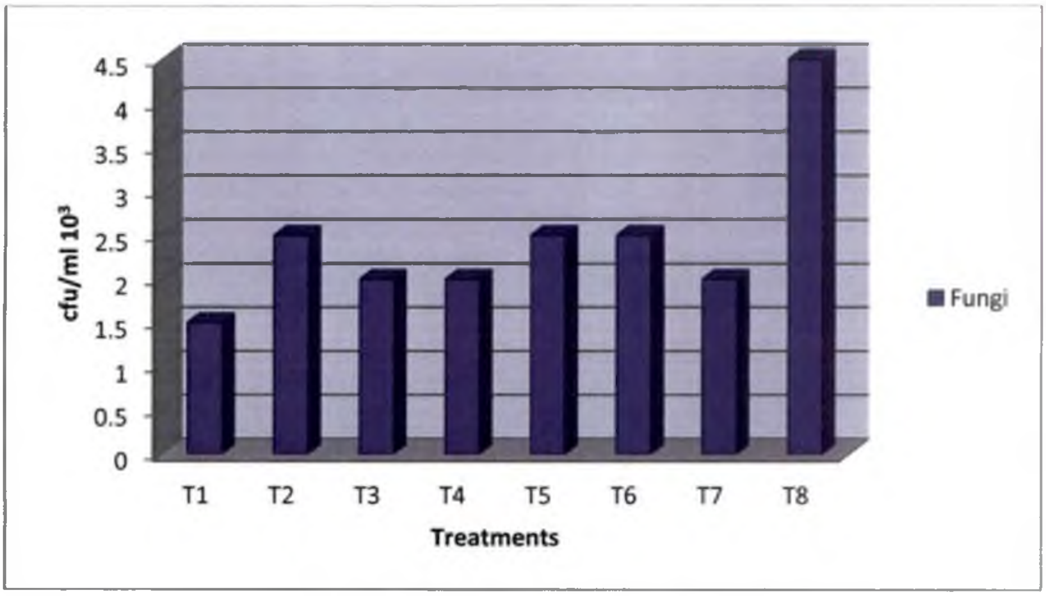

Fig. 24. Effect of different prestorage treatments on fungal count of papaya var. Coorg Honeydew for distant market

Summary

6. SUMMARY

The present investigation entitled "Postharvest management practices in papaya (*Carica papaya* L.) for improving shelf life" was conducted at Department of Processing Technology, College of Agriculture, Vellayani. The experiment was conducted with the objective of reducing postharvest losses in papaya through postharvest management practices.

The investigation was carried out in three continuous experiments to standardize stage of harvest, surface sterilization and to study the effect of waxing and ethylene absorbent for local and distant market.

The papaya fruits were harvested at different maturity stages for local and distant market and physical, physiological, and quality studies were carried out. For local market, papaya fruits harvested at ¼ yellow (144.37 Days From Full Bloom) showed maximum shelf life (4.25 days) compared to ½ yellow (146.12 Days From Full Bloom) stage (2.87 days). However there was no difference in physiological parameters, quality parameters and sensory parameters between fruits harvested at ½ yellow and ¼ yellow and hence ¼ yellow was considered as best stage for continuing the experiment on local market.

For distant market, the fruits were harvested at one stripe yellow (142.00 Days From Full Bloom) and fully mature green (139.38 Days From Full Bloom). The fruits harvested at fully mature green stage had more shelf life (5.85 days) compared to one stripe yellow (4.71 days) and there was apparently no significant difference in physiological parameters, quality parameters and sensory parameters between one stripe yellow and fully mature green stage and hence fully mature green stage was selected as best stage of harvest for distant market.

The investigation on the efficacy of different sanitizing agents on surface decontamination of papaya fruits harvested at ¼ maturity stage for local market revealed that hot water treatment at 50° C for 20 minutes resulted in highest shelf life, low physiological loss in weight and lowest bacterial and fungal population. This treatment was on par with fruits treated with 150 ppm of warm sodium

hypochlorite for 10 minutes. The control sample had least shelf life and highest count of bacterial and fungal population.

For distant market, fruits were harvested at fully mature green stage and subjected to different sanitizing agents. Hot water treatment at 50° C for 20 minutes followed by cooling represented the best treatment with high shelf life and lowest bacterial and fungal population which was on par with warm sodium hypochlorite 150 ppm for 10 minutes. The control sample showed lowest shelf life with highest count of bacterial and fungal population. The physiological loss in weight was not significant.

The two sanitizing agents selected as best treatments for next part of the experiment were hot water treatment at 50° C for 20 minutes followed by cooling and warm sodium hypochlorite 150 ppm for 10 minutes.

The effect of waxing and ethylene absorbent was studied on papaya fruits harvested at ¼ yellow stage for local and fully mature green for distant markets, sanitized with two best selected sanitizing agents.

For local market, the fruits were harvested at ¼ maturity stage and different combination of best sanitizing agents with or without waxing (6 per cent) and with or without ethylene absorbent ($KMnO_4$ @ 8.0 g/kg of fruit in sachets) packed in corrugated fibre board boxes and studied along with control.

The fruits for local market harvested at ¼ yellow sanitized with hot water at 50° C for 20 minutes followed by cooling, waxing (6 per cent) and packed with ethylene absorbent ($KMnO_4$ @ 8.0 g/ kg fruit) recorded highest shelf life (11.00 days), lowest physiological loss in weight (1.84 per cent), least loss in membrane integrity (58.18 percent leakage), lowest respiration rate (30.33 CO_2 mg/kg/hr), highest total soluble solids (12.66° Brix), lowest microbial population and less mechanical damage. The control sample recorded lowest shelf life (4.00 days), highest physiological loss in weight (3.70 per cent), highest loss in membrane integrity (96.52 percent leakage), respiration rate (39.00 mg CO_2/kg/hr), mechanical damage and microbial load.

The fruits harvested at ¼ yellow stage for local market sanitized with warm sodium hypochlorite 150 ppm for 10 minutes with waxing (6 per cent) and packed with ethylene absorbent ($KMnO_4$ @ 8.0 g/ kg fruit) was the second best treatment showing a shelf life of 10.33 days and with less physiological loss in weight, less loss in membrane integrity, TSS, pH and carotenoids which was on par with best treatment and had significantly less microbial load.

For distant market, the fruits were harvested at fully mature green stage and sanitized with combinations of two best sanitizing treatments with waxing, ethylene absorbents and without these were tried.

The fruits harvested at fully mature green stage washed and sanitized with hot water at 50° C for 20 minutes followed by cooling, waxing and packed in a corrugated fibre board box with ethylene absorbent in sachet ($KMnO_4$ 8g/ kg fruit), improved the shelf life (12.33 days) of fruits, showed lowest physiological loss in weight (2.98 per cent), least loss in membrane integrity (57.82 percent leakage), lowest respiration rate (35.00 CO_2 mg/kg/hr), higher total soluble solids (11.33° Brix), lowest microbial population and less mechanical damage. The control sample recorded least shelf life (5.33 days), highest physiological loss in weight (6.85 per cent), highest loss in membrane integrity (97.48 percent leakage), highest respiration rate (42.33 CO_2 mg/kg/hr), highest mechanical damage and microbial load.

The result of the experiment revealed that for local market, harvesting the papaya fruits at ¼ yellow maturity followed by washing and sanitizing with hot water at 50° C for 20 minutes followed by cooling, coated with wax (6 per cent) and packed in corrugated fibre board boxes with ethylene absorbent in sachet @ 8.0 g/kg of fruit, improved the shelf life from 4 to 11 days.

For distant market, the fruits harvested at fully mature green stage, washed and sanitized with hot water at 50° C for 20 minutes followed by cooling, coated with carnauba wax (6 per cent) and packed in corrugated fibre board boxes with ethylene absorbent in sachet @ 8.0 g/ kg of fruit, increased the shelf life from 5.33 to 12.33 days under ambient condition with improved physiological parameters.

Further studies are required for the refinement of the technology for transport of fruits for distant market.

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Postharvest Management Practices in Papaya (*Carica papaya* L.) for Improving Shelf Life

by

JAYASHEELA D.S.

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ABSTRACT

The present investigation entitled "Postharvest management practices in papaya (*Carica papaya* L.) for improving shelf life" was conducted at Department of Processing Technology, College of Agriculture, Vellayani, to determine the stage of harvest maturity of papaya for local and distant market and to standardize postharvest practices for improved shelf life with minimum nutritional loss. The study was carried out in three different continuous experiments.

For local market, papaya fruits harvested at ¼ yellow (144.37 DFFB-Days From Full Bloom) and ½ yellow (146.12 DFFB) stages revealed ¼ maturity as the best stage of harvest due to increased shelf life. For distant market, the fruits were harvested at one stripe yellow (142.00 DFFB) and fully mature green (139.38 DFFB) and fruits harvested at fully mature green stage had more shelf life and hence selected as best stage of harvest for distant market.

Investigation on the efficacy of different sanitizing agents on surface decontamination revealed that papaya fruits harvested at ¼ yellow for local market and fully mature green fruits for distant market, washed and treated with hot water at 50° C for 20 minutes and warm sodium hypochlorite at 150 ppm was effective in reducing bacterial and fungal population.

The effect of waxing and ethylene absorbent was studied on papaya fruits harvested for local and distant markets, sanitized with the two best sanitising agents. For local market, fruits harvested at ¼ maturity and sanitised with hot water at 50° C for 20 minutes followed by cooling, waxing and packing with ethylene absorbent ($KMnO_4$ – Potassium permanganate) 8.0 g/ kg fruit as sachet in corrugated fibre board boxes recorded highest shelf life (11.00 days), lowest physiological loss in weight (1.84 per cent), lowest loss in membrane integrity (58.18 percent leakage), lowest respiration rate (30.33 mg CO_2 /kg/hr), highest total soluble solids (12.66° Brix), least microbial population and less mechanical damage. For distant market, fruits harvested at fully mature green stage sanitised with hot water at 50° C for 20 minutes followed by cooling, waxing and packed in corrugated fibre board boxes with ethylene absorbent in sachet ($KMnO_4$ 8.0 g/ kg fruit) improved the shelf life (12.33 days) of fruits and showed lowest

physiological loss in weight (2.98 per cent), lowest loss in membrane integrity (57.82 percent leakage), lowest respiration rate (35.00 mg CO_2/kg/hr) higher total soluble solids (11.33° Brix), microbial population and less mechanical damage. Further studies are required for the refinement of the technology for reducing postharvest losses in papaya fruits for transport to distant market.

Appendices

Appendix I

Kerala Agricultural UniversityCollege of Agriculture

Department of Processing Technology

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF PAPAYA FRUIT

Name of student: Jayasheela, D.S.
Title of thesis: Postharvest management practices in papaya (*Carica papaya* L.) for improving shelf life.

Sample:

Criteria	1	2	3	4	5	6	7	8	9
Appearance									
Colour									
Flavour									
Texture									
Taste									
Overall acceptability									

Like extremely - 9

Like very much - 8

Like moderately - 7

Like slightly - 6

Neither like nor dislike - 5

Dislike slightly - 4

Dislike moderately - 3

Dislike very much - 2

Dislike extremely - 1

Date:

Name:
Signature :

APPENDIX II

Cost of production for local market

Particulars	Rate	Quantity	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Purchasing of fruits	Rs. 5/kg	20 kg	100	100	100	100	100	100	100	100
CFB Boxes	Rs.24/box	4	96	96	96	96	96	96	96	96
Sodium hypochlorite	Rs. 100 /litre	500ml	-	-	-	-	50	50	50	50
Hot water treatment	Rs. 0.50/kg	-	10	10	10	10	-	-	-	-
Waxing	Rs. 1000/litre	33 ml	33.33	33.33	-	-	33.33	33.33	-	-
Potassium permanganate	Rs.720/kg	160 g	115.2	-	115.2	-	115.2	-	115.2	-
Labour			20	20	20	10	20	20	20	10
Miscellaneous	–		10	10	10	10	10	10	10	10
Cost of production (Rs)		20 kg	384.53	269.33	351.2	226	424.53	309.33	391.2	266
Cost per of production per kilo (Rs.)		1 kg	19.2265	13.4665	17.56	11.3	21.2265	15.4665	19.56	13.3
Selling price per kilo	Rs. 20/kg		20	20	20	20	20	20	20	20
B:C ratio			1.04	1.48	1.13	1.76	0.94	1.29	1.02	1.50
Profit (Rs.)			0.77	6.53	2.44	8.70	-1.22	4.53	0.44	6.70

APPENDIX III

Cost of production for distant market

Particulars	Rate	Quantity	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Purchasing of fruits	Rs. 5/kg	20 kg	100	100	100	100	100	100	100	100
CFB Boxes	Rs.24/box	4	96	96	96	96	96	96	96	96
Sodium hypochlorite	Rs. 100 /litre	500ml	-	-	-	-	50	50	50	50
Hot water treatment	Rs. 0.50/kg	-	10	10	10	10	-	-	-	-
Waxing	Rs. 1000/litre	33 ml	33.33	33.33	-	-	33.33	33.33	-	-
Potassium permanganate	Rs.720/kg	160 g	115.2	-	115.2	-	115.2	-	115.2	-
Labour		-	20	20	20	10	20	20	20	10
Miscellaneous	_	-	10	10	10	10	10	10	10	10
Cost of production (Rs.)		20 kg	384.53	269.33	351.2	226	424.53	309.33	391.2	266
Cost per of production per kilo (Rs.)			19.2265	13.4665	17.56	11.3	21.2265	15.4665	19.56	13.3
Selling price per kilo	Rs. 24/kg		24	24	24	24	24	24	24	24
B:C ratio (Rs.)			1.248277	1.7822	1.366743	2.123894	1.130662	1.551741	1.226994	1.804511
Profit (Rs.)			4.7735	10.5335	6.44	12.7	2.7735	8.5335	4.44	10.7