POST HARVEST MANAGEMENT PRACTICES IN MANGO (*Mangifera indica* L.)

By

HARYA KRISHNA V.

(2018-12-016)

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR- 680 656

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THESIS

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Faculty of Agriculture
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DEPARTMENT OF POST HARVEST TECHNOLOGY
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
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KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"POST HARVEST MANAGEMENT PRACTICES IN MANGO (*Mangifera indica* L.)"** 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, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date:

HARYA KRISHNA V.

(2018-12-016)

CERTIFICATE

Certified that this thesis entitled **"POST HARVEST MANAGEMENT PRACTICES IN MANGO (*Mangifera indica* L.)"** is a record of research work done independently by Ms. Harya Krishna V. (2018-12-016), 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 her.

Ms. MEAGLE JOSEPH P.

(Chairperson, Advisory Committee)

Professor and Head

Department of Post Harvest Technology

College of Horticulture, Vellanikkara

Kerala Agricultural University

Thrissur, Kerala

Vellanikkara

Date: 12. 8. 2020

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Harya Krishna V. (2018-12-016), a candidate for the degree of Master of Science in Horticulture with major field in Post Harvest Technology, agree that the thesis entitled **"POST HARVEST MANAGEMENT PRACTICES IN MANGO (*Mangifera indica* L.)"** may be submitted by Ms. Harya Krishna V., in partial fulfilment of the requirement for the degree.

Ms. Meagle Joseph P.
(Chairperson, Advisory Committee)
Professor and Head
Department of Post Harvest Technology
College of Horticulture, Vellanikkara

Dr. K. Ajith Kumar
Associate Director of Research
RARS, Ambalavayal and
Special Officer
College of Agriculture, Ambalavayal

Dr. Saji Gomez
Assistant Professor
Department of Post Harvest Technology
College of Horticulture, Vellanikkara

Dr. Seeja Thomachan Panjikkaran
Assistant Professor and Head
Department of Community Science
College of Horticulture, Vellanikkara

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INTRODUCTION

1. INTRODUCTION

Mango (*Mangifera indica* L.), the king of fruits is a great source of carbohydrates, proteins, vitamin A, vitamin C, fats and minerals like calcium, iron and phosphorus. Its excellent flavour, attractive fragrance, colour, taste and nutritional properties made them the most popular fruit in international markets (Arauz, 2000). It also has the antioxidant, immunomodulatory, diuretic and wound healing properties (Chaudhary *et al*., 2017).

The leading mango producing countries in the world are India, China, Thailand, Indonesia and Mexico. India is the largest mango producing country in the world with an annual production of about 16,337,400 tons accounting for 42.2 per cent of the world's total production (Madhavan *et al*., 2019). Uttar Pradesh, Andhra Pradesh, Karnataka, Bihar, Gujarat, Tamil Nadu, Odisha, West Bengal, Jharkhand and Maharashtra are major states cultivating mangoes. Uttar Pradesh ranks first in mango production with a share of 23.47 per cent and highest productivity.

In Kerala, mango is cultivated in 79,496 ha, with an annual production of 4,20,048 MT and an average yield of 5.2 tons per hectare (GOK, 2017). The most significant aspect regarding mango of Kerala is the earliness. The flowering starts from November- December and harvesting starts by March - April. So they are the first mango fruits in Indian markets in every season (Radha and Nair, 2000). It helps the Kerala mango farmers to fetch maximum price due to higher demand of mango fruits during the earlier season.

Palakkad, Malappuram and Kozhikode are the major mango growing districts of Kerala (GOK, 2017). Muthalamada, Chittur taluk, Kollemkode block in Palakkad district, is known as the 'Mango City' of Kerala. The mango orchards in Muthalamada cover around 4,500 hectares with about 3000 mango cultivators. The production of mango in Muthalamada Panchayat is approximately 40,000 tons (Nadhika, 2017). The varieties cultivated in Muthalamada region are Alphonso, Bennet Alphonso, Banganapalli, Bangalora, Neelum, Kalapady, Guddadat and Priyur.

The farmers of Muthalamada export mangoes to foreign markets and also finds market in North India and within the state. The usual practice they follow are harvesting the mature fruits throughout the day, by using traditional bamboo poles with nets, followed by de-sapping and packing in ventilated corrugated fibre board (CFB) boxes with straw as base and transport to distant markets during night.

The fruits when sent to distant markets, perish within 12-15 days, due to various reasons. The post harvest loss in mango is estimated as 25 - 40 per cent (Singh *et al*., 2017). The principle causes for postharvest losses are infections of pathogens, rough handling, improper packaging, improper mode of transportation and unhygienic storage conditions (Burondkar *et al*., .2018).

Safe artificial ripening of mango fruits is also a necessary operation for getting the quality fruits. Therefore, the need for alternative safe methods of artificial ripening is of utmost importance for providing good quality and safe fruits for consumers.

Hence the present study is undertaken to standardize the post harvest treatments after harvesting of the commercial mango varieties grown in Muthalamada area, and to improve the market quality of fruits.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Mango (*Mangifera indica* L.), the king of fruits, relished by majority, occupies first position in production in India and world. The problems featured in the journey of the fruits from field to market are numerous. It is obvious from the reduction in shelf life of these fresh commodities when compared to that of processed products and hence enough care should be taken during handling. Burondkar *et al*. (2018) estimated that about 20 - 30 per cent of harvested mango fruits became sub-standard due to rough handling, pathogenic infestations, improper packaging, unhygienic storage and indecorous mode of transportation. This shows the necessity of improving post harvest management practices to enhance shelf life without deteriorating its quality. A brief review of various aspects of post harvest treatments and ripening treatments of mango in particular and other fruits is presented.

2.1 POST HARVEST TREATMENTS IN FRESH FRUITS

Mango fruits with good colour and appearance fetch good market price. The treatments given to improve the quality of mango after harvesting has improved appearance and also maintain the sensory and nutritive qualities.

2.1.1 Hydro cooling

Ganpatrao (2008), has reported that precooling the fruits at 6^0 C for 8 hours, delayed ripening and extended shelf life of Rajapuri mango fruits. The fruits pre-cooled at 8ºC for 8 hours proved to be most effective with respect to number of days taken to ripeness and it also contributed to longer shelf life with lower percentage of spoilage. It is recommended that mango and sapota fruits should be pre-cooled at 8ºC temperature for 8 hours immediately after harvest for increasing shelf life, quality and marketability (Mackwana, 2011). Hydro cooling (13° C for 4 hours) in Kesar variety of mango fruits resulted late ripening (21.33 days), longer shelf life (31.71 days), lowest physiological loss in weight (12.21%), lesser spoilage percentage (6.23%) and higher firmness (5.08 kg/cm^2) after a storage period of 15 days. It was also effective in increasing total soluble solids and total sugars with a low decrease in ascorbic acid and acidity (Devani, 2011). Mackwana *et al*. (2014) also reported higher score of organoleptic characters like colour, taste and overall acceptability in hydro cooled fruits of mango variety Kesar.

2.1.2 Hot water treatment

Hot water treated (55^{0}C for 5 minutes) fruits of mango cv. Nam Doc Mai, remarkably delayed the onset of disease infection, reduced the number of infected fruits and lowered the severity of infection than untreated fruits (Benitez *et al*., 2006). Mansour *et al.* (2006) also reported that when mango fruits were treated with hot air at 50^{0}C for 4 hours followed by hot water treatment at 40^{0}C for 5 minutes in combination, resulted in retarding post harvest diseases without peel darkening. *Alternaria* rot on mango fruits could be controlled by spraying and brushing of hot water at 50-55^{0}C for 20 seconds (Prusky *et al*., 2009). Hot water treatment also had potential in reducing the post harvest loss due to anthracnose and improving the quality and shelf life of mango fruits (Le *et al*., 2010, Jabbar *et al*., 2011, Seid *et al*., 2017). Hot water treatment (52 to 55^o C) for 5 minutes was found to be best in controlling the microbial spoilage percentage in Himasagar variety of mango fruits (Thokchom and Mandal, 2019).

Ndlela *et al*. (2017) opined that hot water treatment (46.1^{0}C for 68 min.) of Apple variety of mango is an effective post harvest disinfestation treatment against mango fruit fly (*Bactrocers dorsalis*).

According to Zhang *et al*. (2012), chilling injury of 'Tainong 1' mango fruits, stored under 5^0 C for 3 weeks was lower when they were hot water treated at 55^{0}C for 10 minutes. The chilling injury of mango cv. Keitt could be effectively controlled by hot water treatment (46.1^{0}C for 75-90 minutes) and a combination of hot water treatment and 0.5 per cent calcium lactate resulted in fruits with higher antioxidant content (Lopez- Lopez *et al*., 2018).

Chatha *et al*. (2020) observed that both hot water treatment and gamma irradiation treatment can be effectively used commercially to enhance the storage life of black and white Chaunsa varieties of mango.

When *Nam Doc mai* mango fruits were dipped in hot water at 50^{0}C for 11 minutes, it had higher firmness compared to fruits of var. Keitt mango (Zakariya and Alhassan, 2014). Keitt variety of mango fruits subjected to hot water treatment at 50 or 55ºC for 10 minutes, significantly maintained firmness, vitamin C content and reduced weight loss during storage under ambient condition (Pholoma *et al*., 2020).

2.1.3 Chlorine treatment

Mango fruits of var. Kesar treated with 8 per cent calcium chloride ($CaCl_2$) and 100ppm gibberellic acid (GA_3) showed superiority with respect to quality attributes like total soluble solids and total sugars whereas titrable acidity, ascorbic acid and physiological loss in weight recorded linear decrease during ripening (Sakhale *et al*., 2009). Post harvest dip in 2 per cent calcium chloride was found more effective and economical to improve storage life and quality of Dusehri mangoes (Kumari, 2011). Dashehari mangoes dipped in aqueous solutions of calcium chloride and calcium nitrate (2 and 4% each) for five minutes, reduced post harvest losses along with a delay in the ripening. It also resulted in maintaining higher firmness and lower physiological loss in weight (Periyathambi *et al*., 2013). The fruits of mango cvs. Sendhura and Neelum, packed in polythene packaging, after dipping in calcium chloride (1.5 %) solution was found to be most effective in extending the shelf life fruits with excellent fruit quality up to 12 days (Madhavan *et al*., 2019).

APEDA (2007) had recommended postharvest treatment of hot water (52^0C for 3 to 4 minutes) and sodium hypochlorite (200 ppm) to reduce fungal disinfection of mango fruit for increasing shelf life.

2.1.4 Ozonisation

Ozone (O_3) can be used as an agent to delay the physiological and biochemical changes in fruits during storage and ozonisation is an effective sanitizing method employed to reduce microbial spoilage of fresh fruits, vegetables and liquid based food products. The application of ozone gas is offered as a solution to preserve food by reducing the amount of harmful microbes and chemical contaminants attached to food. Bacteria were inactivated by the attack of ozone molecule on various primary cells, proteins, unsaturated lipids, enzymes and nucleic acids in the cytoplasm and protein and peptidoglycans in coatings of spores and virus capsids (Khadre *et al*., 2001). Ozonized water has been reported as a safe form of sanitization in several fruits such as guava, honey pineapple, banana (Alothman *et al*., 2010), broccoli (Lima *et al*., 2014) and papaya (Yeoh *et al*., 2014). Microbial inactivation by ozone is mainly due to the rupturing of cellular membrane of microorganisms (Sukarminah *et al*., 2017).

Fruits immersed in ozonized water had increased its total soluble solids in tomato (Tzortzakis *et al*., 2007), papaya (Ali *et al*., 2014) and mango (Monaco *et al*. 2016). When the fruits of mango variety 'Nam Dok Mai No. 4' were fumigated with ozone at 10 µl L^{-1} for 10 minutes before storage at ambient condition (25°C), it significantly decreased the respiration rate at day 4 and 6 compared with the control. It also decreased ethylene production and resulted in lower weight loss (Tran *et al*., 2015). Monaco *et al*. (2016) reported that ozone treated mangoes (var. Palmer) stored under cold storage maintained antioxidant activity even after 14 days of storage life. The ozonized water was also efficient for maintaining fruits without microorganisms and preventing the reduction of quality.

The blackberries treated with ozone at different concentrations (0.1 and 0.3 ppm) suppressed the fungal decay by *Botrytis cinerea*, during the storage period of 12 days at 2^0 C, where control fruits had shown 20 per cent decay (Barth *et al.*, 2011). Ozone treated (158 mg/h) fruits of tomato (*Lycopersicum esculentum*) packed in perforated polyethylene packages significantly affected the physical and biochemical changes during storage, and also suppressed the microbiological contamination on the fruit and maintained fruit freshness or quality even after 12 days of storage (Zainuri *et al*., 2017).

Exposure of some fruits and vegetables to ozone increase the total phenolic content (Gonzalez-Aguilar *et al*., 2007; Alothman *et al*., 2010; Yeoh *et al*., 2014) and other molecules with antioxidant activity (Lima *et al*., 2014).

2.1.5 Waxing

The fruits have a waxy coating which progresses during maturation and ripening process. However, during rough handling of fruits, the natural shield gets destroyed and bruises occur. The use of food grade wax coating on fruits is safe and is approved for application on fresh fruits and vegetables (PFA, 2008). Coating or waxing reduces shrivelling, wilting, and respiration rate of fruits and enhances the gloss and cosmetic appearance of fruits (El-Anany *et al*., 2009). Food Safety and Standards Authority of India permits the use of white and yellow bee wax, carnauba wax or shellac wax , on fresh fruits , at a level not exceeding good manufacturing practices under proper label declaration as provided in Regulation 2.4.5 (44) of Food Safety and Standards regulations (FSSAI, 2011).

Edible coatings also provide additional benefit of reducing the volume of non-bio degradable packaging materials (Valero *et al*., 2013). Application of any commercial food grade edible coating can act as a substitute and moderate the loss during postharvest period (Sethy and Kumar, 2018).

The Nipro Fresh SS 40T^{TM} and SS 50^{TM} coatings on chlorine treated Kinnow fruits reduced the weight loss, retained the firmness and maintained the overall quality up to 45 days in cold storage with 5-7 °C and 90-95% RH and it was for ten days under ambient conditions (Mahajan *et al*., 2013).

Coating formed by synergetic antifungal mixtures of chitosan (5g/l) and *Mentha piperita* essential oil (0.6ml/l) improved post harvest quality characteristics in mango cv. Tommy Atkins during 30 days of cold storage (de Oliveira *et al*., 2019). Coating of ethanolic extract of mango (cv. Manila) seed kernel (3g/l) on Ataulfo mango fruits effectively prevented anthracnose disease by producing 100 per cent mycelial growth inhibition even after nine days of storage (Gomez-Maldonado *et al.*, 2020).

According to Jakhar and Pthak (2015), Amprapali fruits treated with a combination of wax (6%) and hot water treatment was best to prolong the shelf life of fruits up to 15 days with lowest physiological loss in weight and highest organoleptic quality on comparison with the fruits without any treatments having nine days of storage life.

Aloe vera gel (50% or 75%) coating on mango fruits stored at 13 ^{0}C maintained quality evidenced by reduced increase in weight loss and extended shelf life up to 20 days with good total soluble solids, acidity and firmness (Sophia *et al*., 2015). Apple variety of mango fruits dipped in gum arabic solution, delayed the increase in total soluble solids and β-carotene, reduced weight loss and maintained the ascorbic acid content of fruit even after15 days of storage life (Lanoi *et al*., 2020).

Benzalconic chloride (2g/l) with carnauba wax (18.5-20.5%) is a viable alternative to benomyl in the control of rotting caused by *Colletotrichum gloesporioides* in mango Haden stored under ambient condition (Fonseca *et al*., 2004). The combined application of Bavistin (50ppm) with wax (6%) found to be the most effective method for increasing fruit marketability and quality of Dashehari mango (Singh *et al*., 2012). Soomro *et al.* (2013) reported that the sunflower wax coating on Langra variety of mango completely inhibited the fungal growth of the *Aspergillus flavus.*

2.1.6 Sodium bicarbonate treatment

Sodium bicarbonate ($NaHCo_3$) an inorganic salt having antimicrobial activity (Deliopoulos *et al*., 2010) is being widely used in the food industry and they are among compounds that are generally recognized as safe (GRAS).

Pre harvest treatment with either salicylic acid or potassium phosphonate at1000 mg L^{-1} combined with post harvest dip in three per cent aqueous sodium bicarbonate at 51.5 ^{0}C reduced severity of anthracnose in mango fruits (Dessalegn, *et al*., 2013). Post harvest dip in $NaHCo_3$ solution (1% and 2%) found to be effective in inhibition of mycelial growth of *Alternaria solan*i, causal organism of fruit rot in tomato (Ashok, 2019).

Chandel (2015) recommended the dipping of mangoes in $NaHCO_3$ solution (2%) for 12 hours, to remove arsenic residue from fruit surface.

2.2 ARTIFICIAL RIPENING OF FRUITS

Hastening of the ripening process, in case of many fruits, has mainly been done to satisfy high market demand and fruit supply. The mango fruits harvested and transported at mature green stage are ripened at market places and early ripening is planned for better monetary value of fruits. A conventional way of mango ripening includes harvesting of fruits at complete mature stage and ripening them at ambient temperature in a stack of hay, usually paddy straw either open or in corrugated fibre board (CFB) boxes having holes for aeration. Ripening period of mangoes varies from 6-15 days after harvest depending on cultivar and usually found over-ripe and excessive soft beyond this (Tharanathan, 2006).

The climacteric nature of mango fruits enhances the ripening in the presence of ethylene gas, the universal ripening agent in fruits. The ethylene can be provided by an external source either from a natural source or from synthetic chemicals compounds like ethrel, ethephon, acetylene or propylene.

2.2.1 Hot water treatment

Mango fruits treated with hot water at 55^0C, for 20 minutes and stored at room temperature ($38±4^0$C) ripened in three days, followed by hot water at 45^0C treatment which ripened in four days as reported by Sheikh *et al*. (2012). These mangoes showed best sensorial properties like peel colour, fruit softness, pulp colour, taste, flavour, texture and aroma. The study conducted by Zhang *et al*. (2012), revealed that in variety 'Tainong 1' after treatment with hot water at 55^0C for ten minutes, when fruits were subjected to lower temperature of 5^0C, ripening process was more rapid as indicated by changes in firmness, respiration rate and ethylene production .

2.2.2 Ethrel

The Food Safety and Standards (Prohibition and Restriction on Sales) Regulations (2011) had permitted use of ethrel/ethylene gas for the artificial ripening of fruits.

Climacteric fruits such as guava (Mahajan *et al*., 2008), banana (Kulkarni *et al*., 2011), papaya (Singh *et al*., 2012), tomato (Dhall and Singh, 2013) and mango (Venkatesan and Tamilmani, 2013; Gupta *et al*., 2015) were recommended for artificial ripening, but concentration is permitted only up to 100ppm as per the FSSAI specification. According to Wolterink *et al.* (2015) the acceptable daily intake of ethephon is 0-0.05 mg kg^{-1} body weight per day on the basis of a no-observed-adverse-effect in studies in humans.

Ethrel was also reported to accelerate chlorophyll destruction in many fruits including mango (Haithem and Goukh, 2003; Siddqui and Dhua, 2009; Gupta *et al*., 2015), banana (Kulkarni *et al*., 2011) and papaya (Singh *et al*., 2012).

Earlier and uniform ripening could be achieved by either dipping, spraying or exposing fruits into diluted ethrel (2 - Chloroethyl phosphonic acid) solution. Mango fruits of cv. Kesar ripened by ethephon dip treatment (750 ppm for 5 min.) showed a shelf life of eight days (Kad *et al*., 2017). 'Carabao' mangoes treated with higher concentrations of ethephon (1000 or 1500 μL L^{-1}) had reduced ripening time by two to three days as compared to untreated fruits (Lacap *et al.*, 2019).

2.2.2.1. Ethrel dip

Kulkarni *et al.* (2004) found that ethrel dip (500ppm) in Neelum variety of mango fruit resulted enhanced ripening by attaining respiratory climacteric peak (140 mg/CO_2/kg/h) on fourth day of storage whereas, control fruits reached respiratory climacteric peak (95 mg/CO_2/kg/h) on sixth day of storage. During 2011, Kulkarni *et al*. conducted a trial to induce uniform ripening in mature banana fruits and they found that ethrel dip (500 ppm) for five minutes was optimum for uniform ripening in six days at 20±1^0C. These fruits also showed an increasing trend in total soluble solids (TSS), acidity, total sugars and total carotenoids during ripening. Ethrel (500 ppm) dip treatment reduced chilling injury in 'Kensington Pride' variety of mango, stored at 5ºC for four weeks as reported by Nair and Singh (2013) and it also enhanced respiration rate, ethylene production, TSS, TSS/acid ratio, sugars and eating quality as compared to the untreated fruit. Dashehari fruits dipped in ethephone (600ppm) for five minutes had fully ripened in three days and maintained excellent quality even up to six days under ambient storage condition (Jawandha *et al*., 2017).

Application of ethrel at 1000 ppm, 750 ppm and 500 ppm on mature Kesar mango fruits had resulted ripening of maximum number of fruits within six, nine and 12 days respectively (Patil *et al*., 2009). Similarly, Singh *et al*. (2011) found that ethrel (750 ppm) dipped Amrapali fruits showed better results in respect of specific gravity (0.88), moisture loss (8.45%), decay (2.5%), total soluble solids (TSS, 20.7^0 brix), sugar (14.39%) and acidity (0.32) followed by ethrel 500 ppm, with specific gravity (0.90), moisture loss (8.82%), decay (3.5%), TSS (20.7^0 brix), sugar (13.99%) and acidity (0.36 %).

When fruits of mango cv. Sendura were dipped in ethrel (500 ppm) for 5 minutes at 52°C and stored at ambient conditions, uniform ripening was induced in three days as against six days in control, with pleasant flavour, desirable texture and acceptable quality, which is not only in mature fruits but also in early harvested mango fruits with 18.50° brix TSS, 0.29 per cent titrable acidity and 31.43mg/100g ascorbic acid (Das and Balmohan, 2013). Fruits of mango cv. Suvarnarekha harvested at 9-11^0 brix, dipped in ethrel (500ppm) and packed in 150 guage polypropylene bag with 1 per cent ventilation maintained quality up to nine days of storage at ambient condition (Rose, 2013).

Haithem and Abu-ghokh (2004) had reported that ethrel (500ppm) dipped mangoes reached full yellow colour, one day earlier than control fruit; while exogenous application of ethrel at same concentration had changed into yellow colour, about three to four days earlier.

Combination of ethrel (750ppm) and carbendazim (0.1%) proved to be most effective in regulating the ripening and enhancing the post harvest quality of Dashehari mango (Gourav, 2015).

2.2.2.2. Ethrel spray

Ethrel spray (600 ppm) in Dashehari mango fruit induced uniform ripening with attractive yellow colour within four days while untreated control fruits remained green even after eight days of storage (Gurjar *et al*., 2017).

2.2.2.3. Ethylene gas

Ataulfo mangoes subjected to exogenous application of 100ppm ethylene for 12 hours ripened within four days (Montlavo *et al*., 2007). Kad *et al*., 2017 opined that, mango fruits of variety Kesar, when exposed to ethylene gas (100 ppm) in ripening chamber for 18 hours and stored at ambient condition recorded a maximum shelf life of six days.

Venkatram and Pandiarajan (2014) reported that the treatment combination of 600 ppm ethylene for an exposure time of 25 hours had better physiological loss in weight (3.78%), firmness (5.99N), pH (5.84) and TSS (16.2^0 brix) in Alphonso variety of mango; whereas the combination of 500 ppm ethylene for 24 hours of exposure time had given fruits of higher score for overall acceptability. Chandel (2015) had recommended a ripening technology without any presence of harmful residue and could be adopted by the small scale traders and farmers to ensure safe fruit to the consumers. Ethylene gas (100 ppm) was generated by dissolving ethrel and sodium hydroxide inside the ripening chamber (1.7 m^3), having an evaporative cooler found most suitable for ripening of mangoes. Banganapalli fruits exposed to ethylene (100 ppm) showed the highest TSS of 24.45 ± 0.42^0 brix in $9\text{-}11^0$ brix harvested mangoes on 12^{th} day of storage while ethylene (150 ppm) treated fruits reported the highest total sugar (23.64

± 0.06^0 brix) with good palatability than that of naturally ripened fruits (Lakshmi *et al*., 2017).

2.2.3 Bioethylene / Natural sources of ethylene

Artificial ripening of fruits can be done by using bioethylene, or ethylene from natural sources. The use of fresh leaves of kakawate (*Gliricidia sepium* Jacq. Steud), rain tree (*Samanea saman* Jacq. Prain), and star fruit (*Averrhoa carambola* L.) to ripen fruits is a common practice in the Philippines (Bautista *et a*l., 1990). Biological ethylene sources are being used as an alternative to the chemical application. Some of which are squash peel, bilimbi fruit and leaves of *Gliricidia sepium* have been proven to increase the rate of ripening (Lualhati and Rodeo, 2013).

2.2.3.1 Bilimbi

Bilimbi *(Averrhoa bilimbi,* L.) is a tropical plant belongs to the family Oxalidaceae commonly called cucumber tree or tree sorrel. The fruits and leaves of bilimbi have wide range of applications in the field of medicine (D Souza *et al*., 2019). They are also used as ripening agent in several tropical fruits such as banana (Masilungan and Absulio, 2012), mango (Basak and Akter, 2018) etc.

Fruit extracts of bilimbi includes flavonoids, saponins and triterpenoids. The chemical constituents of fruit are amino acids, citric acid, cyaniding-3-O-h-D-glucoside, phenolics, potassium ion, sugars and vitamin A (Kumar *et al*., 2013). Azeem and Vrushabendraswami (2015) had reported the presence of 14 volatile components in ethanolic extracts of bilimbi leaves, and among it the major one is octanone (23.21%). it also showed high foaming index, indicate the presence of saponin contents. According to Nair *et al*. (2016) hydro methanolic extracts of bilimbi fruits had higher total phenolic content as rutin (358 ± 0.7 μg per g plant extract) than that of 80% ethnolic extract of leaves (47 ± 1.2 μg per g plant extract) which include, phytochemicals such as flavonoid, alkaloids and phenols.

Mature green 'Saba' bananas packed along with 10 per cent (w/w) injured bilimbi fruits for 24 hours, hastened ripening, due to the presence of ethylene (2403.8 nL g^{-1} h^{-1}) produced by bilimbi fruits. The injured bilimbi fruits effectively ripened bananas to table ripe stage after five days, while the control fruits were just beginning to develop colour, so the fruits were believed to be a possible source of bioethylene as they were observed to soften fast especially when injured, which could mean that they produce a high level of ethylene (Masilungan and Absulio, 2012). Basak and Akter (2018) reported that Sagor banana fruits kept along with bilimbi fruits ripened in three days and showed higher shelf life than the fruits stored with castor leaves (*Ricinus conmunis L.)*, CaC_2 and Bangi fruit (*Cucumis melo*). The use of bilimbi fruit allowed ripening of Cavendish banana for 76 hours while a 25-75 per cent concentration of bilimbi fruit extract allowed ripening for 76-96 hours. The bananas treated with bilimbi extract (75%) had the highest level of acceptability and titratable acidity while the bananas treated with bilimbi fruit had the highest level of reducing sugar (Dave *et al*., 2020).

Gas chromatography showed that uninjured bilimbi leaves evolved 13.3 nL $g^{-1}h^{-1}$ ethylene while the uninjured fruits evolved almost seven times as much, 86.8 nL $g^{-1}h^{-1}$ ethylene in 27 hours whereas injured fruits (incision of 15mm depth) increased ethylene production by 65 times (59.42 nL g^{-1} h^{-1}) within an hour (Masilungan and Absulio, 2012).

Venna leaves (*Ricinus conmunis L.)* are the natural ripening agent in Sobri banana, where ripening started from the first day and completed within three days of storage. The colour and texture of fruits were good and damaging started only on day five (Basak and Akter, 2018).

2.2.3.2 Apple

Ethylene, a natural phytohormone, produced by some fruits upon ripening promotes additional ripening of produce exposed to it (Gerald *et al*., 2006). Fruits like avocado, banana, mango, pear and tomato evolve 500, 40, 3, 40, 35 µg/l of ethylene at the climacteric maximum (Belitz *et al*., 2009).

The threshold level of ethylene for fruits like avocado (var. Choqeutte), banana (var. Lacatan, var. Silk fig), lemon (var. Frot meyors), mango (var. kent), and tomato (var. VC243-20) ranges from 0.1 to 0.5 ppm respectively (Reid, 1985). Initiation of ripening occurs when a threshold level of ethylene is reached in the cells of the fruits (Thompson, 2003). The concentration of ethylene and treatment duration to achieve the desired effect will vary with the product. For most products, the threshold concentration is 0.1 ppm and the maximum effect is achieved at 10 ppm or less (Chakraverty *et al*., 2003).

Being a fruit which release a higher ethylene gas during ripening, apple could be exploited as a natural, safe and faster ripening agent to facilitate ripening of fruits (Bautista *et al*., 1990; Fasanya *et al*., 2019).

Early-maturing summer varieties of apple such as Astrachan, Red June, Gravenstein, Delicious and Newtown were found to be higher ethylene producers during ripening; the amount of ethylene released by these varieties are 11.38, 9.27, 5.16, 1.77 and 1.78 ml/kg/24 hours respectively (Hansen, 1945).

The temperature at which the fruits were stored also have effect on ethylene production during ripening. Apple stored under 20^0C had produced 8-11 times higher ethylene than that of fruits stored at 0^0 C (Hansen, 1945).

Banana fruits kept along with an apple ripened in three days at open condition of 15-25°C temperature and 85% of relative humidity. The ethylene released from the ripened apple reduced the time of ripening of mature banana fruits by seven days than that of control fruits (Singal *et al*., 2012). Gandhi *et al*. (2016) also found that the banana fruits packed in a plastic cover along with an apple (5:1) completely ripened in four days and the fruits kept in plastic cover without apple ripened only after ten days.

Fruits of banana when ripened by red apple had developed bright peel colour and good taste within a short ripening period (3 days) than that of naturally ripened fruits. Red apple ripened, *Musa dwarf Cavendish* and *Musa sapientum Linn* had also reported a higher protein content of 1.57 and 1.73 per cent respectively (Fasanya *et al*., 2019).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study on the "Post harvest management practices in mango (*Mangifera indica* L.)" was carried out at the Department of Post Harvest Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 2018-2020. Vellanikkara situated 22.25 m above mean sea level at 10^0 32' N latitude and 70^0 10' E longitude.

The research programme was divided into two experiments.

3.1 Standardization of post harvest treatments for important mango varieties in Muthalamada area

3.2 Standardization of ripening techniques

Mango fruits were collected from the field of a mango farmer Shri. C. A. Saleem, Chettiyarchalla, Meenkaradam, Muthalamada-678507 Palakkad. Commercial varieties of mangoes were harvested at optimum stage of harvest maturity by using bamboo pole with net during late evening. The harvested fruits were collected in plastic crates after de-sapping and cleaning. Then they were brought to the Department of Post Harvest Technology, College of Horticulture, Vellanikkara during night, on the same day for further studies.

3.1 STANDARDIZATION OF POST HARVEST TREATMENTS FOR IMPORTANT MANGO VARIETIES IN MUTHALAMADA AREA

The fruits of commercial mango varieties namely, Alphonso, Bennet Alphonso, Banganapalli and Bangalora were collected at their full maturity from Muthalamada during the last month of March 2018, for post harvest treatment studies. The treated fruits were packed in five per cent ventilated corrugated fibre board (CFB) boxes and stored under both cold storage and ambient condition.

3.1.1 Treatments

T_0S_0: Absolute control; stored under ambient condition

T_0S_1: Absolute control; stored in cold storage (12 ± 2^0C)

T_1S_0: Hot water dip (50 ± 2^0C) for one minute and stored under ambient condition

T_1S_1: Hot water dip (50±2^{0}C) for one minute and stored in cold storage (12±2^{0}C)

T_2S_0: Hydro cooling for five minutes and stored under ambient condition

T_2S_1: Hydro cooling for five minutes and stored in cold storage (12±2^{0}C)

T_3S_0: Sanitization with sodium hypochlorite solution (100 ppm) for five minutes and stored under ambient condition

T_3S_1: Sanitization with sodium hypochlorite solution (100 ppm) for five minutes and stored in cold storage (12±2^{0}C)

T_4S_0: Ozonisation (2ppm O_3) for 15 minutes and stored under ambient condition

T_4S_1: Ozonisation (2ppm O_3) for 15 minutes and stored in cold storage (12±2^{0}C)

T_5S_0: Waxing (Nipro Fresh 1%) and stored under ambient condition

T_5S_1: Waxing (Nipro Fresh 1%) and stored in cold storage (12±2^{0}C)

T_6S_0: Sodium bicarbonate treatment (1%) for five minutes and stored under ambient condition

T_6S_1: Sodium bicarbonate treatment (1%) for five minutes and stored in cold storage (12±2^{0}C)

3.1.2 Lay out

The experiment was designed with 14 treatments and two replications of each in a Completely Randomized Design (CRD).

3.1.3 Observations

Observations on both chemical and physical parameters were taken in detail as below.

3.1.3.1 Physical parameters

3.1.3.1.1 Physiological loss in weight (PLW)

PLW was determined by the formula of Srivastava and Tandon (1968).

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

Mango orchard

Collection in plastic crates

Mango harvest by using bamboo poles with net

Plate 1. Mango harvest from Muthalamada orchard

T1 Hot water dip

T2 Hydrocooling

T3 NaOCl

T4 Ozonisation

T6 NaHCO3

Nipro fresh - natural MTS 40 (1L/5L)

T5 Dip in wax (3-10 Sec)

Surface dry (10-30 min)

Plate 2. Post harvest treatments on mango

Mangoes stored under ambient condition

Mangoes at cold storage

Plate 3. Storage condition

3.1.3.1.2 Shelf life (days)

The days from the harvest to the day of consumption was taken as the shelf life of fruits.

3.1.3.1.3 Change in colour (IPGR descriptor)

The change in colour of fruits were determined by the help of International Plant Genetic Resources (IPGR) descriptor of mango. The skin colour of ripe fruit of mango are given below.

Fruit ground colour

1. Green
2. Yellow
3. Orange
4. Purple
5. Red

Fruit blush

1. Orange
2. Purple
3. Red

3.1.3.1.4 Firmness (N)

Firmness of the mango fruits at full ripened state was measured by using hand held fruit pressure tester.

3.1.3.2 Biochemical parameters

3.1.3.2.1 Acidity (%)

A known weight of fruit sample was digested with distilled water and then made up the volume to 100 ml after filtering. An aliquot of the solution was treated with standard alkali using phenolphthalein as indicator (Ranganna, 1997).

3.1.3.2.2 Ascorbic acid (mg/100g)

Five grams of fruit pulp was extracted with three per cent meta-phosphoric acid. The ascorbic acid content was then estimated by redox titration with 2, 6 - dichlorophenol indophenol dye (Sadasivam and Manickam, 1996).

3.1.3.2.3 Sugars

Total sugar and reducing sugar were determined by using Fehling's solution in titrimetric method (Ranganna, 1997). The non reducing sugar was obtained by subtracting reducing sugar from total sugar.

3.1.3.2.4 Total Soluble Solids (TSS)

TSS was measured by using a digital refractometer ranges from 0-32 degree brix.

3.1.3.2.5 Total carotenoids

Total carotenoids was estimated by grinding five gram of fruit with acetone using pestle and mortar. The extract is decanted into a conical flask and continued the extraction till the residue is colourless. The extract was transferred to a separating funnel containing petroleum ether and mixed gently. The solution was shaked and kept for some time after adding five per cent Sodium sulphate. The separated yellow colour pigment is transferred in to petroleum ether and colour intensity was measured at 452nm by using a spectrophotometer. The total carotenoid content was calculated by the formula

Total carotenoid content (mg/100g) = $\frac{3.857 \times OD \times \text{Volume made up} \times 100}{\text{Weight of the sample} \times 100}$

3.1.3.3 Pesticide residue studies before and after treatment

Pesticide residue analysis of mangoes was done at the Pesticide Residue Analysis Laboratory of College of Horticulture, Vellanikkara. The analysis was done by GC (Gas Chromatography). The variety, Alphonso was taken for the pesticide residue analysis at their full ripened stage.

Ten gram of ground mango sample was taken in a centrifuge tube (50 ml) along with ten ml of ethyl acetate. The mixture was vortexed for 30 sec. and then homogenized (13000-14000 rpm) for 3 min. by adding 9 g of sodium sulphate (activated at 500°C for 5-6 hrs.) and 1 g of sodium chloride. Later, the contents were centrifuged at 3000 rpm for 5 min. at 10°C in a refrigerated centrifuge. The supernatant (7 ml) was taken in separate centrifuge tube (15 ml) along with primary secondary amine (0.35 g) and magnesium sulphate (1.05 g). The sample mixture were again vortexed and centrifuged (5000 rpm) for 5 min. at 10°C. After centrifugation, three ml of the supernatant was transferred to labelled test tubes and then into labelled vials after filtering through 0.2 µ PVDF membrane filter, to estimate the residue by gas chromatograph. Parameters of gas chromatograph is given in the Table 1 below.

Table 1. Operating parameters of gas chromatograph

Gas chromatograph	Agilent 7890 B
Colum	Agilent HP-5 column (30 m x 320 µm)
Film thickness	0.25µm
Carrier gas	Nitrogen (99.9995% purity)
Flow rate	1 ml/min
Injection volume	1 µl
Injector temperature	260^0C
Injector mode	Splitless
Oven temperature	70^0C ramped to 120°C @ 40^0C/min (held for 5 min.), then ramped to 300°C @ 50^0C/min (held for 8 min.)
Detector temperature	300^0C

3.1.3.4 Post harvest pathogens

Post harvest diseases of mango fruits were observed and recorded during the storage period. Infected portion of mango fruit was taken and subjected to microbial examination, by using normal slide preparation method. Clean glass slides were taken, on which a drop of cotton blue stain was added. The infected portion of mango fruit was transferred to the stain using a needle. Then cover slip was gently placed over this and viewed through 40X magnification.

3.2 STANDARDIZATION OF RIPENING TECHNIQUES

The mango fruits at proper harvest maturity were subjected to the following treatments to improve their ripening. The treated fruits then packed and kept under ambient condition.

3.2.1 Treatments

T_0: Absolute control

T_1: Hot water dip (50 ± 2^0C for one minute)

T_2: Ethrel dip (100 ppm)

T_3: Ethrel spray (100 ppm)

T_4: Ethrel dip (200 ppm)

T_5: Ethrel spray (200 ppm)

T_6: Placing ripened apple fruit along with mature unripe mango fruits (1:20) in a closed container

T_7: Ethrel (5 ml 40% Ethephone/ m^3 + 3g NaOH for 24 hrs.)

T_8: Keep fruits along with leaves of Bilimbi *(Averrhoa bilimbi)*

3.2.2 Lay out

The experiment was designed with nine treatments and three replications of each in a Completely Randomized Design (CRD).

Ethrel (2- Chloroethyl phosphonic acid)

0 DAS

5 DAS

10DAS

T6- Placing ripened apple fruit along with mango fruits in a closed container (1:20)

Bilimbi leaves (*Averrhoa bilimbi*)

0 DAS

5 DAS

T8 - Keeping mango fruits along with bilimbi leaves

Plate 4. Ripening treatments on mango var. Bennet Alphonso

3.2.3 Observations

Observations on both chemical and physical parameters were taken in detail as below.

3.2.3.1 Physical parameters

3.2.3.1.1 Physiological loss in weight (PLW)

PLW was recorded as mentioned in 3.1.3.1.1.

3.2.3.1.2 Shelf life (days)

Shelf life of fruits were measured as mentioned in 3.1.3.1.2.

3.2.3.1.3 Change in colour (IPGR descriptor)

Change in colour of fruits were observed as mentioned in 3.1.3.1.3.

3.2.3.1.4 Firmness (N)

Firmness recorded as mentioned in 3.1.3.1.4.

3.2.3.2 Biochemical parameters

3.2.3.2.1 Acidity (%)

Acidity was calculated as mentioned in 3.1.3.2.1.

3.2.3.2.2 Ascorbic acid (mg/100g)

Ascorbic acid was calculated as mentioned in 3.1.3.2.2.

3.2.3.2.3 Sugars (%)

Sugars were obtained as mentioned in 3.1.3.2.3.

3.2.3.2.4 Total Soluble Solids (TSS)

TSS was measured as mentioned in 3.1.3.2.4.

3.2.3.2.5 Total carotenoids

Total carotenoids was calculated as mentioned in 3.1.3.2.5.

3.2.3.3 Sensory evaluation

Sensory evaluation was done by using a panel of 20 semi - trained people on a nine point hedonic scale. It measures the level of liking of the product by people. Headonic ratings were converted to ranks and analysis was done.

Quality attributes like colour, appearance texture, taste etc. were evaluated in ripe mango fruits. Score card used in the evaluation is given in the Appendix 1.

RESULTS

4. **RESULTS**

The results of the research project entitled 'Post harvest management practices in mango (*Mangifera indica* L.)' conducted under the Department of Post Harvest Technolgy, College of Horticulture, Vellanikkara during the year of 2018-2020 are presented here under the following titles.

4.1 Standardization of post harvest treatments for important mango varieties in Muthalamada area

4.2 Standardization of ripening techniques

4.1 STANDARDIZATION OF POST HARVEST TREATMENTS FOR IMPORTANT MANGO VARIETIES IN MUTHALAMADA AREA

Post harvest treatments on fresh fruits help to improve the storage life. The commercial mango varieties of Muthalamada area, such as Alphonso, Bennet Alphonso, Banganapalli and Bangalora were harvested from the farmer's field and subjected to different post harvest treatments. The results of both physical and biochemical parameters of fruit after ripening are recorded here.

4.1.1 Physical parameters

4.1.1.1 Physiological loss in weight (PLW)

The physiological loss in weight (PLW) of fruits is one of the parameters which indicate its quality during storage. After harvest every fresh commodity loses its weight with respect to time and storage condition. The loss in weight leads to shrinkage and finally affects the market quality. In this experiment, PLW was recorded during five, ten, 13, 16, 19 and 22 days after storage. The treatments given to the varieties gave significantly different results with respect to PLW in Alphonso, Bennet Alphonso, Banganapalli and Bangalora as given in Table 2.

Wax coated fruits of Alphonso stored under cold storage (T_5S_1) showed the lowest PLW (2.67 %) after five days of storage and the highest was when fruits were ozonized and stored under ambient condition (11.18 %). Bennet Alphonso fruits showed minimum PLW (5.88 %) when fruits were sanitized in sodium hypochlorite solution and stored under cold storage (T_3S_1). The lowest PLW (10.98 %) in Banganapalli and (4.69%) in Bangalora was observed when fruits were waxed and kept in cold storage (T_5S_1) after 13 and ten days after storage respectively.

Generally fruits which are kept in cold storage showed lower PLW as compared to the fruits stored at ambient condition. The fruits stored under cold storage after wax coating showed lower PLW in Alphonso, Banganapalli and Bangalora varieties.

T_0S_0: Absolute control; stored under ambient condition

T_0S_1: Absolute control; stored in cold storage

T_1S_0: Hot water dip (50 ± 2^0C) and stored under ambient condition

T_1S_1: Hot water dip (50 ± 2^0C) and stored in cold storage

T_2S_0: Hydro cooling and stored under ambient condition

T_2S_1: Hydro cooling and stored in cold storage

T_3S_0: Sanitization with sodium hypochlorite (100 ppm) and stored under ambient condition

T_3S_1: Sanitization with sodium hypochlorite (100 ppm) and stored in cold storage

T_4S_0: Ozonisation (2ppm O_3) and stored under ambient condition

T_4S_1: Ozonisation (2ppm O_3) and stored in cold storage

T_5S_0: Waxing (Nipro-Fresh 1%) and stored under ambient condition

T_5S_1: Waxing (Nipro-Fresh 1%) and stored in cold storage

T_6S_0: Sodium bicarbonate treatment (1%) and stored under ambient condition

T_6S_1: Sodium bicarbonate treatment (1%) and stored in cold storage

Table 2a. Effect of postharvest treatment on PLW (%) of Alphonso

Treatments	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS	22 DAS
T_0S_0	3.26 (9.60)[c]	3.92 (15.34)[b]	18.80	-	-	-
T_0S_1	2.11 (3.44)[fg]	2.15(4.62)[de]	5.36	7.10	-	-
T_1S_0	3.28 (9.77)[bc]	3.99(15.95)[b]	_	-	-	-
T_1S_1	2.20 (3.83)[efg]	2.22(4.94)[de]	5.79	7.45	8.62	-
T_2S_0	3.40(10.58)[abc]	4.13(17.09)[b]	20.07	-	-	-
T_2S_1	2.35 (4.52)[e]	2.28(5.18)[d]	6.2	7.38	-	-
T_3S_0	3.36(10.29)[abc]	4.10 (16.84)[b]	20.67	24.24	27.12	-
T_3S_1	2.27 (4.16)[ef]	2.22(4.94)[de]	5.53	-	-	-
T_4S_0	3.49 (11.18)[a]	4.08(16.67)[b]	-	-	-	-
T_4S_1	2.06 (3.26)[gh]	2.08(4.06)[ef]	4.87	6.38	7.28	7.69
T_5S_0	2.67 (6.15)[d]	3.12(9.73)[c]	11.97	14.12	16.09	16.75
T_5S_1	1.81 (2.67)[h]	1.91(3.28)[f]	3.92	5.34	6.22	6.52
T_6S_0	3.45 (10.92)[ab]	4.37(19.08)[a]	23.5	-	-	-
T_6S_1	2.01 (3.32)[gh]	2.07(4.09)[ef]	4.93	6.16	-	-
C.D.	**0.182**	**0.222**				
SE(d)	0.084	0.097				

Table 2b. Effect of postharvest treatment on PLW (%) of Bennet Alphonso

Treatments	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS	22 DAS
T_0S_0	3.54(11.56)^{a}	4.57(19.86)^{a}	4.97(24.73)^{b}	29.01	31.91	-
T_0S_1	2.55(5.51)^{c}	2.96(7.78)^{cd}	3.10(9.62)^{ef}	12.71	14.83	15.70
T_1S_0	3.45(10.90)^{ab}	4.39(18.25)^{a}	4.79(22.92)^{bc}	-	-	-
T_1S_1	2.29(4.22)^{c}	2.55(5.52)^{de}	2.56(6.53)^{gh}	8.21	9.90	10.49
T_2S_0	3.80(13.47)^{a}	4.61(20.22)^{a}	4.97(24.68)^{b}	-	-	-
T_2S_1	2.46(5.06)^{c}	3.06(8.42)^{c}	3.17(10.14)^{e}	15.18	-	-
T_3S_0	3.75(13.00)^{a}	4.76(21.62)^{a}	5.48(30.00)^{a}	-	-	-
T_3S_1	2.24(3.98)^{c}	2.42(5.10)^{e}	2.47(5.88)^{h}	7.32	8.44	8.84
T_4S_0	3.52(11.34)^{a}	4.67(20.84)^{a}	5.81(33.73)^{a}	-	-	-
T_4S_1	2.40(4.80)^{c}	2.72(6.50)^{cde}	2.78(7.57)^{fgh}	9.18	-	-
T_5S_0	3.06(8.39)^{b}	3.81(13.55)^{b}	4.35(18.89)^{d}	21.82	-	-
T_5S_1	2.39(4.70)^{c}	2.68(6.18)^{cde}	2.80(7.82)^{efgh}	9.82	10.87	11.11
T_6S_0	3.44(10.86)^{ab}	4.46(18.95)^{a}	4.54(20.61)^{cd}	-	-	-
T_6S_1	2.45(5.06)^{c}	2.84(7.08)^{cde}	2.89(8.36)^{efg}	9.89	12.37	12.93
C.D.	**0.44**	**0.485**	**0.426**			
SE(d)	0.14	0.158	0.133			

Table 2c. Effect of postharvest treatment on PLW (%) of Banganapalli

Treatments	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS	22 DAS
T_0S_0	3.86(14.07)^{a}	4.87(22.96)^{a}	5.40(28.48)^{a}	5.31(27.23)^{b}	-	-
T_0S_1	2.69(6.25)^{cd}	2.98(7.89)^{d}	3.25(9.55)^{c}	3.52(11.37)^{def}	12.94	13.35
T_1S_0	3.64(12.29)^{ab}	4.69(20.99)^{a}	5.24(26.51)^{a}	5.58(30.16)^{ab}	-	-
T_1S_1	2.49(5.21)^{d}	2.80(6.85)^{d}	3.01(8.07)^{c}	3.27(9.70)^{ef}	11.23	11.73
T_2S_0	3.78(13.34)^{a}	4.74(21.52)^{a}	5.30(27.17)^{a}	6.08(35.96)^{a}	-	-
T_2S_1	2.47(5.12)^{d}	2.70(6.28)^{d}	2.91(7.47)^{c}	3.14(8.86)^{f}	10.28	10.92
T_3S_0	3.56(11.73)^{ab}	4.47(19.14)^{ab}	5.01(24.23)^{ab}	5.47(29.11)^{b}	33.68	37.79
T_3S_1	2.72(6.38)^{cd}	3.05(8.30)^{d}	3.26(9.67)^{c}	3.49(11.20)^{def}	12.93	13.42
T_4S_0	3.70(12.76)^{a}	4.71(21.33)^{a}	5.06(24.69)^{ab}	5.30(27.06)^{b}	31.62	-
T_4S_1	2.94(7.68)^{cd}	3.35(10.26)^{cd}	3.56(11.73)^{c}	3.85(13.90)^{d}	13.98	14.10
T_5S_0	3.17(9.02)^{bc}	3.92(14.35)^{bc}	4.38(18.16)^{b}	4.72(21.25)^{c}	24.36	-
T_5S_1	2.86(7.19)^{cd}	3.18(9.13)^{d}	3.46(10.98)^{c}	3.70(12.75)^{de}	13.14	14.05
T_6S_0	4.00(15.01)^{a}	5.05(24.48)^{a}	5.61(30.46)^{a}	6.08(35.95)^{a}	-	-
T_6S_1	2.92(7.51)^{cd}	3.28(9.78)^{cd}	3.51(11.33)^{c}	3.81(13.49)^{d}	15.29	15.46
C.D.	**0.541**	**0.686**	**0.699**	**0.502**		
SE(d)	0.250	0.317	0.323	0.232		

Table 2d. Effect of postharvest treatment on PLW (%) of Bangalora

Treatments	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS	22 DAS
T_0S_0	3.09(9.54)^{abcd}	4.05(16.39)^{ab}	20.89	25.38	29.75	36.78
T_0S_1	2.16(4.65)^{f}	2.23(5.05)^{c}	5.40	7.02	-	-
T_1S_0	3.49(12.19)^{ab}	4.49(20.19)^{a}	24.85	-	-	-
T_1S_1	2.50(6.28)^{def}	2.79(7.80)^{c}	8.96	11.66	-	-
T_2S_0	3.10(9.62)^{abc}	4.25(18.14)^{ab}	23.90	29.02	-	-
T_2S_1	2.36(5.57)^{ef}	2.59(6.75)^{c}	7.88	11.21	-	-
T_3S_0	3.65(13.40)^{a}	4.38(19.22)^{ab}	24.35	-	-	-
T_3S_1	2.52(6.38)^{cdef}	2.77(7.69)^{c}	8.87	10.97	-	-
T_4S_0	3.64(13.44)^{a}	4.10(16.81)^{ab}	-	-	-	-
T_4S_1	2.50(6.26)^{def}	2.73(7.50)^{c}	9.25	10.66	11.63	12.49
T_5S_0	2.94(8.81)^{bcde}	3.74(14.19)^{b}	13.35	16.15	-	-
T_5S_1	1.95(3.82)^{f}	2.16(4.69)^{c}	5.51	6.57	7.24	7.56
T_6S_0	3.14(9.90)^{ab}	4.07(16.61)^{ab}	21.07	25.35	29.60	-
T_6S_1	2.28(5.23)^{f}	2.55(6.53)^{c}	8.81	-	-	-
C.D.	**0.595**	**0.660**				
SE(d)	0.264	0.293				

4.1.1.2 Shelf life (days)

Although the treatments did not show any significant effect on the shelf life of all the four mango varieties, the variety Bennet Alphonso had the highest shelf life of 32 days in control fruits stored under cold storage (T_0S_1), followed by Banganapalli with maximum shelf life of 29.50 days in fruits sanitized with sodium hypochlorite and stored under cold storage (T_3S_1). Maximum shelf life of 26.5 days in Bangalora and 23 days in Alphonso was observed when fruits were waxed and kept in cold storage (T_5S_1). The shelf life of mango varieties are depicted in Table 3.

Table 3. Effect of post harvest treatments on storage life (days)

Treatments	**Shelf life (days)**			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	15.00	19.50	18.00	22.50
T_0S_1	16.50	32.00	27.00	17.50
T_1S_0	12.00	15.00	16.50	15.50
T_1S_1	21.50	25.00	26.50	16.50
T_2S_0	15.00	14.00	16.50	18.00
T_2S_1	16.50	18.50	26.50	16.50
T_3S_0	19.50	15.00	27.50	14.00
T_3S_1	15.00	28.50	29.50	18.00
T_4S_0	9.50	15.00	19.50	12.50
T_4S_1	22.00	18.50	23.00	25.00
T_5S_0	22.50	18.00	19.50	16.50
T_5S_1	23.00	24.00	26.50	26.50
T_6S_0	15.50	15.00	16.50	21.00
T_6S_1	16.50	23.00	26.50	15.00
C.D.	**NS**	**NS**	**NS**	**NS**
SE(d)	5.464	3.827	4.777	6.835

NS denotes the non-significance of treatments.

Values with different alphabets as superscripts are significantly different.

4.1.1.3 Change in colour (IPGR descriptor)

The colour change of Alphonso, Bennet Alphonso, Banganapalli and Bangalora fruits during storage is shown in Table 4a, 4b, 4c and 4d respectively. In all the four varieties, the colour change was slower when fruits were waxed and kept in cold storage (T_5S_1). These fruits completely turned into yellow colour with in a time period of 26 days in Bangalora followed by 21days in Banganapalli and 16 days in both Alphonso and Bennet Alphonso.

4.1.1.4 Firmness (N)

Firmness of mature fruits reduced during ripening. At the stage of full ripening, Bangalora showed the highest firmness (0.394 N) when fruits were treated with hot water and kept in ambient storage condition (T_1S_0). The same trend was also observed in Bennet Alphonso (0.34 N) fruits. In Alphonso, fruits sanitised with sodium hypochlorite solution and kept in ambient storage condition (T_3S_0) recorded the highest firmness of 0.275 N. Fruits of Banganapalli reported highest firmness (0.290 N) in sodium bicarbonate treated fruits kept under ambient storage condition (T_6S_0). The firmness of mango fruits is depicted in Table 5.

Table 4a. Change in colour of Alphonso fruits during storage (IPGR descriptor)

Treatments	0 DAS	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS
T_0S_0	G	G	GY	Y	Y	Y
T_0S_1	G	G	GY	GY	GY	Y
T_1S_0	G	GY	GY	Y	Y	Y
T_1S_1	G	G	G	G	Y	Y
T_2S_0	G	GY	Y	Y	Y	Y
T_2S_1	G	GY	Y	Y	Y	Y
T_3S_0	G	GY	GY	Y	Y	Y
T_3S_1	G	GY	Y	Y	Y	Y
T_4S_0	G	GY	Y	Y	Y	Y
T_4S_1	G	GY	GY	Y	Y	Y
T_5S_0	G	GY	Y	Y	Y	Y
T_5S_1	G	G	G	GY	Y	Y
T_6S_0	G	GY	GY	Y	Y	Y
T_6S_1	G	GY	GY	Y	Y	Y

G-Green, GY- Greenish Yellow, Y-Yellow

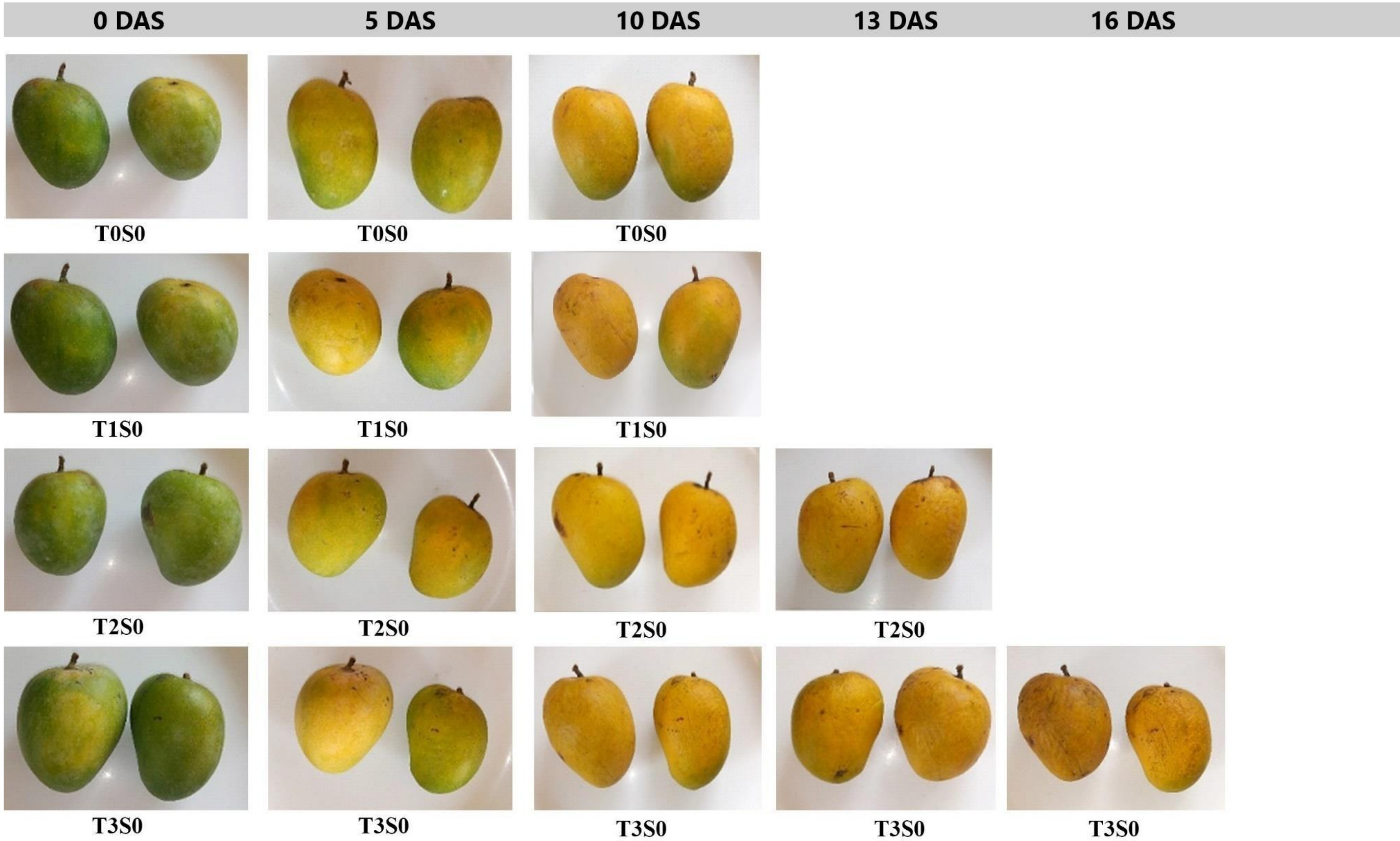

Plate 5a. Effect of post harvest treatments on colour change of Alphonso stored under ambient condition

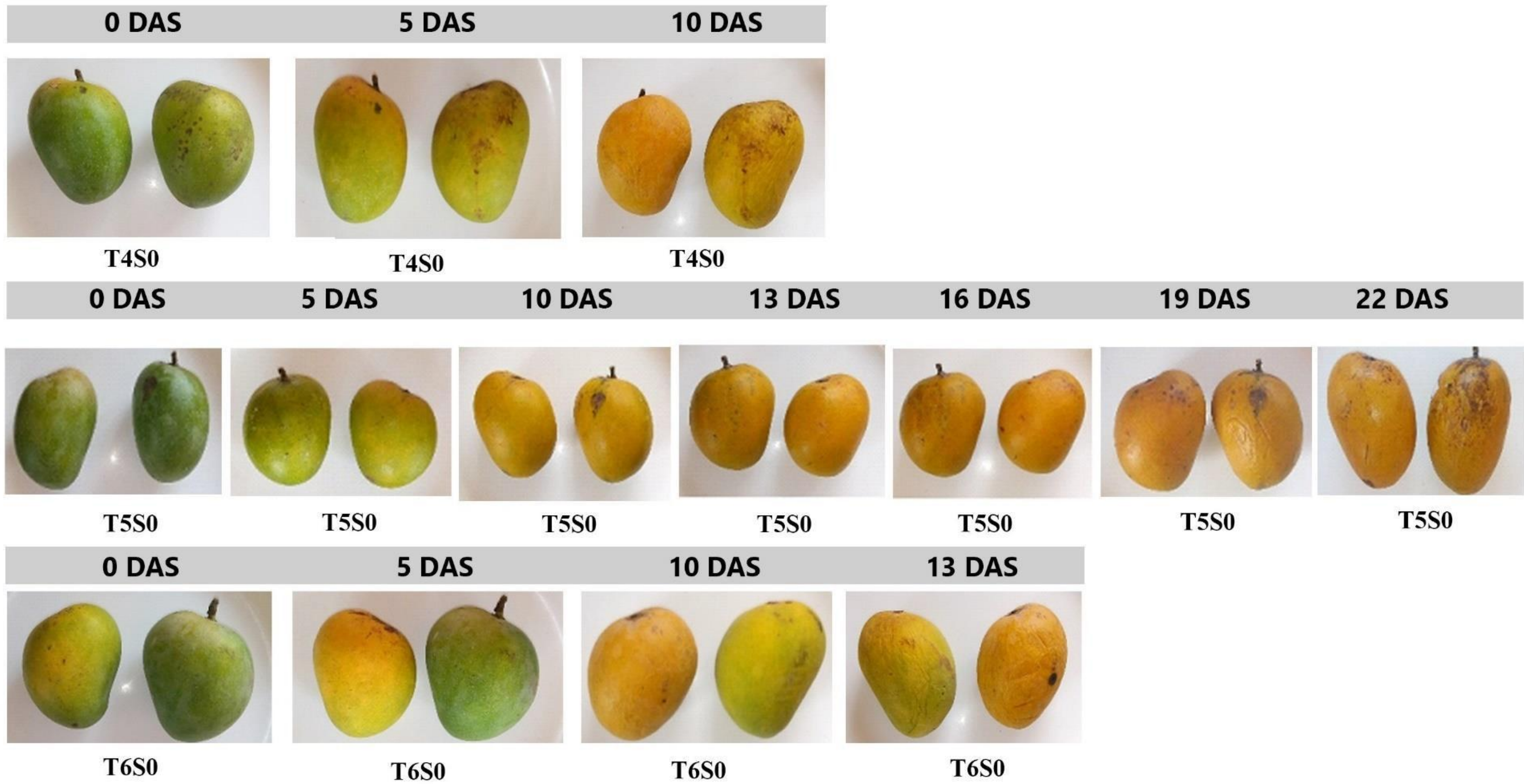

Plate 5b. Effect of post harvest treatments on colour change of Alphonso stored under ambient condition

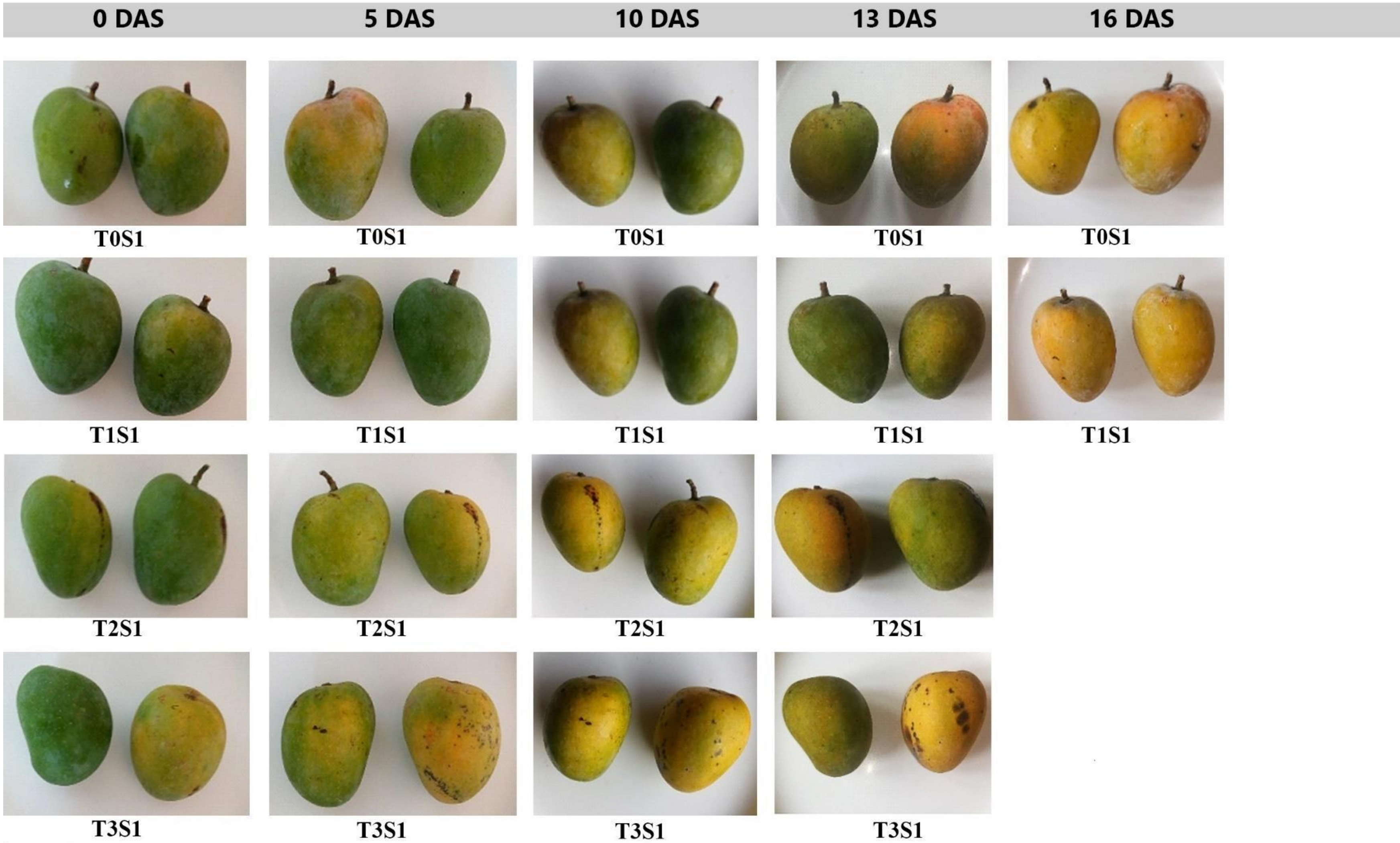

Plate 6a. Effect of post harvest treatments on colour change of Alphonso stored undercold storage

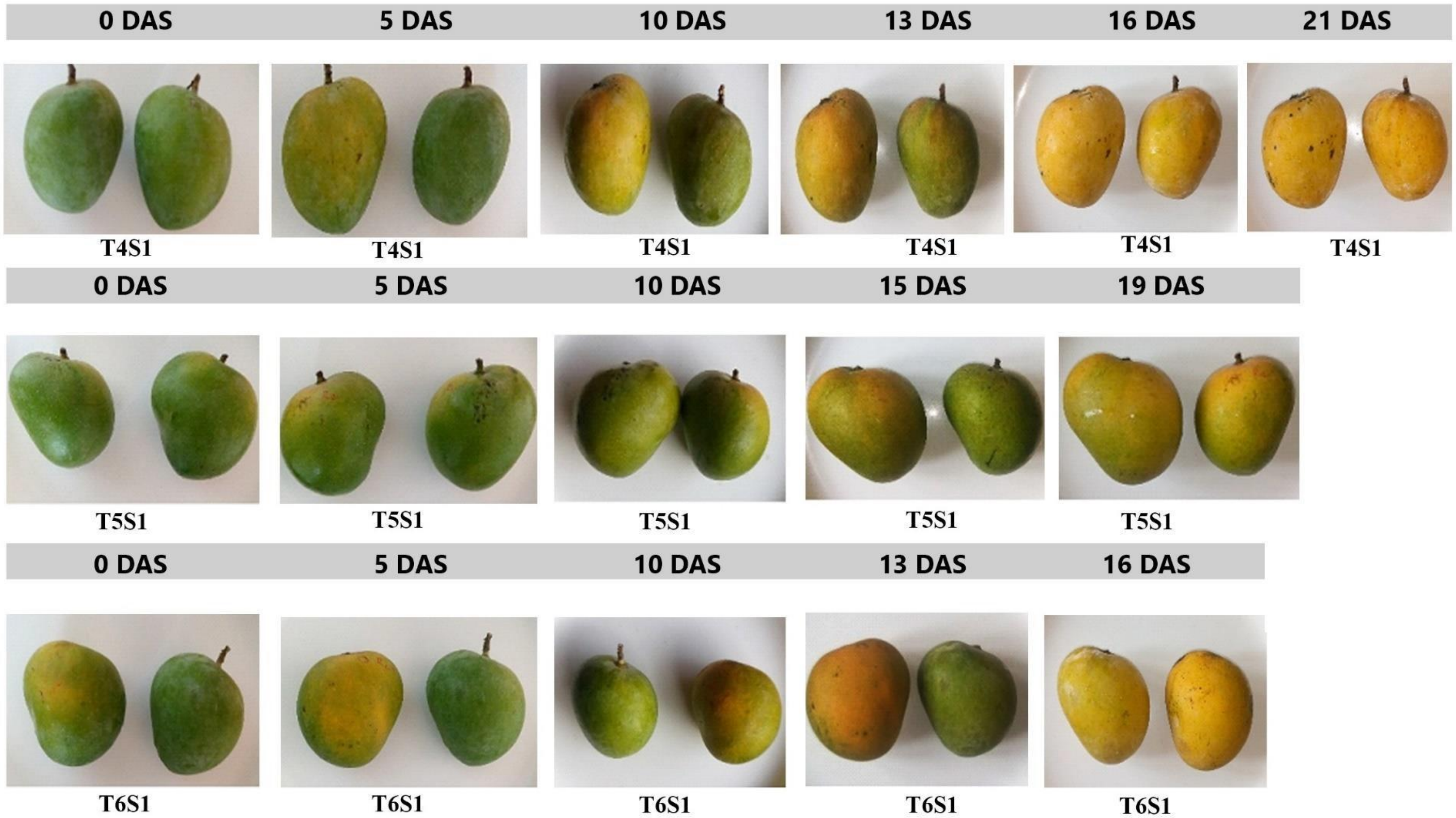

Plate 6b. Effect of post harvest treatments on colour change of Alphonso stored under cold storage

Table 4b. Change in colour of Bennet Alphonso fruits during storage (IPGR descriptor)

Treatments	0 DAS	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS
T_0S_0	G	GY	Y	Y	Y	Y
T_0S_1	G	G	G	GY	Y	Y
T_1S_0	G	GY	GY	GY	Y	Y
T_1S_1	G	GY	GY	Y	Y	Y
T_2S_0	G	GY	Y	Y	Y	Y
T_2S_1	G	GY	GY	Y	Y	Y
T_3S_0	G	GY	Y	GY	GY	Y
T_3S_1	G	G	G	Y	Y	Y
T_4S_0	G	G	GY	Y	Y	Y
T_4S_1	G	G	GY	GY	Y	Y
T_5S_0	G	GY	GY	Y	Y	Y
T_5S_1	G	G	G	G	G	Y
T_6S_0	G	G	GY	Y	Y	Y
T_6S_1	G	G	G	GY	Y	Y

G-Green, GY- Greenish Yellow, Y-Yellow

Plate 7a. Effect of postharvest treatments on colour change of Bennet Alphonso under ambient storage

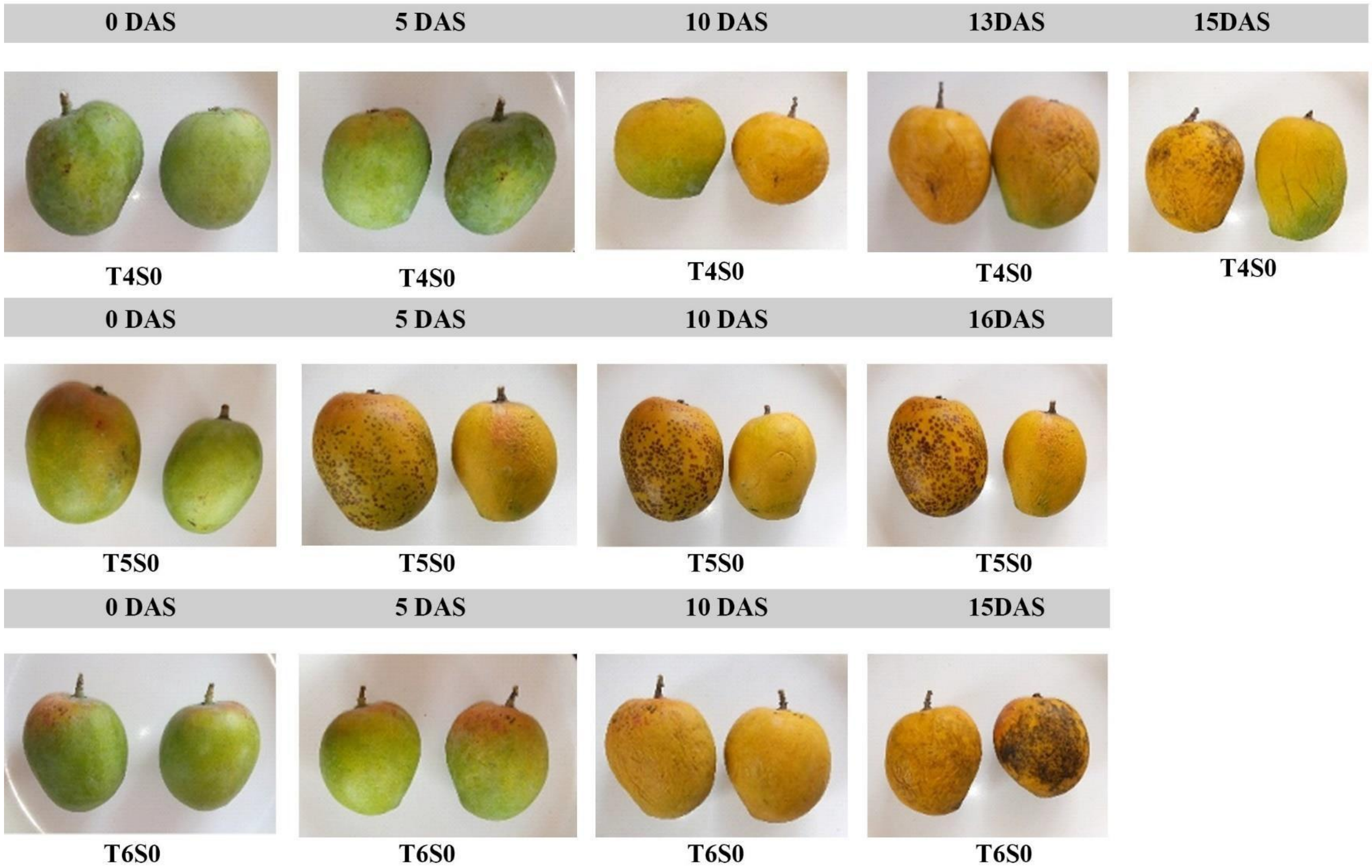

Plate 7b. Effect of postharvest treatments on colour change of Bennet Alphonso under ambient storage

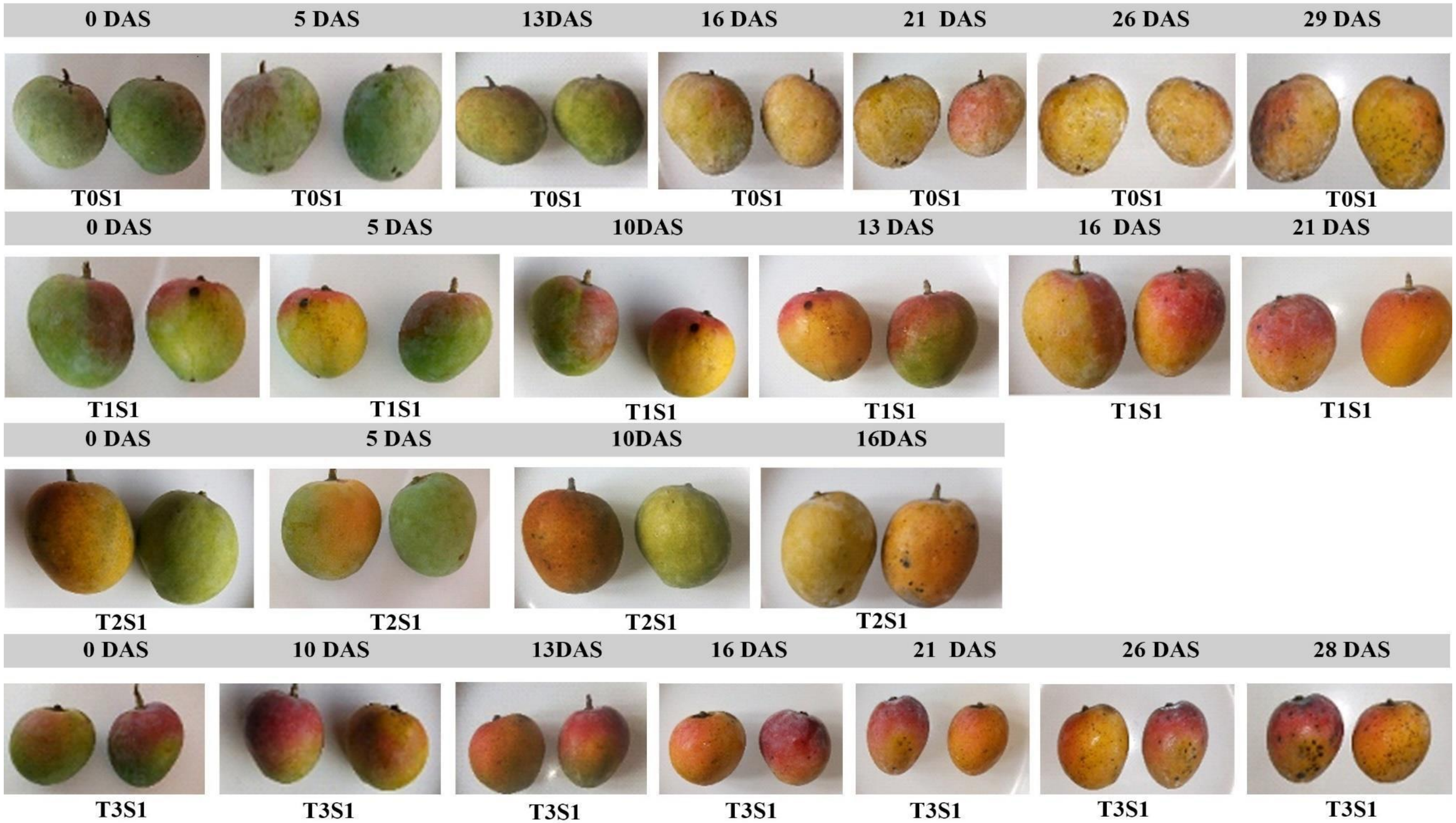

Plate 8a. Effect of postharvest treatments on colour change of Bennet Alphonso under cold storage

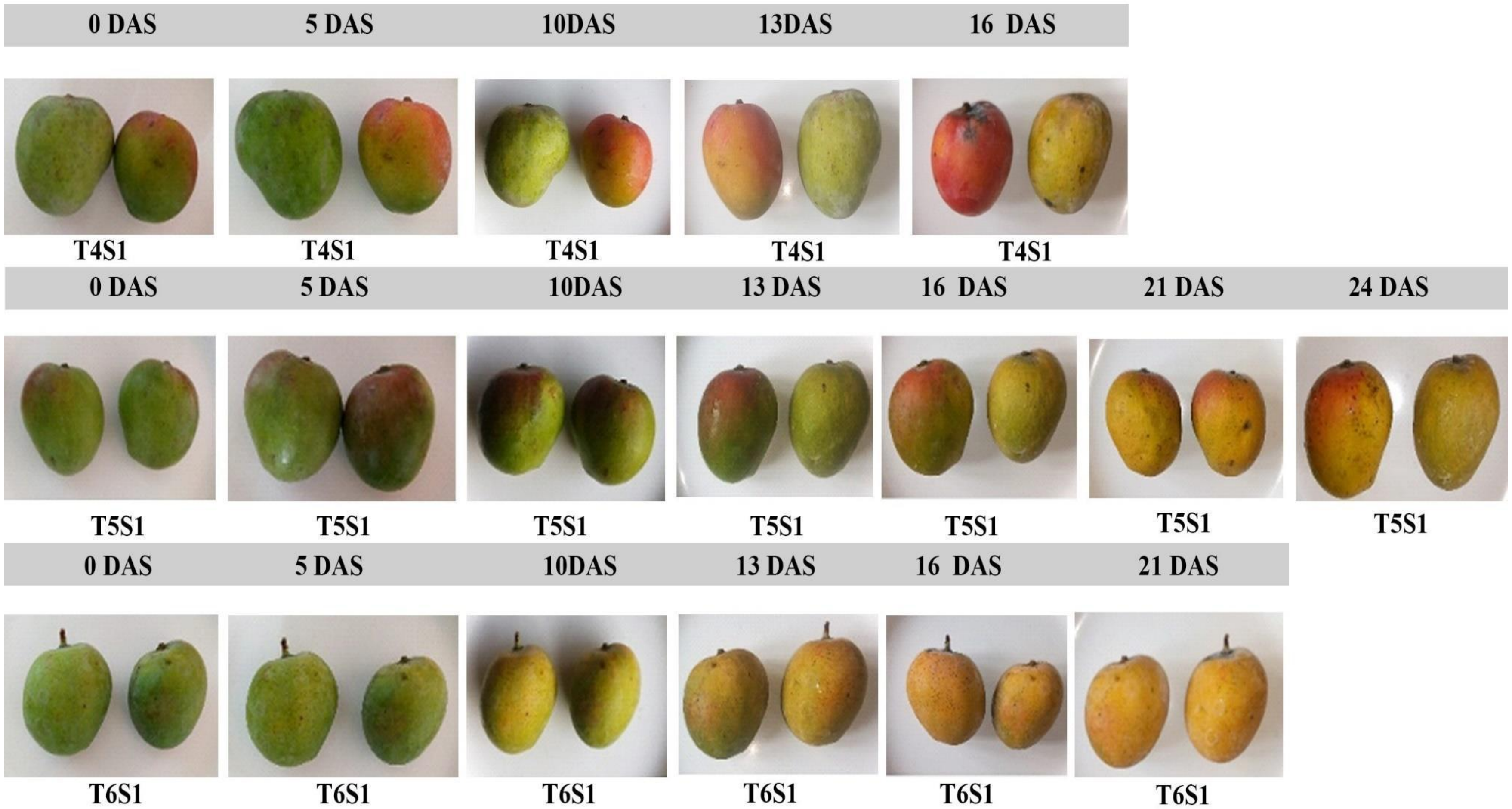

Plate 8b. Effect of post harvest treatments on colour change of Bennet Alphonso under cold storage

Table 4c. Change in colour of Banganapalli fruits during storage (IPGR descriptor)

Treatments	0 DAS	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS
T_0S_0	G	G	GY	GY	Y	Y
T_0S_1	G	GY	GY	GY	Y	Y
T_1S_0	G	GY	Y	Y	Y	Y
T_1S_1	G	G	G	GY	Y	Y
T_2S_0	G	GY	Y	Y	Y	Y
T_2S_1	G	G	G	GY	Y	Y
T_3S_0	G	GY	GY	GY	Y	Y
T_3S_1	G	G	G	GY	Y	Y
T_4S_0	G	GY	GY	Y	Y	Y
T_4S_1	G	GY	G	GY	Y	Y
T_5S_0	G	GY	GY	GY	Y	Y
T_5S_1	G	G	G	GY	GY	Y
T_6S_0	G	G	Y	Y	Y	Y
T_6S_1	G	G	GY	GY	Y	Y

G-Green, GY- Greenish Yellow, Y-Yellow

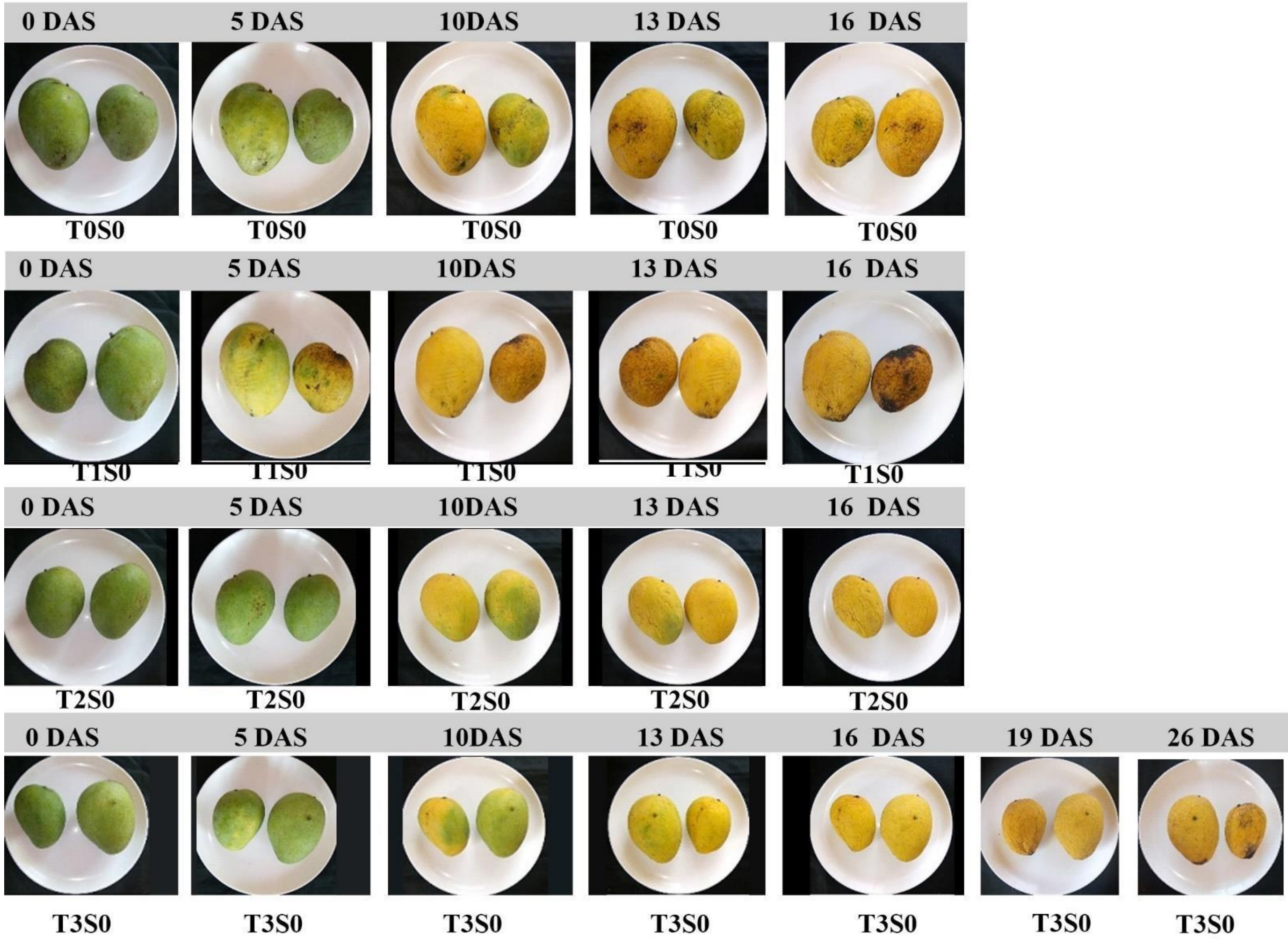

Plate 9a. Effect of post harvest treatments on colour change of Banganapalli stored under cold storage

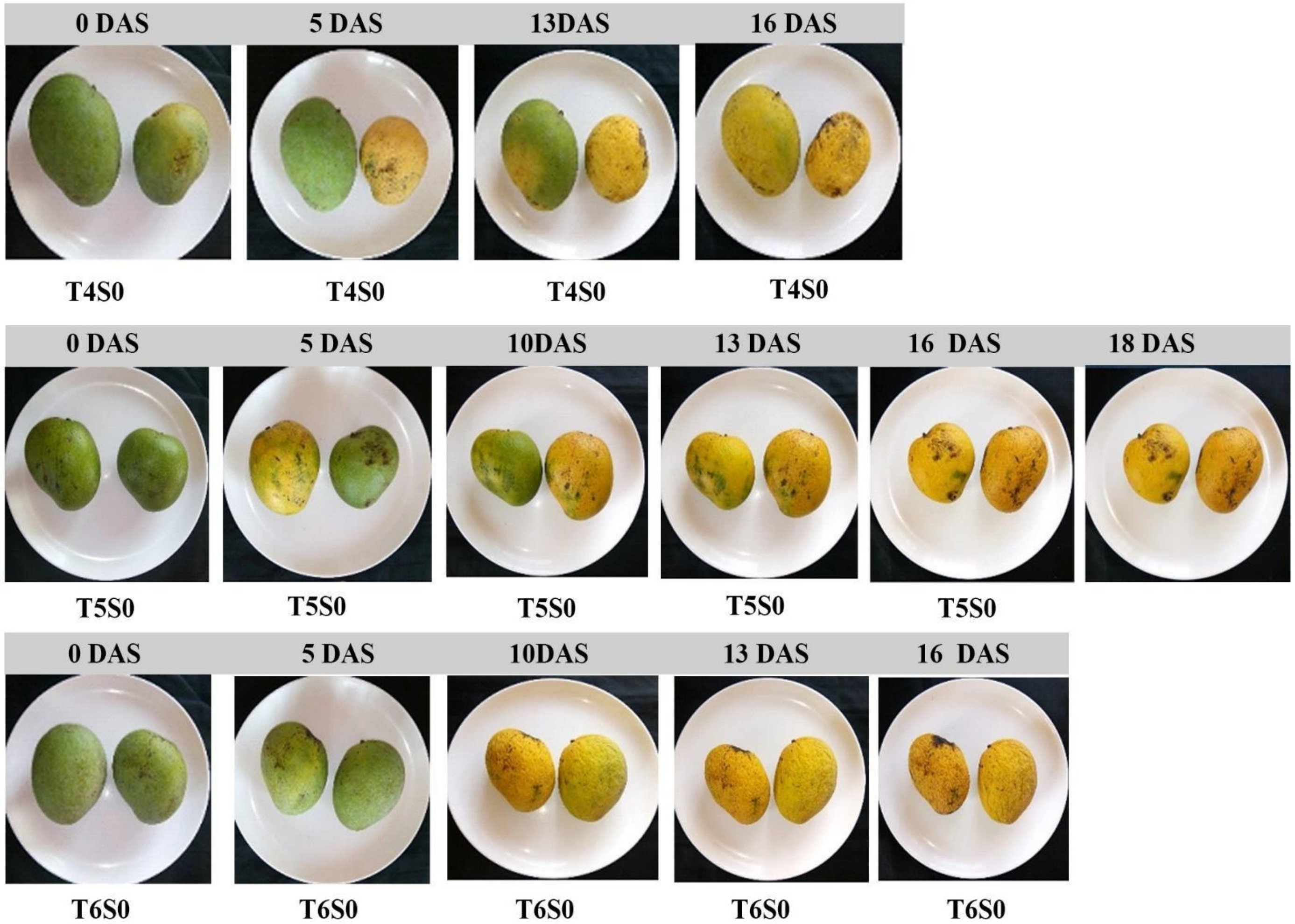

Plate 9b. Effect of postharvest treatments on colour change of Banganapalli kept under ambient storage

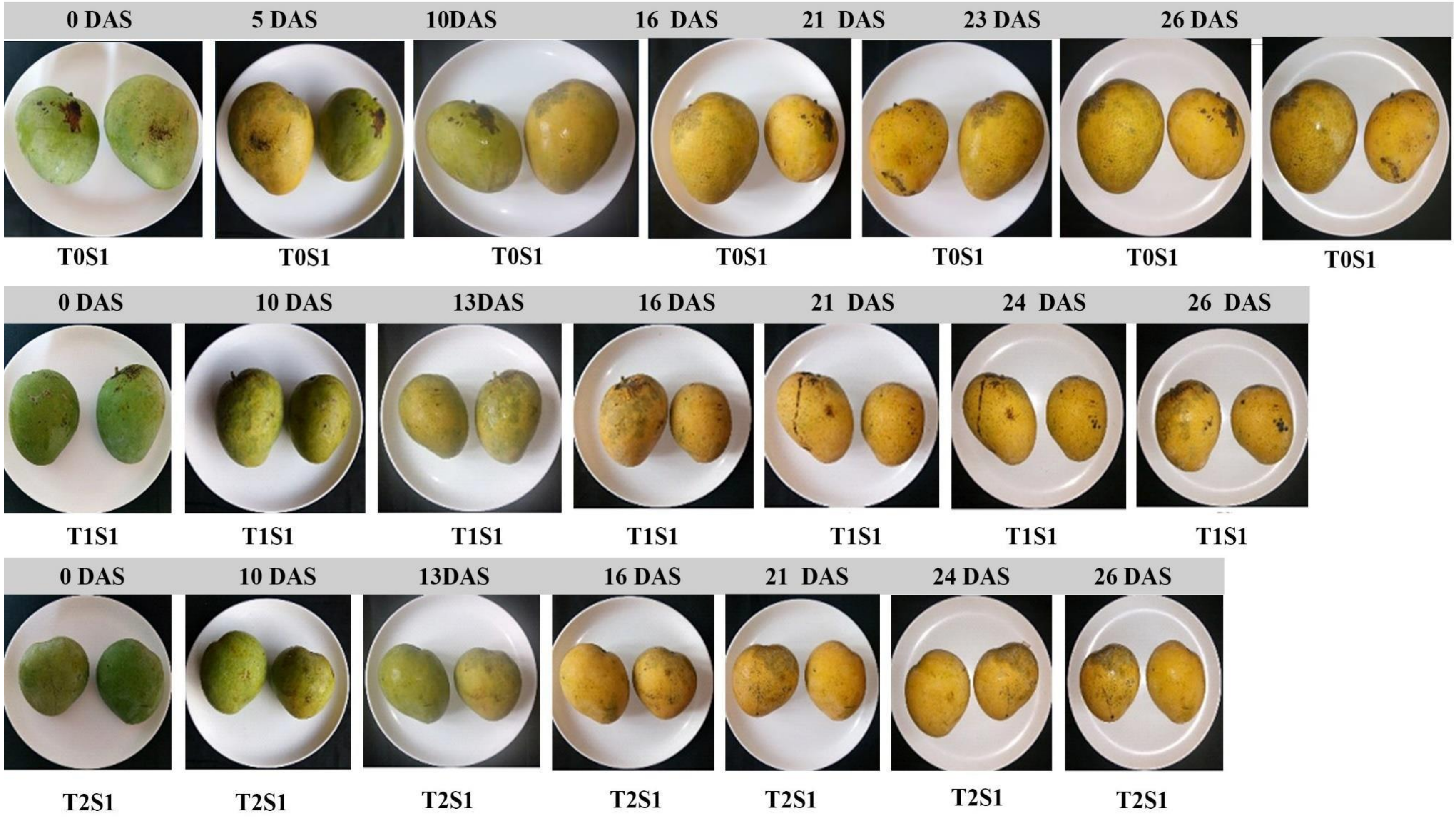

Plate 10a. Effect of postharvest treatments on colour change of Banganapalli under cold storage

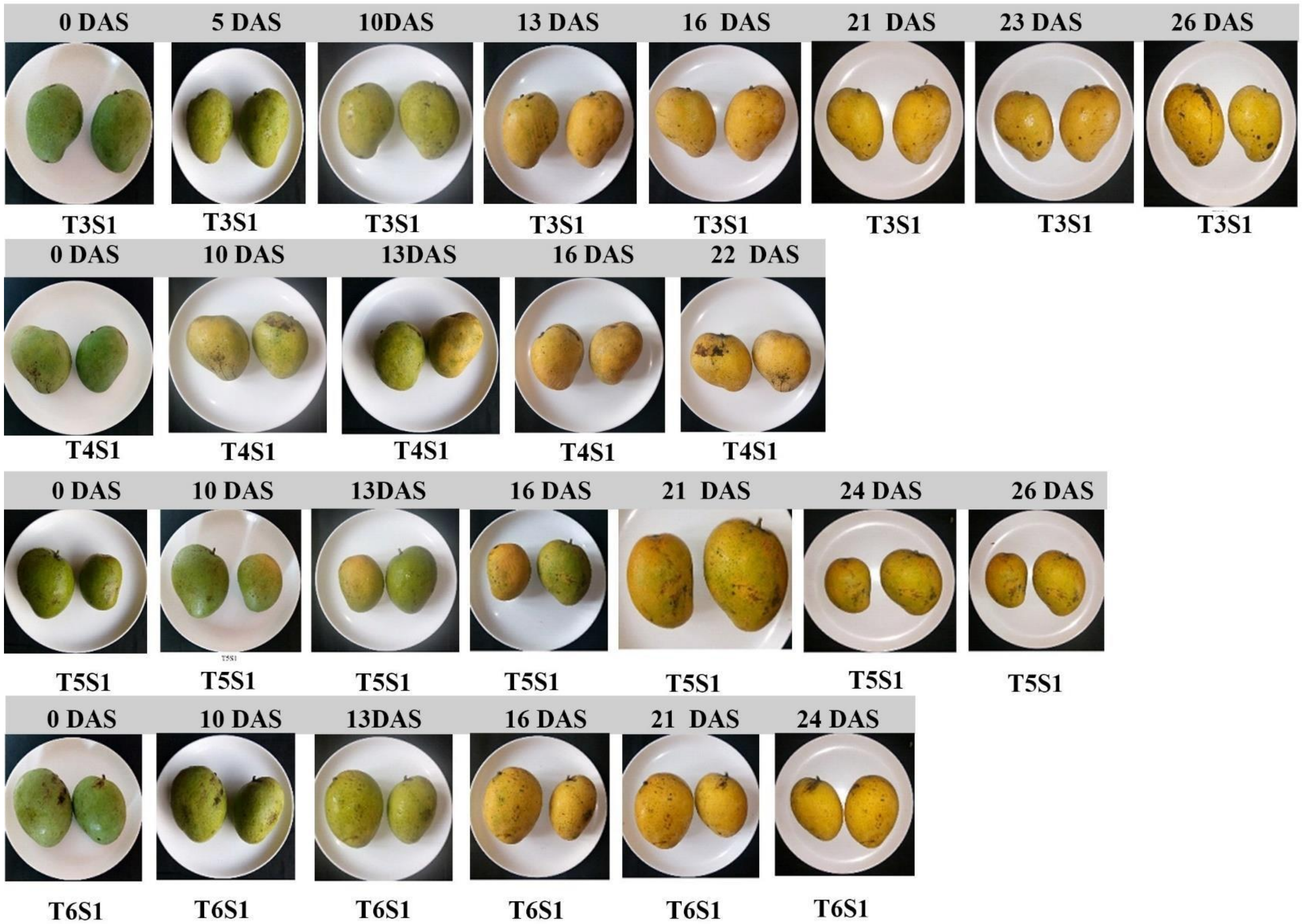

Plate 10b. Effect of postharvest treatments on colour change of Banganapalli under cold storage

Table 4d. Change in colour of Bangalora fruits during storage (IPGR descriptor)

Treatments	0 DAS	5 DAS	10 DAS	13 DAS	16 DAS	19 DAS
T_0S_0	G	G	GY	GY	GY	Y
T_0S_1	G	G	G	G	G	Y
T_1S_0	G	G	G	GY	GY	Y
T_1S_1	G	G	G	GY	Y	Y
T_2S_0	G	G	GY	GY	Y	Y
T_2S_1	G	G	G	GY	Y	Y
T_3S_0	G	GY	GY	GY	GY	Y
T_3S_1	G	G	G	GY	Y	Y
T_4S_0	G	GY	GY	GY	Y	Y
T_4S_1	G	G	G	GY	GY	Y
T_5S_0	G	G	GY	GY	GY	Y
T_5S_1	G	G	G	GY	GY	Y
T_6S_0	G	G	G	GY	GY	Y
T_6S_1	G	G	G	G	G	Y

G-Green, GY- Greenish Yellow, Y-Yellow

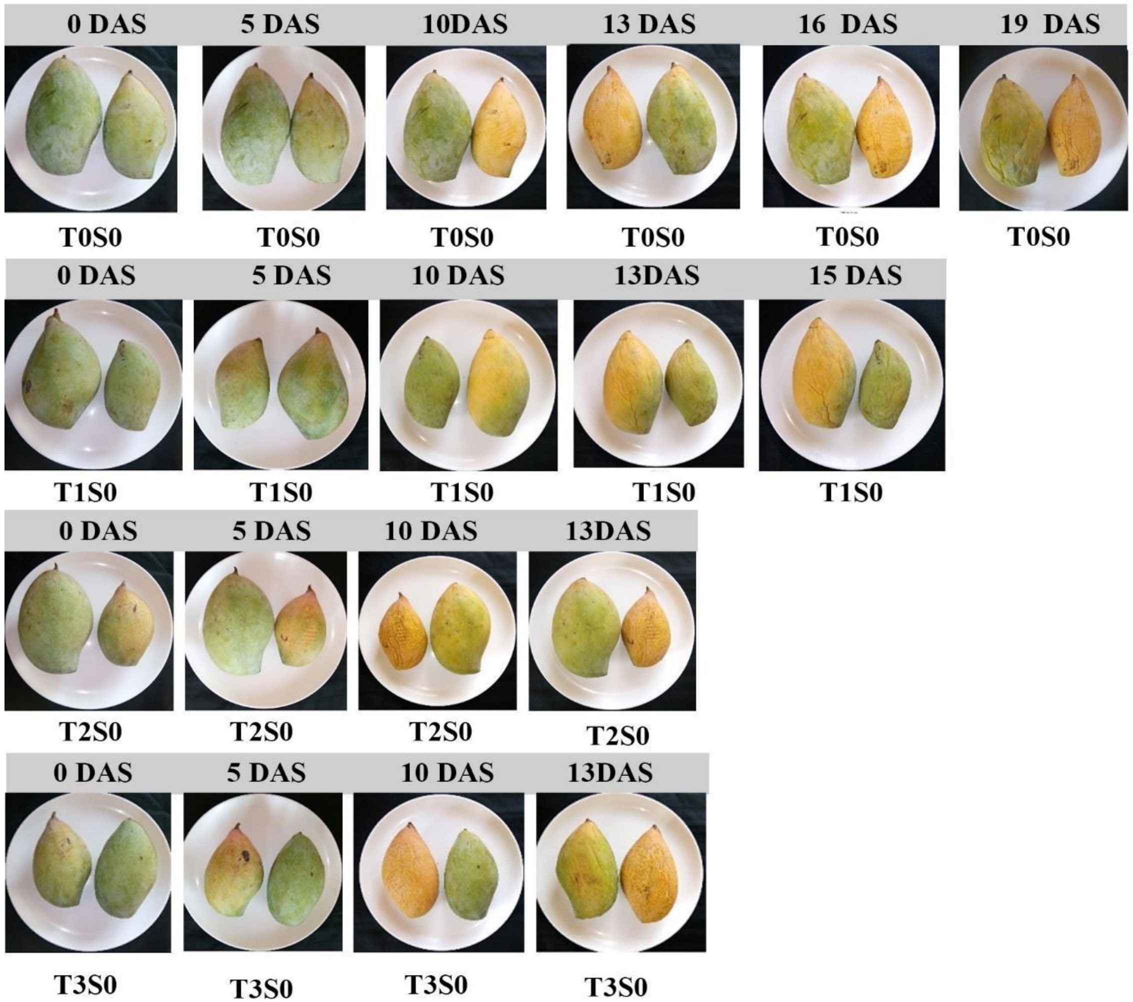

Plate 11a. Effect of postharvest treatments on colour change of Banglora under ambient storage

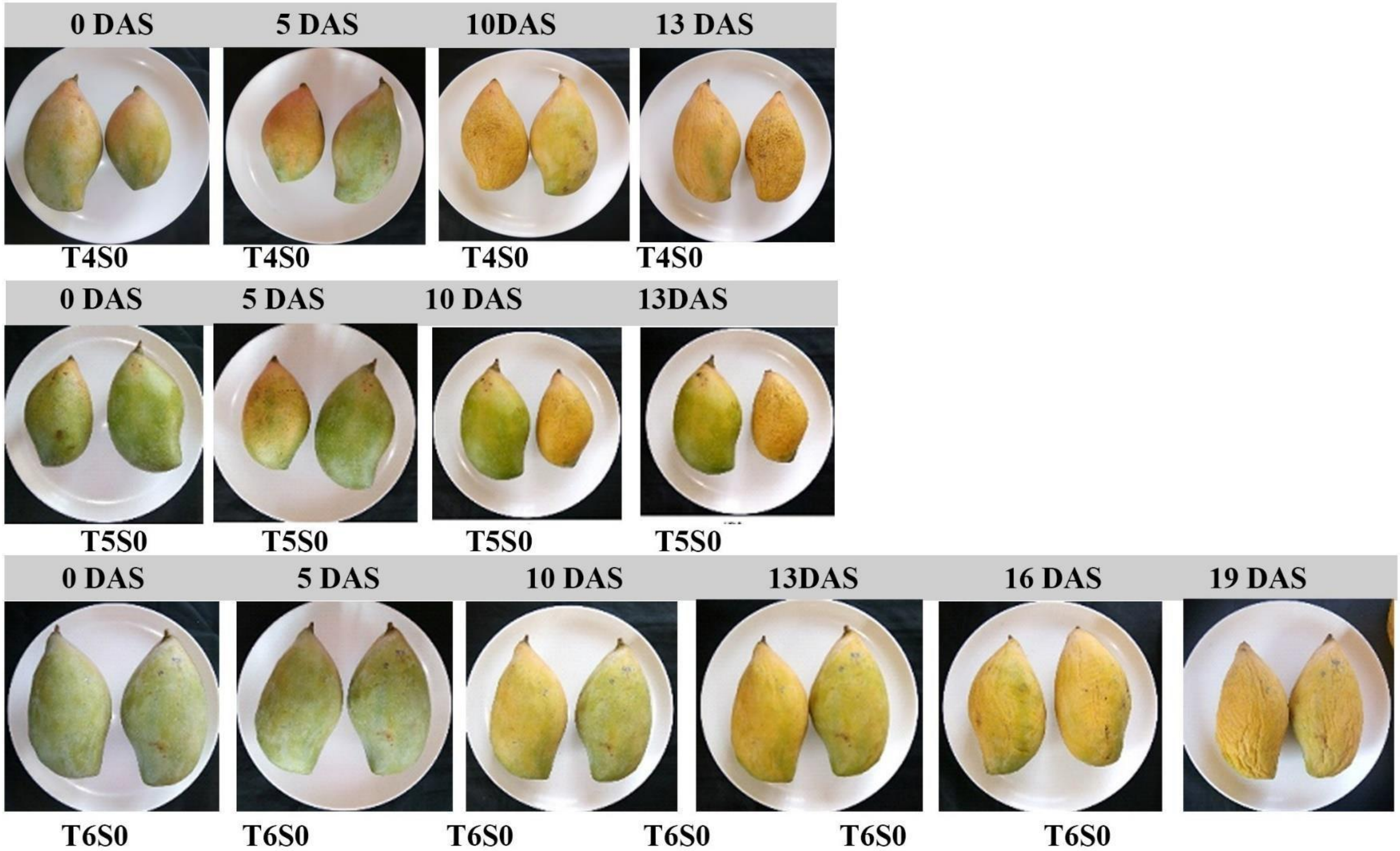

Plate 11b. Effect of postharvest treatments on colour change of Banglora under ambient storage

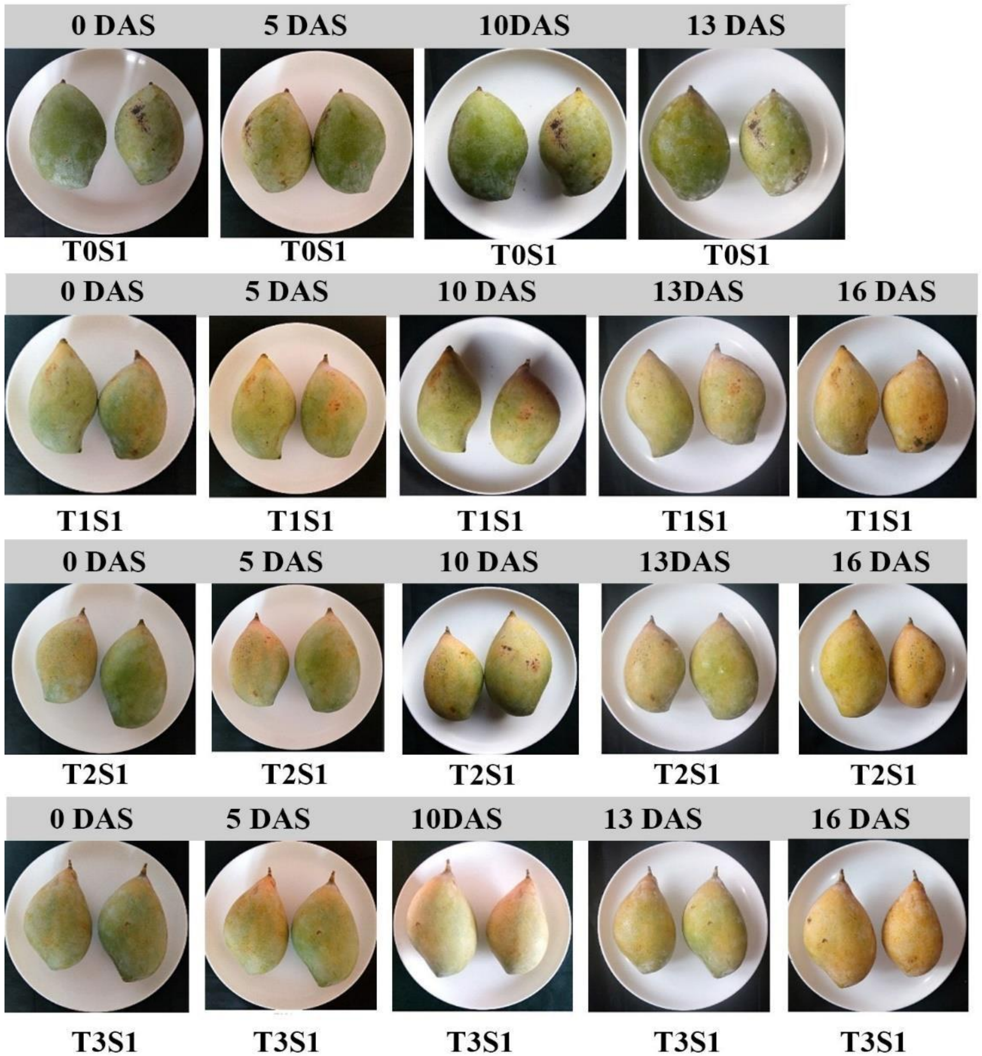

Plate 12a. Effect of postharvest treatments on colour change of Banglora under ambbient storage

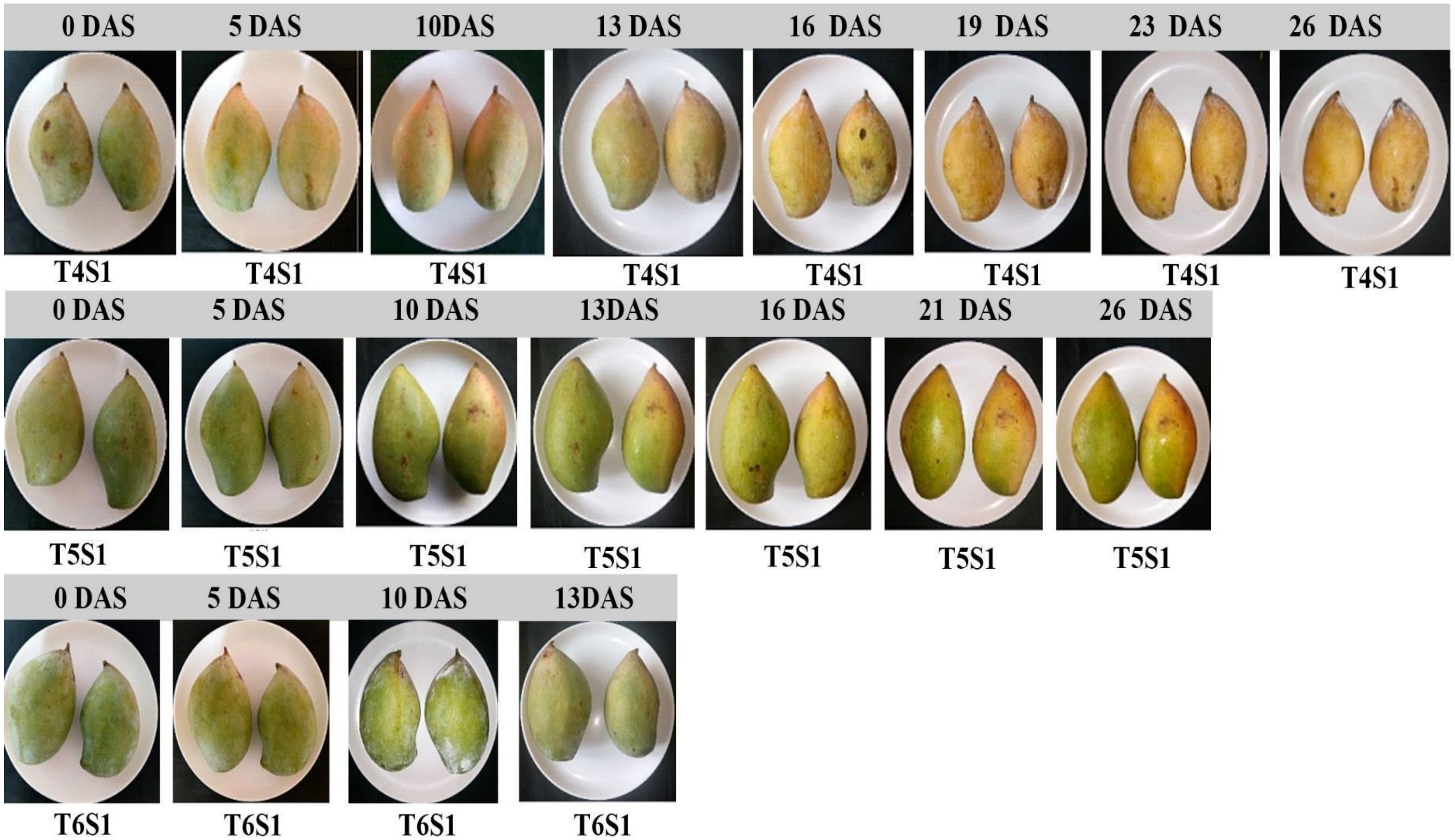

Plate 12b. Effect of postharves treatments on colour change of Banglora under cold storage

Table 5. Effect of post harvest treatments on firmness (N)

Treatments	Firmness (N)			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	0.250^{ab}	0.27^{ab}	0.263^{abc}	0.350^{ab}
T_0S_1	0.170^{de}	0.11^{de}	0.125^{e}	0.134^{de}
T_1S_0	0.210^{bcd}	0.34^{a}	0.205^{cd}	0.394^{a}
T_1S_1	0.110^{f}	0.10^{de}	0.215^{cd}	0.134^{de}
T_2S_0	0.230^{abc}	0.19^{bcd}	0.205^{cd}	0.250^{abcde}
T_2S_1	0.180^{de}	0.10^{de}	0.123^{e}	0.200^{cde}
T_3S_0	0.275^{a}	0.21^{bcd}	0.213^{cd}	0.280^{abc}
T_3S_1	0.160^{e}	0.07^{e}	0.133^{e}	0.225^{bcde}
T_4S_0	0.190^{cde}	0.17^{bcde}	0.169^{de}	0.352^{ab}
T_4S_1	0.110^{f}	0.15^{cde}	0.278^{ab}	0.106^{e}
T_5S_0	0.090^{f}	0.19^{bcd}	0.226^{bcd}	0.257^{abcd}
T_5S_1	0.090^{f}	0.10^{de}	0.137^{e}	0.320^{e}
T_6S_0	0.200^{cde}	0.26^{abc}	0.290^{a}	0.336^{abcd}
T_6S_1	0.160^{e}	0.14^{de}	0.144^{e}	0.380^{a}
C.D.	**0.048**	**0.114**	**0.059**	**0.146**
SE(d)	0.022	0.037	0.027	0.067

4.1.2 Biochemical parameters

General analysis of variance for biochemical parameters like acidity, ascorbic acid, TSS, sugars and total carotenoids are given below.

4.1.2.1 Acidity (%)

Acidity in fruits was ranged from 0.05% to 1.08%. In Alphonso, the lowest acidity (0.21 %) was observed both in wax coated and control fruits stored under cold storage (T_5S_1 and T_0S_1). In Bennet Alphonso the treatments did not show any significant difference in acidity. Whereas cold stored fruits of Banganapalli and Bangalora recorded the lowest acidity in $NaHCo_3$ treated (0.05 %) fruits and wax coated fruits (0.10%) respectively.

Table 6. Effect of postharvest treatments on acidity (%) of fruits

Treatments	**Acidity(%)**			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	0.42^{d}	0.18	0.18^{bcde}	0.33^{d}
T_0S_1	0.21^{i}	0.20	0.13^{cde}	0.54^{bc}
T_1S_0	0.27^{ghi}	0.28	0.37^{ab}	0.38^{cd}
T_1S_1	0.38^{de}	0.12	0.23^{abcde}	0.23^{de}
T_2S_0	0.36^{def}	0.15	0.26^{abcd}	0.37^{cd}
T_2S_1	0.26^{hi}	0.15	0.10^{cde}	1.18^{a}
T_3S_0	0.31^{fgh}	0.18	0.13^{cde}	0.23^{de}
T_3S_1	0.33^{efg}	0.17	0.08^{de}	0.67^{b}
T_4S_0	0.54^{c}	0.18	0.28^{abc}	0.37^{cd}
T_4S_1	0.23^{i}	0.28	0.13^{cde}	0.54^{bc}
T_5S_0	0.23^{i}	0.13	0.26^{abcd}	0.53^{bc}
T_5S_1	0.21^{i}	0.25	0.10^{cde}	0.10^{e}
T_6S_0	0.64^{b}	0.27	0.41^{a}	0.61^{b}
T_6S_1	0.85^{a}	0.17	0.05^{e}	0.28^{d}
C.D.	**0.067**	**NS**	**0.20**	**0.181**
SE(d)	0.031	0.06	0.09	0.083

4.1.2.2 Ascorbic acid (mg/100g)

The mango varieties varied in ascorbic acid content with the highest in Alphonso (57.14 mg/100g) followed by Bennet Alphonso (35.38 mg/100g). The treatments done after harvest also had significant effect on the ascorbic acid content. Alphonso fruits recorded the highest ascorbic acid (57.14 mg/100g) when the fruits were ozonized and kept in cold storage, but it reduced drastically and reached to a lowest level (18.00 mg/100g) when kept in ambient condition. The highest value in Bennet Alphonso, Banganapalli and Bangalora were 35.38 mg/100g (T_4S_0), 14.50 mg/100g (T_1S_0, T_6S_0) and 15.09 mg/100g (T_3S_0) respectively (Table 7).

4.1.2.3 Sugars (%)

Table 8, 9 and 10 shows the details regarding sugars. The total sugar of Alphonso, Banganapalli and Bangalora was found maximum in T_5S_1 (13.90 %), T_4S_1 (15.20 %) and T_0S_1 (14 %) respectively, but there is no significant difference in the total sugar content of Bennet Alphonso fruits with the treatments.

Except in the variety Bennet Alphonso, in other varieties the treatments had no significant difference in non-reducing sugar of fruits. In Bennet Alphonso the highest non reducing sugar (8.75 %) was observed in control fruits stored under ambient storage. Reducing sugar were highest in T_5S_1 (12.10 %), T_2S_0 (11.06 %), T_4S_1 (8.84 %) and T_0S_1 (8.17 %) in Alphonso, Bennet Alphonso, Banganapalli and Bangalora respectively.

4.1.2.4 Total Soluble Solids (^{0} brix)

The treatments showed significant difference on total soluble solids (TSS) at full ripening state of Alphonso, Bennet Alphonso and Banganapalli varieties of mango. The highest TSS (21.50^0 brix) was reported in Bennet Alphonso, when fruits were waxed and kept in cold storage (T_5S_1). Hot water treated fruits stored under ambient condition (T_1S_0) recorded the highest TSS (20.50^0 brix) in both Alphonso and Banganapalli. The treatments did not show any significant difference on TSS of Bangalora fruits. The lowest TSS observed were 11.50^0 brix (T_2S_0), 14.50^0 brix (T_2S_1, T_3S_0) and 9^0 brix (T_4S_0) in Alphonso, Bennet Alphonso, and Banganapalli respectively.

Table 7. Effect of postharvest treatments on ascorbic acid (mg/100g) of fruits

Treatments	Ascorbic acid (mg/100g)			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	27.69^{de}	15.00^{g}	6.15^{ef}	15.00^{a}
T_0S_1	42.85^{c}	23.32^{cd}	6.75^{de}	14.50^{ab}
T_1S_0	50.90^{b}	22.50^{d}	14.50^{a}	10.00^{d}
T_1S_1	41.41^{c}	18.33^{f}	11.78^{b}	7.45^{e}
T_2S_0	26.15^{ef}	30.00^{b}	8.00^{cd}	10.00^{d}
T_2S_1	42.70^{c}	15.50^{g}	5.50^{ef}	15.00^{a}
T_3S_0	29.99^{d}	31.00^{b}	8.58^{c}	15.09^{a}
T_3S_1	30.00^{d}	23.32^{cd}	6.65^{ef}	10.25^{d}
T_4S_0	18.00^{g}	35.38^{a}	5.75^{ef}	11.42^{c}
T_4S_1	57.14^{a}	20.04^{ef}	6.75^{de}	14.95^{a}
T_5S_0	24.28^{f}	30.50^{b}	5.40^{f}	14.10^{b}
T_5S_1	49.50^{b}	21.65^{de}	8.86^{c}	9.95^{d}
T_6S_0	29.00^{d}	25.00^{c}	14.50^{a}	11.30^{c}
T_6S_1	49.98^{b}	19.99^{ef}	11.78^{b}	14.50^{ab}
C.D.	**12.616**	**5.20**	**3.063**	**1.414**
SE(d)	5.88	2.40	1.414	1.414

Table 8. Effect of postharvest treatments on total sugar of fruits

Treatments	Total sugar (%)			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	9.33^{bcd}	9.21	7.00^{cd}	7.00^{b}
T_0S_1	11.38^{ab}	5.26	8.23^{cd}	14.00^{a}
T_1S_0	11.21^{abc}	10.14	8.53^{cd}	6.79^{b}
T_1S_1	12.96^{a}	12.28	11.62^{b}	7.77^{b}
T_2S_0	9.27^{bcd}	16.66	7.70^{cd}	7.77^{b}
T_2S_1	8.97^{bcd}	8.97	8.58^{cd}	9.09^{b}
T_3S_0	9.85^{bcd}	8.86	8.86^{bc}	6.86^{b}
T_3S_1	11.29^{abc}	12.60	9.09^{bc}	6.48^{b}
T_4S_0	8.80^{bcd}	8.13	7.86^{cd}	7.52^{b}
T_4S_1	11.20^{abc}	11.28	15.20^{a}	7.00^{b}
T_5S_0	8.04^{d}	9.72	5.80^{d}	8.14^{b}
T_5S_1	13.90^{a}	10.60	9.21^{bc}	7.86^{b}
T_6S_0	8.38^{cd}	12.72	6.80^{cd}	6.83^{b}
T_6S_1	9.58^{bcd}	13.46	8.58^{cd}	12.96^{a}
C.D.	**2.996**	**NS**	**3.063**	**7.00**
SE(d)	1.397	192.15	1.414	6.79

Table 9. Effect of postharvest treatments on reducing sugar of fruits

Treatments	Reducing sugar (%)			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	3.50	8.75^{a}	5.60	3.33
T_0S_1	2.05	2.66^{de}	4.11	5.83
T_1S_0	2.83	6.36^{abc}	4.24	4.38
T_1S_1	1.46	2.05^{e}	6.08	5.18
T_2S_0	5.16	5.60^{bcd}	5.80	6.66
T_2S_1	3.41	2.61^{de}	5.22	7.77
T_3S_0	3.24	6.36^{abc}	5.38	5.83
T_3S_1	3.18	3.18^{de}	5.18	5.95
T_4S_0	2.03	7.77^{ab}	5.00	5.19
T_4S_1	1.89	4.24^{cde}	6.36	4.74
T_5S_0	5.64	7.77^{ab}	5.60	4.51
T_5S_1	1.81	4.24^{cde}	4.66	4.82
T_6S_0	4.57	2.85^{de}	6.30	6.09
T_6S_1	4.74	3.68^{cde}	3.41	6.36
C.D.	**NS**	**3.06**	**NS**	**NS**
SE(d)	1.421	1.41	1.414	1.414

Table10. Effect of postharvest treatments on non reducing sugar of fruits

Treatments	Non reducing sugars (%)			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	4.73^{efg}	0.46^{l}	1.40^{l}	3.67^{c}
T_0S_1	9.33^{abc}	2.60^{i}	4.12^{f}	8.17^{a}
T_1S_0	6.36^{cdef}	3.78^{h}	4.29^{e}	2.4^{2g}
T_1S_1	11.50^{ab}	10.23^{b}	5.54^{b}	2.59^{f}
T_2S_0	4.07^{fg}	11.06^{a}	1.90^{k}	1.12^{k}
T_2S_1	5.56^{defg}	6.36^{g}	3.36^{h}	1.32^{j}
T_3S_0	8.41^{bcd}	2.50^{j}	3.06^{i}	1.03^{l}
T_3S_1	8.11^{bcde}	9.42^{e}	3.91^{g}	0.53^{n}
T_4S_0	7.18^{cdef}	0.36^{m}	2.86^{j}	2.34^{h}
T_4S_1	9.31^{abc}	7.05^{f}	8.84^{a}	2.26^{i}
T_5S_0	2.40^{g}	1.95^{k}	0.20^{n}	3.63^{d}
T_5S_1	12.10^{a}	6.36^{g}	4.55^{d}	3.04^{e}
T_6S_0	3.81^{fg}	9.87^{c}	0.50^{m}	0.74^{m}
T_6S_1	4.84^{defg}	9.78^{d}	5.17^{c}	6.60^{b}
C.D.	**3.621**	**0.031**	**0.031**	**0.031**
SE(d)	1.688	0.014	0.014	0.014

Table 11. Effect of postharvest treatments on TSS of fruits

Treatments	TSS (^{0} brix)			
	Alphonso	Bennet Alphonso	Banganapalli	Bangalora
T_0S_0	12.00^{d}	17.00^{bcdf}	16.50^{bc}	8.50
T_0S_1	20.00^{a}	16.50^{cdef}	11.90^{fgh}	14.00
T_1S_0	13.50^{bcd}	15.00^{ef}	20.50^{a}	9.50
T_1S_1	16.00^{bc}	17.00^{bcdef}	15.00^{cde}	12.00
T_2S_0	11.50^{d}	15.50^{def}	16.00^{bcd}	12.00
T_2S_1	16.00^{bc}	14.50^{f}	13.80^{cdefg}	13.00
T_3S_0	12.50^{cd}	14.50^{f}	12.00^{efgh}	13.50
T_3S_1	17.00^{ab}	18.50^{abcd}	13.00^{defg}	12.50
T_4S_0	13.00^{cd}	20.00^{ab}	9.00^{h}	12.00
T_4S_1	16.00^{bc}	19.00^{abc}	18.20^{ab}	12.00
T_5S_0	15.00^{bcd}	15.50^{def}	14.50^{cdef}	11.50
T_5S_1	17.00^{ab}	21.50^{cdef}	12.80^{efg}	11.00
T_6S_0	13.00^{cd}	17.25^{bcdef}	16.75^{bc}	10.00
T_6S_1	15.00^{bcd}	18.00^{bcde}	11.00^{gh}	12.00
C.D.	**3.759**	**3.177**	**3.12**	**NS**
SE(d)	1.753	1.467	1.020	1.637

4.1.2.5 Total carotenoids (mg/100g)

The total carotenoids in fruits was ranged from 0.77 mg/100g to 15.40 mg/100g among the four mango varieties. In Alphonso, the highest total carotenoids (15.40 mg/1100g) was reported in control fruits stored under both ambient and cold storage (T_0S_0 and T_0S_1). Hot water treated fruits recorded the highest total carotenoids both in Bennet Alphonso stored under cold storage (7.36 mg/100g) and Banganapalli stored in ambient storage (3.25 mg/1100g). Wax coated fruits stored under ambient condition (T_5S_0) recorded the highest (2.85mg/100g) in Bangalora.

Table 12. Effect of postharvest treatments on total carotenoids (mg/100g) of fruits

Treatments	Total carotenoids (mg/100g)			
	Alphonso	**Bennet Alphonso**	**Banganapalli**	**Bangalora**
T_0S_0	15.40^{a}	7.20^{b}	1.72^{e}	1.85^{cd}
T_0S_1	15.40^{a}	4.93^{g}	0.90^{k}	1.65^{ef}
T_1S_0	9.86^{abc}	2.35^{l}	1.28^{g}	1.95^{c}
T_1S_1	9.86^{abc}	4.04^{h}	0.81^{l}	1.45^{g}
T_2S_0	12.95^{ab}	3.23^{j}	3.25^{a}	0.77^{i}
T_2S_1	12.95^{ab}	7.35^{a}	1.02^{i}	1.15^{h}
T_3S_0	13.60^{ab}	1.78^{m}	2.66^{c}	2.35^{b}
T_3S_1	13.60^{ab}	6.00^{d}	1.08^{h}	2.22^{b}
T_4S_0	4.60^{c}	5.39^{f}	2.45^{d}	1.80^{d}
T_4S_1	4.60^{c}	5.42^{f}	1.72^{e}	1.45^{g}
T_5S_0	7.80^{bc}	3.47^{i}	3.03^{b}	2.85^{a}
T_5S_1	7.80^{bc}	5.78^{e}	0.95^{j}	1.45^{g}
T_6S_0	9.24^{abc}	2.56^{k}	1.34^{f}	1.75^{de}
T_6S_1	9.24^{abc}	6.58^{c}	1.02^{j}	1.55^{fg}
C.D.	**9.207**	**17.76**	**2.99**	**3.063**
SE(d)	4.292	8.20	1.38	1.414

4.1.3 Pesticide residue studies before and after treatment

Pesticide residue analysis were done in Alphonso variety of mango, treated with different post harvest treatments. The insecticides, Dimethoate, Malathion and Methyl parathion were detected and they were below the limit of quantification (LOQ). Only the residues of Chlorpyriphos was reported above LOQ in control fruits. Applying various treatments to mangoes resulted a decrease in the pesticide residues below LOQ.

Table 13 depicts the details regarding pesticide residue in mango fruits.

T0: Absolute control

T1: Hot water dip (50±20C)

T2: Hydro cooling

T3: Sanitization with sodium hypochlorite solution (100 ppm)

T4: Ozonisation (2ppm O3)

T5: Waxing (Nipro-Fresh 1%)

T6: Sodium bicarbonate treatment (1%)

Table 13. Effect of postharvest treatments on pesticide residue in Alphonso fruits

PESTICIDE RESIDUE (ppm)								MRL (ppm)
Treatment/ Pesticide	**T0**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	
Dimethoate	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	**0.2**
Methyl parathion	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	**-***
Malathion	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	**0.4**
Chlorpyriphos	0.1032	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	below LOQ	**0.05**
Profenophos	-	-	-	-	-	-	-	
4-4 DDE	-	-	-		-	-	-	
4-4 DDT	-	-	-	-	-	-	-	-
Ethion	-	-	-	-	-	-	-	-
DDT 2	-	-	-	-	-	-	-	-
Bifenthrin	-	-	-	-	-	-	-	-
Phosalone	-	-	-	-	-	-	-	-
Cyhalothrin	-	-	-	-	-	-	-	-
Fenvalerate 1	-	-	-	-	-	-	-	-
Fenvalerate 2	-	-	-	-	-	-	-	-
Deltamethrin	-	-	-	-	-	-	-	-

LOQ - Limit of quantification

*MRL not fixed

4.1.4 Post harvest pathogens

Fruits of Alphonso, Bennet Alphonso, Banganapalli and Bangalora affected with post harvest diseases such as anthracnose, stem end rot, soft rot and bacterial rot in all the treatments.

The pathogenic fungi which were isolated from the rotted fruits of mango were *Colletotrichum gloeosporioides, Diplodia natalensis* and *Aspergillus sp*. These causal organisms were identified based on their morphology and symptoms of diseases on fruits at Department of Plant Pathology, College of Horticulture, Vellanikkara. The post harvest diseases and their causal organisms were recorded in Table 14.

Table 14. Post harvest disease and causal organisms

Post harvest diseases	Causal organisms
Anthracnose	*Colletotrichum gloeosporioides*
Stem end rot	*Diplodia natalensis*
Soft rot	*Aspergillus sp*
Bacterial rot	-

Soft rot

T0S0 | T6S0 | T5S0 | *Aspergillus sp*

Bacterial rot

T6S0 | T0S0 | T2S0 | T1S0

Plate 13a. Post harvest diseases

Stem end rot

T0S0 T4S0 T2S0 T5S0 T5S0 T1S0 *Diplodia natalensis*

Anthracnose

T3S0 T2S0 T1S0 T2S0 T1S0 T3S0

Plate 13b. Post harvest diseases

4.2 STANDARDIZATION OF RIPENING TECHNIQUES

Bennet Alphonso variety of mango was selected for the standardization of ripening techniques at their full mature stage. The fruits were subjected to ripening treatments and kept for storage under ambient condition. The results obtained for both physical and biochemical observations are recorded here.

The fruits sprayed with 200 ppm ethrel (T_5) reported earlier ripening (4 days) followed by hot water treated fruits (5 days). The ripening time of control fruits was 8 days after storage.

4.2.1 Physical parameters

4.2.1.1 Physiological loss in weight (%).

Physiological loss in weight (PLW) of fruits observed higher (16.41 %) in hot water treatment (T_1) followed by control (16.21%) after nine days of storage. The lowest PLW (5.38 % and 8.38 %) was recorded in fruits kept along with Apple (T_6) during five and nine days after storage respectively (Table 15).

4.2.1.2 Shelf life (days)

Although the treatments did not show any significant difference on shelf life of fruits, maximum shelf life (18 days) was obtained in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits (T_7) followed by hot water treated (T_1) fruits and fruits kept along with bilimbi leaves (17.33 days). The shelf life was recorded minimum (10.67 days) in ethrel (100ppm) sprayed (T4) fruits.

4.2.1.3 Change in colour (IPGR descriptor)

The colour change of fruits during storage was reported faster in hot water (T_1) treated and Ethrel (200ppm) sprayed fruits (T_5). The fruits completely turned to bright yellow colour within five days after treatment (Table 16).

4.2.1.4 Firmness (N)

The lowest firmness (0.08 N) was reported in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits (T_7) followed by (0.20 N) in ethrel (200ppm) sprayed (T_5) after 18 and 15.33 days after storage. The hot water treated (T_1) fruits showed the highest firmness (0.49 N). Table 15 depicts firmness of fruits.

T0: Absolute control

T1: Hot water dip (50 ± 2 ^{0}C for one minute)

T2: Ethrel dip (100 ppm)

T3: Ethrel spray 100ppm

T4: Ethrel dip (200ppm)

T5: Ethrel spray (200ppm)

T6: Placing ripened apple fruit along with mature unripe mango in a closed container (1:20)

T7: Ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs)

T8: Keep fruits along with leaves of Bilimbi *(Averrhoa bilimbi)*

Table 15. Effect of ripening treatments on PLW, shelf life and firmness of mango fruits

Treatments	**PLW (%)**				**Shelf life (Days)**	**Firmness (N)**
	5DAS	**9DAS**	**13DAS**	**16DAS**		
T_0	3.15(8.95)^{a}	4.15(16.21)^{a}	23.49	-	15.33	0.29^{b}
T_1	3.13(8.80)^{a}	4.17(16.41)^{a}	24.44	29.09	17.33	0.49^{a}
T_2	2.86(7.19)^{ab}	4.01(15.13)^{ab}	-	-	15.33	0.21^{b}
T_3	3.03(8.23)^{ab}	4.00(14.97)^{ab}	-	-	10.67	0.25^{b}
T_4	2.78(6.76)^{bc}	3.68(12.58)^{b}	19.01	-	14.00	0.22^{b}
T_5	2.89(7.38)^{ab}	3.83(13.74)^{ab}	21.33	-	15.33	0.20^{bc}
T_6	2.52(5.38)^{c}	3.06(8.38)^{c}	14.39	-	14.00	0.26^{b}
T_7	2.98(7.96)^{ab}	3.80(13.59)^{ab}	16.31	19.55	18.00	0.08^{c}
T_8	2.86(7.20)^{ab}	3.85(13.82)^{ab}	20.14	23.24	17.33	0.23^{b}
C.D.	**0.317**	**0.403**	**-**	**-**	**NS**	**0.121**
SE(m)	1.953	0.134	-	-	2.076	0.04
SE(d)	2.762	0.19	-	-	2.936	0.057

Table 16. Change in colour of Bennet Alphonso fruits during storage (IPGR descri ptor)

Treatments	0 DAS	5 DAS	9 DAS	13 DAS	16 DAS
T_0	G	GY	Y	Y	Y
T_1	G	GY	Y	Y	Y
T_2	G	G	GY	Y	Y
T_3	G	GY	Y	-	-
T_4	G	GY	Y	Y	-
T_5	G	GY	Y	Y	-
T_6	G	GY	Y	Y	
T_7	G	G	G	GY	Y
T_8	G	GY	Y	Y	Y

G-Green, GY- Greenish Yellow, Y-Yellow

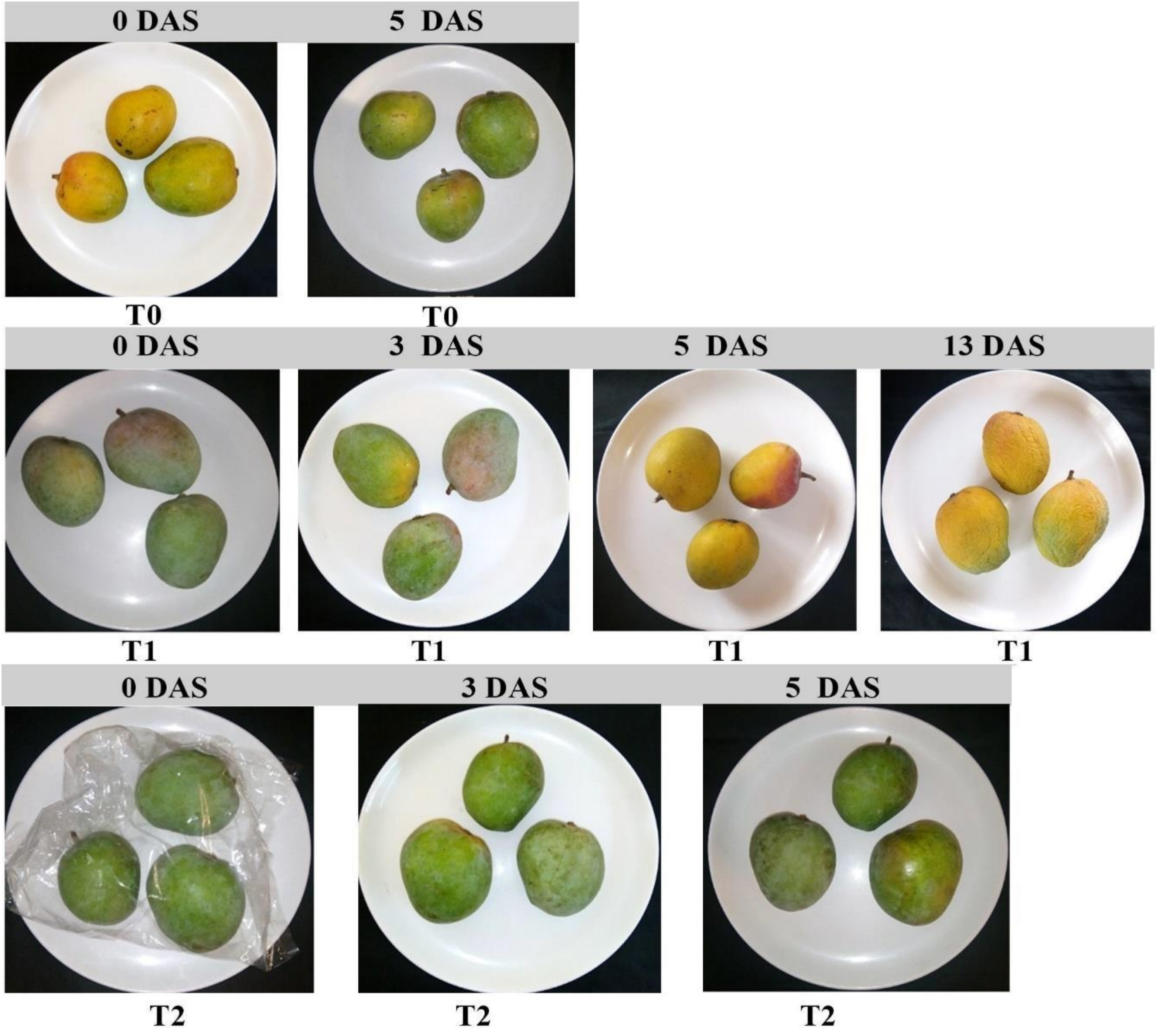

Plate 14a. Effect of ripening treatments on colour change of Bennet Alphonso during storage

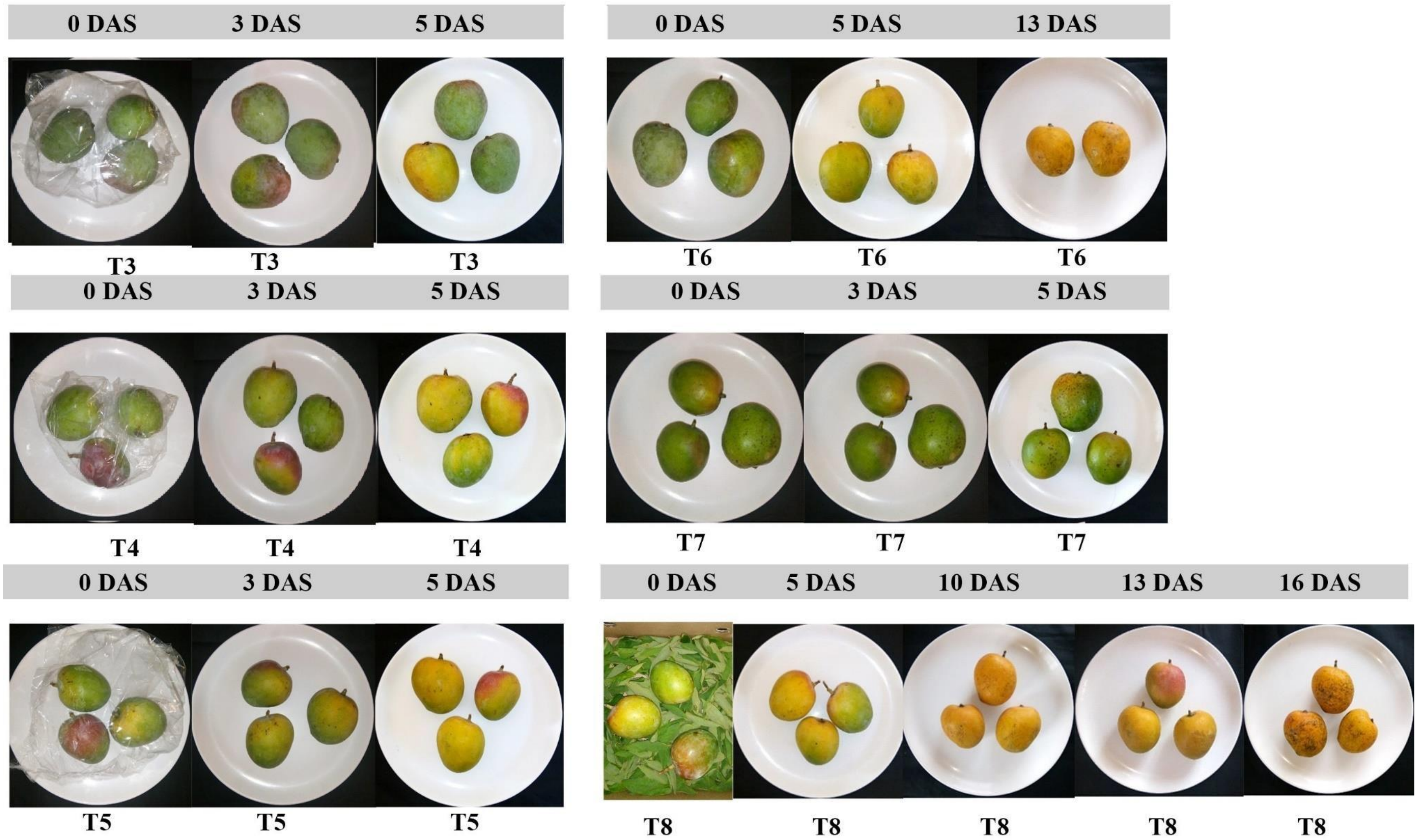

Plate 14b. Effect of ripening treatments on colour change of Bennet Alphonso during storage

4.2.2 Biochemical parameters

Biochemical parameters like acidity, ascorbic acid, sugars, TSS and total carotenoids were assessed in Bennet Alphonso fruits at their full ripe stage. All the biochemical parameters showed significant variation between treatments (Table 17).

4.2.2.1 Acidity (%)

The lowest acidity (0.15 %) was recorded in mango fruits kept along with bilimbi leaves (T_8) followed by ethrel (100ppm) spray (0.16%) and ethrel (100ppm) dip (0.21%).

4.2.2.2 Ascorbic acid (mg/100g)

Ascorbic acid content was ranged from 1.80 mg/100g to 22.50 mg/100g. The highest ascorbic acid (22.50 mg/100g) was observed in mangoes treated with hot water (T_1) followed by ethrel (100ppm) dipped (20.68 mg/100g) fruits. The lowest was reported in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits (1.80 mg/100g).

4.2.2.3 Sugars (%)

The maximum total sugar (12.96 %) was observed in mango fruits kept along with bilimbi leaves (T_8) followed by control (12.60%) and ethrel (200ppm) sprayed (12.56%) fruits. The lowest is reported in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits (6.14 %). The highest reducing sugar of 11.40 per cent were reported in both ethrel (200ppm) dipped (T_4) and fruits kept along with bilimbi leaves. Non reducing sugars reported maximum (7.12 %) in hot water treated (T_1) followed by ethrel (200ppm) sprayed (T_5) fruits (6.19%).

4.2.2.4 Total Soluble Solids (^{0} brix)

The highest TSS (20^0 brix) was observed in both control (T_0) and ethrel (5 ml 4% Ethephone/m^3+ 3 g NaOH for 24 hrs) treated (T_7) fruits followed by (19.50^0 brix) 200 ppm ethrel dipped fruits (T_4).

4.2.2.5 Total carotenoids (mg/100g)

Total carotenoids were maximum (33.98mg/100g) in in mangoes treated with hot water (T_1) followed by (27.90 mg/100g) fruits kept along with bilimbi leaves (T_8). The lowest total carotenoids were recorded in T_7 (6.90 mg/100g).

5.2.3 Sensory evaluation

The total score was highest in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated (56.75) followed by ethrel (200ppm) sprayed fruits (54.53). The lowest total score was recorded in hot water treated fruits (48.03).

Ethrel (200ppm) sprayed fruits and fruits kept along with apple were recorded the highest score in appearance whereas hot water treated fruits showed maximum score in both taste and after taste. The treatment, ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) was the one which scored the highest score in half of the total attributes evaluated (colour, texture, flavour and odour). The overall acceptability was highest in fruits treated with ethrel (200ppm spray).

Table 17. Effect of ripening treatments on biochemical parameters of fruit

Treatments	Acidity (%)	Ascorbic acid(mg/100g)	Sugars (%)			TSS (^{0} brix)	Total Carotenoids (mg/100g)
			Reducing	Non reducing	Total		
T0	0.78^{b}	14.77^{e}	8.26^{b}	4.34^{bc}	12.60^{b}	20.00^{a}	11.47^{c}
T1	0.37^{cd}	22.50^{a}	4.07^{de}	7.12^{a}	11.19^{e}	15.00^{d}	33.98^{a}
T2	0.21^{d}	20.68^{b}	3.03^{e}	3.77^{cd}	6.79^{h}	14.50^{d}	31.03^{a}
T3	0.16^{d}	10.00^{g}	3.07^{e}	5.32^{abc}	8.39^{f}	15.50^{cd}	23.48^{ab}
T4	0.35^{cd}	8.18^{h}	11.20^{a}	0.76^{e}	11.96^{d}	19.50^{ab}	10.64^{c}
T5	0.64^{bc}	12.86^{f}	6.37^{bc}	6.19^{ab}	12.56^{c}	18.17^{ab}	16.10^{bc}
T6	0.43^{cd}	16.34^{d}	3.67^{de}	4.26^{bc}	7.93^{g}	17.75^{abc}	11.90^{bc}
T7	1.45^{a}	1.80^{i}	5.38^{cd}	0.76^{e}	6.14^{i}	20.00^{a}	6.90^{c}
T8	0.15^{d}	17.50^{c}	11.20^{a}	1.76^{de}	12.96^{a}	17.50^{bc}	27.90^{a}
C.D.	**0.323**	**0.018**	**2.238**	**2.051**	**0.017**	**2.421**	**11.745**
SE(d)	0.153	0.008	1.057	0.969	0.008	1.143	5.547

Table 18. Effect of ripening treatments on sensory qualities of fruit

Treatment	Appearance	Colour	Texture	Flavour	Taste	After taste	Odour	Overall acceptability	Mean score	Total score
T0	6.06 (5.10)	7.00 (3.29)	6.67 (5.05)	6.29 (3.43)	6.00 (3.45)	6.00 (3.69)	6.80 (4.36)	6.60 (3.90)	6.43	51.42
T1	5.86 (3.67)	7.83 (2.69)	5.29 (4.33)	5.74 (3.71)	5.86 (3.33)	5.67 (3.19)	5.23 (3.14)	6.55 (3.29)	6.00	48.03
T2	5.97 (6.21)	7.00 (6.95)	6.67 (6.30)	6.29 (7.5)	7.29 (7.64)	7.17 (7.5)	6.40 (6.62)	6.80 (7.43)	6.70	53.59
T3	5.53 (4.31)	7.63 (4.90)	6.33 (5.23)	6.56 (5.52)	6.62 (5.5)	5.63 (5.33)	6.12 (5.57)	5.07 (5.52)	6.19	49.49
T4	9.84 (4.86)	7.20 (4.45)	6.61 (4.33)	6.00 (4.19)	6.14 (4.12)	5.50 (3.83)	6.44 (4.24)	6.80 (3.69)	6.82	54.53
T5	4.80 (6.21)	8.00 (7.76)	6.17 (6.65)	5.86 (7.29)	5.86 (7.38)	6.67 (7.00)	5.80 (6.79)	7.20 (7.40)	6.30	50.36
T6	9.84 (5.07)	6.40 (5.55)	5.64 (4.33)	6.00 (5.14)	6.43 (5.48)	6.67 (5.71)	5.58 (5.21)	6.60 (5.29)	6.65	53.16
T7	6.14 (6.02)	8.40 (5.38)	7.67 (5.5)	7.00 (4.9)	6.71 (4.95)	6.83 (5.43)	7.40 (5.45)	6.60 (5.29)	7.09	56.75
T8	9.07 (3.55)	6.90 (4.02)	6.24 (3.30)	6.29 (3.31)	5.57 (3.14)	6.50 (3.31)	4.97 (3.62)	6.80 (3.19)	6.54	52.34
K	0.16	0.40	0.17	0.35	0.41	0.37	0.25	0.39		

T0

T1

T2

T3

T4

T5

T6

T7

T8

Plate 15. Sensory evaluation of mango fruits

DISCUSSION

5. **DISCUSSION**

5.1 STANDARDIZATION OF POST HARVEST TREATMENTS FOR IMPORTANT MANGO VARIETIES IN MUTHALAMADA AREA

5.1.1 Physical parameters

5.1.1.1 Physiological loss in weight (PLW)

After harvest every fresh commodity loses its weight with respect to time and environmental parameters where it is kept for storage. The loss in weight is mainly due to water loss, which lead to shrinkage and finally it affects the market quality of fruits. The loss of weight in fresh mango fruits during storage is possibly due to the physiological activities like respiration, transpiration and other biochemical changes (Thinh *et al*., 2013). In the present study, PLW showed significant variation, when different post harvest treatments were given (Fig.1). The mango fruits stored under ambient condition, showed significantly greater weight loss throughout the ripening period as compared to fruits stored in cold storage (13^0 C). Similar trend was also observed by (Gill *et al*., 2017) in Dasheri fruits which showed an increased physiological loss in weight with the advancement of ripening and the maximum weight loss recorded at the end of ripening period.

The PLW of fruits was significantly influenced by mode of storage irrespective of post harvest treatments in all four mango varieties. The fruits stored under cold storage showed the lowest PLW without any significant difference with the post harvest treatments given after harvest. The experiment also revealed that, the fruits with wax coating showed the lowest PLW in all four mango varieties, stored under ambient condition. In cold storage also, wax coated fruits of Alponso and Bangalora varieties showed the same trend in PLW, whereas sodium hypochlorite treated Bennet Alphonso and hydro cooled Banganapalli fruits recorded the lowest PLW after a storage life of ten days. This may be due to the low moisture loss from fruits. As reported by Hoa *et al*. (2002) the wax coating act as a barrier for moisture and gases like oxygen, carbon dioxide and ethylene, there by reduces respiration, transpiration and other metabolic activities. Similar results have also been reported in Ataulfo mango by Figueroa *et al.* (2011).

5.1.1.2 Shelf life

Fruits having a longer shelf life is always preferred by farmers and traders as it promises good quality during storage and transportation to distant markets. Being a perishable commodity, the extension in storage life of fruits including mango is an area of research interest.

In the present study, the post harvest treatments did not show any significant difference on the shelf life of fruits. In Alphonso the wax coated fruits showed maximum shelf life of 23 and 22 days under cold and ambient storage respectively. The ozone treated fruits of Alphonso, under cold storage also reported shelf life of 22 days (Fig. 2).

Fruits of Bangalora also reported the maximum shelf life of 26 days when coated with wax followed by ozone treatment (25 days) under cold storage. Coating with wax and storing under cold storage had some effect in improving shelf life. The extended shelf life in waxed fruits might be due to the delayed onset of the climacteric peak, possibly by changing the internal concentration of gases like oxygen, carbon dioxide and ethylene (Worrell *et al*., 2002). Jayantilal (2017) also had reported a shelf life of 18 days in Amrapali fruits coated with aloe vera gel (6 %). Delayed ripening in ozonised fruits may be due to the oxidization of evolved ethylene by ozone (Li *et al*. 1989; Skoog and Chu., 2001).

In Bennet Alphonso, the highest shelf life was observed in fruits kept under cold storage without any treatment (32 days) followed by sodium hypochlorite treatment (28 days) and wax coating (24 days).

Banganapalli variety of mango recorded maximum shelf life when sodium hypochlorite treated fruits were stored under cold storage (29 days) and ambient storage condition (27 days).

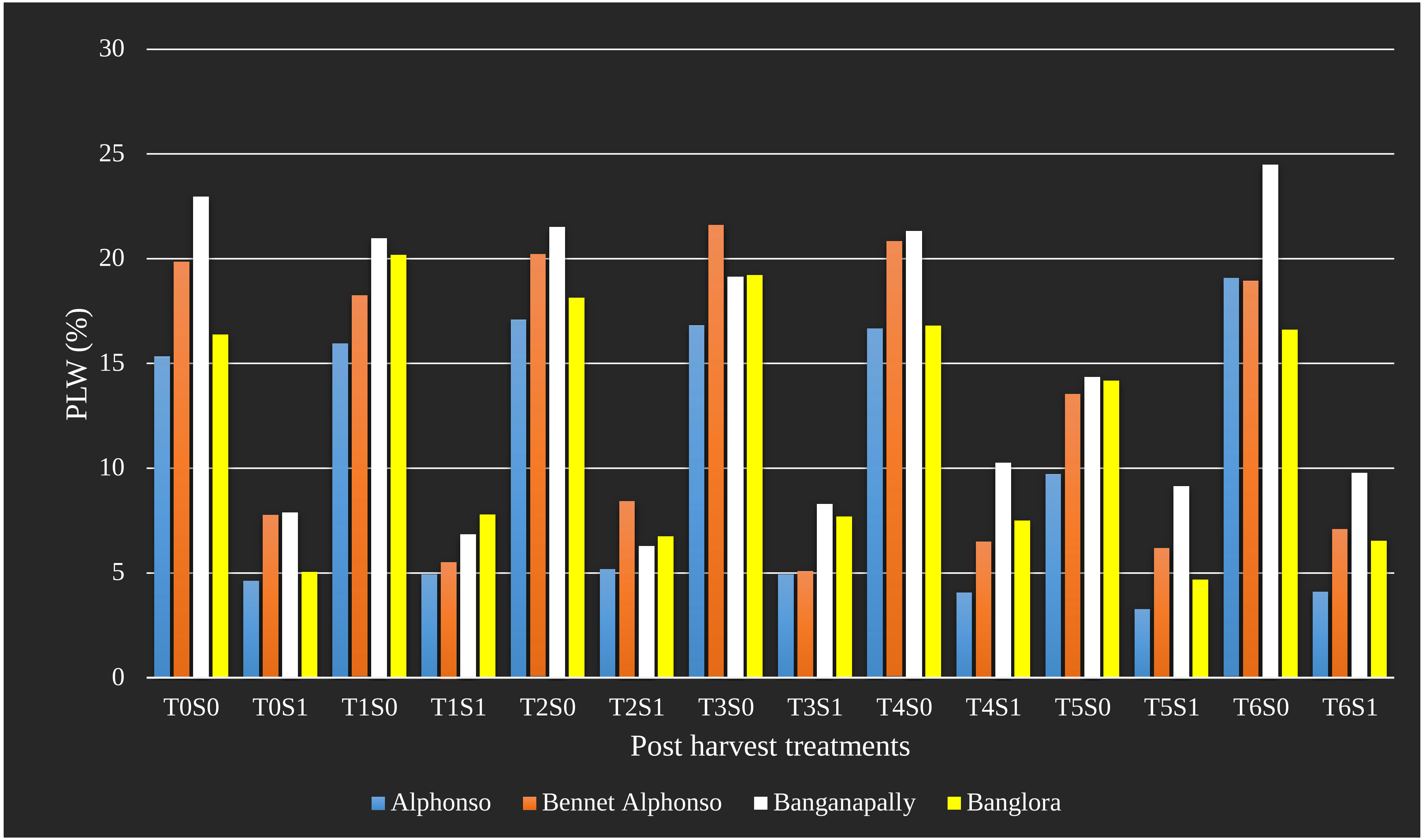

Figure 1. Effect of post harvest treatments on PLW of fruits

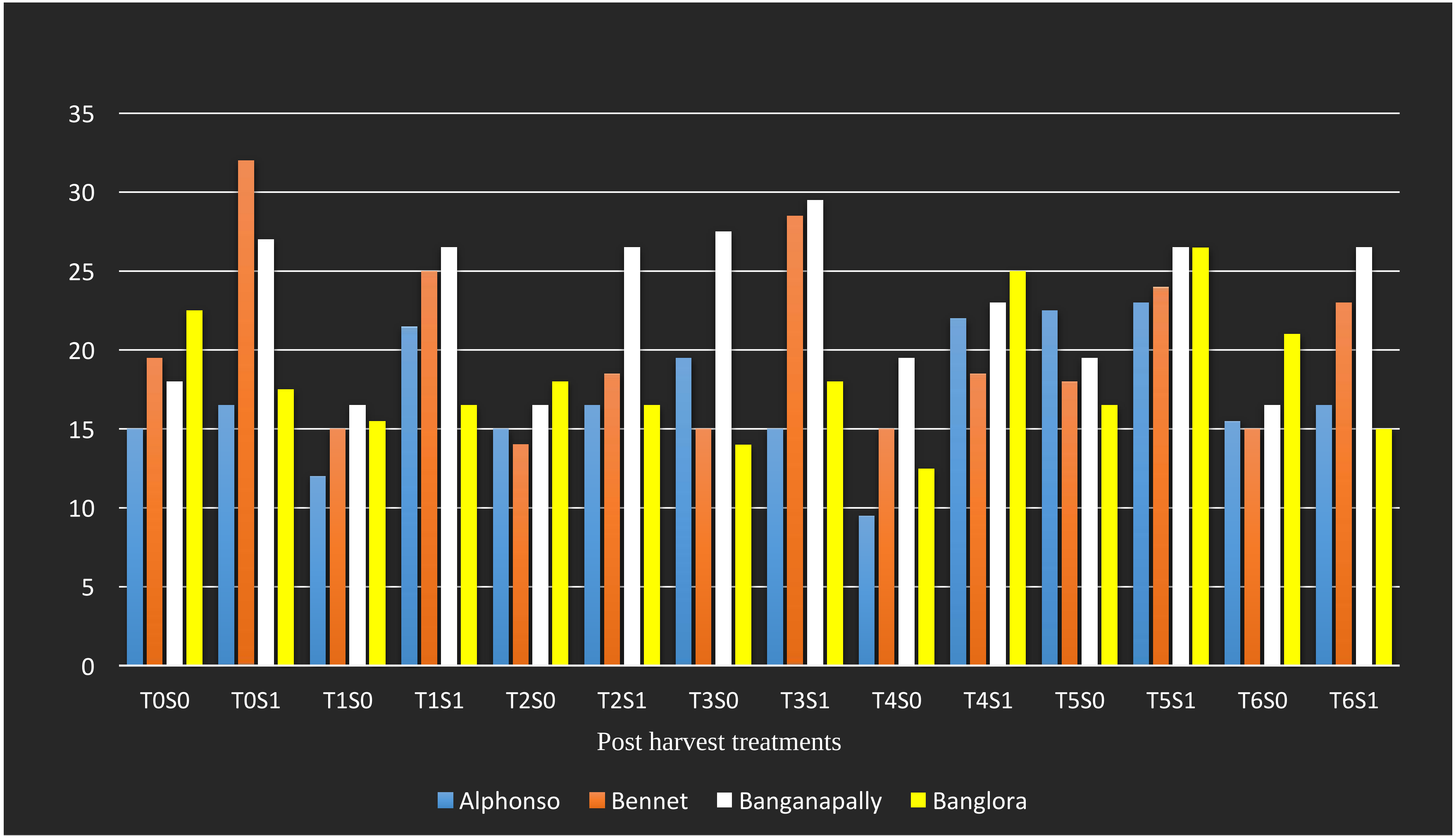

Figure 2. Effect of post harvest treatments on shelf life of fruits

5.1.1.3 Change in colour

Peel and fruit pulp colour are among the most important visual attributes affecting overall quality perception of fruits by consumers (Cissé *et al*., 2015). Mango peel changes the colour during ripening from green to yellow colour with respect to varieties.

Mango fruits stored under ambient condition changed colour from green to yellow as faster than fruits stored under cold storage. Alphonso fruits started colour change after five days of storage and completely changed into yellow within ten days at ambient condition whereas at cold storage condition it had taken about 16 days. The delay in colour change was highest in wax coated mangoes stored in cold storage. Similar trend was observed in case of Bennet Alphonso, Banganapalli and Bangalora fruits which completely turned in to yellow colour after 16, 21 and 26 days of storage respectively. In the fruits of Bennet Alphonso, there was a pink-red coloured blush development along with ripening.

These colour changes in mango are mostly credited to chlorophyll degradation and carotenoids synthesis (Tadmor *et al*., 2010). Wax coatings have been reported to maintain the gloss, flavour and aroma of fruits (Olivas and Barbosa-Canovas, 2005), which might be because of the reduced shrivelling, wilting, and respiration rate of fruits (El-Anany *et al*., 2009). Since consumers buy fruits using sight for sensorial evaluation, fruits that displays a better visual quality will be perceived by a consumer superior over the others.

5.1.1.4 Firmness

Firmness is one of the important indicators widely used to describe the quality of mango fruits, because it reflects the ripening state of the fruit (Jha *et al*., 2011). In general, the firmness decreases as fruits become more mature and decreases rapidly as they ripe. Each cultivar has specific firmness which is related to its sensory attributes (Jarimopas and Kitthawee, 2007). The softening of fruit pulp occur with progression of ripening period regardless of ripening temperatures (Gill *et al*., 2017). The softening or decrease in firmness is due to enzymatic degradation of cell walls (Johnston *et al*., 2002), by an increase in activity of poly galacturonase and cellulase during ripening (Zoghbi, 1994).

In this study, the treatments showed significant difference on firmness of fruits in all four mango varieties. Among the varieties studied, highest firmness exhibited by Bangalora (0.394 N) when, the fruits were dipped in hot water at (50±2^{0}C) for one minute. When the varieties are considered individually, Alphonso fruits treated with sodium hypochlorite solution (100ppm) showed the highest firmness (0.275 N) after 19 days of storage under ambient condition. In Bennet Alphonso, hot water dipped fruits stored under ambient condition showed the highest firmness (0.34 N) at 15th day of storage life.

Application of coatings help in retardation of firmness as observed in the fruits which were treated. Sethy and Kumar (2018) explained that, it can be due to the retarded degradation of insoluble protopectin to more soluble pectic acid during storage. According to Martinez-Romero *et al*. (2006), coating of aloe vera gel on fruits of sweet cherry resulted reduction in firmness loss during cold storage.

Fruits of Banaganapalli recorded highest firmness (0.290 N) in $NaHCO_3$ treated fruits kept under ambient condition followed by ozone treated fruits (0.278) kept under cold storage. Bangalora had a highest firmness of 0.394 N in hot water treated fruits kept under ambient storage (after 15 days) followed by $NaHCO_3$ treated, cold stored fruits (0.380 N) after 15 days storage.

5.1.2. Biochemical parameters

Biochemical parameters like acidity, ascorbic acid, sugars, total soluble solids (TSS) and total carotenoids were assessed in fruits at their full ripe stage. All the biochemical parameters showed significant variation between treatments.

5.1.2.1 Acidity

In fruits when stored, showed a decreasing trend in acidity for all the post harvest treatments, which is a positive aspect with regard to the fruit quality .The decrease in acidity was attributed towards the conversion of citric acid into sugars, which was further utilized by fruit in its metabolic process (Lee *et al*., 2010; Baloch and Bibi, 2012; Ellong *et al*., 2015).

Alphonso fruits coated with wax and kept under cold storage recorded lowest (0.21%) acidity after a storage life of 23 days. When the wax coated fruits were kept in ambient condition, the same lowest acidity was recorded in 22nd day of storage. According to Garg *et al*. (2009), this slower loss in acidity in coated fruits might be due to lower rate of respiration during storage, resulted less oxidation of organic acids.

Fruits of Banganapalli showed the lowest acidity in $NaHCO_3$ treatment (0.05%) followed by sodium hypochlorite treated (0.08%), wax coated (0.10%) and hydro cooled (0.10%) fruits after 26, 29, 26 and 27 days under cold storage.

Bangalora fruits showed the lowest acidity (0.10%) when fruits were coated with wax and stored under cold storage after 26 days. In Bennet Alphonso, the post harvest treatments did not show any significant difference in acidity of fruits.

5.1.2.2 Ascorbic acid

The ascorbic acid content of mango fruits varied according to varieties. Regardless of the post harvest treatments, highest ascorbic acid was observed in Alphonso fruits, ranges from 18 to 57.14mg/100g. The post harvest treatments given also influenced the ascorbic acid content. Alphonso fruits, when treated with ozone, after a period of 22 days in cold storage recorded the highest ascorbic acid content (57.14 mg/100g). The same trend was also observed in Bennet Alphonso, and the content of ascorbic acid was 35.38 mg/100g after 15 days storage under ambient storage condition. The highest ascorbic acid content in ozone treated fruits may be due to inhibitory roles of ozone on the activity of several enzymes such as ascorbate peroxidase and ascorbate oxidase (Yeoh *et al*., 2014). It has been found that the enzymatic activity of ascorbate peroxidase was reduced in ozone treated asparagus (An *et al*., 2007) and in fresh cut papaya fruits (Yeoh *et al*., 2014).

Hot water treated Alphonso fruits kept under ambient condition also recorded higher ascorbic acid content of 50.9mg/100g, after 15 days of storage followed by

$NaHCO_3$ treated (49.98 mg/100g) and wax coated fruits (49.50mg/100g) after 16 and 23 days of cold storage respectively. Bennet Alphonso fruits treated with sodium hypochlorite solution and stored under ambient condition also reported a higher ascorbic acid content (31mg/100g) followed by wax coated and ambient stored (30.50mg/100g) and hydro cooled fruits kept in ambient storage(30mg/100g) after 28, 18 and 14 days respectively. The possible reason for the higher ascorbic acid content in waxed fruits may be that wax coatings slowdown the oxidation of ascorbic acid by regulating oxygen permeability into fruits resulting in slower reduction in ascorbic acid content during storage (Jakhar and Pathak, 2015).

In Banganapalli fruits stored under ambient condition, showed the highest ascorbic acid content (14.5 mg/100g) in both hot water treated and $NaHCO_3$ treated fruits after 16 days of storage. Under cold storage also these fruits showed similar results. Hot water treated and $NaHCO_3$ treated fruits recorded 11.78 mg/100g followed by wax coated fruits 8.86mg/100g after a storage period of 26 days.

Fruits of Bangalora recorded the highest ascorbic acid content in sodium hypochlorite treated (15.09 mg/100g) followed by control fruits (15mg/100g) after 14 and 22 days of ambient storage. Under cold storage, the treatments recorded higher ascorbic acid content were hydro cooling (15mg/100g), ozonisation (14.95mg/100g), $NaHCO_3$ treatment (14.50mg/100g) after a storage life of 16, 25 and 15 days.

5.1.2.3 Sugars

The total sugar content of mango increases with increase in days of storage and ripening, making the fully ripened fruits sweeter (Othman and Mbogo, 2009). The value of total sugar increases initially and after attaining the peak it decreases, due to its faster utilization in respiration, when the fruits over-ripe (Hoda, 2001). In this study, post harvest treatments showed significant differences on total sugars of Alphonso, Banganapalli and Bangalora fruits.

In Alphonso fruits, the highest total sugar was recorded in wax coated (13.90 %) followed by hot water treated (12.96%), after a cold storage period of 23 and 21 days respectively. The wax coated fruits maintained the total sugar content of 8.04 per cent even up to 22 days under ambient storage condition. This slower rate of increase in sugar content in wax coated fruits might be due to the delayed degradation processes and less conversion of starch in to simple sugars(Jakhar and Pathak, 2015; Jhagolkar and Reddy., 2007).

In Banganapalli ozone treated fruits showed the highest total sugar (15.20 %) followed by hot water treated (11.62 %) under cold storage after a storage life of 23 days and 26 days respectively.

Bangalora stored under cold storage without any treatment showed the highest total sugar (14 %) followed by $NaHCo_3$ (12.96%) treated fruits after 17 and 15 days after storage respectively. The Bennet Alphonso fruits did not show significant difference on total sugars.

Only the Bennet Alphonso fruits showed significant difference on reducing sugars. The highest value of reducing sugar (8.75%) recorded in fruits stored under ambient storage without any treatment, after 19 days of storage.

Non reducing sugars were highest in wax coated fruits (12.10 %) after 23 days of cold storage in Alphonso. In Bennet Alphonso, hydro cooled fruits kept under ambient storage recorded the highest value (11.06 %) after 14 days. The highest non reducing sugars recorded were ozone treated fruits stored in cold storage (8.84 %), after 23 days and control fruits stored under cold storage (8.17 %) after 17 days in Banganapalli and Bangalora fruits respectively.

5.1. 2.4 Total soluble solids

The Total Soluble Solids (TSS) of mature fruit undergoes an increasing trend with increase in storage time. The increase in TSS during storage is due to the breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch into sugars (Wills *et al*., 1980). In this study, Alphonso, Bennet Alphonso and Banganapalli varieties of mango showed significant difference between the treatments on TSS at their full ripening state.

Alphonso fruits without any treatment stored under cold storage reported the highest TSS (20^0 brix) at 16 days of storage followed by fruits treated with sodium hypochlorite solution (17^0 brix) after 15 days. The wax coated fruits also showed same TSS of 17^0 brix even after 23 days of storage life. The delayed increase in TSS over a longer period of time in wax coated Alphonso fruits might be because the coatings delayed the metabolic and respiratory activity of fruits and hence might have retarded the fruit ripening and senescence processes. The results are in agreement with the findings of Sidhu *et al*. (2009) for wax coated pear fruits and Mahajan *et al*. (2013) for Kinnow fruits.

The storage temperature also affect the TSS of fruits. The Alphonso control fruits kept under ambient condition showed a TSS of 12^0 brix at 15 days of storage whereas under cold storage it was 20^0 brix at 16 days. The data revealed that TSS of fruits stored under cold storage was higher than that of fruits stored in ambient storage condition at their fully ripened state.

Bennet Alphonso showed highest TSS (21.50^0 brix) in wax coated fruits stored under cold storage followed by ozonised fruits stored under ambient (20.00^0 brix) condition after 24 days and 15 days of storage life respectively. These treatments are on par.

Banganapalli showed the highest TSS of 20.50^0 brix in hot water treated fruits kept under ambient condition after 16 days of storage followed by ozonised fruits under cold storage (18.20^0 brix) after 23 days of storage.

Under ambient storage condition Alphonso (13.50^0 brix at12 days), Bennet Alphonso (15^0 brix, 15 days) and Banganapalli (20.5^0 brix, 16 days) fruits treated with hot water fastened the increase in TSS. The treatments did not show any significant difference on TSS of Bangalora fruits.

5.1.2.5 Total carotenoids

The concentration of carotenoids generally increase exponentially with ripening (Ornelas Paz *et al*., 2008) due to carotenoid accumulation in fruits. Among the four mango varieties Alphonso showed highest total carotenoid content and Bangalora reported lowest (Fig. 3).

Total carotenoids in Alphonso reported the highest (15.40 mg/100g) in control fruits stored under both ambient and cold storage condition after 15 and 16 days

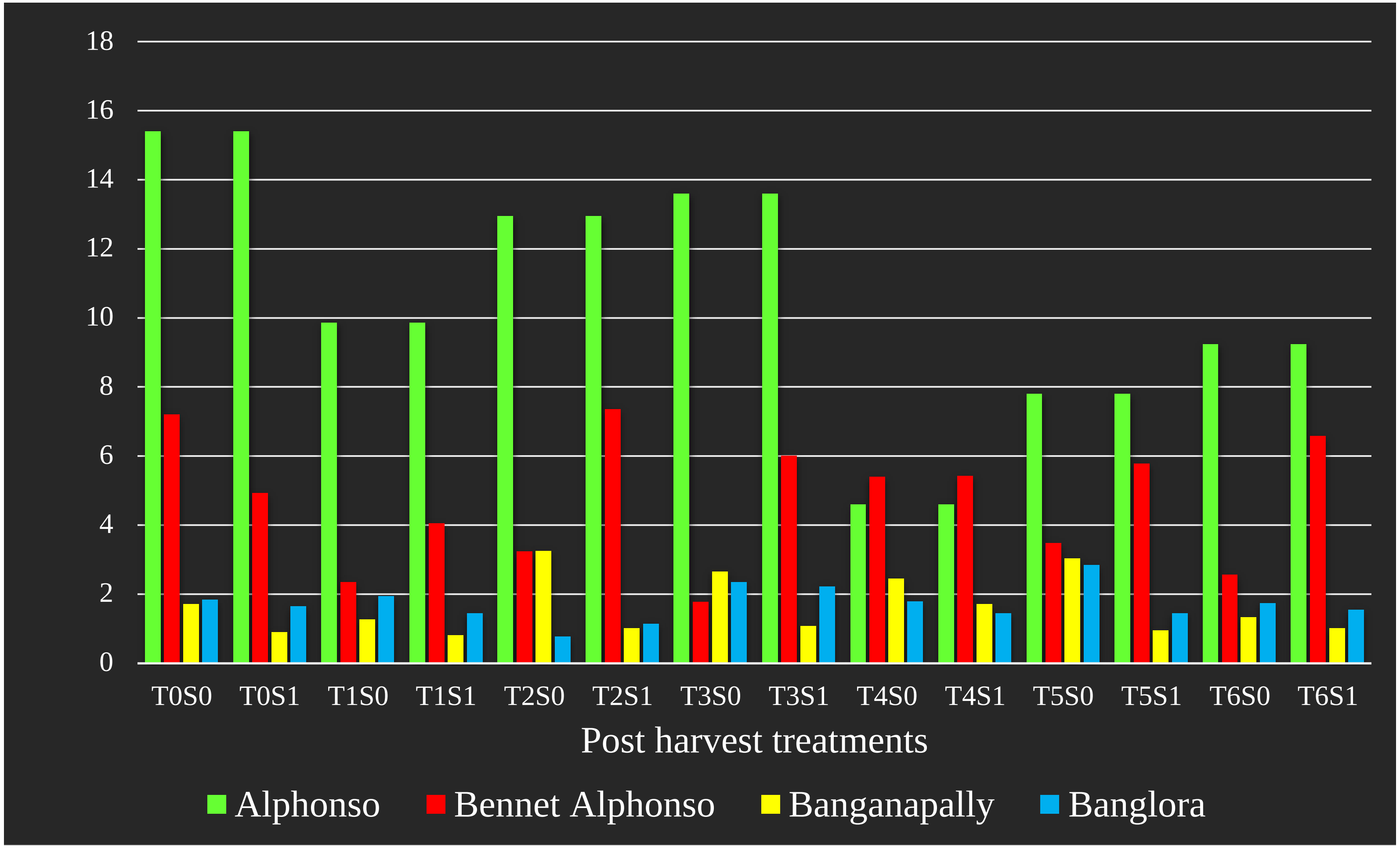

Figure 3. Effect of post harvest treatments on total carotenoids

respectively. Anwar and Malik (2007) had also reported higher total carotenoid content, when fruits were washed with ordinary water, when compared to hot water treatment in Sindri fruits. The lowest total carotenoids (4.50 mg/100g) was obtained in fruits treated with ozonised water, both in ambient (after 9 days) and cold storage condition (after 22 days). This result is in line with the findings of Monaco *et al.* (2016), where ozonised water used as a sanitizer did not cause any decrease in β-carotene content when the mango cv. Palmer fruits stored in cold chamber.

Hydro cooled Bennet Alphonso and Banganapalli fruits showed the highest total carotenoid content under cold storage (7.36mg/100g, 18 DAS) and ambient storage (3.25 mg/100g, 16 DAS) respectively. Bangalora showed maximum total carotenoids in wax coated fruits kept at ambient condition (2.85mg/100g) after a storage life of 16 days.

5.1.3 Pesticide residue analysis

The farmers of Muthalamada area, use common pesticides like Dimethoate, Chlorpyriphos, Fenvalerate etc. The pesticide residue analysis was done for these pesticides in Alphonso variety which fetch premium price in the market.

The insecticides, Dimethoate, Malathion and Methyl parathion were detected and they were below the limit of quantification (LOQ). Only the residues of Chlorpyriphos was above LOQ in control fruits. The residue of Chlorpyriphos (0.1032ppm) detected was higher than that of the Maximum Residual Limit (MRL) of 0.05ppm as given under PFA Rules, 1955 (Rule 65).

All the treatments given to the mango fruits resulted a decrease in the pesticide residues below LOQ. Ozonisation and chlorination were effective in degradation of aqueous pesticides in fresh and processed fruits through the process of chemical oxidation (Ong *et al*., 1996). According to Hwang *et al*. (2002) ozonisation (3 ppm) and chlorination (500 ppm) were the most effective in removing the residues of mancozeb and ethylene-thiourea from fresh apple fruits.

5.1.4 Postharvest pathogen

Post harvest decay causes severe losses in the fruit and vegetable segments around the world. It can reach up to 30 per cent in tropical countries (Mutungi, 2015). Primary causes of the post harvest decay are related to deficient preharvest control of pathogens, mechanical damage during harvest, transport, and inappropriate storage (Snowdon, 2010).

In the production chain of mango, the bacteria, *Colletotrichum spp* Pens. and fungi belonging to the Botryopheriacea family as *Fusicoccum aesculi* Corda, *Lasiodiplodia theobromae* (Pat.) and *Neofusicoccum parvum* (Pennycook & Samuels) Crous cause most important post harvest mango fruit rot in tropical regions (Costa *et al*. 2010; Lima *et al*., 2014). The stem-end rot caused by *Lasiodiplodia theobromae* and *Dothiorella spp*., and anthracnose (*Colletotrichum spp.*) together cause losses commonly around 15 per cent, reaching even up to 50 per cent in mango production chain around the world (Singh *et al*., 2013). The infections can occur during fruit development, even in flowering, remaining quiescent until fruit ripening (Prusky *et al*., 2013).

In the present study, fruits of mango varieties, Alphonso, Bennet Alphonso, Banganapalli and Bangalora showed severe decay during storage by pathogens. The reported post harvest diseases were anthracnose (*Colletotrichum gloeosporioides)*, stem end rot (*Diplodia natalensis)*, bacterial rot and soft rot (*Aspergillus sp*). All the fruits decayed by these post harvest pathogens in all treatment. So it was clear that the treatments of this study did not have any effect on of post harvest disease development. Stem end rot (*Diplodia natalensis)* and antharcnose (*Colletotrichum gloeosporioides)* were severe in all four varieties of mango fruits stored under both ambient and cold storage. Bacterial rot was only seen in Banganapalli and Bangalora fruits. Although the development of these post harvest diseases were slower in wax coated fruits stored under cold storage.

5.2 STANDARDIZATION OF RIPENING TECHNIQUES

The Bennet Alphonso fruits sprayed with Ethrel (200 ppm) reached full ripening stage, four days earlier than control fruits followed by hot water treated fruits (3 days earlier). The ripening advance by four days had also reported in Dashehari fruits sprayed with ethrel (600 ppm) when compared to unsprayed control fruits (Gurjar *et al*., 2017).

Hot water treated fruits were ripened within five days of storage. Anwar and Malik (2007) had also reported lower ripening period of three days in hot water treated (48°C for 60min) Sindhuri fruits. The onset of respiratory climacteric could be hastened by three to six days in hot water treated ($50+2^0$ C for five minutes) Alphonso fruits (Lakshminarayana *et al*., 1974).

5.2.1 Physical parameters

5.2.1.1 Physiological loss in weight

Physiological loss in weight (PLW) of fruits was increased with the advancement of ripening and reached maximum weight loss at the end of ripening period.

PLW of fruits was reported the highest (16.41 %) in hot water treatment followed by control (16.21%) after 9 days of storage. The lowest was recorded in fruits which were kept along with apple (5.38 %, 8.38 %) during five and nine days after storage respectively. PLW of ethrel treated fruits were ranged from 12.58% - 15.13% after a storage period of nine days.

Ethrel treated fruits reported early ripening with moderate moisture loss through respiration and transpiration. This trend was also reported in Alphonso (Das *et al*., 2011) and Sindhura (Das and Balamohan, 2013) varieties of mango.

5.2.1.2 Shelf life

The treatment did not show any significant variation on shelf life of fruits. Although, a maximum shelf life of 18 days was obtained in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits and minimum in ethrel (100ppm) sprayed (10 days) fruits.

Longer keeping quality of 11 days was reported in ethrel (200ppm) sprayed fruits, which were ripened in four days. Hot water dipped fruits also showed a longer shelf life (12 days) after full ripening, within five days. This result is in line with the findings of Lakshminarayana *et al*. (1974), where fruits were harvested at their full mature stage and subjected to hot water dip (50 ± 2^0C for five minutes), exhibited a shelf life of 12 days.

5.2.1.3 Change in colour

The colour change of fruits during storage was faster in ethrel (200ppm) sprayed fruits followed by hot water treated fruits which completely turned to bright yellow colour within four and five days respectively. This earlier colour change in ethrel sprayed fruits might be because of the accelerated diffusion of exogenous ethylene into the peel of fruits which could be triggered the rapid degradation of chlorophyll pigments (Terai *et al*., 1973; Gurjar *et al*., 2017). The enhancement in the peel colour development in hot water treated fruits was also reported in mango fruits (Jacobi and Wong, 1991; Anwar and Malik, 2007).

5.2.1.4 Firmness

Firmness is one of the most widely used indicator for fruit quality, which influence appearance, texture and consumer acceptability of fresh fruits. Firmness value of less than 0.31 Kg/cm^2 was indication of over ripe fruits (Gurjar *et al*., 2017). In this study the highest firmness (0.49 N) was recorded in hot water treated fruits after a storage period of 17 days. The lowest firmness observed in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits (0.08 N) followed by ethrel (200ppm) sprayed (0.20 N) after 18 and 15 days of storage.

The faster decrease rate in firmness of ethrel treated fruits could be due to enhanced activity of polygalactouronase and pectin lyase enzymes, resulted in breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability (Ali *et al*., 1995; Brinston *et al*. 1988; Yashoda *et al*., 2006). In control fruits, firmness of fruits was 0.29 N after a storage period of 15 days. Similar results were obtained by Haithem and Goukh (2003) in mango, Kulkarni *et al*. (2011) in banana.

5.2.2. Biochemical parameters

Ripening process of fruits involves a series of metabolic activities including increase rate of respiration, conversion of starch to sugars, reduction in acidity, softening of fruit, development of typical flavour, aroma and colour development of skin and pulp (Peter, 2007). In this study biochemical parameters like acidity, ascorbic acid, sugars, total soluble solids and total carotenoids were assessed in Bennet Alphonso fruits at their full ripe stage. All the biochemical parameters were showed significant variation between treatments.

5.2.2.1 Acidity

The lowest acidity was recorded in fruits kept along with leaves of bilimbi (0.15 %) followed by ethrel (100ppm) sprayed (0.16%) and dipped (0.21%) fruits (Fig.4). The decreasing trend of acidity during ripening was might be due to the metabolic changes in fruits or was due to the use of organic acid in respiratory process (Echeverria and Valich, 1989; Das *et al*., 2011).

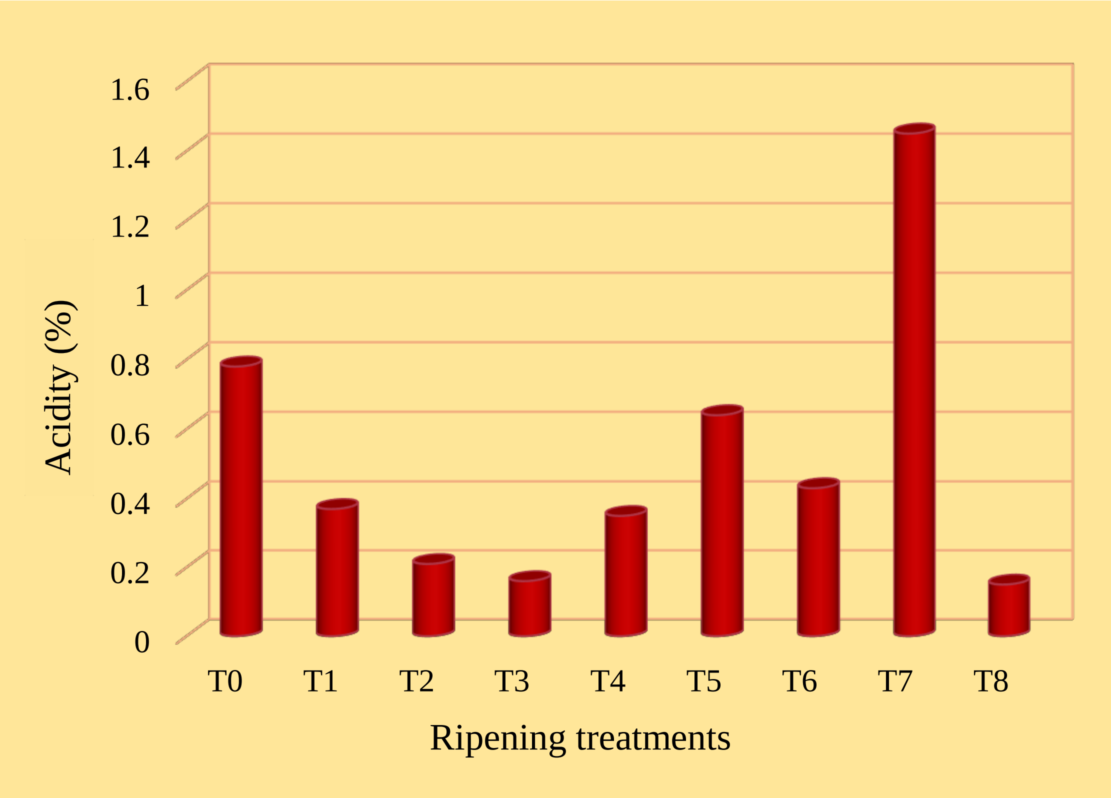

Figure 4. Effect of ripening treatments on acidity of fruits

5.2.2.2 Ascorbic acid

In mango ascorbic acid content gradually decreases with advancement of ripening. The highest ascorbic acid was observed in mangoes treated with hot water, (22.50 mg/100g) followed by ethrel (100ppm) dipped (20.68 mg/100g) fruits (Fig.5). The increased acid content in mango fruit with the exogenous application of ethylene has also been reported earlier (Medlicott, 1987; Chaplin, 1988; Lizada, 1991; Reid, 1992; Nair and Singh, 2013).

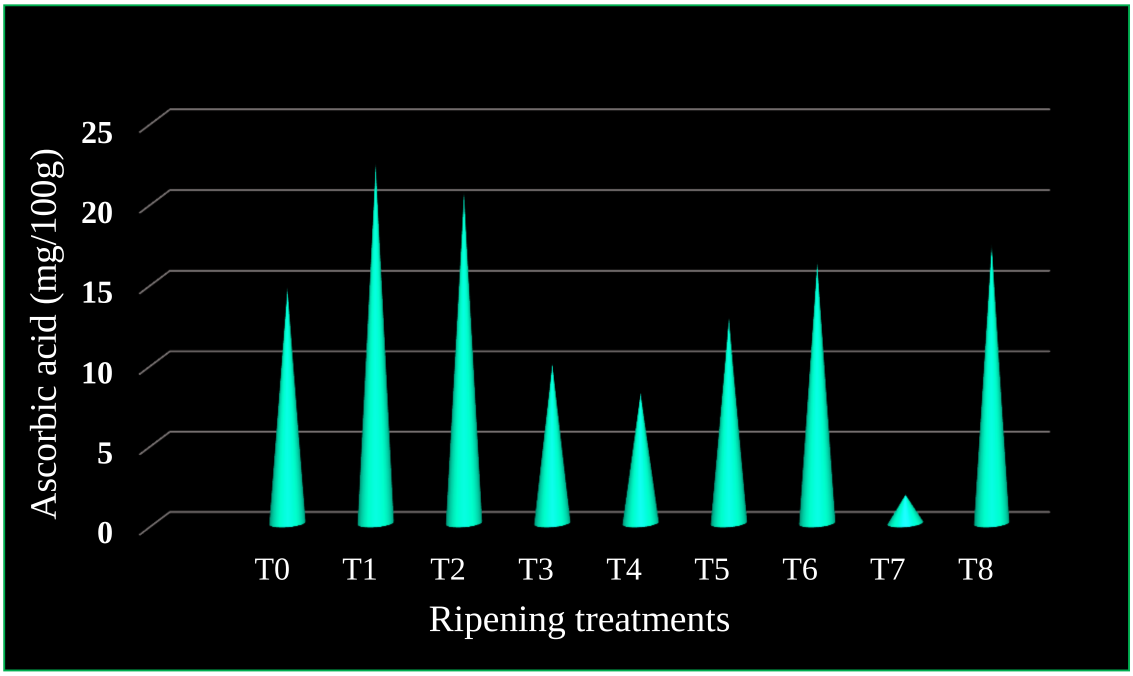

Figure 5. Effect of ripening treatments on ascorbic acid content of fruit

5.2.2.3 Sugars

Mango ripening is accompanied by increase in sugar content. Enzymatic conversion of free organic acid to simple sugar along with breakdown of complex carbohydrates to simple form during ripening causes increase in total sugar content (Jassi *et al*., 2019).

The maximum total sugar is observed in fruits kept along with bilimbi leaves (12.96 %) followed by control (12.60%) and ethrel (200ppm) sprayed (12.56%). The highest reducing sugar of 11.40 per cent were reported in both ethrel (200ppm) dip and fruits kept along with bilimbi leaves. Non reducing sugars reported maximum in hot water treated (7.12 %) and respectively.

Nair and Singh (2013) also reported the increased reducing, non-reducing and total sugars of fruits with increase in concentration of ethrel. The increased sugar contents with ethrel treatments may be attributed to the increased conversion of starch into sugars.

5.2.2.4 Total soluble solids

The highest (20^0 brix) TSS were observed both in control and ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated fruits after a storage period of 15 and 18 days respectively. Ethrel (200ppm) treated fruits also showed higher TSS of 19.50^0 brix in dipped fruits followed by 18.17^0 brix in sprayed fruits after a storage time of 14 and 15 days respectively. The increased TSS content in fruits might be due to the conversion of carbohydrates into sugars, organic acids and other soluble materials by metabolic process during repining (Das and Balamohan, 2013).

The fruits dipped in ethrel (200ppm) was reported higher TSS (19.50^0 brix) than that of fruits dipped in 100ppm ethrel (14.50^0 brix) after a storage period of 14 days. This might be due to the fact that the higher concentration accelerate the conversation of starch to sugar molecules by activating the hydrolytic enzymes than that of the lower concentration (Das *et al*., 2011; Das and Balamohan, 2013).

5.2.2.5 Total carotenoids

Total carotenoids were maximum (33.98mg/100g) in hot water treated mangoes followed by 100ppm ethrel dipped (31.03 mg/100g) and fruits kept along with bilimbi leaves (27.90 mg/100g). Higher carotenoid content in ethrel treated fruits could be due to enhancement in the activity of carotenoid β-hydroxylase enzyme responsible for carotene synthesis (Yah *et al.*, 1998). These results were in line with the findings of Siddqui and Dhua (2009) in 'Himsagar' mango dipped in 700 ppm ethrel and Singh *et al*. (2012) in papaya treated with 1000 ppm ethrel. The total carotenoids of mango fruits are depicted in Fig. 6.

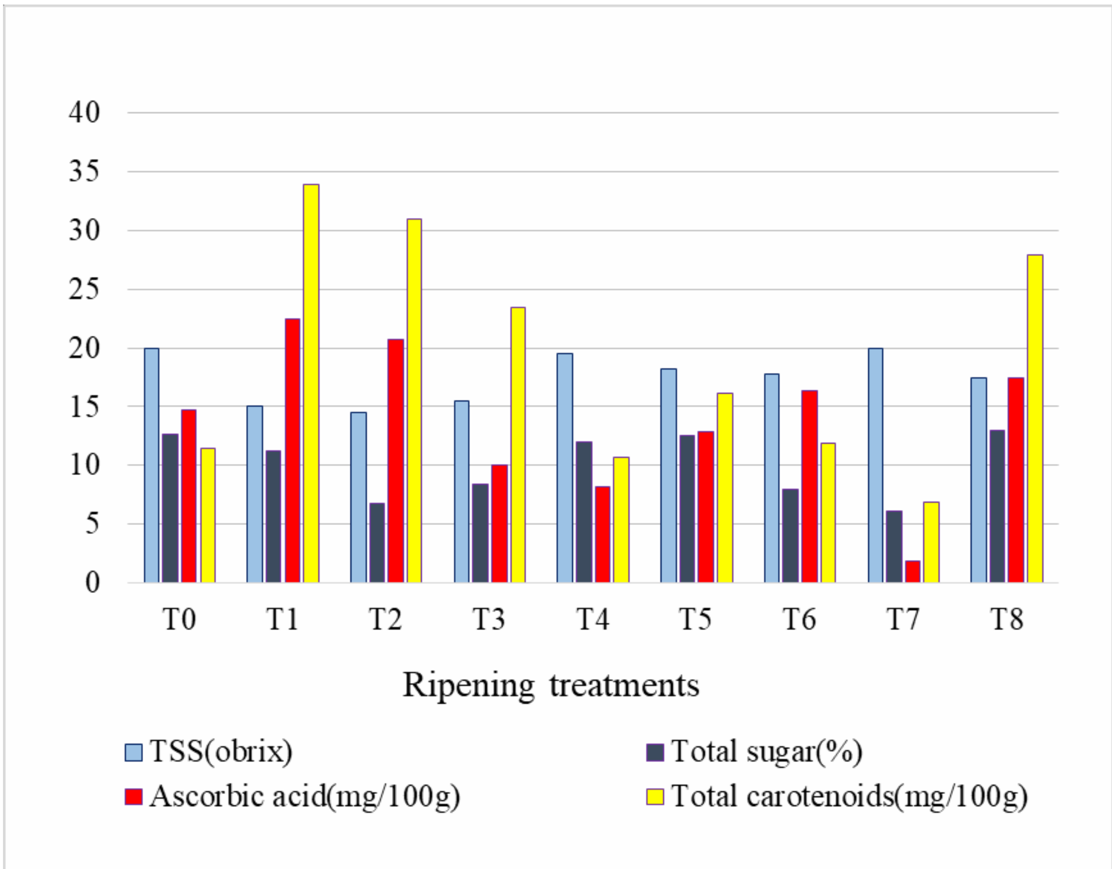

Figure 6. Effect of ripening treatments on biochemical parameters of fruit

5.2.3 Sensory evaluation

The total score was highest in ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) treated (56.75) followed by ethrel (200ppm) sprayed fruits (54.53). Ethrel (200ppm) sprayed and fruits kept along with apple were recorded the highest score in appearance whereas hot water treated fruits showed maximum score in both taste and after taste. The treatment, ethrel (5 ml 4% Ethephone/m^3+3g NaOH for 24 hrs) was the one which scored the highest score in half of the total attributes evaluated (colour, texture, flavour and odour). The overall acceptability was highest in fruits treated with ethrel (200ppm spray). Figure 7 depicts the sensory attributes of fruit.

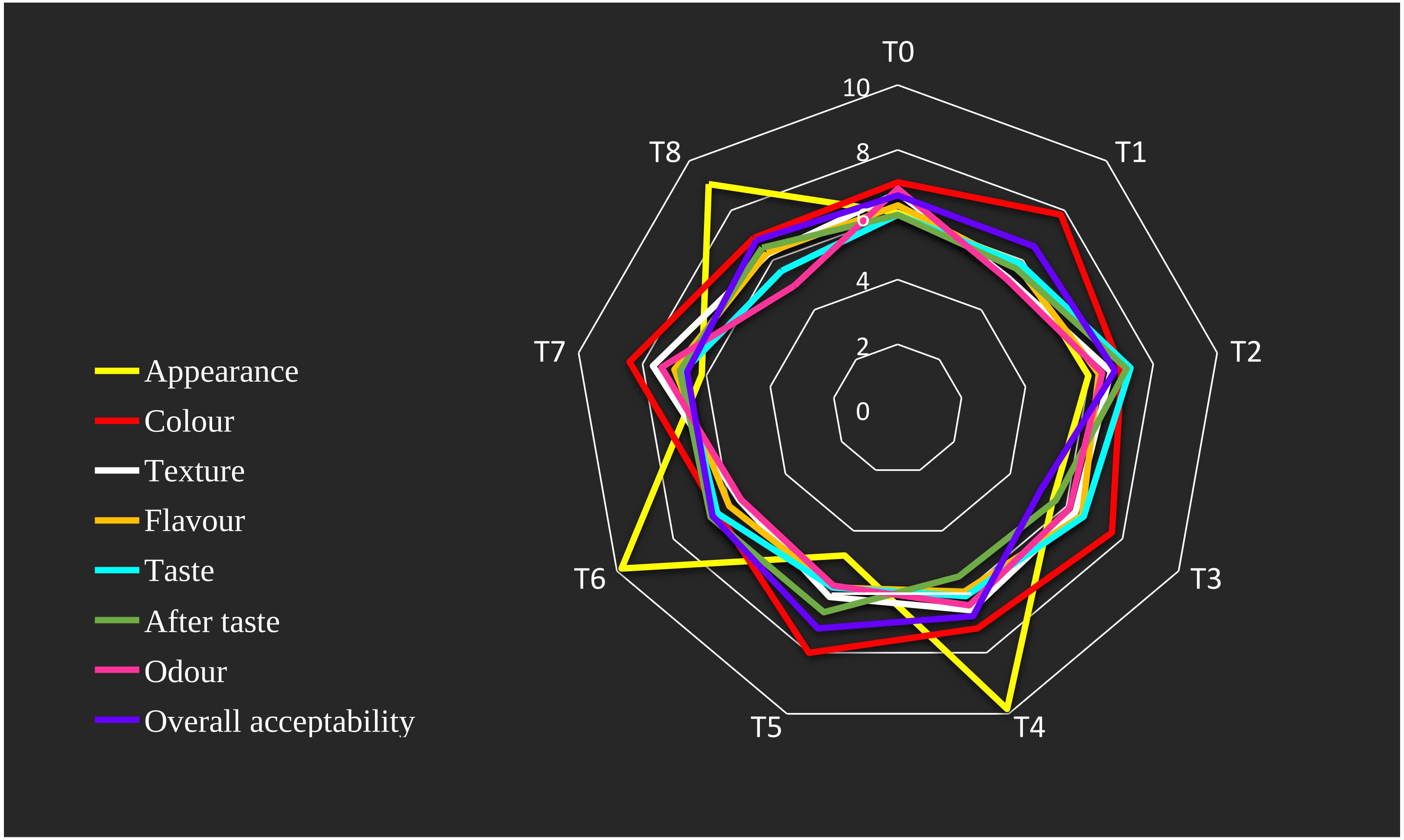

Figure 7. Effect of ripening treatments on sensory attributes of fruit

SUMMARY

6. **SUMMARY**

The present study on the "Post harvest management practices in mango (*Mangifera indica* L.)" was carried out at the Department of Post Harvest Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 2018-2020. The objectives were to standardise post harvest and ripening treatments for important commercial mango varieties from Muthalamada, Palakkad, from where the mango fruits reach Indian markets in early season.

The effect of different post harvest treatments on mango fruits during storage were investigated in four mango varieties such as Alphonso, Bennet Alphonso, Banganapalli and Bangalora. The physical and biochemical changes of treated fruits, stored under both ambient and cold storage conditions were studied. The findings are as summarized below;

- Among the different treatments, 1 per cent Niprofresh (carnauba wax) coated fruits stored under cold storage at 12 ± 2^0C recorded good quality attributes in both Alphonso and Bangalora varieties.
- Coated fruits of Alphonso maintained quality as evidenced by reduction in PLW (6.52 %), delayed colour change (16 days), firmness (0.09 N), acidity (0.21%), ascorbic acid (49.50mg/ 100g), total carotenoid (7.80mg/100g), total sugar (13.90 %), non reducing sugar (12.10%) and TSS (17^0 brix) even after a storage period of 23 days.
- Fruits of Bangalora coated with wax had extended the shelf life up to 26.50 days against control fruits (17.50days) with lowest PLW (7.80%), delayed colour change (26 days), acidity (0.10%), firmness (0.32 N), ascorbic acid (9.95 mg/100g), total sugar (7.86%) and a TSS of 11^0 brix.
- In Bennet Alphonso, sodium hypochlorite (100ppm) treated fruits were found to be better in quality with respect to PLW (9.63%), firmness (0.07 N), acidity (0.17%), ascorbic acid (23.32 mg/ 100g), total sugar (12.60%), reducing sugar (3.18%), total carotenoid (6 mg/ 100g) and TSS (18.5^0 brix) after a storage period of 28.50 days.

- Banganapalli had the highest storage life of 29.50 days in fruits sanitised with sodium hypochlorite solution. But the fruits treated with ozone were the superior in other quality attributes like TSS (18.20^0 brix), total sugar (15.20%), non reducing sugar (8.84%), ascorbic acid (6.76 mg/ 100g), delayed colour change (15 days), firmness (0.28 N), acidity (0.13%), total carotenoid (1.72 mg/ 100g) and PLW of 14.10 per cent after 23 days of cold storage.
- Among the various ripening treatments, ethrel (200 ppm) sprayed fruits induced uniform ripening within four days followed by hot water dipped (50±2^{0}C, for one minute) fruits which ripened in five days as against eight days in control. Spraying ethrel (200 ppm) had a longer keeping quality of 11 days with good quality attributes like TSS (18.17^{0}brix), total carotenoids (16.10mg/100g), ascorbic acid (12.86mg/100g), firmness (0.20 N), total sugar (12.56%) and a highest score (7.20) in overall acceptability in sensory evaluation.
- Hot water treated fruits were fully ripened in five days and exhibited longer keeping time of 12 days with good quality parameters like TSS (15^{0}brix), acidity (0.37%), total carotenoids (33.98mg/100g), ascorbic acid (22.50mg/100g), firmness (0.49 N), total sugar (11.19%) and non reducing sugar (7.12%) with a score of 6.55 in overall acceptability in sensory evaluation.

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APPENDICES

APPENDIX I

Score card for sensory evaluation of mango

9 point headonic scale

Product code	**Appearance**	**Colour**	**Texture**	**Flavour**	**Taste**	**After taste**	**Odour**	**Overall acceptability**

Note: You are provided with samples of mango fruits and requested to rank them according to the scale given below as per your liking.

Scale:

9	**Like extremely**
8	**Like very much**
7	**Like moderately**
6	**Like slightly**
5	**Neither like nor dislike**
4	**Dislike slightly**
3	**Dislike moderately**
2	**Dislike very much**
1	**Dislike extremely**

Date:

Name:

Signature:

POST HARVEST MANAGEMENT PRACTICES IN MANGO (*Mangifera indica* L.)

By

HARYA KRISHNA V.
(2018-12-016)

ABSTRACT OF A THESIS

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VELLANIKKARA

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Abstract

Mango (*Mangifera indica* L.), the king of fruits, relished by majority, occupies first position in production in India and world. The problems featured in the journey of the fruits from field to market are numerous. Burondkar *et al*. (2018) estimated that about 20 - 30 per cent of harvested mango fruits became sub-standard due to rough handling, pathogenic infestations, improper packaging, unhygienic storage and indecorous mode of transportation. This shows the necessity of improving post harvest management practices to enhance shelf life without deteriorating its quality. The investigation on the "Post harvest management practices in mango (*Mangifera indica* L.)" was carried out at the Department of Post Harvest Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 2018-2020. The objectives were to standardise post harvest and ripening treatments for important commercial mango varieties of Muthalamada, Palakkad, from where the mango fruits reach Indian markets in early season.

The effect of different post harvest treatments on mango fruits during storage were studied in four mango varieties such as Alphonso, Bennet Alphonso, Banganapalli and Bangalora. The physical and biochemical changes of treated fruits, stored under both ambient and cold storage conditions were studied. The postharvest treatments given were hot water dip, hydro cooling, sanitization with sodium hypo chlorite solution, ozonisation, waxing and dipping in sodium bicarbonate solution. Among the different treatments, 1 per cent Nipro fresh (carnauba wax) coated fruits stored under cold storage at 12 ± 2^0C recorded good quality attributes in both Alphonso and Bangalora varieties. Coated fruits of Alphonso maintained quality evidenced by reduction in PLW (6.52 %), delayed colour change (16 days), firmness (0.09 N), acidity (0.21%), ascorbic acid (49.50mg/ 100g), total carotenoid (7.80mg/100g), total sugar (13.90 %), non reducing sugar (12.10 %) and TSS (17^0 brix) even after a storage period of 23 days. Fruits of Bangalora coated with wax had extended the shelf life up to 26.50 days against control fruits (17.50days) with lowest PLW (7.80 %), delayed colour change (26 days), acidity (0.10%), firmness (0.32 N), ascorbic acid (9.95 mg/100g), total sugar (7.86%) and a TSS of 11^0 brix.

In Bennet Alphonso, dip in sodium hypochlorite solution (100ppm) for five minutes was suitable for getting a lowest PLW (9.63 %), firmness (0.07 N), acidity (0.17 %), higher TSS (18.5^0 brix), ascorbic acid (23.32 mg/ 100g), total sugar (12.60 %), reducing sugar (3.18 %), total carotenoid (6 mg/ 100g) and a storage period of 28.50 days.

In Banganapalli, the fruits treated with ozone were good in quality attributes like TSS (18.20^0 brix), total sugar (15.20 %), non reducing sugar (8.84 %), ascorbic acid (6.76 mg/ 100g), delayed colour change (15 days), firmness (0.28 N), acidity (0.13 %), total carotenoid (1.72 mg/ 100g) and PLW of 14.10 per cent with a storage life of 23 days in cold storage.

Standardization of ripening techniques was done in the variety Bennet Alphonso at their full mature stage. The fruits were subjected to different ripening treatments and kept for storage under ambient condition. Among various treatments, ethrel (200 ppm) sprayed fruits induced uniform ripening within four days followed by hot water dipped (50 ± 2^0C, for one minute) fruits which ripened in five days as against eight days in control. Spraying ethrel (200 ppm) had a longer keeping quality of 11 days with good quality attributes like TSS (18.17^0brix), total carotenoids (16.10mg/100g), ascorbic acid (12.86), firmness (0.20 N), total sugar (12.56%) and a highest score (7.20) in overall acceptability in sensory evaluation. Hot water treated fruits were fully ripened in five days and exhibited longer keeping time of 12 days with good quality parameters like TSS (15^0brix), acidity (0.37%), total carotenoids (33.98mg/100g), ascorbic acid (22.50mg/100g), firmness (0.49 N), total sugar (11.19%) and non reducing sugar (7.12%) with a score of 6.55 in overall acceptability in sensory evaluation.