POST HARVEST MANAGEMENT PRACTICES IN PINEAPPLE (*Ananas comosus* (L.) Merr.)

ELSO REMYA RAJAN

(2018-12-034)

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

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by

ELSO REMYA RAJAN

(2018-12-034)

THESIS

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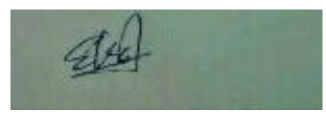
KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"POST HARVEST MANAGEMENT PRACTICES IN PINEAPPLE (*Ananas comosus* (L.) Merr.)"** 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.



Vellayani **ELSO REMYA RAJAN**

Date: 02-11-2020 **(2018 -12-034)**

CERTIFICATE

Certified that this thesis entitled **"POST HARVEST MANAGEMENT PRACTICES IN PINEAPPLE (*Ananas comosus* (L.) Merr.)"** is a record of bonafide research work done independently by Ms. ELSO REMYA RAJAN 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.

Dr. Mini C.
(Major advisor, Advisory committee)
Professor and Head
Department of Post Harvest Technology
College of Agriculture, Vellayani

Vellayani
Date: 02-11-2020

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Elso Remya Rajan (2018-12-034) a candidate for the degree of **Master of Science in Horticulture** with major in Post Harvest Technology, agree that the thesis entitled **"POST HARVEST MANAGEMENT PRACTICES IN PINEAPPLE (*Ananas comosus* (L.) Merr.)"** may be submitted by Ms. Elso Remya Rajan, in partial fulfillment of the requirement for the degree.

Dr. Mini C.
(Chairperson, Advisory Committee)
Professor & Head
Department of Post harvest Technology
College of Agriculture, Vellayani

Dr. P. R. GeethaLekshmi
(Member, Advisory Committee)
Assistant Professor
Department of Post harvest Technology
College of Agriculture, Vellayani

Dr. Manju, R.V.
(Member, Advisory Committee)
Professor
Department of Plant Physiology
College of Agriculture, Vellayani

Dr. K. N. Anith
(Member, Advisory Committee)
Professor
Department of Agricultural Microbiology
College of Agriculture, Vellayani

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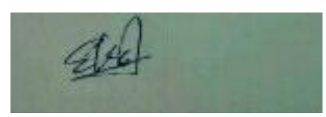

ELSO REMYA RAJAN

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LIST OF ABBREVIATIONS

%	Per cent
Cm	Centimetre
et al.	Co-workers
G	Gram
Kg	Kilogram
Hr	Hour
KAU	Kerala Agricultural University
Mg	Milligram
mL	Millilitre
L	Litre
µl	micro litre
ºC	Degree Celsius
RH	Relative Humidity
viz.	Namely
var.	Variety
ºB	Degree Brix
CO_2	Carbon dioxide

Cv	Cultivar
Fig.	Figure
NS	Non Significant
O_2	Oxygen
PLW	Physiological Loss in Weight
Ppm	Parts per million
CD	Critical difference
SE	Standard Error
P	P- two tail value
TSS	Total Soluble Solids
Sl.	Serial
NA	Nutrient Agar
RBA	Rose Bengal Agar
T	Tonne
MT	Metric ton
Ha	Hectare
NaoH	Sodium hydroxide
Cfu	Colony forming unit

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Introduction

1. INTRODUCTION

Pineapple (*Ananas comosus* (L.) Merr.) is a delicious fruit widely cultivated in tropical and subtropical areas. The edible portion of fruit is composed of 77-91% water and 9.7-12% sugar which together make up over 98% of the fruit weight (Ray, 2006). Pineapple is one of the widely consumed fruits in all parts of the world due to presence of pleasant flavour and exquisite taste. It is so called as nature's wonderful medicines, rich in anti-oxidants and phyto-nutrients without which human body cannot maintain proper health. Pineapple is a digestive aid and a natural anti-inflammatory fruit containing a group of sulphur-containing proteolytic enzymes, bromelain which helps in digestion.

India ranks fifth in terms of production of pineapple in the world and the leading producers are West Bengal, Assam, Kerala and Karnataka. Total area, production and productivity of pineapple in the country during 2017- 2018 are 1,03,000 ha, 17,05,800 MT, and 16.6 t/ha respectively (GOI, 2018).

In Kerala pineapple is cultivated in an area of 8220 ha with a production of 69,720 tons (NHB, 2018). Due to the arrival of new market avenues cultivation of pineapple has become an enterprising business. Mauritius is a dominant cultivated variety recommended for large scale commercial cultivation in Kerala due to its unique aroma, flavour and sweetness, high sugar content and low acidity. In international trade 'Mauritius' is often called 'European Pine', 'Malacca Queen', 'Red Ceylon' and 'Red Malacca'. The commercial cultivation of Mauritius is extensive in Ernakulam, Kottayam, Pathanamthitta and some parts of Idukki districts due to its high market preference and consumer acceptability. Mauritius is popular variety grown in Vazhakulam, in Ernakulum district, and known as “vazhakulam pineapple”, and has got the registration under Geographical Indication. Currently, Vazhakulam is known as the centre of pineapple trade in India.

Pineapple is a potential foreign exchange earner but Indian exporters find it extremely difficult to compete in the global market due to relatively poor quality which fetches only low price in international market. It has been observed that at post harvest stage a significant proportion (15-25%) of the produce get spoiled due to improper post harvest handling practices, which causes huge economic loss to the growers. To reduce this loss, postharvest management practices have to be improved.

Quantitative and qualitative losses of pineapple are the main concerns in all stages of the post-harvest chain until the fruits are delivered to the final consumers. Losses occur mainly due to mechanical damage, physiological disorders, diseases, moisture loss and normal deterioration process. These losses are not only a waste of the product, but they also represent a similar waste of human effort, farm inputs and livelihood. Due to the fleshy and bulky nature, it performs poorly during storage and transportation. The quality of the fruit is influenced by environmental factors such as temperature, rainfall, light; cultural factors *viz*. variety, nutrition, irrigation, pest, disease ,weed control (Thompson, 2003), postharvest treatments and handling method. Hence, postharvest management plays an important role in maintaining the quality of the fruit until the final consumption stage and is also a critical component to reduce postharvest losses both quantitatively and qualitatively.

Postharvest management practices start immediately after the harvesting of fruits, eliminating undesirable elements and improve product appearance, as well as ensuring that the product complies with established quality standards for fresh products. Correct stage of harvest and good storage conditions help to increase the shelf life of pineapple. A small difference in maturity of pineapple influences eating quality and consequently consumer satisfaction (Smith and Harris, 1995). It is necessary to determine the precise stage of maturity at which fruits are to be harvested for distant and local market.

Even though pineapple has good demand and vast export potential, it is traded in fresh form only in a limited scale because of its perishable nature. Suitable postharvest management practices can extend the shelf life by preserving its nutritional quality and thereby increasing its availability for domestic and distant market. Hence the present study on “Postharvest management practices in pineapple” was undertaken at Department of Post Harvest Technology, College of Agriculture, Vellayani with the objective to standardize the post-harvest management practices in pineapple for improved fruity quality.

Review of literature

2. REVIEW OF LITERATURE

Pineapple *(Ananas comosus* (L.) Merr.) belonging to family Bromeliaceae is originated in South America, most probably from the region between Brazil and Paraguay (Paull and Lobo, 2012). It is one of the most popular fruits of the tropical region of the world. India is the fifth largest producer of pineapple in the world accounting to 1.96 MT (NHB, 2018) and the leading producers are West Bengal, Assam, Kerala and Karnataka. But a considerable amount of the produce is lost due to improper harvesting, absence of pre-treatments and lack of good storage facilities. So the present study was conducted to standardize postharvest management practices in pineapple for improved fruit quality.

The present chapter reviews the available literature on postharvest management practices *viz.,* stage of harvest, postharvest treatments, storage of pineapple and other fruit and vegetable crops

2.1 Postharvest Losses

Pineapple fruits are highly perishable if postharvest management practices are not adopted properly and need to be handled with extreme care from the time they are harvested until they reach the consumer. Quality of pineapple depends on the interaction of several factors in the production line (Wijesinghe and Sarananda, 2002).

According to Kader (2003) the losses occurred during processing, packaging, and marketing should not be undermined; however, according to Baha and Msafiri (2016) postharvest losses in developing countries are highly pronounced during harvesting, transporting and storing which creates a challenge throughout the whole supply chain.

The major causes of losses in pineapple fruit is due to physical injuries, sun burn, rodent infestation, contamination with pathogenic fungi and bacteria. Due to lack of awareness, knowledge and skills related to pre and postharvest management practices of produce among the handlers and marketers supplemented by unavailability of efficient cold chain infrastructure aggravate the postharvest loss. The poor handling during transportation and use of inappropriate marketing structures also contribute to postharvest loss (Hossain and Bepary, 2015).

A survey conducted by Deka *et al.* (2004) had reported that the post harvest loss of pineapple in Assam state is about 9.25%, out of which 4.22% is at growers level and 5.03% at middleman's level. It has been observed that 15-25% of the pineapple fruit get spoiled at post production level due to improper post harvest handling practices, which causes huge economic loss to the growers (Hossain and Bepary, 2015). According to Mba (2019) the losses can be reduced to 5% by improved postharvest handling practices.

Other losses result due to changes in weather, pests and diseases at production level and harvesting before time (Aulakh and Regmi, 2013).

Adoption of adequate postharvest treatments, good storage facilities and harvesting at correct stage of maturity would help to reduce the postharvest losses in pineapple.

2.2 Stage of harvest

Fruits at different maturity stages are not of uniform quality (Dhar *et al.,* 2008). Harvesting of fruits at proper stage of maturity is important for attaining desirable quality. The level of maturity helps in selection of storage methods, estimation of shelf life and selection of processing operations. Along with maturity, harvest date contributes to quality of fruit (Lechaudel and Joas, 2006). The development process by which the fruit attains maturity is called maturation (Dhatt and Mahajan, 2007).

In 1997, Baldwine and Mitra reported that maturity of pineapple is evaluated on the extent of 'eye' flatness and skin yellowing. When base of the fruit has changed from green to yellow or light green, it indicates the time of harvesting. Fruits may be harvested for the local market before striking colour changes have occurred.

The level of yellow colouration of 'eyes '(Wijesinghe and sarananda, 2002) and colour of pineapple peel (Joomwong, 2006) are the two external factors used to determine the various stages of pineapple maturity.

Green and colour break stages have a slower peel colour development. Although pineapple is intended as a non-climacteric fruit, the peel acts as a climacteric due to increase in peel colour after harvesting. In pineapple, as the maturity stage increases yellow colour of the fruit increases from peduncle and reaches to the upper part of the fruit (Rohana *et al.,* 2009).

Radha and Mathew (2007) reported that pineapple harvested at $1/3^{rd}$ to$1/4^{th}$ basal portion of fruits become yellow is advisable to prevent post harvest losses. Pineapple is harvested when the fruit colour changes from green to greenish yellow, with smooth surface around the eyes and the bracts start drying up (John, 2008). Harvesting is done between 20% to 40% yellow stage for export purposes depending upon the time it will take to reach destination (Saraswathy *et al.*, 2008). The least incidence of spoilage and maximum shelf life was observed for fruits harvested at quarter yellow stage (Reshma, 2014).

Ray (2006) reported that a less mature grade must be selected for distant market. For distant market, fruits should be harvested at 10-20% yellow stage or even 100% green but it should be mature (Adikaram and Abayasekara, 2012). Pineapple meant to be transported to distant markets, should be harvested when $1/3^{rd}$ to $1/2^{th}$ portion become yellow (Singh, 2012).

Sairi *et al*. (2004) reported that immature fruits are not shipped since they do not develop good flavour, have low brix and are more prone to chilling injury. Pineapple harvested at early maturity has poor organoleptic properties but longer storage life, whereas the fruit of advanced maturity is more pleasant in terms of physical appearance and organoleptic quality but the potential storage life is reduced (Abdullah, 2011).

Maturity index can also be estimated by computational method relating it to the time after flowering or mid-flowering, but the number of days may vary from place to place. The period from flower induction to ripening varies from 140–221 days (Thompson, 2003).

The physiological loss in weight was higher in premature pineapple fruits than the optimum mature fruits during the storage period (Kabir *et al*., 2010). The highest non-reducing sugar, total sugar and TSS were recorded in optimum mature fruits while it was minimum in fruits harvested 14 days before optimum mature stage (Dhar *et al*., 2008). The maximum total sugar and TSS were recorded in full mature fruit while it was minimum in premature fruits. Freshly harvested premature pineapple fruits exhibited the maximum total titratable acidity and ascorbic acid when compared to optimum mature fruits (Kamol *et al.,* 2014).

The minimum TSS should be 12.0 to 13.0°B in the world market, which is attained if the fruits are harvested at correct maturity stage. As a non- climacteric fruit its compositional changes after harvest are mostly confined to degreening and decrease in acidity (Kader, 2002).

2.3 Postharvest treatments

Postharvest treatments are given to increase storage period without deteriorating the quality of produce. It includes curing, surface sanitation and chemical treatments with calcium compounds, growth regulators, fungicide, chlorine water and sprout inhibitors to maintain quality of produce for a longer time (Pal and Sharma, 2010).

2.3.1 Hot water treatment

Heat treatment after harvest is a non-contaminating physical treatment that delays the ripening process, reduces chilling injury and controls the activity of pathogens and hence are currently used commercially for quality control of fresh products (Ferguson *et al*., 2000). Methods of heat treatment as well as length of exposure may also influence the response of the commodity.

Heat treatment is used successfully, to control the incidence of postharvest disease in several commodities (Fallik, 2004). Mild heat treatment reduces microbial load and improves fruit texture and taste of a number of fruits (Valero *et al.,* 2002; Abreu *et al.,* 2003; Lamikanra *et al.,* 2005).

Heat treatment also has been found to be an effective means of maintaining the sensory and nutritional attributes of a number of horticultural crops (Williams *et al.,* 1994; Paull and Chen, 2000) while increasing the shelf-life and product quality (Wang *et al.,* 2001)

Hot water temperatures of 50^0C to 60^0C up to 10 minutes could control many postharvest plant pathogens (Lurie, 1998; Rathore *et al*., 2012) during storage and transportation (Pal and Sharma, 2010).

Hot water is a heat transfer medium, which is more efficient than treatment with hot air (Shellie and Mangan, 1994). Moreover, hot water dip effectively controls fungal pathogens (Paull, 1994). Pajaro strawberry fruit treated at 45^0C by hot air or hot water prior to storage at 3^0C for 10 days improved fruit resistance to fungal infection. Hot air treatment also improved resistance to fungal infection and preserved firmness (Lara *et al.*, 2006).

Hot water treatment is a feasible method for controlling postharvest decay in banana. Immersion of Gros Michel and Namwa in hot water at 42^0C for 15 minutes delayed blackening in peel during storage (Promyou *et al.*, 2008). Hot water treatment at 50^0C for 20 minutes is effective in controlling crown rot and delayed ripening of banana cv. Bungulan (Alvindia, 2012). Hot water treatment at 50^0C for 20 minutes has found to be very effective in controlling anthracnose (*Colletotrichum musae*) in Berangan banana instead of using fungicide (Mirshekari *et al*., 2012).

Hot water treatment at 50^0C for 20 minutes was reported as the best sanitising agent (Jayasheela, 2014) for papaya. According to Sanchez *et al.* (2013) hot water treatment of 55^0C for 3 minutes delays decay development during papaya marketing at non-refrigerated temperature of 25^0C. Papaya fruit treated with hot water at 54^0C for 4 minutes showed an obvious effect on controlling postharvest decay and delayed ripening (Zhao *et al*., 2013). Hot water treatment at 47^0C for 10 minutes can maintain the postharvest quality of Eksotika papaya fruit and prevent it from insect infestation (Arina *et al*., 2010). Papaya fruit with hot water treatment at 48-50^0C for 20 minutes control the *C. gleosporioides* and *Phoma caricae* (Martins *et al*., 2010).

Hot water treatment is widely used in many countries for insect and decay control in mango (Aveno and Orden, 2004). Mangoes treated with hot water have exhibited increase in polyphenols and carotenoids and better antioxidant capacity compared with untreated ones (Talcott *et al.*, 2006).

Hot water at 52^0C for 30 minutes has found to be very effective in controlling postharvest anthracnose disease of mango *cv*. Dashehari (Prakash and Pandey, 2000). Mango treated with hot water at 55^0C for 5 minutes stored under controlled atmosphere at 8^0C for 45 days showed no symptoms of morphological chilling injury and ripened normally at ambient conditions (Niranjana *et al.,* 2009).

Hot water pre-treatment at 52^0C for one minute slowed the rate of rot development in litchi (Olsen *et al.,* 2004). Litchi fruit treated with hot water at 49^0C for 20 minutes followed by hydrocooling in ambient (24 ± 4^0C) temperature water for 20 minutes was proved to be effective against potential infestations of mediterranean fruit fly and oriental fruit fly (Armstrong and Follett, 2007).

Pre-treatment of rambutan with lukewarm water delayed external browning and effectively inhibited the softening of fruit and weight loss (Supapavinch, 2015).

Hot water dip treatment at 54^0C for 3 minutes is effective in controlling the incidence of black rot in pineapple (Wijeratnam *et al*., 2005). Pineapple fruits when dipped in hot water (45-55^0C) for about few minutes can enhance uniform and rapid ripening and can be used to control fungal pathogens, spores and latent infections (John, 2008). Pineapple fruit should be subjected to hot water treatment of 53^0C temperature for 5-7 minutes to kill the mealy bug, scale insects, thrips, mites and to prevent from storage rots (Joy, 2014). Pineapple fruits dipped in hot water at 50^0C for 1 minute had enhanced shelf life and quality (Reshma, 2014).

An in vitro study conducted in pineapple had proved that fruits dipped in hot water at 54^0C for 3 minutes were free of black rot disease caused by C. *paradoxa* when stored at 10^0C for 21 days. No significant difference was occurred between hot water treated and untreated controls with respect to flesh, shell colour of fruit, ascorbic acid levels and acidity. Mean ascorbic acid level was 18.8 mg in fruit stored at 10^0C whereas 9.3 mg in fruit stored at 28 ± 2^0C. A significant difference in total soluble solids (mean Brix of 14^0), occurred in hot water treated fruit compared with untreated fruit (mean Brix of 11.5^0) irrespective of storage temperature (Wijeratnam *et al.,* 2005).

Pre heat treatments decrease the enzyme catalysed browning and reduces some physiological changes related to browning and maintains fruit quality, thereby increasing the storability (Selvarajah *et al*., 1998). Pineapple *cv*. Mauritius fruit under low temperature of 10°C and 85% RH develops internal browning symptoms. During prolonged low temperature storage, post-harvest heat-treatment in the form of a hot water dip, induced fruit tolerance to cold injury and reduce internal browning. Pineapple fruits treated at 38°C for 60 minutes developed 70% less browning than untreated controls in the flesh regions (Weerahewa and Adikaram, 2005a). Hot water treatment was more effective in reducing bacterial population from surface of pineapple than 200 ppm chlorine and 10 ppm Aqua plus 5 (Har and Perera., 2013).

2.3.2 Hydro cooling

Washing in cold water can reduce the field heat, hence the storage life can be enhanced (John, 2008). Hydro cooled cashew apple fruit showed greater freshness, higher firmness and acidity, and slower losses of fresh weight loss and vitamin C (Sena *et al*., 2019).

Hydrocooling seems to be a viable method for rapid cooling of tomatoes. Tomatoes intermittently submerged in cold water 10-20 minutes followed by 30 second pauses absorbed significantly less water than those continuously submerged for 20 minutes and reduced associated risk of pathogen internalization (Vigneault *et al*., 2000).

In Peach, hydrocooling in combination with low temperature storage is considered as the best treatment maintaining fruit firmness due to the lowered respiration rate and the content of relevant carotenoids (Caprioli *et al.*, 2009).

Hydrocooling has found to be effective in delaying browning and enzymatic activity in litchi cv. Feizixiao. Hydrocooling for 30 minutes reduced the temperature of the pericarp by 6.2 ± 0.3 °C and delayed the polyphenol oxidase and peroxidase activity in the pericarp (Liang *et al*., 2013).

2.3.3 Sanitization

Efficiency of the sanitizers used to reduce microbial load generally depends upon the type of treatment, type and physiology of the target microorganisms, characteristics of produce surfaces, exposure tissue and concentration of sanitizer, pH and temperature.

Chlorine-based chemicals, especially liquid chlorine and hypochlorite, are probably the most widely used sanitizers for decontaminating fresh produce (Conway, 1982). Chlorinated compounds mainly hypochlorites are widely used in microbial control and have immense application in the food processing industry (Wei *et al*., 1985). Besides their economic benefits, hypochlorites are effective in inactivating microorganisms suspended in water and on non porus surfaces (Brackett, 1987).

Chlorine can be used as a disinfectant in the form of sodium hypochlorite solution or calcium hypochlorite powder in wash water. Calcium hypochlorite, beyond disinfection benefits, is used to improve the shelf life and disease resistance by adding calcium to the cell wall (Kumari, 2013).

Sodium hypochlorite has an excellent cleaning action and moreover it fulfills many requirements as the ideal disinfectant. The effectiveness of sodium hypochlorite in the disinfection processes depends on the concentration of available chlorine and the pH of the solution (Fukuzaki, 2006).

According to Balla and Farkas (2006) whole fresh fruits before processing are washed with water containing chemical sanitizing agents such as chlorine, chlorine dioxide, trisodium phosphate, hydrogen peroxide and organic acids to decontaminate the surface of the fruit with chlorine being the more effective chemical additives in reducing pathogenic or naturally occurring microorganisms by the order of 10 to 100 fold. Surface sanitization with 30 ppm sodium hypochlorite is most effective for enhancing shelf life of vegetables (Varghese, 2006).

Dufkova (2000) reported that sodium hypochlorite was the best antimicrobial agent in the washing bath for processed cabbage, carrot, onion and Chinese cabbage. Surface sanitization with sodium hypochlorite is effective in extending the shelf life of fresh-cut tomato (Hong and Gross, 2001). In minimally processed cabbage sanitization with sodium hypochlorite at 200 mg/l for ten minutes reduced microbial population (Fantuzzi and Pushmann, 2004).

Application of chlorine dioxide, hydrogen peroxide and sodium hypochlorite can reduce populations of total aerobic bacteria, yeasts and moulds on strawberry (Kim *et al*., 2010).

Papaya treated with 150 ppm sodium hypochlorite for 10 minutes had recorded highest shelf life, less physiological loss in weight and less microbial load (Jayasheela, 2014).

Surface sanitization with sodium hypochlorite at 120 ppm exhibited least number of bacterial population in mango, papaya pineapple and pomegranate. In pineapple 90 ppm sodium hypochlorite solution was selected as the best sanitising agent (Amith, 2012).

2.3.4 Ozonization

Ozone is one of the most important sanitizers used against a wide spectrum of microorganisms (Khadre *et al*., 2001). It is also reported to be efficient in reducing pesticide residues from the fresh produce (Glowacz *et al*., 2015).

Ozone is a highly effective sanitizer at concentrations of 0.5 to 2ppm (Suslow, 1998). It can be used as an antimicrobial agent for the treatment, storage and processing of fruits and vegetables in gaseous and aqueous phase (FDA, 2001). It decomposes to oxygen in a very short time and does not leave any toxic residues and is unstable in water (Rivera, 2005). Ozone treatment has a beneficial effect in extending the storage life of fresh produce such as cucumber, apples, grapes, oranges, pears and strawberries by reducing microbial populations and by oxidation of ethylene (Kim, 2007). Use of ozonated water may improve the quality characteristics of tomato fruits, which may reduce fruit damage and excessive softening (Rodoni *et al*., 2009).

Effectiveness of its action against microorganisms depends on the amount applied, its application method, type of material, target microorganisms and physiological state of bacteria cells at the time of treatment (Das and Kim, 2010).

The thermal treatment combined with ozonization controlled the inner rot of some fruits (Kechinski *et al*., 2012). Ozone application has been shown to reduce the number of microbes in some fruits and vegetables and is considered effective as common sanitizing agent (Sukarminah *et al*., 2017).

In oranges, ozone exposure had reduced ageing and weight loss more efficiently compared to those stored in a non-ozonized environment (Di-Renzo *et al*., 2004).

Kiwi fruits treated with ozone showed highest retention of TSS (12°B to 14°B) (Tavarini *et al*., 2008).

Papaya fruits treated with 2.5 ppm of ozone water had higher levels of TSS, ascorbic acid, antioxidant and reduced level of PLW (Tzortzakis and Chrysargyris, 2017). Papaya fruits treated with ozone upto 3.5 ppm had reported highest antioxidant activity (Ali *et al.,* 2014).

Amaranthus treated with 2 ppm ozonised water showed lowest PLW (George, 2015) highest percentage of microbial reduction, highest retention of vitamin C and anthocyanin content (Ambareesha, 2016).

Exposure of blueberries to 18 mg ozone for 10 minutes was found to be the most suitable treatment to reduce fungal decay without causing an excessive loss of weight along with cold storage. Exposure times beyond 15 minutes significantly increased physiological loss in weight and did not achieve greater fungal inhibition with respect to 10 and 15 minutes ozonized fruit (Jaramillo-sanchez *et al*., 2019).

2.4 Storage Studies

Storage is one of the components in value chain management practices which maintains food quality by retaining flavour, colour, texture and nutrients, while reducing the chance of contracting a food-borne illness. It also plays a vital role in reducing post harvest losses of edible commodities, by enhancing their storability and shelf-life. Refrigeration is the most widely used method for extending the postharvest life of fruits and vegetables and temperature and humidity control is one of the main tools for extending postharvest life. The physiological processes like respiration and ethylene production, leading to senescence are controlled by temperature and relative humidity (Wills *et al.*, 1998).

The optimal storage temperature of cashew apples without deteriorating the quality is 5^0C (Sena *et al.*, 2019). Sweet passion fruit, *Passiflora alata*, kept under refrigeration in a cold room at a temperature of 10^0C and relative humidity between 85% and 90% showed a maximum shelf life of 14 days compared to fruits stored under ambient condition (Rinaldi *et al*., 2019).

Cold storage temperature recommended for pineapple fruits at mature and ripened stage are 10-13^0C and 8-10^0C respectively both at 85-90% RH. It increases shelf life up to 4 weeks (Thompson, 1996).

The optimum temperature for storage of pineapple fruit is 10^0C (Jobling, 2000); but very often they are prepared, shipped and stored below 10^0C (Medina, 2004). Abdullah *et al*. (2009) stated that the optimal storage temperature for Malaysian pineapple is between 8 to 10^0C for a period of 3 to 5 weeks.

Quarter-yellow stage pineapples stored at 8^0C have a shelf life of approximately 3 weeks (Anon, 2002). Pineapple fruits when stored below 8^0C develop brown/ dull skin colour, water soaked flesh, wilting of crown and also failure to develop full flavour at room temperature (John, 2008). Pineapple fruits should be stored at 10^0C for better texture and flavour (Joseph-Adekunle *et al*., 2009). The storage of pineapple fruit at 8^0C is recommended for retention of better fruit quality by preventing chilling injury and decay (Sanchez *et al*., 2012). Pineapple fruit kept in cold storage at 8 ± 2^0C after packaging by keeping the crown in downward position had enhanced shelf life and quality (Reshma, 2014).

Temperature management is the most important factor to maintain vitamin C; losses are accelerated at higher temperatures and with longer storage durations (Lee and Kader, 2000). Internal browning is a physiological disorder that develops when pineapple fruit is exposed to low temperature during storage (Weerahewa and Adikaram, 2005 b) and the cultivar Mauritius is more susceptible than Kew.

Green fruit should be stored at 10^{0}C and 7.5^{0}C for sea-shipment and air transport respectively, with 85 to 95% RH for a storage life of two to three weeks (APEDA, 2015).

2.5 Biochemical changes during postharvest period of pineapple

Many changes occur in the chemical composition of pineapple fruits after harvest. Freshly harvested pineapple fruit contains significant portion of water (86%), 8g sugars, 0.5- 1.6g acids, 1g protein, 0.5 g ash, 0.1 g fat, some fibre and vitamins (Pongjanta *et al*., 2011).

The yellow flesh of pineapple fruit is best eaten when sugar content is 10-18% and 0.5-0.6% titratable acidity (Bartholomew *et al*., 2003). A mature pineapple fruit used for canning should have TSS 12% and acidity 0.5 to 0.6% (John, 2008). A minimum soluble solids content of 12% and a maximum acidity of 1% will be accepted by most consumers (Kumar *et al*., 2009).

Harvest maturity, harvesting method and post harvest operation affect the vitamin C content of fruits and vegetables (Kader, 1988). The vitamin C content of fruit varies from 10 to 25 mg/ 100g of pineapple (Pongjanta *et al*., 2011).

According to Medina and Garcia (2005) ascorbic acid should fall between 20 and 65 mg/100g of fresh weight, it varies with cultivar and stage of maturity. Fresh pineapple fruit contains an average ascorbic acid content of 24.8 mg/100g of fruit (Uckiah *et al.*, 2009).

A study conducted by Rai (2006) revealed that ascorbic acid of Mauritius fruit was decreased during storage which was more at ambient than at low temperature storage.

There was a gradual decrease in vitamin C content of pineapple fruit as the storage temperature increased (Hong *et al.*, 2013). The vitamin C content of fruits such as sour orange, mango, pine apple, orange and guava is higher when they are slightly immature, and declines as they reach peak ripeness (Muhammad *et al.*, 2014). Ascorbic acid content was slightly decreased in ripening stage of Mauritius pineapple fruits. A decline in the content of ascorbic acid was noticed with the advancement of storage period (Reshma, 2014).

Total soluble solid content of Mauritius pineapple increased at full ripening stage (Wijesinghe and sarananda, 2002). Rashmi *et al.* (2005) reported that TSS of Mauritius fruit was 14.5°B. A study conducted by Rai (2006) reported that TSS of Mauritius variety of pineapple increased during storage. During cold storage of summer pineapple TSS increased initially and then decreased during the course of storage period (Hong *et al.*, 2013). The total soluble solids value of pineapple varies from 13.3% - 15.3% (Hemalatha and Anbuselvi, 2013). During cold storage, TSS was found to increase during the initial period and then decreased during course of storage and it ranged from 17 to 18.3°brix (Reshma, 2014). During the storage of mature green pineapple fruits of cultivar Kew and MD-2 at ambient condition, TSS was found to increase during the storage period (Hossain *et al.*, 2018).

The acidity of Mauritius variety of pineapple ranged from 0.460-1.167 per cent (Latha *et al.*, 1990). The titratable acidity of pineapple declines during storage of harvested pineapple (Paull, 1993). The titrable acidity for the pineapple fruits ranged from 0.80% to 1.50% (Hemalatha and Anbuselvi, 2013). The titratable acidity of summer pineapple fruits reduced as storage temperature increased (Hong *et al.*, 2013). There was a decreasing trend in acidity during initial period of storage and then an increasing trend was observed and it varies from 0.68% - 0.85% during cold storage (Reshma, 2014). The titratable acidity of pineapple cultivar kew and MD-2 were found to decrease with increase in storage time (Hossain *et al.*, 2018).

Pineapple contains 12-15% sugar of which majority is in the form of sucrose and the rest are glucose and fructose (Masniza *et al.*, 2000). Sweetness is an indicator of fruit quality and it is highly correlated with ripeness in most fruit (Ersoy *et al*., 2007).

In Mauritius fruits total sugars and reducing sugars were 13.76 and 6.44 per cent respectively (Rashmi *et al*., 2005). Rai (2006) found that total sugar content of Mauritius fruit was increased during storage while reducing sugar decreased. He reported that temperature had a significant influence on the rate of depletion of reducing sugars during storage which was more in case of ambient than at low temperature storage. During the storage of summer pineapple fruits sucrose declined rapidly, with a more rapid decrease at higher temperature while fructose and glucose increased during storage (Hong *et al.*, 2013). A decreasing trend was observed in reducing, non-reducing and total sugars content of Mauritius variety of pineapple during the entire storage period (Reshma, 2014). During the storage of pineapple cultivars of Kew and MD-2 reducing sugar content of the fruits increased during storage while non reducing sugar decreased (Hossain *et al.*, 2018).

Materials and Methods

3. MATERIALS AND METHODS

The experiment entitled “Post harvest management practices in pineapple (*Ananas comosus* (L.) Merr.)” was conducted with the objective to standardize the post-harvest management practices in pineapple for improved fruit quality. The materials used and methodologies adopted for the investigation are described in this chapter.

3.1. Experimental site

The experiment was conducted at PG research lab of Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, during the year 2018 - 2020.

3.2. Selection of pineapple fruits

Pineapple fruits (var. Mauritius) were harvested with crown and two cm stalk from fields of pineapple growers of Thiruvananthapuram district at the following two maturity stages meant for distant and local market which were maintained as per the package of Practice Recommendations of Kerala Agricultural University (KAU, 2016).Fruits with uniform quality parameters *viz.*, size, weight and shape, without any pests, diseases, and other damages were selected for the experiment.

Stage 1: 0 -25% eyes predominantly yellow, meant for distant market

Stage 2: 25-50% eyes predominantly yellow, meant for local market

3.3. Details of the Experiment

The experiment was planned independently for the above two maturity stages.

The investigation was carried out as two different continuous experiments.

1. Effect of pre-treatments on shelf life
2. Effect of pre-treatment on storage stability of pineapple

3.3.1. Effect of pre-treatments on shelf life

Pineapple fruits harvested at two different maturity stages were subjected to the following different pre-treatments.

T_1: Hot water dip (50±2^{0}C for 1 minute)

T_2: Hydro cooling for 5 minutes

T_3: Sanitization (30ppm sodium hypochlorite solution for 10 minutes)

T_4: Ozonization (2ppm Ozone for 15 minutes)

T_5: Absolute control (without pre-treatment)

The pre-treated fruits were spread out to remove excess moisture and stored under ambient conditions without any specific packaging along with untreated fruits.

Total number of treatments - 5

Replication- 4

Design of experiment - CRD

3.3.1.1 Shelf life (days)

The shelf life of pineapple fruits was assessed as number of days from harvest till the fruits remained in consumer acceptable stage. Freshness assessment was done based on the physical appearance as judged by retention of quality, colour variation and shrivelling (Nanda *et al*., 2000).

3. 3.1.2 Physiological loss in weight (PLW)

Weight of pineapple fruit was recorded at three days interval till the end of shelf life and cumulative weight loss was calculated using the formula suggested by (Koraddi and Devendrappa, 2011) and expressed as percentage.

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

3. 3.1.3 Total microbial load

The quantitative assay of micro flora present in pre and post treated pineapple fruits was carried out by serial dilution spread plate technique (Somasegaran and Hoben, 1985). Nutrient agar and Rose Bengal Agar medium were used for the enumeration of bacterial and fungal population on the fruit surface respectively.

The separated pineapple fruit skin piece of one cm^2 area was added to 100 ml sterile distilled water and shaken thoroughly for 2 minutes to get 10^{-1} dilution. From this suspension, 100µl of the suspension was accurately pipetted into eppendroff tube containing 900µl of sterile distilled water to get 10^{-2} dilution. This procedure was repeated to get 10^{-3} dilution. Aliquotes of 100 µl from each of the dilutions were plated on to NA and RBA plates and incubated at 28°C.

Bacterial count was recorded from the next day of inoculation whereas fungal count was noted from three days after inoculation.

Number of microorganisms (bacteria and fungi) per cm^2 was calculated as per the following formula:

$$No. of\ colony\ forming\ units/cm^2 = \frac{Total\ number\ of\ colony\ formed\ X\ dilution\ factor}{Aliquot\ taken}$$

Based on the efficiency and economics in maintaining maximum shelf life, least PLW and microbial load, the best pre-treatment was selected for pineapple fruits harvested at two different maturity stages independently.

Plate 1. 0-25% eyes yellow (Stage1)

Plate 2. 25-50% eyes yellow (Stage 2)

3. a. Ozonization

3. b. Hot water treatment

Plate 3. Pre-treatments of pineapple fruits

3.3.2. Effect of pre-treatment on storage stability of pineapple

The experiment was conducted as two independent experiments separately for two different maturity stages.

Harvested pineapple fruits of two different maturity stages were subjected to the best pre-treatment selected from the previous experiment (3.3.1). The pre-treated fruits were stored under different conditions along with the untreated fruits to study the influence of pre-treatment and storage on fruit quality.

T_1- Pre-treated fruits stored under low temperature (24^0C)

T_2- Pre-treated fruits stored under ambient temperature (32^0C)

T_3- Untreated fruits stored under low temperature (24^0C)

T_4- Untreated fruits stored under ambient temperature (32^0C)

Average temperature and relative humidity of ambient condition during storage mentioned in Appendix II.

Total number of treatments - 4

Replication- 4

Design of experiment - CRD

The stored fruits were evaluated for the following quality parameters.

3. 3.2.1 Shelf life

Shelf life of stored fruits were estimated as in 3.3.1.1

3.3.2.2 Physiological loss in weight (PLW)

Physiological loss in weight of stored pineapple fruits were estimated as mentioned in 3.3.1.2

3. 3.2.3 Chemical quality parameters

The following chemical quality parameters of the treated and untreated fruit stored under different conditions were analyzed initially at the time of storage and at three days intervals till the end of shelf life.

TSS

Total Soluble Solids (TSS) of pineapple fruits stored under different conditions were recorded using a digital refractometer (Atago-0 to 53 %) and expressed in degree brix (^{0}B).

Acidity

The method described by Ranganna (1986) was followed to determine titrable acidity.

Five gram of pineapple fruit pulp was ground using a mortar and pestle, added 100 mL distilled water, boiled for 30 minutes, the solution was filtered using muslin cloth and made up to 100 mL with distilled water. Twenty five mL solution was taken, mixed with 25 mL of distilled water and three drops of phenolphathalein indicator was added to it. This was titrated against 0.1N NaOH until the pink colour was attained. The acidity of pineapple was expressed in terms of citric acid equivalent using following formula.

$$Acidity = \frac{\begin{array}{c}(Titre\ value\ X Normality\ of\ NaOH(0.1N) X\\ Volume\ make\ up(100\ mL) X\\ Equivelent\ weight\ of\ citric\ acid\big((0.064)\big)\end{array}}{Volume\ of\ aliqot\ (25mL) X\ Weight\ of\ sample\ (5g)}$$

Reducing sugars

The titrimetric method of Lane and Eynon described by Ranganna (1986) was adopted for the estimation of reducing sugar in pineapple.

Twenty five gram of pineapple fruit pulp was ground using a mortar and pestle, and made up to 100 mL with distilled water. Neutralization was done with 1 N NaOH, 2 mL neutral lead acetate was added and kept for 10 minutes after shaking. Excess lead acetate was removed by addition of 2 mL potassium oxalate, the solution was filtered and made up to required volume to produce a clarified solution.

Fehling's solution A and B, 5 mL each were pipetted out, added 50 mL of distilled water and was transferred into a 250 mL conical flask. The burette was filled with the clarified sample and was then added drop by drop to the Fehling's solution. When blue colour of the Fehling's solution changed, three drops of methylene blue indicator was added and the titration was completed till a brick red colour formed. Percentage of reducing sugar was estimated according to the given formula

$$Reducing\ Sugar(\%) = \frac{Glucose\ Eq.(0.05)\ X\ Total\ volume\ made\ up(mL)}{Titre\ value(mL)\ X\ Weight\ of\ the\ sample}$$

Total Sugar (%)

The total sugar content in pineapple was expressed as percentage in terms of invert sugar (Ranganna, 1986).

Twenty five mL of clarified sample solution prepared for the estimation of reducing sugar was pipetted into 250mL conical flask to which distilled water 50 mL and citric acid (5 g) were added. The solution was boiled for 10 minutes to complete the inversion, cooled, and neutralized with 1N NaOH using phenolphthalein indicator and was made up to required volume. Fehling's solutions A and B, 5 mL each were pipetted and 50 mL distilled water was added and boiled vigorously. The burette was filled with clarified fruit sample and added to the boiling Fehling solution drop by drop until the blue colour faded. When the blue colour of the solution changed, 3 drops of methylene blue indicator were added and the titration was completed till the indicator was completely discoloured and a brick red colour developed.

$$Total\ Sugar = \frac{\begin{array}{c}Glucose\ Eq.(0.05) X\ Total\ volume\ made\ up(mL) X \\ Volume\ made\ after\ inversion(mL)\end{array}}{\begin{array}{c}Titre\ value(mL) X\ Weight\ of\ pulp\ taken(g) X \\ Aliquot\ taken\ for\ inversion(mL)\end{array}} X\ 100$$

Non Reducing Sugar (%)

The observations under total sugar and reducing sugar were used for estimating non reducing sugar based on the procedure suggested by and expressed as percentage on fresh weight basis.

Non reducing sugar = Total sugar – Reducing sugar

Vitamin C (mg 100g^{-1})

Vitamin C content in pineapple was estimated by the titrimetric method described by Ranganna (1986) using 2, 6-dichloro phenol indophenol (DCPIP) dye (expressed as mg/100g).

Five gram of pineapple fruit was made into pulp with 4% oxalic acid and made up to a known volume (100 mL) and centrifuged. The supernatant was collected and 5mL of the aliquot was pipetted into a conical flask to which 10mL of 4% oxalic acid was added. This was titrated against 2, 6-dichlorophenol indophenol dye solution, until the end point of pink colour (V_2) was attained, which persisted for a few minutes. Vitamin C was estimated as follows:

$$Vitamin\ C\ (mg\ 100g^{-1}) = \frac{\begin{array}{c} Titrevalue(V1)XDye\ factorX \\ Volume\ made\ up(mL) \end{array}}{\begin{array}{c} Aliquot\ of\ extract\ taken(mL)X \\ Weightof\ sample(g) \end{array}}$$

3. 3.2.4. Organoleptic parameters (hedonic rating)

Sensory quality parameters of the stored pineapple fruits were evaluated initially and at regular intervals till they lost their shelf life by conducting organoleptic scoring/hedonic rating performed by a 30 member semi- trained panel. The panel constituted the research students and staff members of College of Agriculture, Vellayani and they were asked to score the fruit for different sensory attributes viz. colour, texture, appearance, flavour and taste on a numerical scoring method (Amerine *et al*., 1965) using a nine point hedonic scale (Appendix I) in descending order of acceptability, which were briefly described to the panel members before evaluation.

Like extremely -9

Like very much -8

Like moderately- 7

Like slightly- 6

Neither like nor dislike- 5

Dislike slightly – 4

Dislike moderately -3

Dislike very much -2

Dislike extremely-1

3. 3.3. Statistical Analysis

The data generated from each experiment were tabulated and analysed statistically using analysis of variance (ANOVA). The treatment at final stage were compared using two sample case t-test The sensory score of the fruits were statistically analysed using Kruskall-Wallis test (Chi- Square value) and ranked (Shamrez *et al.,* 2013).

Results

4. RESULTS

The experimental data collected from the study "Postharvest management practices in pineapple (*Ananas comosus* (L.) Merr.)" were analyzed statistically, the results tabulated and are presented in this chapter.

The investigation was carried out as two continuous experiments *viz.*, evaluation of effect of pre-treatments on shelf life of pineapple and evaluating the effect of selected pretreatment and storage temperature on storage stability of pineapple fruit.

As the whole experiment was conducted independently for two maturity stages *viz.*, stage1 (0-25% eyes predominantly yellow) and stage 2 (25-50% eyes predominantly yellow) meant for distant market and local market respectively, the results are also presented independently for two maturity stages.

4.1. Effect of pre-treatments on shelf life of pineapple

Pineapple fruits were assessed to study the effect of different pre-treatments on shelf life of pineapple fruits.

4.1.1. Stage 1. (0- 25% eyes predominantly yellow) for distant market

The results of the effect of pre-treatment on the shelf life of stage 1 pineapple fruit with 0- 25% eyes predominantly yellow, meant for distant market are described below

4.1.1.1 Shelf life (days)

Shelf life of stage 1 pineapple fruits as influenced by different pre- treatments are shown in Table 1.

Maximum shelf life (15.2 days) was recorded by pineapple fruits treated with hot water dip (T_1), which was on par with the fruits sanitized using 30 ppm sodium hypochlorite solution for 10 minutes (T_3) with 15 days shelf life.

The least shelf life (11.4 days) was recorded by the untreated fruits which was on par with the fruits subjected to hydro cooling for 5 minutes with 12.2 days shelf life.

4.1.1.2 Physiological loss in weight (%)

Effect of pre-treatments on PLW of pineapple fruits with 0- 25% eyes yellow stage meant for distant market recorded at three days interval is depicted in Table 2.

After 9 days of storage minimum mean value for PLW (4.91%) was recorded when fruits were given hot water dip (T_1) which was followed by samples treated with 30ppm sodium hypochlorite solution (5.42%). The highest loss in physiological weight (11.14%) was recorded when fruits were stored without any pre-treatments (T_5) and it was significantly different from all the other treatments.

Physiological loss in weight was significantly influenced by the days of storage. PLW of all pineapple fruits increased with storage period with 4.05% on 3rd of storage to 7.76% on 6th and 11.18% on 9th day of storage.

Pineapple treated with hot water (T_1) recorded the lowest physiological loss in weight (1.69%) on 3rd of storage which was followed by fruits sanitized with 30ppm sodium hypochlorite solution for 10 minutes (T_3) (2.91%). The highest loss in weight (6.10%) was recorded by T_5 (absolute control).

Loss in weight was the lowest (5.07%) in fruits subjected to sanitization with 30ppm sodium hypochlorite solution for 10 minutes which was on par with fruits treated with hot water dip after 6th day of storage (T_1) (5.43%) .The highest physiological loss in weight (9.73%) was noticed in untreated fruits (T_5) which was on par with the hydro cooled fruits (T_2) (9.62%) and fruits subjected to ozonisation with 2ppm ozone for 15 minutes with 8.97% PLW.

On 9th day of storage, the lowest loss in weight (7.60%) was recorded in fruits treated with hot water (T_1) which was on par with fruits sanitized with 30ppm sodium hypochlorite solution for 10 minutes (8.27%). The highest physiological loss in weight (17.60%) was recorded in untreated pineapple fruits. (T_5)

Untreated pineapple fruits were discarded after 9 days of storage due to spoilage and comparison of PLW was made between treated fruits.

On 12th day of storage, fruits subjected to sanitization with 30 ppm sodium hypochlorite solution for 10 minutes (T_3) recorded the lowest PLW (10.35%) which was on par with fruits treated with hot water (10.41%) and the highest physiological loss in weight (14.02%) was noticed by T_2 (hydrocooling for 5 minutes) which was on par with fruits subjected to ozonisation with 2 ppm ozone for 15 minutes (T_4) with 12.82% PLW.

Fruits subjected to ozonisation and hydrcooling were discarded after 12 days of storage due to spoilage.

On 15th day of storage, fruits treated with hot water recorded a lower PLW (12.33%) which was followed by fruits subjected to sanitization with 30ppm sodium hypochlorite solution for 10 minutes (T_3) (15.13%).

Table 1. Effect of pre-treatments on shelf life in stage 1 pineapple fruit

Pre-treatments	Shelf life (days)
T_1 (Hot water dip)	15.2
T_2 (Hydro cooling)	12.2
T_3 (Sodium hypochlorite solution)	15.00
T_4 (Ozonisation)	13.2
T_5 (No treatments)	11.4
CD (0.05) - 1.173 SE ± (m) - 0.395	

Table 2. Effect of pre-treatments on physiological loss in weight (%) of stage 1 pineapple fruit

Pre-treatments	Physiological loss in weight (%)					
	Days after storage			Treatment mean	12	15
	3	6	9			
T_1 (Hot water dip)	1.69(1.64)	5.43(2.53)	7.60(2.93)	4.91(2.37)	10.41(3.37)	12.33(3.65)
T_2 (Hydro cooling)	4.68(2.38)	9.62 (3.26)	11.32(3.51)	8.54(3.05)	14.02(3.87)	-
T_3(Sodium hypochlorite)	2.91(1.97)	5.07(2.46)	8.27(3.04)	5.42(2.49)	10.53(3.37)	15.13(4.02)
T_4(Ozonization)	4.86(2.42)	8.97(3.15)	11.12(3.48)	8.31(3.02)	12.82(3.72)	-
T_5 (No treatments)	6.10(2.66)	9.73(3.27)	17.60(4.31)	11.14(3.41)	-	-
Days mean	4.05(2.21)	7.76(2.93)	11.18(3.45)			
	SE± (m)	CD (0.05)			CD - 0.172	P value – 0.000169
Treatments (T)	- 0.038	0.108			SE(m) - 0.057	
Days (D)	-0.029	0.084				
Treatments (T) × Days (D)	- 0.066	0.187				
(Values in parenthesis are the square root transformed values)						

4.1.1.3 Total Microbial Load

The total microbial load on the surface of the pineapple fruits were estimated before and after treatments and shown in Table 3. Microbial count on fruits was seen decreased after pretreatments.

Minimum bacterial count (4.79 log cfu/cm^2) was noticed in pineapple fruits subjected to hot water dip treatment (T_1) which was on par with fruits subjected to 30ppm sodium hypochlorite solution for 10 minutes (T_3) with bacterial count of 4.89 log cfu/cm^2. The maximum bacterial count (5.39 log cfu/cm^2) was noticed in untreated fruits (T_5).

Minimum fungal count (3.03 log cfu/cm^2) was noticed in pineapple fruits dipped in hot water (T_1) which was on par with fruits sanitized with 30ppm sodium hypochlorite solution for 10 minutes(3.14 log cfu/cm^2) (T_3). The maximum fungal count (3.88 log cfu/cm^2) was noticed in untreated fruits (T_5).

Pineapple fruits treated with hot water dip at 50 ± 2^0C for one minute had maximum shelf life (15.2 days) with minimum physiological loss in weight (4.91%) after 9^{th} day of storage. Least bacterial (4.79 log cfu/cm^2) fungal count (3.03 log cfu/cm^2) were also observed in hot water treated fruits.

The fruits sanitized using 30 ppm sodium hypochlorite solution for 10 minutes was equally effective with 15 days shelf life, 5.42% PLW, with minimum bacterial count (4.89 log cfu/cm^2) and fungal count (3.14 log cfu/cm^2).

The least shelf life (11.4 days), highest loss in physiological weight (11.14%) with maximum bacterial (5.39 log cfu/cm^2) and fungal count (3.88 log cfu/cm^2) were noticed in untreated fruits.

Table 3. Effect of pre-treatments on microbial load in stage 1 pineapple fruit

Pre-treatments	Microbial load(Log colony forming units/cm^2)			
	Bacteria×10^4 cfu/cm^2		Fungi×10^2 cfu/cm^2	
	Before treatment	After treatment	Before treatment	After treatment
T_1 (Hot water dip)	5.39	4.79	3.88	3.03
T_2 (Hydro cooling)		5.25		3.67
T_3 (Sodium hypochlorite solution)		4.89		3.14
T_4 (Ozonisation)		5.09		3.37
T_5 (No treatments)		5.39		3.88
CD (0.05)		0.103		0.112
SE± (m)		0.035		0.038

Based on efficiency and economics in maintaining highest shelf life with least PLW and microbial load, hot water dip at 50± 2^{0}C for one minute was selected as the best pre-treatment for stage 1 pineapple with 0- 25% eyes predominantly yellow, which is meant for distant market.

4.1.2. Stage 2. (25-50% eyes predominantly yellow) for local market

The results of the effect of pre-treatment on the shelf life of stage 2 pineapple fruit with 25- 50% eyes predominantly yellow, meant for local market are described below.

4.1.2.1 Shelf life (Days)

Shelf life of stage 2 pineapple fruits as influenced by different pre- treatments is shown in Table 4.

Maximum shelf life (12.6 days) was recorded by pineapple fruits treated with hot water dip (T_1), which was on par with the fruits sanitized using 30 ppm sodium hypochlorite solution for 10 minutes (T_3) and ozonized fruits (T_4). T_3 and T_4 had 12 and 11.4 days shelf life respectively.

The least shelf life (9.0 days) was recorded by the untreated fruits which was on par with the fruits subjected to hydro cooling for 5 minutes with 10.2 days shelf life.

4.1.2.2 Physiological loss in weight (%)

Effect of pre-treatments on PLW of pineapple fruits with 25%-50% eyes yellow stage meant for local market recorded at three days interval is depicted in Table 5.

After 9 days of storage minimum mean value for PLW (3.58%) was recorded when fruits were given hot water dip (T_1) which was on par with the samples treated with 30ppm sodium hypochlorite solution (4%). The highest loss in physiological weight (5.73%) was recorded when fruits were stored without any pre-treatments (T_5) and it was significantly different from all the other treatments.

Physiological loss in weight was significantly influenced by the days of storage. PLW of all pineapple fruits increased with storage period with 2.51% on 3^{rd} of storage to 4.65% on 6^{th} and 7.01% on 9^{th} day of storage.

Pineapple treated with hot water (T_1) recorded the lowest physiological loss in weight (1.78%) on 3^{rd} of storage which was on par with the fruits subjected to ozonization with 2ppm ozone for 15 minutes (T_4) with 2.02% PLW and fruits sanitized with 30ppm sodium hypochlorite solution for 10 minutes (T_3) (2.3%). The highest loss in weight (3.52%) was recorded by T_5 (absolute control).

Loss in weight was the lowest (3.87%) in hot water dip treatment after 6^{th} day of storage (T_1) which was on par with fruits subjected to sanitization with 30 ppm sodium hypochlorite solution for 10 minutes (3.88%) and T_4 (Ozonization with 2 ppm Ozone for 15 minutes) (4.66%). The highest physiological loss in weight (5.81%) was noticed in untreated fruits (T_5) which was on par with the hydro cooled fruits with 5.00%PLW.

On 9^{th} day of storage, the lowest loss in weight (5.08%) was recorded in fruits treated with hot water (T_1) which was on par with fruits sanitized with 30ppm sodium hypochlorite solution for 10 minutes (5.83%). The highest physiological loss in weight (8.94%) was recorded in hydro cooled fruits which was on par with untreated pineapple fruits (7.86%).

Untreated pineapple fruits were discarded after 9 days of storage due to spoilage and comparison of PLW was made between treated fruits.

On 12^{th} day of storage, fruits dipped in hot water (T_1) recorded a lower PLW (6.27%) which was followed by T_3 (Sanitization with 30 ppm sodium hypochlorite solution for 10 minutes) with 9.29% PLW.

Table 4. Effect of pre-treatments on shelf life in stage 2 pineapple fruit

Pre-treatments	Shelf life (days)
T_1 (Hot water dip)	12.6
T_2 (Hydro cooling)	10.2
T_3 (Sodium hypochlorite solution)	12.00
T_4 (Ozonisation)	11.4
T_5 (No treatments)	9.00
CD (0.05) - 1.953 SE± (m) - 0.657	

Table 5. Effect of pre-treatments on physiological loss in weight (%) of stage 2 pineapple fruit

Pre-treatments	Physiological loss in weight (%)				
	Days after storage			Treatment mean	12
	3	6	9		
T_1 (Hot water dip)	1.78(1.66)	3.87(2.20)	5.08(2.46)	3.58(2.11)	6.27(2.69)
T_2 (Hydro cooling)	2.94(1.98)	5.00(2.45)	8.94(3.15)	5.63(2.53)	-
T_3 (Sodium hypochlorite solution)	2.30(1.82)	3.88(2.21)	5.83(2.61)	4.00(2.21)	9.29(3.21)
T_4 (Ozonisation)	2.02(1.74)	4.66(2.37)	7.32(2.88)	4.67(2.33)	-
T_5 (No treatments)	3.52(2.13)	5.81(2.61)	7.86(2.98)	5.73(2.57)	_
Days mean	2.51(1.86)	4.65(2.37)	7.01(2.82)		
	SE± (m)	CD (0.05)			P value – 8.72 x 10^{-6}
Treatments (T)	- 0.038	0.108			
Days (D)	-0.030	0.084			
Treatments (T) × Days (D)	- 0.066	0.188			
(Values in parenthesis are the square root transformed values)					

4.1.2.3 Total Microbial Load

The total microbial load on the surface of the pineapple fruits were estimated before and after treatments and shown in Table 6. Microbial count on fruits was seen decreased after pretreatments.

Minimum bacterial count (5.02 log cfu/cm^2) was noticed in pineapple fruits subjected to hot water dip treatment (T_1) which was on par with fruits subjected to 30 ppm sodium hypochlorite solution for 10 minutes (T_3) and ozonized fruits (T_4) with bacterial count of 5.14 and 5.34 log cfu/cm^2 respectively. The maximum bacterial count (5.69 log cfu/cm^2) was noticed in untreated fruits (T_5).

Minimum fungal count (3.14 log cfu/cm^2) was noticed in pineapple fruits dipped in hot water (T_1) which was on par with fruits sanitized with 30 ppm sodium hypochlorite solution for 10 minutes(3.46 log cfu/cm^2) (T_3). The maximum fungal count (3.69 log cfu/cm^2) was noticed in untreated fruits (T_5).

Pineapple fruits treated with hot water dip at 50 ± 2^0C for one minute had maximum shelf life (12.6 days) with minimum physiological loss in weight (3.58%) on 9th day of storage. Least bacterial (5.02 log cfu/cm^2) fungal count (3.14 log cfu/cm^2) were also observed in hot water treated fruits.

The fruits sanitized using 30 ppm sodium hypochlorite solution for 10 minutes was equally effective with 12 days shelf life, 4% PLW, with minimum bacterial count (5.14 log cfu/cm^2) and fungal count (3.46 log cfu/cm^2).

The least shelf life (9.0 days), highest loss in physiological weight (5.73%)with maximum bacterial (5.69 log cfu/cm^2) and fungal count (3.69 log cfu/cm^2) were noticed in untreated fruits.

Table 6. Effect of pre-treatments on microbial load in stage 2 pineapple fruit

Pre-treatments	Microbial load(Log colony forming units/cm^2)			
	Bacteria×10^4cfu/cm^2		Fungi×10^2 cfu/cm^2	
	Before treatment	After treatment	Before treatment	After treatment
T_1 (Hot water dip)	5.69	5.02	3.69	3.14
T_2 (Hydro cooling)		5.36		3.66
T_3 (Sodium hypochlorite solution)		5.14		3.46
T_4 (Ozonisation)		5.34		3.59
T_5 (No treatments)		5.69		3.69
CD (0.05)		0.320		0.351
SE± (m)		0.108		0.118

Based on efficiency and economics in maintaining highest shelf life with least PLW and microbial load, hot water dip at 50± 2^0C for one minute was selected as the best pre-treatment for stage 2 pineapple with 25 -50% eyes predominantly yellow, which is meant for local market.

4. 2. Effect of pre-treatment on storage stability of pineapple

Pineapple fruits harvested at stage 1 and stage 2 maturity stages were independently subjected to the selected pre-treatment, *viz.*, hot water dip at 50± 2^0C for one minute and stored under two storage temperatures along with untreated fruits. The stored fruits were subjected to evaluation of physiological, chemical and sensory quality parameters.

4.2.1. Stage 1. (0- 25% eyes predominantly yellow) for distant market

The results of the evaluation of the effect of selected pretreatment and storage temperature on storage stability of stage 1 pineapple fruit with 0-25% eyes predominantly yellow, meant for distant market are described below.

4.2.1.1 Shelf life (Days)

Effect of pre-treatment and storage temperature on shelf life of stage 1 pineapple (0- 25% eyes predominantly yellow) is depicted in Table 7.

The highest shelf life of 21.25 days was recorded for hot water treated fruits stored at low temperature (T_1) followed by hot water treated fruits stored under ambient temperature (T_2) with 15.75 days. The untreated fruits stored under ambient temperature (T_4) recorded the lowest shelf life of 12 days followed by untreated fruits stored at low temperature with 13.75 days.

Table 7. Effect of pre-treatment and storage temperature on Shelf life of stage 1 Pineapple fruit

Treatments	Shelf life (days)
T_1 (Hot water treated fruits stored at low temperature)	21.25
T_2 (Hot water treated fruits stored under ambient temperature)	15.75
T_3(Untreated fruits stored at low temperature)	13.75
T_4(Untreated fruits stored under ambient temperature)	12.00
SE± (m) - 0.462 CD (0.05) - 1.44	

4.2.1.2 Physiological loss in weight (PLW) (%)

Effect of pre-treatment and storage temperature on Physiological Loss in Weight (PLW) (%) of stage 1 pineapple is represented in Table 8. Physiological loss in weight of stage 1 pineapple fruits showed significant difference between the treatments as well as between days of storage.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) had least PLW (4.53%) and untreated fruits stored at ambient temperature had highest (12.29%) PLW.

Hot water treated fruits stored at low temperature (T_1) had least PLW (2.01%) during 3rd day of storage and untreated fruits stored under ambient temperature had highest PLW with 3.80% weight loss.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) had least PLW through the storage period with 2.86%, 5.75% and 7.49% PLW during 6th, 9th and 12th day of storage respectively. Pre-treated fruits stored under ambient temperature (T_2) were second best next to T_1 throughout storage. The highest weight loss was observed in untreated fruits stored under ambient temperature (T_4) at 3rd (3.80%), 6th (10.94%), 9th (15.76%) and at 12th (18.64%) day of storage.

Physiological Loss in Weight (%) of stage 1 pineapple increased during storage from 2.97% on 3rd day of storage to 6.76%, 10.40% and 12.40% after 6th, 9th and 12th day of storage.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage and hence discarded. Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a lower loss in weight (10.62%) on 15th day of storage, followed by pre-treated fruits stored under ambient temperature (T_2) with 14.76% PLW.

Table 8. Effect of pre-treatment and storage temperature on Physiological Loss in Weight (%) of stage 1 pineapple fruit

Treatments	Physiological Loss in Weight (%)							
	Days after storage							
	3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	2.01 (1.73)	2.86 (1.96)	5.75 (2.60)	7.49 (2.91)	4.53 (2.30)	10.62 (3.41)	12.78 (3.71)	14.09 (3.88)
T_2 (Hot water treated fruits stored under ambient temperature)	2.80 (1.89)	5.73 (2.56)	8.75 (3.10)	10.47 (3.37)	6.94 (2.73)	14.76 (3.97)	-	-
T_3(Untreated fruits stored at low temperature)	3.28 (2.07)	7.49 (2.91)	11.34 (3.51)	12.99 (3.74)	8.77 (3.06)	-	-	-
T_4(Untreated fruits stored under ambient temperature)	3.80 (2.19)	10.94 (3.45)	15.76 (4.09)	18.64 (4.43)	12.29 (3.54)	-	-	-
Days (D) Mean	2.97 (1.97)	6.76 (2.72)	10.40 (3.33)	12.40 (3.61)				
SE± (m) / CD(0.05) Treatments (T) - 0.065 / 0.187 Days (D) - 0.065 / 0.187 Treatments (T) × Days (D) - 0.131 / 0.374						P value – 0.00017		
(Value in parenthesis is the square root transformed value)								

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature had 12.78% and 14.09% loss in weight on 18th and 21st days of storage respectively.

4.2.1.3 Total Soluble Solids (TSS) (°Brix)

Effect of pre-treatment and storage temperature on TSS of stage 1 pineapple is illustrated in Table 9. Pineapple fruits had a TSS varying from 13.02°Brix to 13.10°Brix at the time of storage.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded the minimum mean TSS of 14.26°Brix which was on par with hot water treated fruits stored under ambient temperature with14.27°Brix. The maximum mean TSS of 15.43°Brix was observed in untreated fruits stored under ambient temperature (T_4).

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) had least TSS throughout the storage period which was on par with the fruits treated with hot water and stored under ambient temperature (T_2). Hot water treated fruits stored at low temperature (T_1) had least TSS at 3rd (13.55°Brix), 6th (13.84°Brix), 9th (14.55°Brix) and 12th (16.36°Brix) day of storage.

The highest TSS was observed in untreated fruits stored under ambient temperature (T_4) at 3rd (14.19°Brix), 6th (15.09°Brix) and 9th (15.91° Brix) and at 12th (18.87°Brix) day of storage. TSS of untreated fruits stored at low temperature was on par with these fruits during 3rd, 6th and 9th day of storage.

TSS of stage 1 pineapple fruits increased from 13.04°Brix to 17.07°Brix during storage. TSS of pineapple fruit was 13.84°Brix, 14.43°Brix, 15.20°Brix and 17.07°Brix after 3rd, 6th, 9th and 12th day of storage respectively.

Table 9. Effect of pre-treatment and storage temperature on TSS (°B) of stage 1pineapple fruit

Treatments	TSS (°B)								
	At the day of storage	Days after storage							
		3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	13.02	13.55	13.84	14.55	16.36	14.26	16.75	16.66	16.63
T_2 (Hot water treated fruits stored under ambient temperature)	13.05	13.62	13.89	14.59	16.19	14.27	17.52	-	-
T_3(Untreated fruits stored at low temperature)	13.01	14.00	14.92	15.74	16.85	14.90	-	-	-
T_4(Untreated fruits stored under ambient temperature)	13.10	14.19	15.09	15.91	18.87	15.43	-	-	-
Days (D) Mean	13.04	13.84	14.43	15.20	17.07				
SE± (m) CD(0.05) Treatments (T) - 0.097 0.275 Days (D) - 0.108 0.308 Treatments (T) × Days (D) - 0.217 0.615							P value - 0.021		

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage and hence discarded. Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded minimum TSS (16.75°Brix) on 15th day of storage which was followed by hot water treated fruits stored under ambient temperature (T_2) with17.52°Brix.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature recorded minimum TSS of 16.66°Brix and 16.63°Brix on 18th and 21st days of storage respectively.

4.2.1.4 Acidity (%)

The changes in acidity of stage 1 pineapple due to the effect of pre-treatment and storage temperature are outlined in Table 10. At the time of storage, acidity of the stage 1 pineapple fruits did not differ significantly and it ranged from 1.01% to 1.06%.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded the highest mean acidity of 0.91% while the lowest acidity of 0.69% was reported in untreated fruits stored under ambient temperature (T_4) after the storage of 12 days.

Though the interaction between treatment and days was non-significant, pineapple fruits pre -treated with hot water and stored at low temperature (T_1) recorded the highest acidity and untreated fruits stored under ambient temperature (T_4) exhibited the lowest acidity throughout the storage period.

Acidity of stage 1 pineapple fruits decreased from 1.04% at the time of storage to 0.92%, 0.80%, 0.68% and 0.56% after 3, 6, 9 and 12days after storage respectively.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage due to spoilage and hence discarded. Pineapple fruits

Table 10. Effect of pre-treatment and storage temperature on acidity (%) of stage 1 pineapple fruit

Treatments	Acidity (%)								
	At the day of storage	Days after storage							
		3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	1.06	1.00	0.92	0.83	0.74	0.91	0.65	0.59	0.54
T_2 (Hot water treated fruits stored under ambient temperature)	1.06	0.92	0.82	0.72	0.60	0.82	0.49	-	-
T_3(Untreated fruits stored at low temperature)	1.04	0.90	0.77	0.67	0.51	0.78	-	-	-
T_4(Untreated fruits stored under ambient temperature)	1.01	0.86	0.69	0.51	0.40	0.69	-	-	-
Days (D) Mean	1.04	0.92	0.80	0.68	0.56				

	SE± (m)	CD(0.05)
Treatments (T)	- 0.022	0.061
Days (D)	- 0.024	0.068
Treatments (T) × Days (D)	– 0.048	NS

P value- 0.045

pre-treated with hot water and stored at low temperature (T_1) recorded a higher acidity of 0.65% on 15th day of storage. This was followed by fruits treated with hot water and stored under ambient temperature (0.49%).

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature recorded acidity of 0.59% and 0.54% on 18th and 21st days of storage respectively.

4.2.1.5 Reducing sugar (%)

Effect of pre-treatment and storage temperature on reducing sugar (%) of stage 1 pineapple is depicted in Table 11.

Reducing sugar of the stage 1 pineapple fruits did not differ significantly among treatments at the beginning of storage and it ranged from 2.44% to 2.80%.

After 12 days of storage pineapple fruits pre -treated with hot water and stored at low temperature (T_1) recorded the lowest reducing sugar content of 4.36%. This was followed by hot water treated fruits stored under ambient temperature (T_2) with 5.18% reducing sugar, which was on par with untreated fruits stored at low temperature (5.45%). The highest reducing sugar of 6.11% was observed in untreated fruits stored under ambient temperature (T_4).

The lowest reducing sugar was recorded in hot water treated pineapple fruits stored at low temperature (T_1) while the highest reducing sugar was observed in untreated fruits stored under ambient temperature (T_4) throughout the storage period. Hot water treated fruits stored at low temperature (T_1) had the lowest reducing sugar at 3rd (2.94%), 6th (4.27%), 9th (5.35%) and 12th (6.80%) day of storage. T_1 was on par with T_2 on 3rd day of storage. Untreated fruits stored under ambient temperature (T_4) exhibited the highest reducing sugar at 3rd (4.48%), 6th (5.97%), 9th (7.74%) and at 12th (9.58%) day of storage.

Table 11. Effect of pre-treatment and storage temperature on reducing sugar (%) of stage 1 pineapple fruit

Treatments	Reducing sugar (%)								
	At the day of storage	Days after storage							
		3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	2.44	2.94	4.27	5.35	6.80	4.36	8.00	8.21	8.70
T_2 (Hot water treated fruits stored under ambient temperature)	2.57	3.38	5.07	6.41	8.45	5.18	9.32	-	-
T_3(Untreated fruits stored at low temperature)	2.73	3.77	5.22	6.73	8.79	5.45	-	-	-
T_4(Untreated fruits stored under ambient temperature)	2.80	4.48	5.97	7.74	9.58	6.11	-	-	-
Days (D) Mean	2.63	3.64	5.13	6.56	8.41				
SE± (m) / CD(0.05) Treatments (T) - 0.096 / 0.274 Days (D) - 0.108 / 0.306 Treatments (T) × Days (D) - 0.216 / 0.612							P value – 0.004		

Reducing sugar content of stage 1 pineapple fruits increased from 2.63% at the time of storage to 3.64%, 5.13%, 6.56% and 8.41% at 3, 6, 9 and 12days after storage respectively.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage due to spoilage and they were discarded. Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a lower reducing sugar 8.00% on 15th day of storage. This was followed by fruits treated with hot water and stored under ambient temperature (9.32%).

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature recorded reducing sugar content of 8.21% and 8.70% on 18th and 21st days of storage respectively.

4.2.1.6 Non reducing sugar (%)

The changes in non reducing sugar (%) of stage 1 pineapple due to the effect of pre-treatment and storage temperature are depicted in Table 12.

Non reducing sugar of stage 1 pineapple varied significantly among treatments. After 12 days of storage pineapple fruits pre- treated with hot water and stored at low temperature (T_1) recorded the highest non reducing sugar content of 6.09% followed by hot water treated fruits stored under ambient temperature (T_2) with 5.60%. The lowest non reducing sugar of 5.10% was observed in untreated fruits stored under ambient temperature (T_4).

The interaction between treatments and days of storage was non- significant. Even then the highest non reducing sugar was recorded in pineapple fruits pre- treated with hot water and stored at low temperature (T_1) and the lowest was observed in untreated fruits stored under ambient temperature (T_4) throughout the storage period.

Table 12. Effect of pre-treatment and storage temperature on non-reducing sugar (%) of stage 1 pineapple fruit

Treatments	Non reducing sugar (%)								
	At the day of storage	Days after storage							
		3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	6.81	6.57	6.13	5.78	5.18	6.09	4.61	4.30	3.77
T_2 (Hot water treated stored under ambient temperature)	6.71	6.34	5.78	5.03	4.16	5.60	3.71	-	-
T_3(Untreated fruits stored at low temperature)	6.57	5.99	5.66	4.83	4.12	5.43	-	-	-
T_4(Untreated fruits stored under ambient temperature)	6.47	5.80	5.30	4.47	3.44	5.10	-	-	-
Days (D) Mean	6.64	6.18	5.72	5.03	4.22				
SE± (m) / CD(0.05) Treatments (T) - 0.120 / 0.340 Days (D) - 0.134 / 0.380 Treatments (T) × Days (D) - 0.268 / NS							P value- 0.045		

Non reducing sugar content of stage 1 pineapple fruits showed significant difference among days of storage. At the initial day of storage, non reducing sugar of stage 1 pineapple fruits was 6.64% which was decreased to 6.18%, 5.72%, 5.03% and 4.22% after 3, 6, 9 and 12days after storage respectively.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage due to spoilage and hence discarded. Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a higher non reducing sugar of 4.61% on 15th day of storage. This was followed by fruits treated with hot water and stored under ambient temperature with 3.71% non- reducing sugars.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature recorded non reducing sugar content of 4.30% and 3.77% on 18th and 21st days of storage respectively.

4.2.1.7 Total Sugar (%)

Effect of pre-treatment and storage temperature on total sugar (%) of stage 1 pineapple is depicted in Table 13.

Total sugar of stage 1 pineapple fruits varied significantly between treatments and between days of storage. At the time of storage total sugar of the stage 1 pineapple fruits did not differ significantly among treatments and it ranged from 9.24% to 9.29%.

Pineapple fruits pre -treated with hot water and stored at low temperature (T_1) recorded the lowest mean total sugar content of 10.45% .This was followed by hot water treated fruits stored under ambient temperature (T_2) with 10.78%, which was on par with untreated fruits stored under ambient temperature (10.88%). The highest total sugar content of 11.21% was observed in untreated fruits stored under ambient temperature (T_4) after 12 days of storage.

The lowest total sugar content was observed in pineapple fruits pre- treated with hot water and stored at low temperature (T_1) throughout the storage period. T_1 was on par with T_2 and T_3 during the 3rd day and with T_2 during the 9th day of storage. The highest total sugar was observed in untreated fruits stored under ambient temperature (T_4) throughout the storage period.

Total sugar content of stage 1 pineapple fruits showed significant difference during the storage. At the initial day of storage total sugar of stage I pineapple fruit was 9.27% which was increased to 9.82%, 10.85%, 11.58% and 12.63% after 3, 6, 9 and 12days after storage respectively.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage due to spoilage and hence discarded. Though not significant, pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a lower total sugar of 12.61% on 15th day of storage.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature recorded total sugar content of 12.50% and 12.48% on 18th and 21st days of storage respectively.

4.2.1.8 Vitamin C (mg 100g^{-1})

The changes in vitamin C content of stage 1 pineapple due to the effect of pre-treatment and storage temperature are illustrated in Table 14.

At the time of storage vitamin C content of the stage 1 pineapple fruits did not differ significantly among treatments and ranged from 28.57 mg 100g^{-1} to 30.95 mg 100g^{1}.Vitamin C content of stored pineapple fruits of stage 1 maturity varied among treatments and among days of storage.

Pineapple fruits pre- treated with hot water and stored at low temperature (T_1) recorded the highest mean vitamin C content of 22.85 mg 100g^{-1} followed by hot water

Table 13. Effect of pre-treatment and storage temperature on total sugar (%) of stage 1 pineapple fruit

Treatments	Total sugar (%)								
	At the day of storage	Days after storage							
		3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	9.24	9.51	10.41	11.12	11.98	10.45	12.61	12.50	12.48
T_2 (Hot water treated fruits stored under ambient temperature)	9.28	9.72	10.85	11.44	12.61	10.78	13.03	-	-
T_3(Untreated fruits stored at low temperature)	9.29	9.76	10.88	11.56	12.90	10.88	-	-	-
T_4(Untreated fruits stored under ambient temperature)	9.27	10.28	11.28	12.21	13.01	11.21	-	-	-
Days (D) Mean	9.27	9.82	10.85	11.58	12.63				
	SE± (m)	CD(0.05)							
Treatments (T)	- 0.062	0.176					NS		
Days (D)	- 0.069	0.196							
Treatments (T) × Days (D)	- 0.139	0.393							

treated fruits stored under ambient temperature (T_2) with 21.18 mg $100g^{-1}$. The lowest vitamin C content of 15.47 mg $100g^{-1}$ was observed in untreated fruits stored under ambient temperature (T_4) after 12 days of storage. Vitamin C content of stage 1 pineapple fruits showed significant difference between the days of storage. At the initial day of storage vitamin C content of pineapple fruits was 29.76 mg $100g^{-1}$ which was decreased to 22.31, 18.74, 15.17 and 11.01 mg $100g^{-1}$ after 3rd, 6th, 9th and 12th days after storage respectively.

The highest vitamin C content was observed in stage 1 pineapple fruits pre-treated with hot water and stored at low temperature (T_1) while the lowest vitamin C was observed in untreated fruits stored under ambient temperature (T_4) throughout the storage period. Hot water treated fruits stored at low temperature (T_1) had the highest vitamin C content at 3rd (27.38 mg $100g^{-1}$), 6th (22.61 mg $100g^{-1}$), 9th (17.85 mg $100g^{-1}$) and 12th (15.47 mg $100g^{-1}$) day of storage. T_1 was on par with T_2 on 6th, 9th and 12th days of storage.

Untreated fruits stored under ambient temperature (T_4) showed the lowest vitamin C content at 3rd (17.85 mg $100g^{-1}$), 6th (14.28 mg $100g^{-1}$), 9th (10.71 mg $100g^{-1}$) and at 12th (4.76 mg $100g^{-1}$) day of storage.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 15th day of storage due to spoilage and discarded. Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a higher vitamin C content of 13.1 mg $100g^{-1}$ on 15th day of storage which was followed by hot water treated fruits stored under ambient temperature (T_2).

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 18th day of storage. Hot water treated fruits stored at low temperature recorded vitamin C content of 8.33 mg $100g^{-1}$ and 5.95 mg $100g^{-1}$ on 18th and 21st day of storage respectively.

Table 14. Effect of pre-treatment and storage temperature on vitamin C content (mg $100g^{-1}$) of stage 1 pineapple fruit

Treatments	Vitamin C (mg $100g^{-1}$)								
	At the day of storage	Days after storage							
		3	6	9	12	Treatment Mean	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	30.95	27.38	22.61	17.85	15.47	22.85	13.1	8.33	5.95
T_2 (Hot water treated fruits stored under ambient temperature)	29.76	23.80	20.23	17.85	14.28	21.18	7.14	-	-
T_3(Untreated fruits stored at low temperature)	28.57	20.23	17.85	14.28	9.52	18.09	-	-	-
T_4(Untreated fruits stored under ambient temperature)	29.76	17.85	14.28	10.71	4.76	15.47	-	-	-
Days (D) Mean	29.76	22.31	18.74	15.17	11.01				
SE± (m) CD(0.05) Treatments (T) - 0.476 1.350 Days (D) - 0.532 1.510 Treatments (T) × Days (D) – 1.065 3.019							P value – 0.017		

4.2.1.9 Fruit quality (sensory scoring)

Effect of pre-treatment and storage temperature on sensory parameters viz., appearance, flavour, texture, taste, flesh colour and overall acceptability of stage 1 pineapple (0-25% eyes predominantly yellow) was assessed using Kruskall-Walis chi square test.

Appearance

Appearance of stage 1 pineapple showed no significant difference between the treatments at the time of storage and till 6th day of storage. The treatments showed significant difference for appearance from 9th day of storage onwards (Table 15.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) had the highest mean score for appearance with 8.30 and 8.73 during 9th and 12th day of storage. Untreated fruits stored under ambient temperature (T_4) recorded the lowest mean score throughout storage period.

By 15th day of storage, all the untreated fruits were discarded due to spoilage and sensory analysis was done between the treated fruits only. Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the higher mean score for appearance (8.77) on 15th day of storage and had sensory scores of 7.99 and 7.37 on 18th and 21st days of storage respectively.

Flavour

Though there was no significant difference between treatments for sensory scores of flavour at the time of storage, significant difference was observed on 3rd, 6th, 9th and 12th day of storage. (Table16.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) had the highest mean scores for flavour and untreated fruits stored under ambient temperature

Table 15. Effect of pre-treatment and storage temperature on appearance of stage 1 pineapple fruit

Treatments	Mean sensory score for appearance on days after storage							
	0	3	6	9	12	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	7.93	8.10	8.17	8.30	8.73	8.77	7.99	7.37
T_2 (Hot water treated fruits stored under ambient temperature)	7.97	8.13	8.20	8.27	8.23	8.20	-	-
T_3 (Untreated fruits stored at low temperature)	7.90	7.90	8.13	8.20	8.20	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.83	7.83	7.97	8.13	7.27	-	-	-
KW value	0.08	1.43	1.50	18.46*	47.93*			
$\chi2$ (0.05)	7.81							

*Significant

Table 16. Effect of pre-treatment and storage temperature on flavour of stage 1 pineapple fruit

Treatments	Mean sensory score for flavour on days after storage							
	0	3	6	9	12	15	18	21
T_1 (Hot water treated fruits stored at low temperature	6.70	7.50	7.77	8.20	8.50	8.53	8.47	8.40
T_2 (Hot water treated fruits stored under ambient temperature)	6.50	7.37	7.47	7.50	8.27	8.23	-	-
T_3 (Untreated fruits stored at low temperature)	6.63	7.47	7.50	8.03	8.07	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	6.77	7.23	7.27	7.33	7.30	-	-	-
KW value	2.54	8.29*	9.74*	14.16*	33.51*			
$\chi2$ (0.05)	7.81							

*Significant

(T_4) recorded the lowest mean scores throughout storage period. After 12th day of storage all the untreated fruits were discarded due to spoilage and sensory analysis was done on 15th day of storage between treated fruits only.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean score for flavour, 8.50 on 12th day of storage. T1 had a flavour score of 8.53, 8.47 and 8.40 on 15th, 18th and 21st day of storage respectively.

Texture

Sensory score for texture showed no significant difference between treatments till 6th day of storage and significant difference was observed between treatments on 9th and 12th day of storage (Table 17.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) had recorded the highest mean scores for texture and untreated fruits stored under ambient temperature (T_4) recorded the lowest mean score throughout storage period.

By 15th day of storage, untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for texture (8.73) on 15th day of storage. T_1 recorded 8.40 and 8.33 mean score for texture on 18th and 21st day of storage respectively.

Taste

A significant difference for sensory score of taste was observed between treatments from 6th day of storage onwards (Table 18.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean score for taste 8.20, 8.43 and 8.50 on 6th, 9th and 12th day of storage respectively. It was observed that untreated fruits stored under ambient

Table 17. Effect of pre-treatment and storage temperature on texture of stage 1 pineapple fruit

Treatments	Mean sensory score for texture on days after storage							
	0	3	6	9	12	15	18	21
T_1 (Hot water treated fruits stored at low temperature	7.67	7.97	8.13	8.52	8.73	8.73	8.40	8.33
T_2 (Hot water treated fruits stored under ambient temperature)	7.63	7.93	7.93	8.03	8.07	7.30	-	-
T_3 (Untreated fruits stored at low temperature)	7.70	7.83	8.10	8.14	8.03	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.77	7.67	7.80	8.00	7.50	-	-	-
KW value	0.35	1.52	1.91	20.39*	20.71*			
$\chi 2$ (0.05)	7.81							

*Significant

Table 18. Effect of pre-treatment and storage temperature on taste of stage 1 pineapple fruit

Treatments	Mean sensory score for taste on days after storage							
	0	3	6	9	12	15	18	21
T_1 (Hot water treated fruits stored at low temperature	7.43	7.83	8.20	8.43	8.50	8.43	8.33	8.23
T_2 (Hot water treated fruits stored under ambient temperature)	7.40	7.70	7.73	8.00	8.27	8.13	-	-
T_3 (Untreated fruits stored at low temperature)	7.47	7.57	7.97	8.03	8.07	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.37	7.63	7.63	7.87	7.20	-	-	-
KW value	0.47	2.99	8.67*	9.82*	37.10*			
$\chi 2$ (0.05)	7.81							

*Significant

temperature (T_4) recorded the lowest mean score for taste on 6th (7.63), 9th (7.87) and 12th (7.20) day of storage.

After 12th day of storage untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only. Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for taste (8.43) compared to treated fruits stored under ambient temperature (8.13) on 15th day of storage.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded mean sensory score of 8.33 and 8.23 for taste after 18th and 21st days of storage respectively.

Flesh colour

Sensory score for flesh colour showed no significant difference between treatments at the time of storage and till 6th day of storage. Significant difference for flesh colour was noticed between treatments from 9th day of storage (Table 19.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean scores for flesh colour ie.,8.53 and 8.57 during 9th and 12th day of storage.

Untreated fruits stored under ambient temperature (T_4) recorded the lowest mean scores, 8.17 and 7.37 on 9th and 12th days of storage for flesh colour. After 12th day of storage untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for flesh colour (8.60) on 15th day of storage. It had 8.30 and 8.10 mean score for flesh colour after 18th and 21st days of storage respectively.

Table 19. Effect of pre-treatment and storage temperature on flesh colour of stage 1 pineapple fruit

Treatments	Mean sensory score for flesh colour on days after storage							
	0	3	6	9	12	15	18	21
T_1 (Hot water treated fruits stored at low temperature	7.90	8.13	8.17	8.53	8.57	8.60	8.30	8.10
T_2 (Hot water treated fruits stored under ambient temperature)	7.53	8.07	8.10	8.23	8.20	8.13	-	-
T_3 (Untreated fruits stored at low temperature)	7.70	8.00	8.07	8.20	8.13	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.73	7.97	8.03	8.17	7.37	-	-	-
KW value	2.79	0.49	0.85	12.41*	23.27*			
$\chi2$ (0.05)	7.81							

*Significant

Overall acceptability

Sensory scores for overall acceptability showed no significant difference between treatments at the time of storage and at 3rd and 6th days of storage. Significant difference for overall acceptability was observed between treatments from 9th day of storage (Table 20.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean scores (7.77 and 8.17) and untreated fruits stored under ambient temperature (T_4) recorded the lowest mean scores (7.23 and 7.00) during 9th and 12th days of storage.

After 12th day of storage all untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only. Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for overall acceptability (8.10) on 15th day of storage compared to treated fruits stored under ambient temperature.

Pineapple fruits treated with hot water and stored under low temperature (T_1) had mean overall acceptability scores of 8.07 and 8.03 on 18th and 21st days of storage respectively.

Table 20. Effect of pre-treatment and storage temperature on overall acceptability of stage 1 pineapple fruit

Treatments	Mean sensory score for overall acceptability on days after storage							
	0	3	6	9	12	15	18	21
T_1 (Hot water treated fruits stored at low temperature)	7.17	7.20	7.33	7.77	8.17	8.10	8.07	8.03
T_2 (Hot water treated fruits stored under ambient temperature)	7.13	7.17	7.23	7.37	8.00	7.47	-	-
T_3 (Untreated fruits stored at low temperature)	7.10	7.13	7.30	7.33	7.97	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.07	7.10	7.13	7.23	7.00	-	-	-
KW value	0.09	0.18	0.91	10.22*	8.29*			
$\chi 2$ (0.05)	7.81							

*Significant

4.2.2. Stage 2. (25-50% eyes predominantly yellow) for local market

The results of the evaluation of the effect of selected pretreatment and storage temperature on storage stability of stage 2 pineapple fruit with 25-50% eyes predominantly yellow, meant for local market are described below.

4.2.2.1 Shelf Life (Days)

Effect of pre-treatment and storage temperature on shelf life of stage 2 pineapple (25-50% eyes predominantly yellow) is depicted in Table 21.

The highest shelf life of 18.25 days was recorded for hot water treated fruits stored at low temperature (T_1) followed by hot water treated fruits stored under ambient temperature (T_2) with 12.75 days. The untreated fruits stored under ambient temperature (T_4) recorded the lowest shelf life of 10.5 days which was on par with untreated fruits stored at low temperature.

4.2.2.2. Physiological Loss in Weight (PLW) (%)

Effect of pre-treatment and storage temperature on Physiological Loss in Weight (PLW) (%) of stage 2 pineapple is shown in Table 22. Physiological loss in weight of stage 2 pineapple fruits showed significant difference among the treatments as well as between days of storage.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) had mean least PLW (2.48%) and untreated fruits stored at ambient temperature had highest PLW with 8.40% weight loss.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) had least PLW through the storage period. T_1 had least PLW at 3^{rd} (1.35%), 6^{th} (2.13%) and at 9^{th} (3.96) day of storage. Hot water treated fruits stored under ambient temperature (T_2) were second best next to T_1 throughout storage. The highest weight loss was observed in untreated fruits stored under ambient temperature (T_4) at 3^{rd} (3.51%), 6^{th} (8.58%) and at 9^{th} (13.11%) day of storage. Untreated fruits stored under ambient temperature (T_4)

Table 21. Effect of pre-treatment and storage temperature on shelf life of stage 2 pineapple fruit

Treatments	Shelf life (days)
T_1 (Hot water treated fruits stored at low temperature)	18.25
T_2 (Hot water treated fruits stored under ambient temperature)	12.75
T_3(Untreated fruits stored at low temperature)	11.5
T_4(Untreated fruits stored under ambient temperature)	10.5
SE± (m) - 0.729 CD (0.05) - 2.271	

Table 22. Effect of pre-treatment and storage temperature on Physiological Loss in Weight (%) of stage 2 pineapple fruit

Treatments	Physiological Loss in Weight (%)						
	Days after storage						
	3	6	9	Treatment Mean	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	1.35 (1.51)	2.13 (1.74)	3.96 (2.21)	2.48 (1.82)	5.32 (2.49)	7.42 (2.90)	8.64 (3.10)
T_2 (Hot water treated fruits stored under ambient temperature)	2.38 (1.84)	4.34 (2.31)	6.74 (2.77)	4.49 (2.31)	8.36 (3.06)	-	-
T_3(Untreated fruits stored at low temperature)	2.99 (2.00)	5.75 (2.59)	8.56 (3.09)	5.77 (2.56)	-	-	-
T_4(Untreated fruits stored under ambient temperature)	3.51 (2.12)	8.58 (3.09)	13.11 (3.76)	8.40 (2.99)	-	-	-
Days (D) Mean	2.56 (1.87)	5.20 (2.43)	8.09 (2.96)				
SE± (m) CD(0.05) Treatments (T) - 0.062 0.180 Days (D) - 0.054 0.156 Treatments (T) × Days (D) - 0.108 0.311					P value – 0.0381		
(Value in parenthesis is the square root transformed value)							

(3.51%) was on par with untreated fruits stored under low temperature (T_3) (2.99%) and hot water treated fruits stored under ambient temperature (T_2) (2.38%) at 3rd day of storage.

Physiological Loss in Weight (%) of stage 2 pineapple increased during storage from 2.56% on 3rd day of storage to 5.20% on 6th and 8.09% on 9th day of storage.

As untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 12th day of storage, they were discarded and comparison was made between fruits subjected to hot water treatment only. Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a lower loss in weight (5.32%) on 12th day of storage which was followed by hot water treated fruits stored under ambient temperature (T_2) with 8.36% PLW.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 15th day of storage. Hot water treated fruits stored at low temperature had 7.42% and 8.64% loss in weight on 15th and 18th days of storage respectively.

4.2.2.3 Total Soluble Solids (TSS) (°Brix)

Effect of pre-treatment and storage temperature on TSS of stage 2 pineapple is illustrated in Table 23. All the pineapple fruits had a similar TSS varying from 14.86°Brix to14.98°Brix at the time of storage.

TSS of stage 2 pineapple was significantly influenced by treatments and days of storage. Pineapple fruits pre- treated with hot water and stored at low temperature (T_1) recorded the minimum mean TSS of 15.78°Brix which was on par with hot water treated fruits stored under ambient temperature (T_2) with 15.82°Brix. The maximum TSS of 17.15°Brix was reported in untreated fruits stored under ambient temperature (T_4).

Pineapple fruits pre -treated with hot water and stored at low temperature (T_1) had least TSS which was on par with the fruits treated with hot water and stored under ambient temperature (T_2) throughout the storage period. Hot water treated fruits stored at low temperature (T_1) had least TSS at 3rd (15.59°Brix), 6th (16.10°Brix) and 9th (16.59 °Brix) day of storage. Pineapple fruits stored under ambient temperature (T_2) had TSS of 15.61 °Brix, 16.19 °Brix and 16.62 °Brix at 3rd, 6th and 9th day of storage.

The highest TSS was observed in untreated fruits stored under ambient temperature (T_4) at 3rd (16.64°Brix), 6th (17.18°Brix) and 9th (19.91°Brix) day of storage. TSS of untreated fruits stored at low temperature was on par with these fruits during 3rd and 6th day of storage

TSS of stage 2 pineapple fruits showed a significant difference during the storage period and it increased from 14.90 °Brix at the time of storage to 17.64 °Brix. TSS of pineapple fruit was 16.08 °Brix, 16.61 °Brix and 17.64 °Brix after 3rd, 6th and 9th day of storage respectively.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 12th day of storage and hence discarded. Comparison was made between fruits subjected to hot water treatment only.

The treatments were non-significant on 12th day of storage. However, pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded minimum TSS (17.21 °Brix) on 12th day of storage.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 15th day of storage. Hot water treated fruits stored at low temperature recorded the TSS of 17.11 °Brix and 17.09 °Brix on 15th and 18th days of storage respectively.

Table 23. Effect of pre-treatment and storage temperature on TSS (°B) of stage 2 pineapple fruit

Treatments	TSS (°B)							
	At the day of storage	Days after storage						
		3	6	9	Treatment Mean	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	14.86	15.59	16.10	16.59	15.78	17.21	17.11	17.09
T_2 (Hot water treated fruits stored under ambient temperature)	14.87	15.61	16.19	16.62	15.82	17.57	-	-
T_3(Untreated fruits stored at low temperature)	14.98	16.50	16.97	17.43	16.47	-	-	-
T_4(Untreated fruits stored under ambient temperature)	14.87	16.64	17.18	19.91	17.15	-	-	-
Days (D) Mean	14.90	16.08	16.61	17.64				
SE± (m)	CD(0.05)					NS		
Treatments (T) - 0.091	0.259							
Days (D) - 0.091	0.259							
Treatments (T) × Days (D) - 0.181	0.517							

4.2.2.4 Acidity (%)

The changes in acidity of stage 2 pineapple due to the effect of pre-treatment and storage temperature are outlined in Table 24.

Acidity of the stored pineapple fruits was significantly influenced by treatment and days of storage. At the time of storage, acidity of the stage 2 pineapple fruits were same varying from 0.81% to 0.88%.

Pineapple fruits pre -treated with hot water and stored at low temperature (T_1) recorded the highest mean acidity of 0.81% followed by hot water treated fruits stored under ambient temperature (T_2) with 0.70%. The lowest acidity of 0.53% was reported in untreated fruits stored under ambient temperature (T_4) after the storage of 9days which was on par with untreated fruits stored under low temperature with 0.6% acidity.

Though the interaction between treatment and days was non-significant, pineapple fruits pre -treated with hot water and stored at low temperature (T_1) recorded the highest acidity and untreated fruits stored under ambient temperature (T_4) exhibited the lowest acidity throughout the storage period.

Acidity of stage 2 pineapple fruits showed a significant difference during the storage and it decreased from 0.85% at the time of storage to 0.70%, 0.60% , and 0.48% after 3, 6 and 9 days of storage respectively.

Untreated fruits stored under low (T_3) and ambient (T_4) temperature were discarded on 12th day of storage due to spoilage and comparison was made between fruits subjected to hot water treatment. The treatments were non-significant on 12th day of storage. However, pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a higher acidity of 0.55% on 12th day of storage.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 15th day of storage. Hot water treated fruits stored at low

Table 24. Effect of pre-treatment and storage temperature on acidity (%) of stage 2 pineapple fruit

Treatments	Acidity (%)							
	At the day of storage	Days after storage						
		3	6	9	Treatment Mean	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	0.87	0.84	0.79	0.72	0.81	0.55	0.46	0.41
T_2 (Hot water treated fruits stored under ambient temperature)	0.88	0.70	0.64	0.58	0.70	0.46	-	-
T_3(Untreated fruits stored at low temperature)	0.81	0.68	0.53	0.37	0.60	-	-	-
T_4(Untreated fruits stored under ambient temperature)	0.84	0.56	0.45	0.27	0.53	-	-	-
Days (D) Mean	0.85	0.70	0.60	0.48				
	SE± (m)	CD(0.05)				NS		
Treatments (T)	- 0.030	0.085						
Days (D)	- 0.030	0.085						
Treatments (T) × Days (D)	- 0.060	NS						

temperature recorded acidity of 0.46% and 0.41% on 15th and 18th days of storage respectively.

4.2.2.5 Reducing sugar (%)

Effect of pre-treatment and storage temperature on reducing sugar (%) of stage 2 pineapple is depicted in Table 25.

Reducing sugar of stage 2 pineapple fruits was significantly influenced by pre-treatment and storage temperature. Reducing sugar of the stage 2 pineapple fruits did not differ significantly among treatments at the beginning of storage and it ranged from 3.08% to 3.49%.

After 9 days of storage pineapple fruits pre -treated with hot water and stored at low temperature (T_1) recorded the lowest mean reducing sugar content of 4.13% which was on par with hot water treated fruits stored under ambient temperature (T_2) with 4.25%. The highest reducing sugar of 5.63% was observed in untreated fruits stored under ambient temperature (T_4)

The lowest reducing sugar was recorded in pineapple fruits pre- treated with hot water and stored at low temperature (T_1) which was on par with fruits treated with hot water and stored under ambient temperature (T_2) while the highest reducing sugar was observed in untreated fruits stored under ambient temperature (T_4) throughout the storage period. Hot water treated fruits stored at low temperature (T_1) had the lowest reducing sugar at 3rd (3.83%), 6th (4.42%) and 9th (5.20%) day of storage. Untreated fruits stored under ambient temperature (T_4) exhibited the highest reducing sugar at 3rd (5.37%), 6th (6.38%) and 9th (7.27%) day of storage.

Reducing sugar content of stage 2 pineapple fruits increased from 3.25% at the time of storage to 4.35%, 5.13% and 6.03% after 3, 6 and 9 days of storage respectively.

Table 25. Effect of pre-treatment and storage temperature on reducing sugar (%) of stage 2 pineapple fruit

Treatments	Reducing sugar (%)							
	At the day of storage	Days after storage						
		3	6	9	Treatment Mean	12	15	18
T_1 (Hotwater treated fruits stored at low temperature)	3.08	3.83	4.42	5.20	4.13	5.96	6.43	6.78
T_2 (Hotwater treated fruits stored under ambient temperature)	3.12	3.87	4.54	5.48	4.25	6.51	-	-
T_3(Untreated fruits stored at low temperature)	3.32	4.35	5.18	6.16	4.75	-	-	-
T_4(Untreated fruits stored under ambient temperature)	3.49	5.37	6.38	7.27	5.63	-	-	-
Days (D) Mean	3.25	4.35	5.13	6.03				
	SE± (m)	CD(0.05)				NS		
Treatments (T)	- 0.090	0.256						
Days (D)	- 0.090	0.256						
Treatments (T) × Days (D)	- 0.180	0.513						

As the untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 12th day of storage due to spoilage, they were discarded and comparison was made between pre-treated fruits only.

Though non- significant, pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a lower reducing sugar 5.96% on 12th day of storage.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 15th day of storage. Hot water treated fruits stored at low temperature recorded reducing sugar content of 6.43% and 6.78% on 15th and 18th days of storage respectively.

4.2.2.6 Non reducing sugar (%)

The changes in non-reducing sugar (%) of stage 2 pineapple due to the effect of pre-treatment and storage temperature are outlined in Table 26.

Non reducing sugar content of stage 2 pineapple was significantly influenced by treatment and days of storage.

After 9 days of storage pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded the highest non reducing sugar content of 7.02% which was on par with hot water treated fruits stored under ambient temperature (T_2) with 6.96% non reducing sugar. The lowest non reducing sugar of 6.07% was observed in untreated fruits stored under ambient temperature (T_4).

The interaction effect between treatments and days of storage on non reducing sugar of stage 2 pineapple was non- significant.

Non reducing sugar content of pineapple fruits showed a significant difference among days of storage. At the initial day of storage, non reducing sugar of stage 2 pineapple fruits was 7.30% which was decreased to 6.68%, 6.43% and 6.21% after 3rd, 6th and 9th days of storage respectively.

Table 26. Effect of pre-treatment and storage temperature on non-reducing sugar (%) of stage 2 pineapple fruit

Treatments	Non reducing sugar (%)							
	At the day of storage	Days after storage						
		3	6	9	Treatment Mean	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	7.62	6.95	6.82	6.69	7.02	6.34	5.95	5.57
T_2 (Hot water treated fruits stored under ambient temperature)	7.49	7.00	6.82	6.55	6.96	6.06	-	-
T_3(Untreated fruits stored at low temperature)	7.14	6.58	6.33	6.21	6.56	-	-	-
T_4(Untreated fruits stored under ambient temperature)	6.95	6.19	5.77	5.39	6.07	-	-	-
Days (D) Mean	7.30	6.68	6.43	6.21				
SE± (m)	CD(0.05)					NS		
Treatments (T) - 0.076	0.218							
Days (D) - 0.076	0.218							
Treatments (T) × Days (D) - 0.153	NS							

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 12^{th} day of storage due to spoilage and hence discarded and comparison was made between pre-treated fruits only.

Hot water treated fruits has similar non- reducing sugar on 12^{th} day of storage. However, pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a higher non reducing sugar of 6.34% on 12^{th} day of storage.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 15^{th} day of storage. Hot water treated fruits stored at low temperature recorded non reducing sugar content of 5.95% and 5.57% on 15^{th} and 18^{th} days of storage respectively.

4.2.2.7 Total Sugar (%)

Effect of pre-treatment and storage temperature on total sugar (%) of stage 2 pineapple is outlined in Table 27.

Total sugar content of stage 2 pineapple was significantly influenced by pre-treatments and storage temperature. Total sugar of the stage 2 pineapple fruits showed no significant difference among treatments at the time of storage and it ranged from 10.44% to 10.70%.

Pineapple fruits pre- treated with hot water and stored at low temperature (T_1) recorded the lowest mean total sugar content of 11.15% which was on par with hot water treated fruits stored under ambient temperature (T_2) with 11.21% and untreated fruits stored at low temperature (T_3) (11.31%). The highest total sugar content of 11.70% was observed in untreated fruits stored under ambient temperature (T_4) after 9 days of storage.

The lowest total sugar content was observed in pineapple fruits pre -treated with hot water and stored at low temperature (T_1) which was on par with hot water treated fruits stored under ambient temperature (T_2). T2 was on par with T3 during 3^{rd} and 6^{th} day

Table 27. Effect of pre-treatment and storage temperature on total sugar (%) of stage 2 pineapple fruit

Treatments	Total Sugar (%)							
	At the day of storage	Days after storage						
		3	6	9	Treatment Mean	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	10.70	10.78	11.24	11.89	11.15	12.30	12.38	12.35
T_2 (Hot water treated fruits stored under ambient temperature)	10.61	10.86	11.36	12.03	11.21	12.56	-	-
T_3(Untreated fruits stored at low temperature)	10.46	10.93	11.51	12.36	11.31	-	-	-
T_4(Untreated fruits stored under ambient temperature)	10.44	11.55	12.15	12.66	11.70	-	-	-
Days (D) Mean	10.55	11.03	11.56	12.23				
SE± (m)	CD(0.05)					NS	-	
Treatments (T) - 0.057	0.162							
Days (D) - 0.057	0.162							
Treatments (T) × Days (D) - 0.113	0.324							

of storage. The highest total sugar was observed in untreated fruits stored under ambient temperature (T_4). Hot water treated fruits stored at low temperature (T_1) had the lowest total sugar at 3rd (10.78%), 6th (11.24%) and 9th (11.89%) day of storage. Untreated fruits stored under ambient temperature (T_4) showed the highest total sugar at 3rd (11.55%), 6th (12.15%) and 9th (12.66%) day of storage. This was on par with untreated fruits stored at low temperature on 9th day of storage throughout the storage period.

At the initial day of storage total sugar of stage 2 pineapple fruits was 10.55% which was increased to 11.03%, 11.56% and 12.23% after 3, 6 and 9 days of storage respectively.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 12th day of storage due to spoilage and hence discarded and comparison was made between pre-treated fruits only

Treatments showed no significant difference on 12th day of storage. However, pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a lower total sugar of 12.30% on 12th day of storage

The pre-treated fruits stored at ambient temperature were also damaged by 15th day of storage. Hot water treated fruits stored at low temperature recorded total sugar content of 12.38% and 12.35% on 15th and 18th days of storage respectively.

4.2.2.8 Vitamin C (mg 100g^{-1})

The changes in vitamin C content of stage 2 pineapple due to the effect of pre-treatment and storage temperature on stage 2 pineapple are illustrated in Table 28.

At the time of storage vitamin C content of fruits did not differ significantly among treatments and it ranged from 26.19 mg 100g^{-1} to 28.57 mg 100g^{-1}.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded the highest mean vitamin C content of 22.91 mg 100g^{-1} followed by hot water treated fruits stored under ambient temperature (T_2) with 20.53 mg 100g^{-1}. The lowest vitamin C content of 16.96 mg $100g^{-1}$ was observed in untreated fruits stored under ambient temperature (T_4) after 9 days of storage.

At the initial day of storage vitamin C content of pineapple fruits were 27.38 mg $100g^{-1}$ which was decreased to 21.42 mg $100g^{-1}$, 17.26 mg $100g^{-1}$ and 13.39 mg $100g^{-1}$ after 3, 6 and 9 days of storage respectively.

The highest vitamin C content was observed in pineapple fruits pre- treated with hot water and stored at low temperature (T_1) while the lowest vitamin C was observed in untreated fruits stored under ambient temperature (T_4) throughout the storage period. Hot water treated fruits stored at low temperature (T_1) had the highest vitamin C content at 3rd (24.99 mg $100g^{-1}$), 6th (22.61 mg $100g^{-1}$) and 9th (16.66 mg $100g^{-1}$) day of storage. T_1 was on par with T_2 after 3 days of storage. Untreated fruits stored under ambient temperature (T_4) showed the lowest vitamin C content at 3rd (19.04 mg $100g^{-1}$), 6th (13.09 mg $100g^{-1}$) and 9th (9.52 mg $100g^{-1}$) day of storage. T_4 was on par with T_3 during 3rd and 6th day of storage.

Untreated fruits stored under low (T_3) and ambient temperature (T_4) were damaged by 12th day of storage due to spoilage and hence discarded.

Pineapple fruits pre-treated with hot water and stored at low temperature (T_1) recorded a higher vitamin C content of 11.90 mg $100g^{-1}$ on 12th day of storage which was followed by fruits treated with hot water and stored under ambient temperature (T_2) with 7.14 mg $100g^{-1}$.

All the fruits except those treated with hot water and stored at low temperature (T_1) were damaged by 15th day of storage. Hot water treated fruits stored at low temperature recorded vitamin C content of 7.14 mg $100g^{-1}$ and 5.95mg $100g^{-1}$ on 15th and18th days of storage respectively.

Table 28. Effect of pre-treatment and storage temperature on Vitamin C content (mg $100g^{-1}$) of stage 2 pineapple fruit

Treatments	Vitamin C (mg $100g^{-1}$)							
	At the day of storage	Days after storage						
		3	6	9	Treatment Mean	12	15	18
T_1 (Hotwater treated fruits stored at low temperature)	27.38	24.99	22.61	16.66	22.91	11.90	7.14	5.95
T_2 (Hotwater treated fruits stored under ambient temperature)	28.57	22.61	17.85	13.09	20.53	7.14	-	-
T_3(Untreated fruits stored at low temperature)	27.38	19.05	15.47	14.28	19.04	-	-	-
T_4(Untreated fruits stored under ambient temperature)	26.19	19.04	13.09	9.52	16.96	-	-	-
Days (D) Mean	27.38	21.42	17.26	13.39				

	SE± (m)	CD(0.05)
Treatments (T)	0.508	1.450
Days (D)	0.508	1.450
Treatments (T) × Days (D)	1.017	2.900

P value – 0.049

4.2.2.9 Fruit quality (sensory scoring)

Effect of pre-treatment and storage temperature on sensory parameters *viz.*, appearance, flavour, texture, taste, flesh colour and overall acceptability of stage 2 pineapple (25-50 % eyes predominantly yellow) was assessed using Kruskall-Walis chi square test.

Appearance

Appearance of stage 2 pineapple showed no significant difference between the treatments at the time of storage and treatments showed significant difference for appearance from 3rd day of storage onwards (Table 29.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean score for appearance and untreated fruits stored under ambient temperature (T_4) recorded the lowest mean score throughout storage period.

After 9th day of storage all the untreated fruits were discarded due to spoilage and sensory analysis was done between the treated fruits only. Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for appearance (8.73) on 12th day of storage. T_1 had a sensory score of 8.77 and 8.63 for appearance after 15th and 18th days of storage respectively.

Flavour

Sensory score for flavour showed no significant difference between treatments till 3rd day of storage and significant difference for flavour was observed between treatments on 6th and 9th day of storage (Table 30.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) had the highest mean scores for flavour, with 8.10 and 8.50 during 6th and 9th day of storage. Untreated fruits stored under ambient temperature (T_4) recorded the lowest mean scores

Table 29. Effect of pre-treatment and storage temperature on appearance of stage 2 pineapple fruit

Treatments	Mean sensory score for appearance on days after storage						
	0	3	6	9	12	15	18
T_1 (Hot water treated fruits stored at low temperature	7.97	8.20	8.30	8.53	8.73	8.77	8.63
T_2 (Hot water treated fruits stored under ambient temperature)	7.93	8.13	8.20	8.30	8.27	-	-
T_3 (Untreated fruits stored at low temperature)	7.53	7.97	8.13	8.17	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.47	7.50	7.60	7.57	-	-	-
KW value	6.80	8.35*	8.83*	7.96*			
$\chi 2$ (0.05)	7.81						

*Significant

Table 30. Effect of pre-treatment and storage temperature on flavour of stage 2 pineapple fruit

Treatments	Mean sensory score for flavour on days after storage						
	0	3	6	9	12	15	18
T_1 (Hot water treated fruits stored at low temperature	7.30	7.53	8.10	8.50	8.53	8.47	8.4
T_2 (Hot water treated fruits stored under ambient temperature)	7.42	7.47	7.53	8.27	8.23	-	-
T_3 (Untreated fruits stored at low temperature)	7.50	7.77	8.03	8.07	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.47	7.47	7.27	7.20	-	-	-
KW value	2.51	4.95	11.28*	37.10*			
$\chi 2$ (0.05)	7.81						

*Significant

for flavour. After 9^{th} day of storage all the untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for flavour, 8.53, 8.47 and 8.4 on 12^{th}, 15^{th} and 18^{th} days of storage respectively.

Texture

Sensory score for texture showed no significant difference between treatments till 3^{rd} day of storage and significant difference was observed between treatments on 6^{th} and 9^{th} day of storage (Table 31.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) had recorded the highest mean scores of 8.13 and 8.17 for texture on 6^{th} and 9^{th} day of storage. Untreated fruits stored under ambient temperature (T_4) recorded the lowest mean score for texture throughout storage period.

By 12^{th} day of storage, untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for texture (8.17) on 12^{th} day of storage. T_1 recorded 8.13 and 8.10 mean score for texture on 15^{th} and 18^{th} days of storage respectively.

Taste

A significant difference for taste was observed between treatments from 6^{th} day of storage onwards (Table 32.).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean score for taste 8.30 and 8.40 on 6^{th} and 9^{th} day of storage. It was observed that untreated fruits stored under ambient temperature (T_4) recorded the lowest mean score for taste on 6^{th} and 9^{th} day of storage.

Table 31. Effect of pre-treatment and storage temperature on texture of stage 2 pineapple fruit

Treatments	Mean sensory score for texture on days after storage						
	0	3	6	9	12	15	18
T_1 (Hot water treated fruits stored at low temperature	7.70	7.93	8.13	8.17	8.17	8.13	8.10
T_2 (Hot water treated fruits stored under ambient temperature)	7.63	7.67	7.80	8.00	7.97	-	-
T_3 (Untreated fruits stored at low temperature)	7.67	7.83	8.10	7.97	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.80	7.80	7.20	7.00	-	-	-
KW value	0.68	0.97	9.17*	8.29*			
$\chi 2$ (0.05)	7.81						

*Significant

Table 32. Effect of pre-treatment and storage temperature on taste of stage 2 pineapple fruit

Treatments	Mean sensory score for taste on days after storage						
	0	3	6	9	12	15	18
T_1 (Hot water treated fruits stored at low temperature	7.97	8.07	8.30	8.40	8.43	8.33	8.30
T_2 (Hot water treated fruits stored under ambient temperature)	8.00	8.03	8.03	8.17	8.13	-	-
T_3 (Untreated fruits stored at low temperature)	8.03	8.13	8.10	8.10	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	8.07	8.33	7.83	7.43	-	-	-
KW value	2.36	3.20	8.85*	17.22*			
$\chi 2$ (0.05)	7.81						

*Significant

After 9th day of storage untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only. Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for taste (8.43) on 12th day of storage.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded mean score of 8.33 and 8.30 for taste after 15th and 18th days of storage respectively.

Flesh colour

Though there was no significant difference between treatments for sensory scores of flesh colour at the time of storage, significant difference was observed on 3rd, 6th and 9th day of storage (Table 33).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean score for flesh colour throughout storage period. T_1 had sensory scores for flesh colour 8.27, 8.50 and 8.63 during 3rd, 6th and 9th day of storage.

Untreated fruits stored under ambient temperature (T_4) recorded the lowest mean score for flesh colour. After 9th day of storage untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only.

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for flesh colour (8.63) on 12th day of storage. It had 8.67 and 8.30 mean score for taste after 15th and 18th days of storage respectively.

Overall acceptability

Though there was no significant difference between treatments for sensory scores of overall acceptability at the time of storage, significant difference was observed from 3rd day of storage onwards (Table 34).

Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded the highest mean score and untreated fruits stored under ambient temperature (T_4) recorded the lowest mean for overall acceptability throughout storage period.

After 9th day of storage all untreated fruits were discarded due to spoilage and sensory analysis was done between treated fruits only. Pineapple fruits treated with hot water and stored under low temperature (T_1) recorded a higher mean score for overall acceptability (8.50) on 12th day of storage.

Pineapple fruits treated with hot water and stored under low temperature (T_1) had overall acceptability mean score of 8.47 and 8.4 on 15th and 18th days of storage respectively.

Table 33. Effect of pre-treatment and storage temperature on flesh colour of stage 2 pineapple fruit

Treatments	Mean sensory score for flesh colour on days after storage						
	0	3	6	9	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	7.80	8.27	8.50	8.63	8.63	8.67	8.30
T_2 (Hot water treated fruits stored under ambient temperature)	7.97	8.17	8.20	8.33	8.20	-	-
T_3 (Untreated fruits stored at low temperature)	7.67	8.03	8.07	8.07	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.70	7.73	7.77	7.60	-	-	-
KW value	2.00	8.30*	8.30*	8.36*			
$\chi 2$ (0.05)	7.81						

*Significant

Table 34. Effect of pre-treatment and storage temperature on overall acceptability of stage 2 pineapple fruit

Treatments	Mean sensory score for overall acceptability on days after storage						
	0	3	6	9	12	15	18
T_1 (Hot water treated fruits stored at low temperature)	7.17	8.10	8.17	8.33	8.50	8.47	8.4
T_2 (Hot water treated fruits stored under ambient temperature)	7.13	7.17	7.37	7.43	7.57	-	-
T_3 (Untreated fruits stored at low temperature)	7.10	7.13	7.30	7.37	-	-	-
T_4 (Untreated fruits stored under ambient temperature)	7.07	7.10	7.13	6.83	-	-	-
KW value	0.085	13.05*	15.24*	23.44*			
$\chi 2$ (0.05)	7.81						

*Significant

Discussion

5. DISCUSSION

Postharvest loss of horticultural commodities takes place due to lack of several management practices to be done from harvest till consumption. About 18-25% of horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rates of bruising, water loss, and subsequent decay during postharvest handling. Nutritional loss and decreased market value are other important losses that occur in fresh produce. Quality of fresh produce is governed by several factors (Siddiqui *et al.*, 2015), the combined effect of which decides the rate of deterioration and spoilage and if not controlled properly, lead to postharvest losses on large scale. Main causes of postharvest loss include lack of temperature management, rough handling, poor packaging material, and lack of education about the need to maintain quality. Due to this huge post-harvest loss it is of utmost importance to adopt appropriate postharvest strategies for keeping up product quality during storage, transportation and marketing.

The main aim of postharvest strategies is to provide favourable conditions to extend the shelf life and retain quality and nutritional attributes of the product. The quality of the harvested commodities cannot be improved further after harvest; instead it can only be retained till consumption by adopting the appropriate postharvest handling operations. For the effective postharvest management of fruits, it is very much essential to understand about their optimum stage of maturity for harvest. Moreover, good storage facilities and appropriate pre-treatments are important factors affecting the quality and perishability of any commodity. Thus harvest maturity, pre-treatments and storage condition play an important role in extending the shelf life of horticultural commodities by reducing the post-harvest decay and maintaining the physicochemical qualities of fruit. Hence the study entitled "Postharvest management practices in pineapple (*Ananas comosus* (L.) Merr.)" was undertaken with the objective to standardize the post-harvest management practices in pineapple for improved fruity quality.

The results obtained in the experiment "Postharvest management practices in pineapple (*Ananas comosus* (L.) Merr.)" are discussed in this chapter.

The whole experiment was conducted independently for two maturity stages viz., stage1 (0- 25% eyes predominantly yellow) and stage 2 (25-50% eyes predominantly yellow) meant for distant market and local market respectively. The study was conducted as two continuous experiments. Harvested pineapple fruits were subjected to different pre-treatments to study their effect on shelf life of pineapple fruits.

5.1. Effect of pre-treatments on shelf life

Harvested pineapple fruits of two different maturity stages were subjected to four different pre-treatments *viz.,* dipping in hot water of 50 ± 2^{0}C for 1 minute, hydro cooling for 5 minutes, sanitization with 30 ppm sodium hypochlorite solution for 10 minutes, and subjecting to ozonisation with 2 ppm ozone for 15 minutes. The treated fruits along with untreated fruits were evaluated to study the effect of different pre-treatments on shelf life, physiological loss in weight and microbial load of pineapple fruits.

Pre-treatments resulted in enhanced shelf life, reduced physiological loss in weight and low microbial load on pineapple fruit surface. Untreated pineapple fruits of stage 1 and 2 maturity were discarded after nine days of storage due to spoilage. Untreated fruits of stage 1 maturity had least shelf life (11.4 days) and highest loss in physiological weight (11.14%). In case of stage 2 maturity also, untreated fruits had least shelf life (9.0 days) and highest loss in physiological weight (5.73%).

Influence of pre-treatments in reducing the PLW has been reported in several fruits including ber (Jawandha *et al*., 2012), banana (Awad *et al.*, 2017; Tapas, 2016) mango (Angasu *et al.*, 2014) and papaya (Promyou and Supapvanich, 2014). The resulting low physiological loss in weight is due to decreased transpiration and respiration rates as reported by Jawandha *et al*. (2012), Promyou and Supapvanich (2014) and due to reduced activity of oxidative and reductive enzymes as well as the production of ethylene (Hiwale and singh, 2003).

Untreated fruits of stage 1 maturity had maximum bacterial (5.39 log cfu/cm^2) and fungal count (3.88 log cfu/cm^2), where as in case of stage 2 maturity also, maximum bacterial (5.69 log cfu/cm^2) and fungal count (3.69 log cfu/cm^2) were noticed in untreated fruits. This is in accordance with the findings of Kumar and Bhatnagar (2014), who had reported that pre-treatments with ethylene inhibitors retarded the microbial growth on the fruit surface and reduced physiological loss in weight.

Pineapple fruits of stage1 maturity with 0- 25% eyes predominantly yellow and stage 2 pineapple with 25- 50% eyes predominantly yellow, when subjected to hot water dip at 50 ± 2^0C for one minute had maximum mean shelf life of 15.2 and 12.6 days respectively (Fig. 1.). Stage of maturity and pre-treatments influenced the shelf life of pineapple as reported by Kamol *et al.* (2014).

Physiological loss in weight was least for fruits of both maturity stages, when subjected to hot water dip at 50 ± 2^0C for one minute. The PLW of stage 1and 2 maturity stages were 4.91% and 3.58% respectively after 9^{th} day of storage. These results are in accordance with the findings of Jayasheela *et al*.(2015) who had observed that hot water dip treatment at 50^0C for 20 minute had reduced physiological loss in weight and enhanced the shelf life of papaya fruit of $1/4^{th}$ maturity stage. The reasons for reduced PLW due to hot water dip treatment are low rate of ripening, delaying the spoilage, and maintenance of firmness as reported by Waskar (2005) and synthesis of heat shock proteins inhibiting the protein synthesis mechanism as reported by Wang *et al.* (2001). The enhanced quality and shelf life of hot water treatment may be due to inhibiting the action of cell wall degrading enzyme such as polygalacturonase and pectin methylesterase by inhibiting the expression of protein gene as observed by Arina *et al.* (2010) and Li *et al*. (2013).

Pineapple fruits of stage1 maturity when subjected to hot water dip at 50 ± 2^0C for one minute had least bacterial (4.79 log cfu/cm^2) and fungal count (3.03 log cfu/cm^2) and in stage 2 pineapple also, least bacterial (5.02 log cfu/cm^2) fungal counts (3.14 log cfu/cm^2) were observed in hot water treated fruits. This is in accordance with the findings of Smilanick *et al*. (2003) in orange and lemons and Sopee and Sangchote (2005) in mango fruits, who had reported that hot water treatment is effective in producing antifungal compounds on the fruit surface and thus delaying the disease incidence.

Heat treatment results in the occlusion of cuticular fractures and micro wounds by melting the damaged cuticular waxes and preventing the attack of prevailing pathogens and change the cuticular structure by reducing the number of cracks in the fruit surface as reported by Lurie *et al.* (1996) in apple. Heat treatment reduces the inoculum by inhibiting the elongation of germ tube or by killing of spores thus effectively reduces the microbial load. Heat treatment can induce defence mechanism against microbes by building up a passive barrier against pathogen by the production of lignin like polymers, phytoalexins, and biosynthesis of several pathogen destructive proteins (Ferguson *et al.*, 2000). Enhanced quality and post-harvest shelf life were reported by Martins *et al.* (2004) in papaya fruit treated with hot water 47±1^{0}C for 10 minutes. Similar results were obtained by Kechinski *et al*. (2012) and Chavez-Sanchez *et al.* (2013).

Chlorine and associated compounds are the most routinely used by the food industry. Sanitization using 30 ppm sodium hypochlorite solution for 10 minutes was equally effective with hot water dip at 50±2^{0}C for one minute. Fruits of stage1 maturity with 0- 25% eyes predominantly yellow when subjected to sanitization using 30 ppm sodium hypochlorite solution for 10 minutes had 15 days shelf life (Fig. 1.), 5.42% PLW with minimum bacterial count (4.89 log cfu/cm^2) and fungal count (3.14 log cfu/cm^2). Fruits of stage 2 maturity subjected to sanitization using 30 ppm sodium hypochlorite solution for 10 minutes had 12 days shelf life (Fig. 1.), 4% PLW with minimum bacterial count (5.14 log cfu/cm^2) and fungal count (3.46 log cfu/cm^2).

Sodium hypochlorite has been proved as an efficient sanitizer in fruits and vegetables including the fresh cut ones (Varghese, 2006; Amith, 2012) by maintaining visual appearance, quality and reduce microbial growth. Application of sodium hypochlorite has been found to reduce microbial population on the surface of strawberry (Kim *et al.,* 2010) and pineapple (Antoniolli *et al.*, 2012). This is due to the germicidal action of hypochlorous acid and the effectiveness of its cleaning and disinfection process depends on the concentration of hypochlorite ion (Fukuzaki, 2006).

Stage 1 and 2 maturity fruits treated with hot water recorded the lowest PLW (12.33% and 6.27%) by the end of the storage period ie., on 15th and 12th day of storage respectively. Sanitization with 30 ppm sodium hypochlorite solution was the second best pre- treatment. In stage 1 maturity, fruits subjected to sanitization with 30 ppm sodium

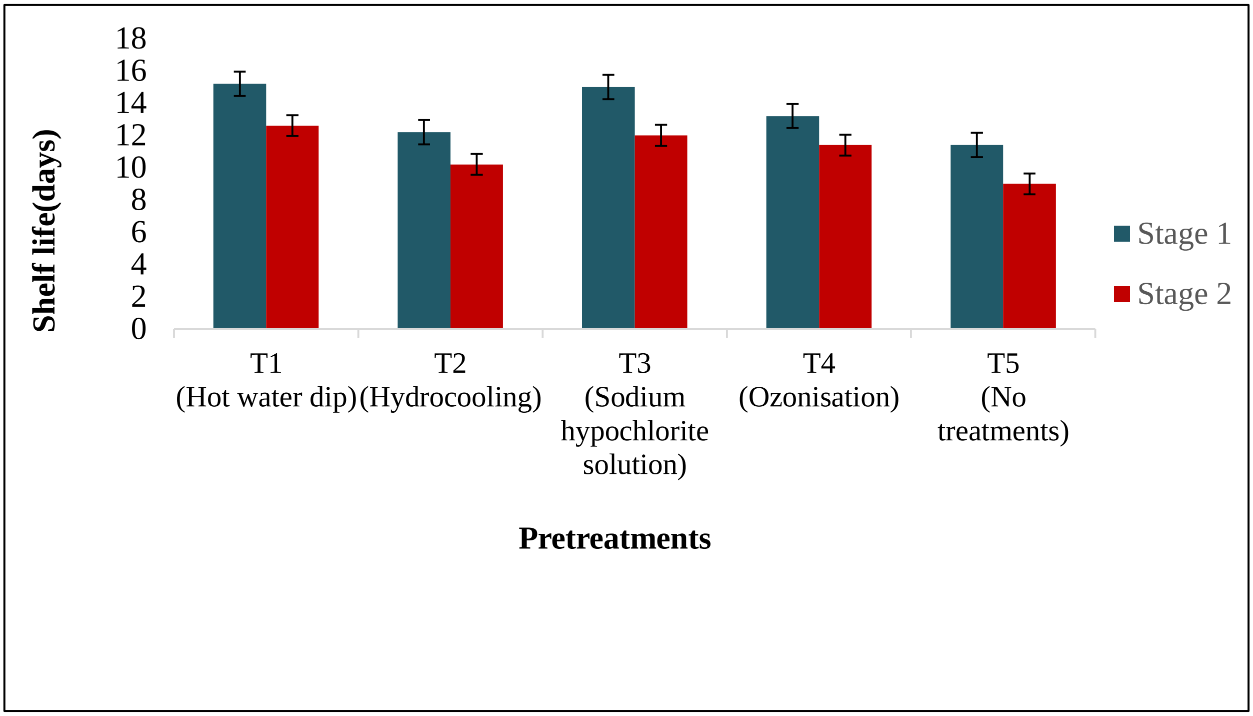


Fig. 1. Effect of pre-treatments on shelf life of stage 1 and stage 2 maturity pineapple

hypochlorite solution had 15.13% PLW on 15th day of storage and in stage 2 maturity, they had 9.29% PLW on 12th day of storage.

Ozonization was effective as hot water treatment in stage 2 pineapple alone. Stage 2 pineapple when ozonized had a shelf life of 11.4 days which was on par with fruit subjected to hot water treatment. In stage 1 pineapple, ozonization was second best treatment, after hot water treatment and sanitization with sodium hypochlorite. Ozone application is a promising one, which is gaining interest in the fruit and vegetable industry. Ozonization had enhanced the post harvest life and maintained the quality of fruits and vegetables (Karaca and Velioglu, 2007), amaranthus (George, 2015; Ambareesha, 2016), and of rambutan (shetty, 2017). Ozonization changes the permeability of microbial cells by causing damage to the cellular constituents (Priyanka *et al.*, 2014). But in the present experiment, ozonisation was inferior to hot water treatments.

Based on efficiency and economics in maintaining the highest shelf life with least PLW and microbial load, hot water dip at 50± 2^0C for one minute was selected as the best pre-treatment for stage 1 pineapple with 0- 25% eyes predominantly yellow, which is meant for distant market and for stage 2 pineapple with 25 -50% eyes predominantly yellow, which is meant for local market. This treatment was selected for the second part of the experiment.

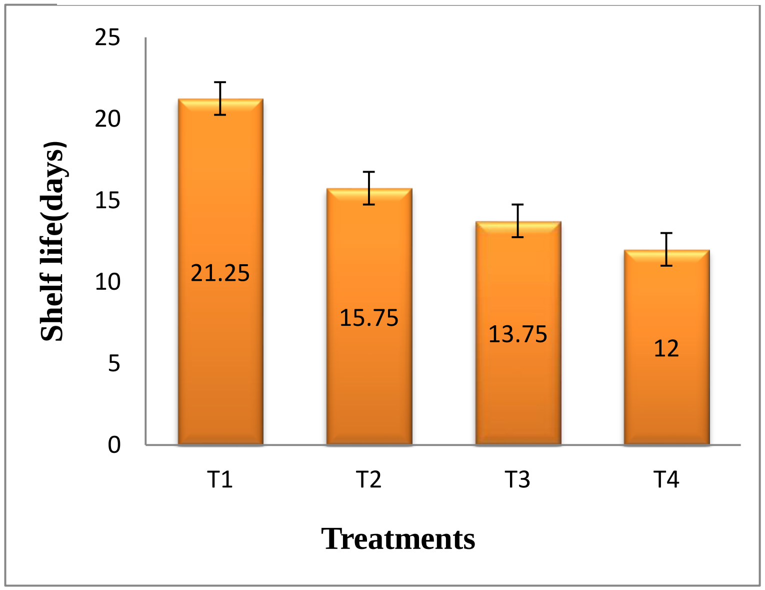
5.2. Effect of pre-treatment on storage stability of pineapple

Harvested pineapple fruits of two maturity stages were subjected to hot water dip at 50± 2^0C for one minute and stored under two conditions along with untreated fruits. The stored fruits were subjected to evaluation of physiological, chemical and sensory quality parameters.

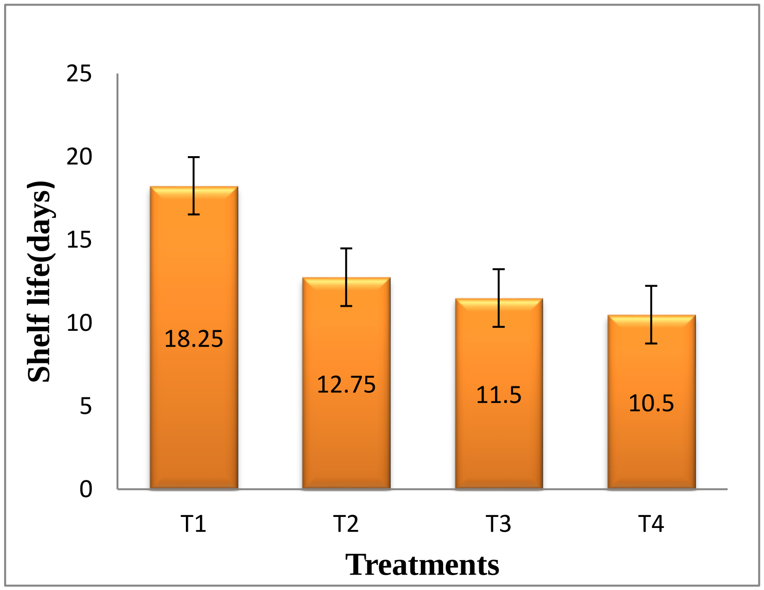
Untreated pineapple fruits stored under ambient temperature of stage 1 were discarded after 12 days and stage 2 were discarded after 9 days of storage due to spoilage. Untreated fruits stored under ambient temperature of stage 1 maturity had least shelf life (12 days) and highest physiological loss in weight (12.29%). In case of stage 2 maturity also, untreated fruits stored at ambient temperature recorded least shelf life (9 days) and highest physiological loss in weight (5.73%). The resulting high physiological loss in weight during ambient storage might be due to high rate of evapotranspiration which leads to shrinkage, wilting and reduced tissue turgor eventually making the fruits unusable as reported by siddiqui *et al.* (1991) in guava, Nayanakkara *et al.* (2002) in Mauritius variety of pineapple, Dhar *et al.* (2008) in pineapple, Sothornvit and Rodsamran (2008) in mango, Gafir *et al.* (2009) in apple and Mahmood *et al.* (2017) in litchi. Temperature of the product and environmental condition play important roles in water loss.

Pineapple fruits of stage 1 maturity with 0- 25% eyes predominantly yellow and stage 2 pineapple with 25- 50% eyes predominantly yellow treated with hot water and stored under low temperature had maximum shelf life of 21.25 days and 18.25 days respectively (Fig. 2). Physiological loss in weight was least for fruits treated with hot water and stored under low temperature in case of two maturity stages (Fig. 3). The PLW of stage 1 maturity stage when subjected to hot water treatment and stored under low temperature is 4.53% after 12 days of storage and in case of stage 2 maturity PLW after 9 days of storage is 2.48%. Fruits harvested at early stage of maturity showed higher physiological loss in weight during storage due to accelerated rate of metabolic process. These results are in accordance with the findings of Kabir *et al.* (2010) in giant kew pineapple and Reshma (2014) in Mauritius variety of pineapple. The preheat treatment followed by storage at low temperature preserved quality and inhibits physiological changes in pineapple (Selvarajah *et al.*, 1998) and Hofman *et al*. (2002) in avocado. Low temperature storage had resulted in least loss in weight as reported by Waskar (2005) in mango, Mahmood *et al*. (2017) in litchi and Dhar *et al.* 2008 in pineapple. Water molecules get less energy in lower temperature attributing slower rate of vapour exchange to atmosphere around the fruits surface and reduced PLW as observed by Kays and Paull (2004) and EL-Naggar and EL-Saedy (2005) in pomegranate. Low temperature storage prolonged the shelf life by reducing the exchange of O_2 and CO_2 from fruit tissue and outer atmosphere as well as due to the decline of hydrolysis process in pineapple (Uddin and Hossain, 1993). An increase in temperature during storage accelerated the

Stage 1 maturity



Stage 2 maturity



T_1 :Hot water treated fruits stored at low temperature

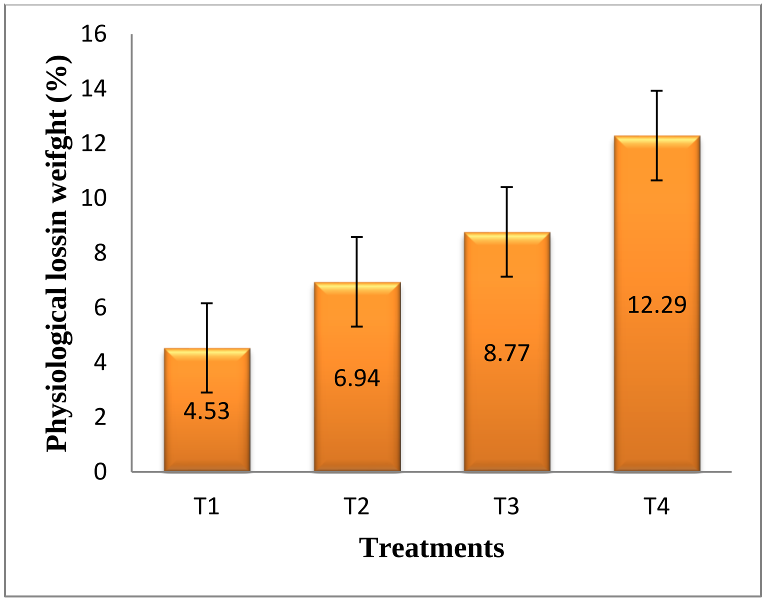
T_2 :Hot water treated fruits stored under ambient temperature

T_3 :Untreated fruits stored at low temperature

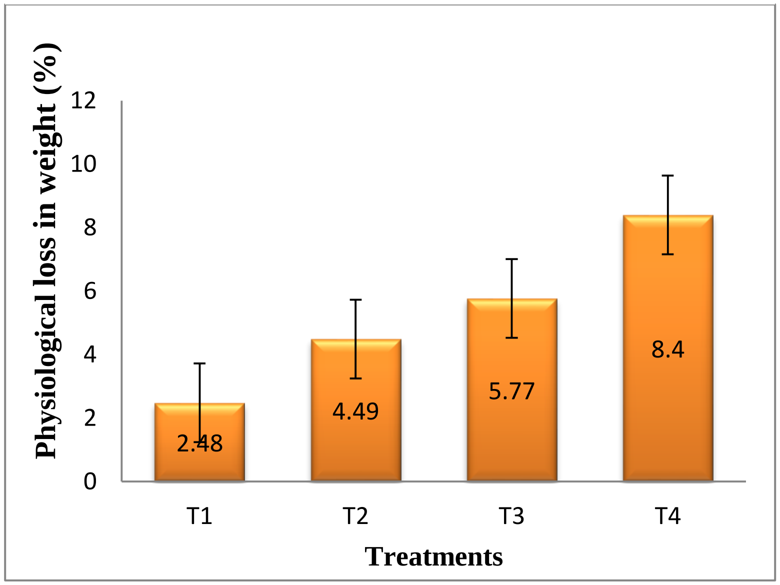
T_4 :Untreated fruits stored at ambient temperature

Fig. 2. Effect of pre-treatment and storage temperature on shelf life of stage 1 and stage 2 pineapple fruits

Stage 1 maturity



Stage 2 maturity



T_1 :Hot water treated fruits stored at low temperature

T_2 :Hot water treated fruits stored under ambient temperature

T_3 :Untreated fruits stored at low temperature

T_4 :Untreated fruits stored at ambient temperature

Fig. 3. Effect of pre-treatment and storage temperature on PLW (%) of stage 1 and stage 2 pineapple fruits

rate of breakdown of cell wall constituents (Kumar *et al.,* 2009). Hot water treatment followed by low temperature storage enhanced the shelf life of papaya cv. Frangi as reported by Shadmani *et al.* (2015) and Benjamin *et al.* (2018) in Papaya cv. Solo.

Pineapple fruits heated with hot water and stored under ambient temperature was second next best treatment. It had recorded a PLW of 6.94% after 12 days of storage and shelf life of 15.75 in stage 1 pineapple. In case of stage 2 pineapple, 4.49% PLW was recorded after 9 days of storage and had a shelf life of 12.75 days. The effect of heat treatment is to increases viscosity and reduce the membrane permeability and contributed to the retention of moisture in treated fruits as reported by Paull and Chen (2000). Heat treatment induced enzymatic alteration in pectin and cell wall resulted in reduced PLW. Similar result was obtained by Williams *et al*. (1994) in valencia orange. Heat treatment inhibits ethylene synthesis which retards respiration rate and cell wall degradation thus extended the shelf life of fruits as reported by paull and chenn (2000).

The combined effect of heat treatment and low temperature enhanced the quality of fruit as explained by Woolf *et al.* (1995) in avocado. Heat treatment effectively produces heat shock proteins and low temperature induces the reduction of heat shock protein mRNA decay and maintaining heat shock proteins transcripts at elevated levels as reported by Lurie (1998). The inhibition of ripening due to heat treatment is by the inactivation of the enzymes involved in ethylene synthesis, cell wall degradation and by the suppression of ripening-related mRNA synthesis. The action of heat treatment is by the prevention of transcription process of proteins. Heat treatment above 35^0C contributes the accumulation of ACC synthase and oxidase thus reduced the ethylene production in fruits (Paull and Chen, 2000).

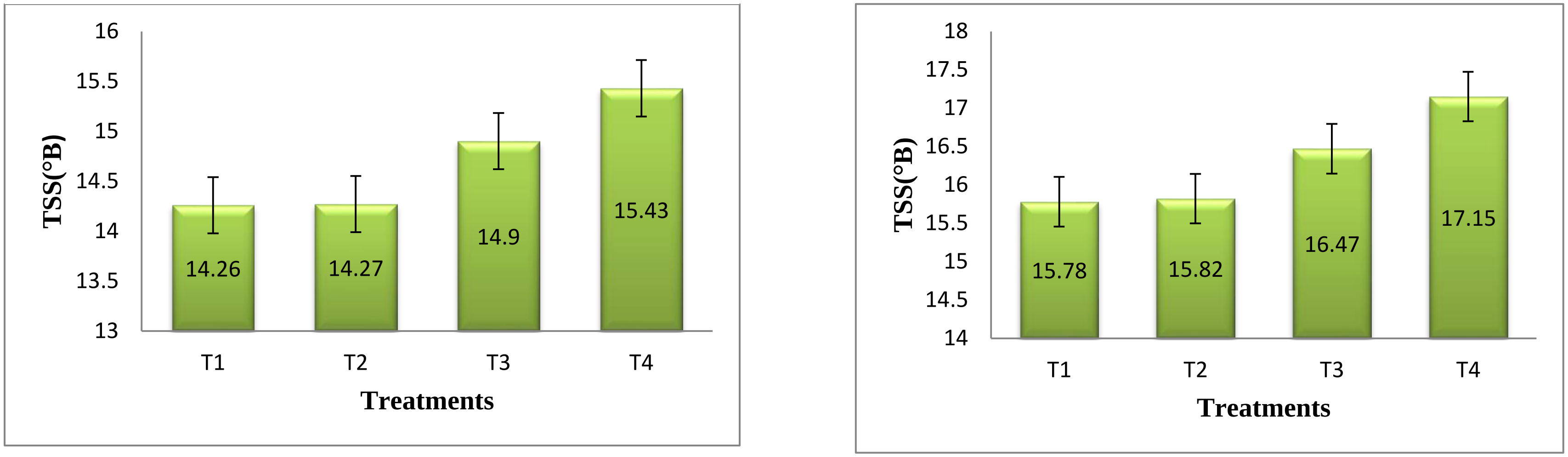
5.2.1 Chemical quality parameters

Chemical quality parameters *viz.*, TSS, acidity, reducing sugars, total sugars, non reducing sugars and vitamin C were influenced by the pre-treatments and storage temperature.

TSS is one of the most important quality factors of pineapple. TSS of stage 1 and stage 2 pineapples increased during storage. This is in accordance with the findings of Hussain *et al.* (2008) in apple and Salari *et al.* (2013) in strawberry. Pineapple fruits treated with hot water and stored under low temperature had increased TSS during storage and then it was decreased at the end of storage in both maturity stages. These results were in tune with the findings of Fisk (2006) in kiwi and Ali *et al*. (2015) in different varieties of pineapple. They observed that increasing trend of TSS during initial day of storage is due to breakdown of complex starch and pectin into simple sugars during ripening and further decrease is due to hydrolysis. The minimum TSS of 14.26°B was recorded in stage 1 pineapple fruits treated with hot water and stored under low temperature after 12 days of storage (Fig. 4). In case of stage 2 pineapples minimum TSS of 15.78°B had found in hot water treated fruits stored under low temperature (Fig. 4). Hot water treatment associated with low temperature storage delayed the ripening process and resulted in minimum TSS as reported by Wills *et al*. (1998) and Weerahewa and Adikaram (2005a) in pineapple. In contrast untreated fruits stored under ambient temperature had maximum TSS in both maturity stages. In case of stage 1 pineapple a maximum TSS of 15.43°B had noticed after 12 days of storage and stage 2 pineapple observed TSS of 17.15°B after 9 days of storage. This might be due to high loss of moisture content during ambient storage resulted in the concentration of dissolved solids as observed by Wijesinghe and Sarananda (2002) in Mauritius variety of pineapple, Kabir *et al.* (2010) in pineapple, Mahmood *et al.* (2017) in litchi and Hossain *et al.* (2018) in Kew and MD2 pineapple.

Acidity of pineapple fruits are mainly associated with organic acids *viz.*, citric acid and malic acid (Saradhuldhat and Paull, 2007). Acidity of stage 1 and stage 2 pineapple fruits showed a declining trend during storage irrespective of the treatments. This was due to the loss of citric acid as reported by Othman (2011). The decline in acidity during storage might be attributed to the utilization of organic acids in respiratory process as reported by Gafir *et al.* (2009) in apple, Yassin *et al.* (2009) in pomegranate, Lee *et al*. (2010) in guava, Kamol *et al. (*2014) and Ali *et al*. (2015) in Pineapple. Pineapple fruit of

Stage 1 maturity **Stage 2 maturity**



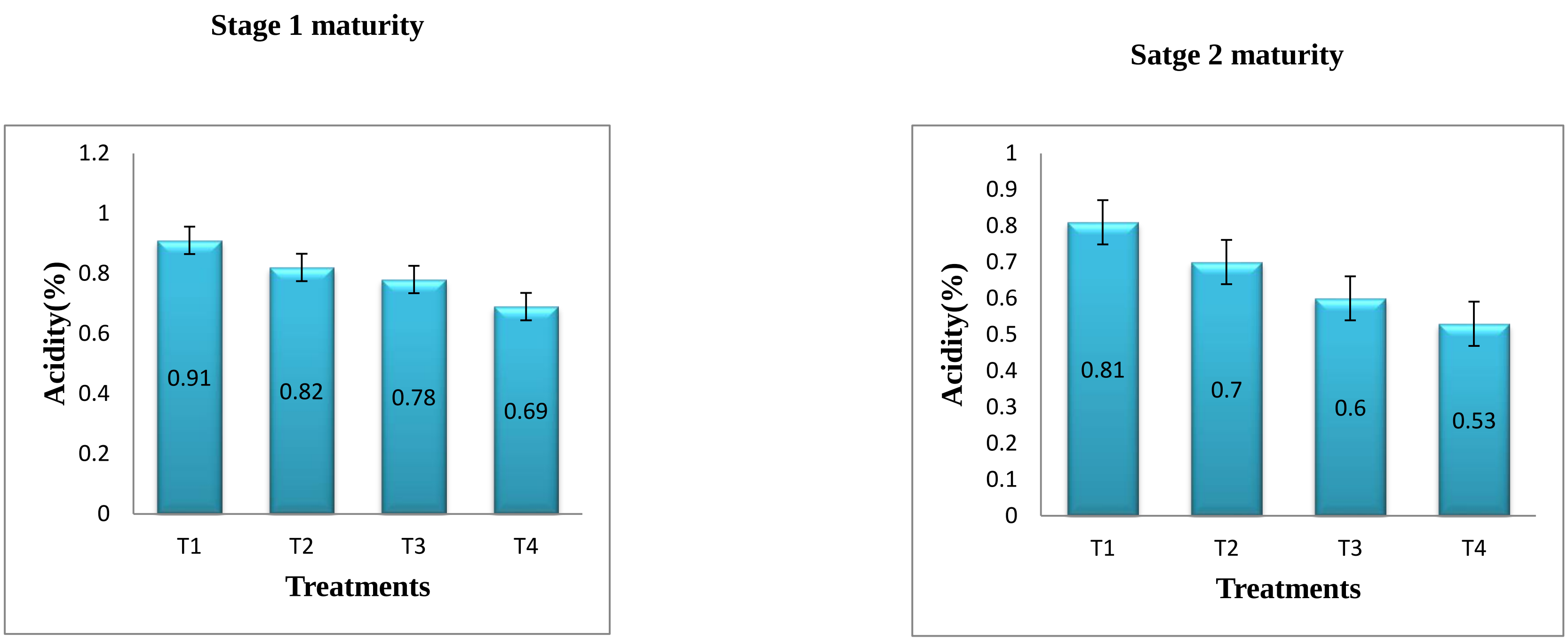
T_1 :Hot water treated fruits stored at low temperature

T_2 :Hot water treated fruits stored under ambient temperature

T_3 :Untreated fruits stored at low temperature

T_4 :Untreated fruits stored at ambient temperature

Fig. 4. Effect of pre-treatment and storage temperature on TSS (^{0}B) of stage 1 and stage 2 pineapple fruits



T_1 :Hot water treated fruits stored at low temperature

T_2 :Hot water treated fruits stored under ambient temperature

T_3 :Untreated fruits stored at low temperature

T_4 :Untreated fruits stored at ambient temperature

Fig. 5. Effect of pre-treatment and storage temperature on acidity (%) of stage 1 and stage 2 pineapple fruits

stage 1 maturity, subjected to hot water treatment and stored under low temperature had highest acidity of 0.91% after 12 days of storage and stage 2 pineapple had maximum acidity of 0.81% after 9 days of storage (Fig. 5). Similar results were reported by Pailly *et al*. (2004) in grape fruit (*Citrus paradise*) and Weerahewa and Adikaram (2005a) in Mauritius variety of pineapple, where fruits stored at low temperature had reported high acidity content. Low temperature storage retarded the rate of metabolic process like respiration and this may account for the high acidity in fruits stored at low temperature. Pineapple fruit subjected to heat treatment showed reduced acidity (Selvarajah *et al.*, 1998). Untreated fruits stored under ambient temperature of both maturity stages had least acidity. As storage temperature increases, acidity will be reduced, because of utilization of organic acids for respiration (Hong *et al*., 2013). A decrease in acidity of pineapple fruit during ripening at ambient temperature might due to rapid utilization of acids as substrate during respiration and it has been converted to sugars as found in Mauritius pineapple fruit (Fernando and De Silva, 2000).

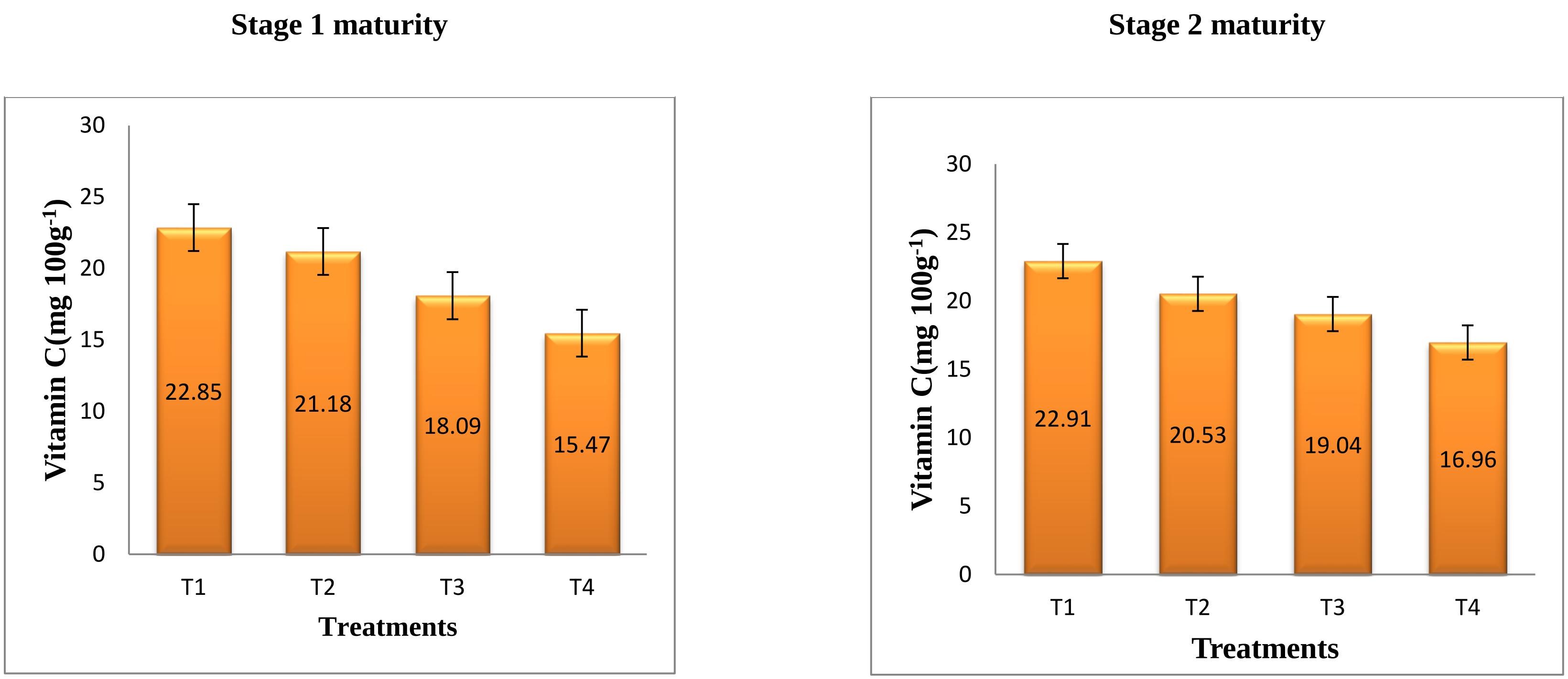
Sugars mainly include total sugar, reducing sugar and non reducing sugar. Sweetness of pineapple fruit is mainly associated with sucrose, glucose and fructose. Total sugar of stage 1 and stage 2 pineapples increased during storage. The reason for increasing total sugars during storage is, due to the breakdown of starch into simple soluble sugars like glucose and fructose by the amylase enzyme or by the breakdown of complex polysaccharides as reported by Jaishankar and Kukanoor (2016) in sapota and Kamol *et al*. (2014), Ali *et al*. (2015) in pineapple. Pineapple fruits treated with hot water and stored under low temperature had increased total sugar during storage and then it was decreased at the end of storage in both maturity stages. These results were in accordance with the findings of Srivastava and Dwivedi (2000) in banana and Lu *et al.* (2011) in pineapple. Initially, increase in total sugar may be due to break down of starch and organic acids into sugars and further decreased due to respiration.

Stage 1 pineapple fruits treated with hot water and stored under low temperature had lowest total sugar of 10.45% after 12 days of storage and stage 2 pineapple had lowest total sugar of 11.15% after 9 days of storage. This may be due to the inhibition of the activity of amylase enzyme by hot water associated low temperature which slowdown the breakdown of starch into simple sugars. Sugar content reached maximum at the optimum ripening stage by the conversion of starch to sugar and further decreased as sugars are used as substrate for respiration as reported by Bhooriya *et al.* (2018) in guava. Untreated fruits of both maturity stages stored under ambient temperature recorded maximum total sugar content.

Reducing sugar of pineapple fruits mainly includes glucose and fructose. Reducing sugar of both maturity stages in all treatments increased with the advancement of storage period. Similar findings were reported by Farooq *et al.* (2012) in apple cv. Gala and Hossain *et al.* (2018) in kew and MD-2 variety of pineapple. Pineapple fruits treated with hot water and stored under low temperature had lowest reducing sugar of 4.36% in stage 1 pineapple after 12 days of storage and 4.13% in stage 2 pineapple after 9 days of storage. Increment in sugar content occurs due to the breakdown of complex polysaccharides in the cell wall. Untreated fruits stored under ambient temperature had highest reducing sugar of 6.11% in stage1 pineapple after 12 days of storage and 5.63% in stage 2 pineapple after 9 days of storage.

Non reducing sugar of stage 1 and stage 2 pineapple decreased during storage irrespective of treatments. Similar findings were reported in pineapple by Dhar *et al*. (2008) and Hong *et al.* (2013). Decrease in sucrose content during storage mainly occurs due to the high activity of invertase enzyme resulting in the conversion of sucrose into glucose and fructose as reported by Fuleki *et al.* (1994) in apple, Cordenunsi *et al*. (2003) in strawberry Gol and Rao (2011) in banana and Sanchez *et al.* (2012) in pineapple. Pineapple fruit treated with hot water and stored at low temperature recorded highest non reducing sugar of 6.09% in stage 1 pineapple after 12 days of storage and 7.02% in stage 2 pineapple after 9 days of storage. These results were in accordance with the findings of Reshma (2014) in Mauritius variety of pineapple. Non reducing sugar content was decreased during storage as reported by Arina *et al*. 2010 in Eksotika papaya.

Vitamin C content determines the nutritional quality of fruits and it decreased with the advancement of storage period in all treatments of stage 1 and stage 2 pineapples.



T_1 :Hot water treated fruits stored at low temperature

T_2 :Hot water treated fruits stored under ambient temperature

T_3 :Untreated fruits stored at low temperature

T_4 :Untreated fruits stored at ambient temperature

Fig. 6. Effect of pre-treatment and storage temperature on vitamin C (mg $100g^{-1}$) of stage 1 and stage 2 pineapple fruits

These results are in conformity with the findings of Kabir *et al*. (2010), Hemalatha and Anbuselvi (2013) Hong *et al*. (2013), Pauziah *et al.* (2013)and Ali *et al.* (2015) in different varieties of pineapple. Decrease in vitamin C content during storage might be due to the enzyme mediated oxidation of ascorbic acid (Lee and Kader, 2000) and by the action of oxidizing enzymes like ascorbic acid oxidase, catalase, polyphenol oxidase and peroxidase on ascorbic acid (Singh and Rao, 2005). The rapid conversion of L-ascorbic acid into dehydro ascorbic acid by the enzyme ascorbinase enhanced the loss of vitamin C during storage. Pineapple fruits treated with hot water and stored under low temperature had highest vitamin C in both maturity stages with 22.85% in stage 1 pineapple after 12 days (Fig. 6) and 22.91% after 9 days of storage in case of stage 2 pineapple (Fig. 6). These observations are in accordance with the report of Dhar *et al.* (2008) in pineapple and Mahmood *et al*. (2017) in litchi where low temperature had resulted in highest acidity and it is more effective in checking the decline in ascorbic acid content during storage.

Sensory Parameters

Sensory parameters viz., appearance, flavour, texture, taste, flesh colour and over all acceptability of stage 1 and stage 2 pineapples were recorded and the highest sensory scores were obtained for pineapple fruits treated with hot water stored at low temperature.

All the treatments were effective in maintaining sensory qualities, of which hot water dip treatment followed by low temperature storage had reported the highest mean score for all sensory parameters while untreated fruits stored under ambient temperature recorded the lowest scores in both maturity stages.

Appearance is an important factor that consumers take into consideration while purchasing a product. Appearance of pineapple fruits increased during storage in both maturity stages irrespective of the treatments. This may be due to the development of carotenoid pigments by the degradation of chlorophyll as reported by Appiah *et al*. (2012). Pineapple fruits treated with hot water had enhanced appearance by altering the shell colour development as reported by Weerahewa and Adikaram (2005a) in Mauritius variety of pineapple. Hot water treatment at 50^0C for 30 minute enhanced the appearance and visual quality as reported by Abreu *et al.* (2003) in Rocha pear and Djioua *et al.* (2009) in mango.

Flavour and aroma of pineapple fruit are mainly contributed by volatile substance like aldehydes, alcohols, esters, lactones, terpenes and sulfur compounds (Kader, 2008). Flavour of pineapple fruits showed an increased trend during storage of both maturity stages due to the production of volatile substances during ripening. Hot water treatment enhanced the flavour and aroma of fruit as reported by Lamikanra *et al.* (2005)

Texture of the fruit is an important quality parameter which ensures good storability. Texture of pineapple fruit increased during storage in both maturity stages. This may be contributed by the moisture loss during storage resulted in decrease in firmness as reported by Ali *et al.* (2015) in pineapple. Initially texture of fruit increased slightly and further decreased during storage due to breakdown of polymeric carbohydrates contributed to weakening of cell walls resulted in the reduction of firmness as reported by Mandal *et al*. (2015) in pineapple. Hot water treatment is reported to reduce the rate of ripening and softening, delaying the spoilage and thus maintaining firmness as reported by Abreu *et al.* (2003), Waskar (2005) and Weerahewa and Adikaram (2005a). Hot water treatment induced greater stability to cell wall and increased firmness by increased cell wall bound constituents (Valero *et al*., 2002). Low temperature contributed an increased firmness as reported by Quyen *et al.* (2013) in pineapple.

Taste of pineapple fruit is mainly associated with sugars and organic acids (Kader, 2008). Taste of pineapple fruit increased with the advancement of storage period in both maturity stages. Increased level of glucose fructose and sucrose during storage contributed to the increase in sweetness of pineapple fruit (Ali *et al.*, 2015 and Lamikanra *et al.*, 2005).

Flesh colour of pineapple fruits increased during storage and decreased at the end of storage due to senescence in both maturity stages. Similar results were obtained by Ali *et al.* (2015) in pineapple. Increased flesh colour during storage might be due to the increase in carotenoid pigments of pulp by enzymatic oxidation (Mandal *et al.*, 2015).

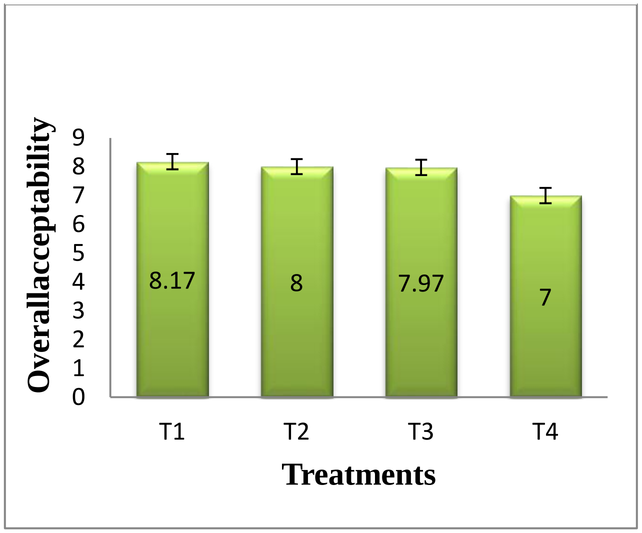
Low temperature resulted in increased flesh colour in pineapple during storage as reported by Quyen *et al.* 2013 in pineapple.

Overall acceptability of fruit increased with the advancement of storage in both maturity stages. Pineapple fruits treated with hot water and stored under low temperature had highest overall acceptability mean score in both maturity stages (Fig. 7). Heat treatment inactivates enzymes such as peroxidase, lipase, and esterase, their reduced activity contributing to the improved sensory quality (Lamikanra and Watson, 2004). Low temperature storage increased flesh colour, taste, aroma, texture and delayed spoilage and softening of fruits thus contributed to the quality of pineapple (Lamikanra *et al.*, 2005).

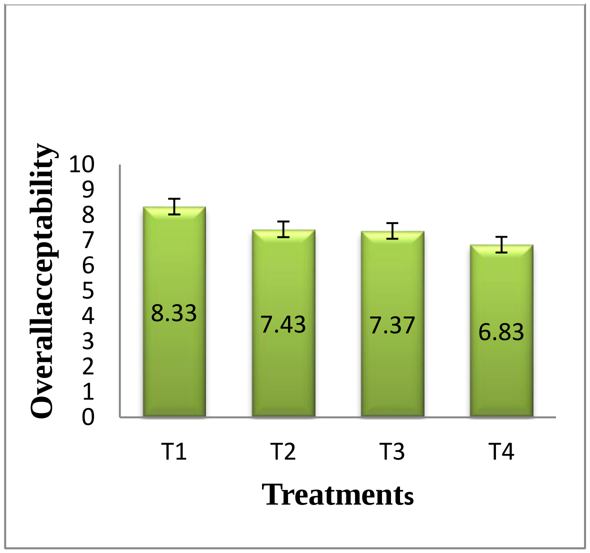
In general, hot water treated fruits when stored under low temperature had resulted in better physiological and chemical quality parameters and the same were reflected in acceptability scores of the commodities. Hot water treatment alone gives a better quality pineapple fruit compared to untreated ones and a combination of hot water treatment and low temperature storage further increased the quality and shelf life of the commodity.

It can be concluded that pineapple fruits (var. Mauritius) harvested with crown and two cm stalk at stage1 (0- 25% eyes predominantly yellow) maturity when subjected to hot water treatment at 50 ± 2^0C for 1 minute followed by low temperature storage (24^0C) could reduce the rate of biochemical changes and extend the shelf life of pineapple meant for distant markets. Same management practice could be adopted for stage 2 (25-50 % eyes predominantly yellow) maturity stage pineapple meant for the local market.

Stage 1 maturity



Stage 2 maturity



T_1 :Hot water treated fruits stored at low temperature

T_2 :Hot water treated fruits stored under ambient temperature

T_3 :Untreated fruits stored at low temperature

T_4 :Untreated fruits stored at ambient temperature

Fig. 7. Effect of pre-treatment and storage temperature on overall acceptability of stage 1 and stage 2 pineapple fruits

Summary

6. SUMMARY

The experiment entitled “Postharvest management practices in pineapple (*Ananas comosus* (L.) Merr.)” was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, during the year 2018-2020, with the objective to standardize the post-harvest management practices in pineapple for improved fruity quality. The major findings of the experiment are summarized below.

The whole experiment was conducted independently for two maturity stages viz., stage1 (0- 25% eyes predominantly yellow) and stage 2 (25-50% eyes predominantly yellow) meant for distant and local markets respectively.

The study was conducted as two continuous experiments. In the first part, harvested pineapple fruits were subjected to four different pre-treatments *viz.*, dipping in hot water of 50±2^{0}C for 1 minute, hydro cooling for 5 minutes, sanitization with 30 ppm sodium hypochlorite solution for 10 minutes and ozonisation with 2ppm ozone for 15 minutes. The treated fruits along with untreated fruits were evaluated to study the effect of pre-treatments on shelf life, physiological loss in weight and microbial load of pineapple fruits for selection of the best pre-treatment. In the second part of the study, effect of the selected pre-treatment on quality and storage stability of pineapple fruit was assessed based on physiological, chemical and sensory quality parameters by storing treated and untreated fruits under two different temperatures.

All the pre-treatments resulted in enhanced shelf life, reduced physiological loss in weight and low microbial load on stage 1 maturity pineapple fruit surface. Pineapple fruits of stage1 maturity when subjected to hot water dip at 50±2^{0}C for one minute had maximum mean shelf life of 15.2 days and least physiological loss in weight (4.91%) after 9th day of storage with least bacterial (4.79 log cfu/cm^2) and fungal count (3.03 log cfu/cm^2). These fruits recorded the lowest PLW (12.33%) by the end of the storage period ie., on 15th day of storage.

Sanitization using 30 ppm sodium hypochlorite solution for 10 minutes was equally effective with hot water dip at 50±2^{0}C for one minute. Fruits when subjected to sanitization using 30 ppm sodium hypochlorite solution for 10 minutes had 15 days shelf life, 5.42% PLW with minimum bacterial count (4.89 log cfu/cm^2) and fungal count (3.14 log cfu/cm^2). They had recorded 15.13% PLW on 15th day of storage.

Ozonization was the second best treatment, after hot water treatment and sanitization with sodium hypochlorite.

Untreated fruits of stage 1 had least shelf life (11.4 days) and highest loss in physiological weight (11.14%) with maximum bacterial (5.39 log cfu/cm^2) and fungal (3.88 log cfu/cm^2) counts.

In pineapple fruits of stage 2 maturity also, all the pre-treatments resulted in enhanced shelf life, reduced physiological loss in weight and low microbial load on fruit surface. Untreated fruits of stage 2 maturity had least shelf life (9.0 days) and highest loss in physiological weight (5.73%) with maximum bacterial (5.69 log cfu/cm^2) and fungal (3.69 log cfu/cm^2) counts.

Pineapple fruits of stage 2 maturity, when subjected to hot water dip at 50±2^{0}C for one minute had maximum mean shelf life of 12.6 days and least physiological loss in weight (3.58%). Least bacterial (5.02 log cfu/cm^2) fungal counts (3.14 log cfu/cm^2) were also observed in hot water treated fruits.

Sanitization using 30 ppm sodium hypochlorite solution for 10 minutes was equally effective with hot water dip at 50±2^{0}C for one minute. Fruits of stage 2 maturity subjected to sanitization using 30 ppm sodium hypochlorite solution for 10 minutes had 12 days shelf life, 4% PLW, with minimum bacterial count (5.14 log cfu/cm^2) and fungal count (3.46 log cfu/cm^2).

Stage 2 maturity fruits treated with hot water recorded the lowest PLW (6.27%) and sanitization with 30ppm sodium hypochlorite solution was the second best pre-treatment with 9.29% PLW by the end of the storage period ie.,on 12th day of storage.

Ozonization was effective as hot water treatment in stage 2 pineapple. Stage 2 pineapple when ozonized had a shelf life of 11.4 days which was on par with fruit subjected to hot water treatment. Based on efficiency and economics in maintaining the highest shelf life with least PLW and microbial load, hot water dip at 50± 2^{0}C for one minute was selected as the best pre-treatment for stage 1 pineapple meant for distant markets and for stage 2 pineapple, which is meant for local markets. This treatment was selected for the second part of the experiment.

In the second part of the experiment, harvested pineapple fruits of two maturity stages were independently subjected to hot water dip at 50± 2^0C for one minute and stored under two temperature conditions along with untreated fruits and the stored fruits were subjected to evaluation of physiological, chemical and sensory quality parameters.

Untreated pineapple fruits stored under ambient temperature of stage 1 were discarded after 12 days of storage due to spoilage. They had least shelf life (12 days) and highest physiological loss in weight (12.29%) which lead to shrinkage, wilting and reduced tissue turgor eventually making the fruits unusable.

Pineapple fruits of stage 1 maturity treated with hot water and stored under low temperature had maximum shelf life of 21.25 days and least physiological loss in weight (4.53%) after 12 days of storage.

Hot water treatment and storage under ambient temperature was the second next best treatment. It had recorded a PLW of 6.94% after 12 days of storage and shelf life of 15.75 in stage 1 pineapple.

In case of fruits of stage 2 maturity, untreated pineapple fruits stored under ambient temperature had least shelf life (10.5 days) and highest physiological loss in weight (8.40%). Fruits treated with hot water and stored under low temperature had maximum shelf life of 18.25 day with least PLW of 2.48% after 9 days of storage.

Chemical quality parameters *viz.*, TSS, acidity, reducing sugars, total sugars, non reducing sugars and vitamin C were influenced by the pre-treatments and storage temperature.

Hot water treatment associated with low temperature storage delayed the ripening process and resulted in minimum TSS (14.26°B) and highest acidity (0.91%) after 12 days of storage. In contrast untreated fruits stored under ambient temperature had maximum TSS of 15.43°B and lowest acidity (0.69%) after 12 days of storage.

Stage 1 pineapple fruits treated with hot water and stored under low temperature had lowest total sugar (10.45%), reducing sugar (4.36%) and highest non reducing sugar (6.09%) after 12 days of storage. Untreated fruits stored under ambient temperature recorded maximum total sugar (11.21%) and reducing sugar (6.11%) after 12 days of storage.

Pineapple fruits treated with hot water and stored under low temperature had highest vitamin C with 22.85% after 12 days.

Untreated pineapple fruits stored under ambient temperature of stage 2 maturity were discarded after 9 days of storage due to spoilage. They had recorded least shelf life (10.5 days) and highest physiological loss in weight (8.40%) eventually making the fruits unusable.

Pineapple fruits of stage 2 maturity treated with hot water and stored under low temperature had maximum shelf life of 18.25 days and least PLW of 2.48% after 9 days of storage

Pineapple fruits heated with hot water and stored under ambient temperature was the next best treatment. It had recorded a PLW of 4.49% after 9 days of storage and shelf life of 12.75 days in stage 1 pineapple.

Hot water treatment associated with low temperature storage delayed the ripening process and resulted in minimum TSS of 15.78°B and untreated fruits stored under ambient temperature had maximum TSS of 17.15°B after 9 days of storage.

Fruits subjected to hot water treatment and stored under low temperature had highest acidity of 0.81% after 9 days of storage. Fruits treated with hot water and stored under low temperature had highest non reducing sugar of 7.02%, lowest total sugar of 11.15% and reducing sugar of 4.13% after 9 days of storage. Untreated fruits stored under ambient temperature recorded maximum total sugar and reducing sugar content.

Pineapple fruits treated with hot water and stored under low temperature had highest vitamin C with 22.91% after 9 days of storage

Chemical quality parameters of the treated and untreated pineapples of both the maturity stages were changed during storage period. TSS, total sugar and reducing sugar of pineapple fruits increased with the advancement of storage period, whereas acidity, non-reducing sugar and vitamin C content showed a declining trend during storage irrespective of the treatments.

All the treatments were effective in maintaining high sensory quality parameters viz., appearance, flavour, texture, taste, flesh colour and over all acceptability, of which hot water dip treatment followed by low temperature storage had the highest mean score while untreated fruits stored under ambient temperature recorded the lowest scores in both maturity stages. In general, hot water treated fruits when stored under low temperature had resulted in better physiological and chemical quality parameters and the same were reflected in acceptability scores of the commodities.

Hot water treatment alone gives a better quality pineapple fruits compared to untreated fruits and a combination of hot water treatment and low temperature storage further increased the quality and shelf life of the commodity.

It can be concluded that pineapple fruits (var. Mauritius) harvested with crown and two cm stalk at stage1 (0- 25% eyes predominantly yellow) maturity when subjected to hot water treatment at 50 ± 2^0C for 1 minute followed by low temperature storage (24^0C) could extend the shelf life of pineapple meant for distant markets up to 21.25 days. The same management practice could be adopted for a shelf life of 18.25 days for stage 2 (25-50% eyes predominantly yellow) maturity stage pineapple meant for the local market.

Future line of work

The standardised technology is to be further tested at field condition to evaluate the efficiency in withstanding transportation hazards, so as to formulate a complete, economically viable value chain, capable of helping farmers to get better returns and reduce post harvest loss with little investment.

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Appendix

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. Of Post Harvest Technology

Title: Post harvest management practices in pineapple (*Ananas comosus* (L.) Merr.)

Sample: Pineapple var. Mauritius

Instructions : Your are given 6 samples. Evaluate them and give scores for each criteria

Criteria	Samples					
	1	2	3	4	5	6
Appearance						
Colour						
Flavour						
Texture						
Taste						
After taste						
Overall acceptability						
Any other remarks						

Score

Like extremely -9

Like very much -8

Like moderately -7

Like slightly -6

Neither like or dislike -5

Dislike slightly -4

Dislike moderately -3

Dislike very much -2

Dislike extremely -1

Date:

Name:

Signature:

APPENDIX II

Average temperature and RH of ambient condition during storage

Month	Average Temperature (°C)		RH (%)
	Maximum	Minimum	
January	32.7	22.3	92.7
February	33.2	23.4	89.5
June	31.3	24.7	91.4
July	30.3	24.3	92.4
August	32.7	25.9	90.1

Abstract

ABSTRACT

The experiment entitled "Postharvest management practices in pineapple (*Ananas comosus* (L.) Merr.)" was conducted at the Department of Post Harvest Technology, College of Agriculture, Vellayani, during the year 2018-2020, with the objective to standardize the post-harvest management practices in pineapple for improved fruit quality. The experiment was conducted separately for two maturity stages viz., stage1 (0- 25% eyes predominantly yellow) and stage 2 (25-50% eyes predominantly yellow) meant for distant and local markets respectively.

The study was conducted as two continuous experiments. In the first part, harvested pineapple fruits were subjected to four different pre-treatments *viz.,* dipping in hot water of 50 ± 2^0C for 1 minute, hydro cooling for 5 minutes, sanitization with 30 ppm sodium hypochlorite solution for 10 minutes and ozonisation with 2 ppm ozone for 15 minutes. The treated fruits along with untreated fruits were evaluated for the effects of pre-treatments on shelf life, physiological loss in weight and microbial load of pineapple fruits for selection of the best pre-treatment.

All the pre-treatments resulted in enhanced shelf life, reduced physiological loss in weight and low microbial load on pineapple fruit surface. Pineapple fruits of stage1 and stage 2 maturity, when subjected to hot water dip at 50 ± 2^0C for one minute had maximum mean shelf life of 15.2 and 12.6 days respectively, with least physiological loss in weight and microbial count.

Sanitization using 30 ppm sodium hypochlorite solution for 10 minutes was equally effective as hot water dip at 50 ± 2^0C, whereas ozonization was effective as hot water treatment in stage 2 pineapple alone.

Based on efficiency and economics in maintaining the extended shelf life with least PLW and microbial load, hot water dip at 50 ± 2^0C for one minute was selected as the best pre-treatment for both maturity stages and was selected for the second part of the experiment.

In the second part of the experiment, harvested pineapple fruits of two maturity stages were independently subjected to hot water dip at 50± 2^0C for one minute and stored under low (24^0C) and ambient (32^0C) temperature conditions along with untreated fruits and the stored fruits were subjected to evaluation of physiological, chemical and sensory quality parameters.

Untreated pineapple fruits of stage 1 maturity stored under ambient temperature had least shelf life (12 days), highest physiological loss in weight (12.29 %) and had to be discarded after 12 days due to spoilage. Fruits treated with hot water and stored under low temperature conditions had maximum shelf life (21.25 days), least PLW (4.53%), minimum TSS (14.26 °B), total sugar (10.45%) and reducing sugar (4.36%), highest acidity (0.91%), non-reducing sugar (6.09%) and vitamin C (22.85%) after 12 days of storage.

In case of fruits of stage 2 maturity, untreated pineapple fruits stored under ambient temperature had least shelf life (10.5 days) and highest physiological loss in weight (8.40%). Fruits treated with hot water and stored under low temperature had maximum shelf life (18.25 days), least PLW (2.48%), minimum TSS (15.78°B), total sugar (11.15%) and reducing sugar (4.13%), highest acidity (0.81%), non-reducing sugar (7.02%) and vitamin C (22.91%) after 9 days of storage.

All the treatments were effective in maintaining high sensory quality parameters viz., appearance, flavour, texture, taste, flesh colour and over all acceptability, of which hot water dip treatment followed by low temperature storage had the highest mean score while untreated fruits stored under ambient temperature recorded the lowest scores in both maturity stages.

In general, fruits treated with hot water when stored under low temperature conditions had better physiological and chemical quality parameters and the same were reflected in acceptability scores of the commodities. Hot water treatment alone gave better quality pineapple fruits compared to untreated ones, and a combination of hot water treatment and low temperature storage further improved the quality and shelf life of fruits of both maturity.

It can be concluded that pineapple fruits (var. Mauritius) harvested with crown and two cm stalk at stage1 maturity when subjected to hot water treatment at 50±2^0C for 1 minute followed by low temperature storage (24^0C) could extend the shelf life of pineapple meant for distant markets up to 21.25 days. Same management practice resulted in extension of shelf life to18.25 days for stage 2 maturity stage pineapple fruits meant for the local market.