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POSTHARVEST EVALUATION OF BITTER GOURD AS INFLUENCED BY GROWING CONDITION, HARVEST MATURITY, PREPACKAGING AND STORAGE

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(2011-12-112)

THESIS

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2013

DECLARATION

I hereby declare that this thesis entitled **"Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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To

My Family

And

My Beloved guide Dr. T.R. Geetha lekshmi

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LIST OF ABBREVIATIONS

%	-	Per cent
°C	-	Degree celsius
CD	-	Critical difference
cm	-	Centimetre
DW	-	Dry weight basis
et al.	-	And others
FCRD	-	Factorial Complete Randomised Block Design
Fig.	-	Figure
g	-	Gram
ha^{-1}	-	Hectare
hr	-	Hour
i.e.	-	That is
Kg	-	Kilogram
L	-	Litre
LDPE	-	Low Density Polyethylene
m	-	Metre
mg	-	Miligram
ml	-	Millilitre
Naclo	-	Sodium hypochlorite
ND	-	Not Developed
O_2	-	Oxygen
PLW	-	Physiological loss in weight
ppm	-	Parts per million
POP	-	Package of practices
RH	-	Relative humidity
SE	-	Standard error
Sl.	-	Serial
Viz	-	Namely

INTRODUCTION

1. INTRODUCTION

Vegetables occupy a significant place in human diet and provide vitamins and minerals essential for human health and growth. Their production being labour-intensive and undertaken largely by small farmers, vegetables play an important role in the household nutritional security, employment generation and alleviation of hunger.

Bitter gourd *(Momordica charantia L.)* is an important cucurbitaceous vegetable of Kerala, cultivated in an area of 2366 ha (FIB, 2013). It is also known as balsam pear, bitter melon, bitter cucumber, karela, and African cucumber. The fruit is considered as 'Nature's Anti-Diabetic', tonic, stomachic, stimulant, antibilous, laxative, useful in gout, rheumatism and sub acute cases of spleen and liver diseases (Goreja, 2003). Bitter gourd also has been documented with antiviral activity against numerous viruses including Epstein-Barr, herpes, and HIV viruses. It also provides. antibacterial protection and could also play an important role in the prevention of some cancers (Kumar *et al.*, 2010). The medicinal value of the gourd in the treatment of infectious diseases and diabetes is attracting the attention of scientists and consumers worldwide. Hence, there is an increasing demand for bitter gourd both in domestic as well as international market.

Agricultural Processed Food Products and Export Development Authority (APEDA) has identified bitter gourd as one of the potent vegetables for export. But there is a wide gap between demand and supply and projected demand of bitter gourd is likely to rise to 193 MT by 2030 (Thangamani *et al.*, 2011).

There has been a major shift in for organic products especially fruits and vegetables. 'Organic vegetables' sector has the potential to grow rapidly mainly because of the increased awareness for health foods, environmental consciousness and rising disposable incomes. Organically grown vegetables are also being increasingly exported. Organic as well as conventional bitter gourd has high demand for domestic consumption and export.

Bitter gourd is highly perishable in nature. Shorter shelf life and higher postharvest losses are critical constraints in its demand-supply scenario. Increased production is significant only when they reach the consumer in acceptable quality and at a reasonable price. It is known that food loss reduction is normally less costly than equivalent increase in production. Reduction of postharvest losses is essential in increasing food availability from existing production and plays an important role in food and nutritional security.

Postharvest quality and shelf life of bitter gourd is greatly influenced by the maturity of fruit at harvest. Precise determination of the stage of maturity is difficult during commercial harvest and some of the fruit harvested at full physiological maturity begin to ripen during handling. Harvesting at proper maturity can not only increase the shelf life but also maximize the yield output from the plant as delayed harvesting affect further bearing adversely. After harvesting at optimum maturity, the produce should be precooled to reduce the field heat which is an important step in postharvest handling. Use of sanitization agents in precooling water has an added advantage to minimize the microbial contamination. Similarly, prepackaging and storage conditions also influence the postharvest life and nutritional quality of bitter gourd.

In view of the above, the present study on "Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage" for the variety Preethi was undertaken at Department of Processing Technology, College of Agriculture, Vellayani with the following objectives.

1. To determine the stage of harvest maturity for organically and conventionally grown bitter gourd var. Preethi
2. To determine the effect of harvest maturity, growing conditions, prepackaging and storage on postharvest life of bitter gourd

3. To develop a postharvest package for bitter gourd with extended shelf life and minimum nutritional loss

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

India is the second largest producer of vegetables in the world and can be considered as vegetable basket of the world. In Kerala, vegetable cultivation is taken up on a commercial basis of which bitter gourd has an important position. In Ayurvedic medicine bitter gourd is popularly known as "Plant insulin" because of antidiabetic property and has many health benefits. The perishable nature of vegetables necessitates importance of postharvest handling of bitter gourd. Any postharvest handling practices aim to reduce postharvest losses in quantity and quality and to maintain safety between harvest and consumption sites. Several factors are affecting the shelf life of vegetables such as harvesting at optimum maturity, postharvest treatments, using different types of packaging materials, and altering storage conditions. Literature on postharvest technology of bitter gourd is comparatively limited. The present studies were conducted on determination of harvest maturity, precooling treatments with sanitizing agent, prepackaging and storage. The available literature related to these aspects has been reviewed in this chapter.

2.1 DETERMINATION OF HARVEST MATURITY

Stage of harvest maturity plays an important role in reducing the postharvest losses. Optimal harvest in bitter gourd is indicated by slight changes in fruit colour and increased exocarp development which are difficult to evaluate. Harvesting at proper maturity can not only increase the shelf life of bitter gourd but also get the maximum yield from the plant as delayed harvesting affects further bearing adversely.

2.1.1 Fruit external characters

The two main external indices of bitter melon harvest maturity are fruit size and skin colour. Bitter melon fruit should be harvested at an immature stage, near full size but before the skin starts to change colour. The proper size depends on the use and the cultivar. The fruit should be firm to the touch with a tender skin. Skin colour is another widely used index of assessing fruit maturity. The peel should be a uniform colour when harvested, ranging from light green to dark green depending on cultivar. The flesh will have a uniform white colour (Anonymous, 2004).

Bitter gourd fruit should be light green, thick and juicy during harvest maturity (Lim 1998). Iswarprasad (2000) found that bitter gourd fruit girth had high genetic variation.

Bitter gourd fruit were harvested when fruit Colour of tender fruits turn to light green or dark green or whitish green (Thamburaj and Singh, 2001). In bitter gourd, fruit size is a reasonable indicator of maturity; fruit should be firm, mid-green colour and free of visual defects. Harvesting should be done before onset of ripening or before the seed cavity shows any pink/ red colour (Traynor, 2005). Fruit length and fruit diameter of bitter gourd fruits had increased when harvesting was delayed from 8 days to 12 days after fruit set (Pal *et al.* 2005).

Narayan *et al.* (2006) evaluated fifteen diverse genotypes of bitter gourd at Jammu and Kashmir for fruit length and fruit diameter. They stated that highest fruit diameter and maximum fruit length was produced by cultivars Preethi and BGR-1, respectively.

Yadav *et al.* (2008) recorded 15.67 cm fruit length, 4.83 cm fruit width, 118.33 g fruit weight with 70 mg/100g of vitamin C for the variety Preethi. Bitter gourd cultivar Preethi recorded an average fruit length 24.56 cm; fruit girth 16.90 cm, fruit weight 189.95 g at harvest (Reshmi, 2009). Bitter gourd recorded a fruit length 23 cm, fruit diameter 6 cm, fruit weight 276 g at harvest time (Gosbee and Marte, 2010). Thangamani *et al.* (2011) found an recorded the average fruit length 17.92 cm; fruit girth 14.39 cm, fruit weight 110.66 g at harvest for bitter gourd Preethi.

Katyal (1977), Thomas (1984) and Jayasree (2005) reported increased mean length of bitter gourd fruits by the combined application of organic and inorganic fertilizers than organic alone.

2.1.2 Fruit internal characters

While commercial maturity in bitter gourd is very hard to judge from the external characters, internal characters are better indicators. The main internal indices of harvest maturity are seed colour, flesh colour, texture, and the amount of bitter taste sensation. The internal flesh of bitter melon turns a brilliant yellow as the fruit ripens and the immature white seeds become tough and darken. Any yellow colouration of the flesh indicates fruit over maturity (Anonymous . 2004).

The seeds should be soft and white creamy to pale green-brown at harvest time (Huyskens *et al.* 1992). Growth and seed development of bitter gourd fruits was influenced by growing temperature. It was rapid under high temperatures (Chang *et al.,* 2000). At optimum harvest maturity seed colour was creamy or pale green –brown and at over maturity placenta turned to pink (Vujovic *et al*., 2000).

Seed coat must be creamy or pale green – brown when bitter gourd fruit harvested with over maturity indicated by any shade of pink seed coat (Morgan and Midmore, 2002). Bitter gourd fruit seed colour goes from white to pink and then red when matured (Owens, 2003). The seeds should be soft and white during harvest time (Palada and Chang, 2003). Reshmi (2009) recorded about 20-45 seeds per fruit, and 100- seed weight as 20.15 g for bitter gourd Preethi.

Behera *et al.* (2010) reported that seed coat colour is a good indicator of optimal harvest maturity which changes from creamy or pale green-brown to pink colouration with over maturity. Bitter gourd fruits can be harvested when the seed colour is white to creamy-white (Mohammed, 2010).

Dhillon (2013) reported 12-18 number of seeds per fruit (small fruit); 35-40 (medium & big fruit) at time of harvest of bitter gourd.

2.1.3 Harvest maturity

Kanellis *et al.* (1986) reported that stage of development at harvest is important in determining postharvest quality of bitter gourd and cucumbers. Bitter gourd fruit takes about 15 to 20 days after fruit set (90 days from planting) to reach marketable age (Reyes *et al.*, 1994). Zong *et al.* (1995) stated that bitter melon can be harvested at two distinct stages: young developing or immature fruits and fully developed but green fruits. The postharvest quality and shelf life of bitter melon were greatly affected by the developmental stage of the fruit at harvest. Bitter gourd fruits are harvested in every 2 to 3 days interval as the fruit ripens quickly (Desai and Musmade 1998).

Morgan and Midmore (2002) opined that harvest maturity is difficult to determine in bitter melon and physiologically mature fruit is unsuitable for marketing. Pal *et al.* (2005) suggested that harvest maturity in bitter gourd had great influence on physiological and nutritional properties of bitter gourd during postharvest life. He also found that harvesting of 'Pusa Hybrid-1' bitter gourd can be extended up to 12 days after fruit set for better nutritional quality and marketability.

Bitter gourd Fruits can be harvested at any stage of development, but are typically harvested at full sized but green, about two weeks after anthesis (Mohammed, 2010). Harvesting of bitter gourd fruits at 15-16 days after flowering opening was reported by Gosbee and Marte (2010). Physiological properties of bitter gourd are greatly influenced by stage of harvest maturity. Dhillon (2013) revealed that bitter gourd can be harvested at 15 to 16 days maturity for marketable quality.

2.2 PRECOOLING TREATMENTS

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

Sodium hypochlorite was the active antimicrobial agent in the washing bath for processed cabbage, carrot, onion and Chinese cabbage (Dufkova, 2000). Suzulow (2000) reported that sodium hypochlorite can be used for sanitization of organically grown vegetables. Surface sterilization with sodium hypochlorite is effective in extending shelf life of fresh-cut tomato (Hong and Gross, 2001).

Chlorine and other sanitizers are effective against microbial growth on inorganic surfaces and cutting equipments (Bacts and Tamplin, 2002). Fruits were harvested along with stalks and subjected to precooling temperatures less than 10°C for a period of 5 minutes to increase shelf life (Sankaran *et al.* 2002). Reduced microbial population in minimally processed cabbage after sanitization for 10 min with sodium hypochlorite at 200 mg/l was reported by Fantuzi and pushman (2004).

Ball and Farkas (2006) opined that whole fresh fruits before processing are washed with water containing chemical sanitizer agents such as chlorine, chlorine dioxide, tri sodium phosphate, hydrogen peroxide, organic acids and ozone to decontaminate the surface of the fruit with chlorine being among the more effective chemical additives in reducing pathogenic or naturally occurring micro-organisms (by the order of 10 to 100 fold).

The effectiveness of sodium hypochlorite in the cleaning and disinfection process depends on the concentration of available chlorine and the PH of solution (Fukuzaki, 2006). Bitter gourd fruits have less keeping quality and should be marketed without any delay and precooling is necessary to reduce field heat (Gopalakrishnan, 2007). Liu *et al* (2007) recorded lower PLW in NaClO treated tomato fruits. Sodium hypochlorite is the most widely used sanitizer in the fresh-cut industry (Lee and Baek, 2008). Sodium hypochlorite was found as effective sanitizer in pointed gourd (Koley *et al.*, 2009).

Several studies demonstrated that the application of chlorine dioxide, hydrogen peroxide and sodium hypochlorite can reduce population of total aerobic bacteria, yeast and moulds on the surface of tomato, sweet pepper, cucumber and strawberry (Alvaro *et al.*, 2009; Kim *et al.*, 2010).

Washing of egg fruits in 100-200 ppm sodium hypochlorite solution is useful for sanitizing to minimize microbial decay during storage (Acedo and Weinberger, 2010).Tomato fruit surface sterilized with sodium hypochlorite (500 ppm) for 10 minutes so as to reduce the fungal infection and air-dried after harvesting was observed by Nirupama *et al.* (2010). Bitter gourds have a relatively high respiration rate and therefore prompt removal of the field heat via hydro-cooling or room cooling is recommended for increasing shelf life (Mohammed, 2010).

Bitter gourd fruit surface sterilized with sodium hypochlorite at a concentration of 150 ppm (15g/L) as a sanitizing agent with maintained pH level of water upto 6.5 for effective cleaning it reduce the fungal infection. (Anonymous 2004).

2.3 PREPACKAGING AND STORAGE

Poor prepackaging and storage practices cause postharvest losses in vegetables. It is estimated that loss of nearly 25-40 % of vegetables occurs due the rough prepackaging and improper post harvest handling and storage practices and the variation often depends on type of vegetables. Deterioration encompasses both quantitative and qualitative, which are estimated as high as 50% in most of the developing countries (Kader, 1992).

2.3.1 Prepackaging and storage on shelf life

Fruits and vegetables are highly perishable, as they continue their metabolic processes after harvest and these bilological activities deteriorate the quality (Singh *et al.*1980). The rate of respiration and multiplication of decay organisms is higher at higher temprature (Desai *et al.*, 1986). Product should have less than 3% to 5% water loss to maintain its marketability. Wilting and shriveling caused by water loss seriously damage the product appearance (Herdenburg *et al.*, 1986 and Mitchell, 1991).

The most effective method to increase the storability of fresh vegetables commodities is the refrigerated storage, where temperature should be reduced to the minimum and the relative humidity need to be elevated to the maximum to guarantee a good safety and quality of the vegetables. Relative humidity in the storage is seldom maintained above 95%, mainly beacause of the fear of increased pathogen activity. Mesophilic microorganisms can be significantely reduced with decreasing storage temperature (Beuchat and Brackett, 1990 ; Nguyen and Carlin , 1994).

The better storage life of spinach grown with organic manure was found to be associated with low free amino acid content and lower level of nitrate accumulation (Lampkin, 1990).

Perforated film may offer a simple solution to the water condensation problèmes. In fact, the permeability of water vapor is increased by holes in the film. The main advantage of such films is that they prevent anarobic conditions, reduces water loss and let the excess water loss is associated with weight loss, shrivelling, wilting, loss of quality and softening of the tissues (Kader, 1991).

Biological changes and decay losses caused by various microbes are the main reasons for the deterioration of vegetables. (Rahaman *et al.*, 1992). Zong *et al.* (1993) opined that bitter melon and fuzzy melon can be stored about 2 weeks at 10°C to 12.5°C (50" to 55°F). When fruits are stored at temperature 59°F fruit development (seed development, colour) changes continued during storage.

Mohammed and Wickham (1993) found that bitter gourd fruits stored individually wrapped in low density polyethylene (LDPE) film or unwrapped for up to 21 days at 5–7°C, 20–22°C and 28–30°C, respectively. Observations were taken on several quality parameters including marketable quality. Storage of film-wrapped fruit at 5–7°C resulted in extension of shelf-life in excess of two weeks and delayed appearance of chilling injury symptoms. Additionally, film-wrapped fruits stored at 5–7°C were still marketable after 21 days, had lowest fresh weight losses, less softening, reduced incidence of postharvest rots and minimal changes in vitamin C content and PH. Postharvest developmental changes resulted in fruit splitting and ripening in bitter melon, thinning the edible fresh (Zong *et al.*, 1993).

The perishable nature of the bitter gourd accounts to 20-30 per cent of spoilage. In bitter gourd, Veenakumari *et al.* (1994) reported that a shelf life of 2.3 days under normal storage and organic bitter gourd recorded more shelf life.

Higher temperatures hasten ripening process. More mature fruit (slightly soft but still green) will rapidly begin to ripen if the temperature is too high, risking the contents of the entire carton/container, but maturity has less effect on postharvest life when fruit is stored at the correct temperature. Fruits of bitter gourd harvested at horticultural maturity can be stored up to 14 days in humidified air at different temperatures. Quality of fruit was best maintained if bitter melon was stored at 10 and 12.5°C. Fruits at 15°C continued to develop, showing undesirable changes including seed development, loss of green color, and fruit splitting. Immature fruit maintained postharvest quality better than fruit harvested at the fully developed green stage (Zong *et al.,* 1995).

Postharvest losses of vegetables can be reduced by many physical and chemical treatments. These may be modified atmosphere packaging. Low temperature storage, correct humidity, inactivation of enzyme and sanitation treatments etc (wills *et al.,* 1998).

Joseph (1998) reported that shelf life of snake gourd grown with organic residues was much higher as compared to that grown with fertilizers when vermicompost was used as nutrient source, it produced fruits with more shelf life, P & K content over FYM & poultry manure. Rajasree (1999) reported more shelf life for bitter gourd with organic manure application. Increased nitrogen content was seen to decrease firmness of vegetables (Sams, 1999).

Field heat, harvest maturity and mode of transportation are all critical in determining shelf life. Temperature has a greater effect on bitter melon shelf life and quality than packaging, and low temperature reduces ripening and hence quality loss. Optimum shelf life is achieved at 5°C but chilling injury (dark watery pits on skin) was observed after 3 weeks at 5°C. When bitter gourd stored in 7-10°C shelf life was recorded up to 2-3 weeks (Gosbee and Lim, 2000). Increased level of nitrogenous fertilizers decreased volatiles, including aromatic compounds which affected the taste adversely (Lee *et al.*, 2000).

Bitter gourd stored in a cool place at 12–13°C with 85–90% relative humidity, fruit storage life can be extended by 2–3 weeks. Temperature above 13°C, will result in fruits turning yellow and splitting open (Palada and Chang, 2003).

Renu (2003) studied the effect of vermicompost on quality of bitter gourd. The author observed that texture, odour and keeping quality was well pronounced in organically treated pots.

The optimum postharvest temperature for bitter melon is 10°C (50°F). At this temperature, bitter melons can be expected to have a 2 to 3 week market life. Holding bitter melons without refrigeration at ambient temperature will result in noticeable shrivelling, softening, and decay after 3 to 4 days. Storage of bitter melons below 7°C (45°F) should be avoided, as this will result in chilling injury and RH- 95 %.(Anonymous, 2004). Same work has done Owens (2003) he has reported that bitter melon is prone to chilling injury and it should be kept between 10°C and 15°C during storage.

Talukder *et al.* (2004) reported that the physical appearance of bitter gourd (colour and degree of shrinkage) at 6 days after storage was better in perforated polyethylene and wet gunny bags.

Rajasree and Pillai (2012) reported that higher levels of inorganic nitrogen reduced ascorbic acid and application of plant nutrients through organic manuring increased the shelf life of bitter gourd.

Optimal storage temperature for bitter gourd fruit is 7–10°C with 85–90% relative humidity Traynor (2005). Gosbee and Marte (2010) revealed that bitter gourds were stored at temperature 10°C with storage life up to 14 days. Mohammed (2010) found that bitter gourd had marketable shelf life up to 7-12 days when stored at 10-12.5°C, 85-90% relative humidity and individually film-wrapped fruits stored at 5-7oC were marketable up to 21 days. Optimum storage period up to 2-3 weeks was reported in bitter gourd when stored at 10-12°C with relative humidity of 85-90 per cent (Anonymous, 2004).

2.3.2 Nutritional qualities

Islam *et al.* (2008) reported that during storage, bitter gourd genotypes showed different types of nutritional changes which result in variation of its nutritional status. Hence, it is essential to understand the favourable storage condition with increased shelf life and minimum nutritional loss.

Illeperuma and Jayasooriya (2002) reported a decrease in titratable acidity with refrigerated storage of mangoes, attributed to the initiation of ripening in the presence of ethylene that is automatically stimulated by low temperatures. Kulkarni *et al.* (2005) reported that titratable acidity of fresh bitter gourd of fruits ranged from0.08 – 0.21 per cent. Fisk *et al.* (2006) also reported decrease in titratable acidity with refrigerated storage of fruits. Aminnah and Anna (2011) found that the titratable acidity of bitter gourd decreased with ripeness of maturity and unripe bitter gourd fruit and mature bitter gourd fruits showed no significant difference.

Bitter gourd is an inexpensive source of protein. Wills *et al.* (1984) found that protein content in mature bitter gourd is 0.90 g /100g. Tomati *et al.* (1990) reported that incorporation of vermicompost increased protein synthesis in lettuce and raddish by 24 and 32 per cent. Florescu *et al.* (1991) reported that the cucumber grown with urban waste compost had higher content of carbohydrate and increased level of N fertilizers decreased the content of glucose and quality of protein in vegetables. Total protein content of young and immature whole bitter melon, containing seed and pericarp, ranged from 14.2% to 18.0% (Yuwai *et al.*, 1991). Organic crops were superior to conventional ones and had higher vitamin C and better protein quality suggested by Worthington (1998). Organically grown french beans had higher protein content (Singh, 2002). Bhadoria *et al.* (2002) reported that protein and total mineral content of okra fruit was high when it was treated with FYM.

Assubaie and El-Garawany, (2004); Donya *et al.* (2007) observed total protein content of young and immature whole bitter melon, containing seed and pericarp, ranged from 14.2% to 18.0%. Horax *et al.* (2010) recorded that protein content of immature bitter melon pericarp (11.5%) was significantly higher than those of mature and ripe bitter melon pericarp (8.8% and 8.5%, respectively) which were not significantly different.

Krishna (2005) noticed that inorganic treatments resulted in high fibre content. Neelam *et al.* (2009) revealed higher fibre content in organically grown brinjal. Horax *et al.* (2010) observed that fibre content of mature bitter melon pericarp was 14.4 per cent. Aziz *et al.* (2011) reported that bitter gourd contain fiber 1.9 g/100 g in skin and flesh 1.8 g/100g. Dhillon (2013) reported that fibre content of mature bitter gourd fruit is 2.8 g/ 100 g.

Mineral content of organic vegetables were reported by many researchers. Tindall (1983) reported that 100 g of fruit contained about 92% water, 1.2 g protein, 0.2 g fat, 1.0 g fibre, 13 mg calcium, 0.2 g iron. Mineral content 100g edible portion of bitter melon fruits is reported as Ca 22 mg, K 260 mg, Mg 16.0 mg, Fe 0.9 mg, Na 3.0 and Zn 0.1mg by Wills et al. (1984).

Florescu *et al* .(1991) reported that cucumber fruits grown with urban waste compost had higher contents of potassium and magnesium. Abusaleha (1992) stated that increased minerals in gourds are the impact of application of organic manures. Auclair *et al.* (1995) proved that organically grown tomato fruits had higher Ca, Cu, Fe, P and Zn contents. In bitter gourd, Tee *et al.* (1997) reported an iron content of 6.3 mg/100g while. Increased mineral content in gourds were found in organically grown vegetable crops (Rani *et al.*, 1997). Kumar and Sagar (2003) found that a 100g edible portion bitter gourd contain 1.8 mg of iron.

Regarding vegetables like potato, carrot, beetroot, lettuce, kale, leek, turnips, onion, celeriac and tomato, a trend has been observed for higher levels of iron and magnesium expressed on a fresh matter basis through organically grown methods (AFSSA, 2003). In a review by Rembialkowska (2007) stated that organic crops on an average contained 21 per cent more iron and 29 per cent more magnesium than its conventional counterparts.

Horax *et al.* (2010) reported that minerals content of mature bitter melon was P - 5.8 mg/g, K - 42.7 mg/g, Mg: - 3.0 mg/g , S- 1.1 mg/g, Ca:- 2.7 In ug/g, Na:- 264 mg/g, Fe:- 45 mg/g, Mn :- 32 mg/g, Zn :- 41 mg/g , Cu :- 13 mg/g, Al :- 11 mg/g. Ullah et al. (2011) observed that magnesium content in bitter gourd ranged from 0.99 to 1.1 mg % and calcium 0.54 to 7.0 mg % of the minerals examined and high amount of calcium was recorded in bitter gourd 137.69 mg / 100 g by Soomro and Ansari (2005). Dhillon (2013) reported that nutrient profile of bitter gourd fruit (100 g raw fruit) as Ca 19 mg , Fe 0.43 mg, Mg 17 mg, P 31 mg ,K 296 mg , Zn 0.8 mg.

An increase in ascorbic acid content of spinach leaves was found with the application of FYM was reported by Kansal *et al.* (1981). Wills *et al.* (1984) found that ascorbic acid content in bitter gourd is 50.0 mg. Vahab (1989) reported that vitamin c content varied from 45.5 to 122.38 mg/100g in 50 genotypes of bitter gourd. Higher vitamin C content (28 per cent higher) was observed in organic vegetables by Lampkin (1990). Florescu *et al.* (1991) recorded that cucumber fruits grown with urban waste compost had higher contents of vitamin C.

Anitha (1997) reported that chilli plants treated with poultry manure recorded the maximum ascorbic acid content in fruits as compared to vermicompost and control treatments. Increased ascorbic acid content in tomato, pyruvic acid in onion were the impact of application of organic manures (Rani et al., 1997). Organic crops were superior to conventional ones and had higher vitamin C and better protein quality suggested by Worthington (1998).

Karla *et al.* (1998) reported that the ascorbic acid content in bitter gourd fruit declined with increasing age. Kumar (2000) reported that organic manure treatments performed significantly superior to POP which recorded 60.93 mg $100g^{-1}$ ascorbic acid content in amaranthus.

Increased vitamin C was reported in organically grown vegetables (beet root, spinach, turnip, cabbage, carrot, lettuce, apples and pears) compared to conventionally cultivated crops by Salunkhe and Desai (1998); Heaten (2001); Kumpulainen (2001) and Worthington, (2001).

In bittergourd Sankaran *et al.* (2002) reported that ascorbic acid content seemed to decrease with maturity and larger fruits had lower ascorbic acid content.

Omae *et al.* (2003) reported that cattle compost application increased freshness and vitamin C content in melon.

Vijayaraghavan *et al.* (2006) also reported that there is decreasing trend in ascorbic acid content with the advancement of age and the fruits harvested at 15 days after anthesis showed high content.

Dey *et al.* (2006) found that ascorbic acid content in Indian bitter gourd varies from 92.15-122.07 (mg/100g). Yadav *et al.* (2008) found that the vitamin C content of bitter gourd genotypes ranged from 44.67 to 120.00 mg/100 g. Aziz *et al.* (2011) reported that bitter gourd fruit contain vitamin c 108.66 (mg / 100mg) in skin and 120.22 mg /100mg in flesh. Dhillon (2013) reported ascorbic acid content of mature bitter gourd fruit as 84 mg.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage" was undertaken at Department of Processing Technology, College of Agriculture, Vellayani during 2011-2013, with the objective to determine the stage of harvest maturity and its influence on postharvest life along with prepackaging and storage condition for organically and conventionally grown bitter gourd (var. Preethi) and to develop a postharvest package for extended shelf life with minimum nutritional loss.

Bitter gourd var. Preethi was cultivated organically at Organic farm of Department of Soil Science and Agiculture, College of Agriculture Vellayani, following the Adhoc recommendations for organic farming (KAU, 2009) and conventionally at seed farm of Department of Olericulture, College of Agriculture Vellayani following the KAU package of practices and recommendations (KAU, 2011). The experimental field was at 8.5°N latitude and 76.9°E longitude, enjoys a humid tropical climate, with red lateritic loamy soil.

The experiment was conducted in the three continues phases

1. **Determination of harvest maturity**
2. **Precooling treatments**
3. **Prepackaging and storage**

3.1 DETERMINATION OF HARVEST MATURITY

Bitter gourd flowers were tagged on the day of opening and fruits with 8 to 17^{th} days maturity (after flower opening) were taken from both growing conditions G_1 (organic) and G_2 (conventional) in three replications. The following external and internal fruit characters were recorded periodically.

Growing conditions – 2

G_1 - Organic

G_2 - Conventional

3.1.1 External fruit characters

3.1.1.1 Fruit length

Fruit length was measured from the stalk end to the blossom end and average expressed in cm.

3.1.1.2 Fruit girth

Girth of fruit was estimated by measuring the individual fruit with a tape at the widest mid point of the fruit and average expressed in cm.

3.1.1.3 Fruit weight

Fruit weight was determined by weighing individual fruits in an electronic weighing balance and average expressed in g.

3.1.1.4 Fruit colour

Fruit colour was recorded by using score card from Bitter Melon Quality Description Language Manual, BMQDL (Vujovic *et al.*, 2000) as shown below.

Fruit colour	Score
Green colour -	1
Light green -	2
Greenish white -	3

3.1.2 Internal fruit characters

3.1.2.1 Flesh thickness

Flesh thickness (cm) was measured by using vernier caliper after cutting the fruit at the centre (Agasiman , 2008).

3.1.2.2 Flesh colour

Flesh colour was recorded by developing score card from Bitter Melon Quality Description Language Manual, BMQDL(Vujovic *et al.*, 2000)

Flesh colour		Score
Green colour	-	1
Light green	-	2
Greenish white	-	3

3.1.2.3 Placenta colour

Placenta colour was recorded by using score card from Bitter Melon Quality Description Language Manual, BMQDL (Vujovic *et al.*, 2000)

Placenta colour		Score
White	-	1
Cream	-	2
Light pink	-	3
Pink	-	4

3.1.2.4 Seed number

Seeds were extracted and average of total number of seeds per fruit was recorded.

3.1.2.5 Seed weight

Seed weight (g) of randomly selected ten seeds of same fruit on fresh weight basis was recorded.

3.1.2.6 Seed colour

Seed colour was recorded by using score card developed from Bitter Melon Quality Description Language Manual, BMQDL (Vujovic *et al.*, 2000)

Seed colour		Score
Whitish yellow	-	1
Creamy	-	2
Light brown	-	3
Brown	-	4

Two harvest maturities were selected from these fruit external and internal observations for further postharvest studies.

3.2 PRECOOLING TREATMENTS

Fruits from plants grown in two growing conditions were harvested at the two maturity stages selected from Part I (3.1) of the experiment. The harvested fruits were precooled to remove field heat using hydro cooling with different concentrations of sodium hypochlorite as sanitizing agent for surface de-contamination and minimizing microbial spoilage during storage. Harvested fruits were immersed in following different treatments for 10 minutes and drained to remove excess water.

Precooling treatments - 5

T_1 - Hydrocooling with 100 ppm sodium hypochlorite

T_2 - Hydrocooling with150 ppm sodium hypochlorite

T_3 - Hydrocooling with 200 ppm sodium hypochlorite

T_4 - Hydrocooling (water only)

T_5 - Control (without precooling)

Harvest maturity-2

M_1 - 14 days maturity

M_2 - 15 days maturity

Growing conditions -2

G_1 - Organic

G_2 - Conventional

Fruits after precooling were stored at room temperature in four replications and the following observations were recorded were recorded daily until the fruits became unacceptable.

3.2.1 Physiological loss in weight

Physiological loss in weight was recorded daily during storage condition and expressed in per cent.

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

3.2.2 Physical and visual characters

The physical and visual characters of fruits like colour, texture, appearance and shriveling were examined daily using the score chart developed by Zong *et al.* (1993).

Fruits characters	Score
Excellent visual quality, colour, fresh, firm	9
Good visual quality, colour, turning soft	7
Fair (suitable) visual quality, yellowing, soft	5
Poor (edible) visual quality, yellowing, soft	3
Inedible, poor visual quality, shriveled, decayed	1

3.2.3 Microbial spoilage

Microbial spoilage were recorded daily during storage following the score chart developed by Matthew and Titus (2011).

Fruit characters	Score
Fruit not showing any decay	0
Slight decay, up to 1% of the surface area of fruit rotted	1
1-5% of total surface exhibiting rotting	2
1- 10% of total surface showing rotting	3
Above 10% of total surface rotted, showing deterioration	4

From these observations the best precooling treatment was selected for further postharvest studies.

3.3 PREPACKAGING AND STORAGE

Bitter gourd fruits from organically and conventionally grown crops were harvested at two maturities and precooled with the best treatment obtained from Part II (3.2) and were prepackaged using following packaging materials and subjected to two storage conditions.

Prepackaging treatments – 5

T_1 - Micro ventilated polyethylene

T_2 - Micro ventilated polypropylene

T_3 - Wrapping with cling film

T_4 - Butter paper

T_5 - Control (without prepackaging)

Storage conditions-2

S_1- room temperature (28 to 32°C)

S_2 - refrigerated condition (10 to 12°C)

Harvest maturity-2

M_1 - 14 days maturity

M_2 - 15 days maturity

Growing conditions-2

G_1 - Organic

G_2 - Conventional

Two uniform sized precooled fruits with approx. weight 400 g were prepackaged in one package after recording the initial weight.

Following observations were recorded on alternate days till fruits became unscceptable.

3.3.1 Physiological loss in weight

Physiological loss in weight (%) was recorded as mentioned in 3.2.1.

3.3.2 Physical and visual characters

Physical and visual characters of fruits were recorded as in 3.2.2.

T1 Micro ventilated polyethylene

T2 Micro ventilated polypropylene

T3 Wrapping with cling film

T4 Butter paper

Plate 1. Prepackaging materials

3.3.3 Microbial spoilage

Microbial spoilage were recorded using the score card described as in 3.2.3.

3.3.4 Nutritional parameters

Following nutritional parameters were analysed before storage and also at the end of shelf life of fruits (when fruits became unacceptable).

3.3.4.1 Acidity

Titratable acidity was estimated as per the procedure described by Ranganna (1986) and expressed as per cent anhydrous citric acid.

3.3.4.2 Crude protein

Crude protein content was calculated by multiplying the nitrogen content of fruit by the factor 6.25 (Simpson et al., 1965; Forbes and Watson, 1992) and expressed as per cent on dry weight basis. Nitrogen content of fruit was estimated by modified micro-kjeldahl method as given by Jackson (1973).

3.3.4.3 Crude fibre

Crude fibre content was determined by the method described by Sadasivam and Manickam (1992) and expressed as per cent on dry weight basis.

3.3.4.4 Calcium

Calcium content was estimated by Ethylene Diamine Tertra Acetic Acid (EDTA) titration method (Jackson, 1973) and expressed as mg/100g on dry weight basis after wet digestion of sample using di -acid mixture.

3.3.4.5 Magnesium

Magnesium content was estimated by Atomic Absorption Spectroscopy after wet digestion of the sample using di-acid mixture as suggested by Perkin-Elmer Corporation (1982) and expressed as mg/100g on dry weight basis.

3.3.4.6 Iron

Iron content was estimated by Atomic Absorption Spectroscopy after wet digestion of the sample using di-acid mixture as suggested by Perkin-Elmer Corporation (1982) and expressed as mg/100g on dry weight basis.

3.3.4.7 Ascorbic acid (Vitamin C)

Ascorbic acid content was estimated by 2, 6-dichlorophenol indophenol dye method (Sadasivam and Manickam, 2002) and expressed as mg/100g.

3.4 STATISTICAL ANALYSIS

The experiment was laid out in Factorial Completely Randomized Design (FCRD) and data analysed using analysis of variance technique (Gomez and Gomez, 1984).

RESULTS

4. RESULTS

Results of the investigation "Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage" are presented in this chapter under the following heads.

4.1 Determination of harvest maturity

4.2 Precooling treatments

4.3 Prepackaging and storage

4.1 DETERMINATION OF HARVEST MATURITY

Fruits of eighth to 17th day maturity (after flower opening) were taken for growth and development studies for both organically and conventionally grown bitter gourd var. Preethi. Physical and visual observations of external and internal fruit characters were recorded periodically to determine the harvest maturity.

4.1.1 Fruit external characters

Results of external characters of fruits recorded during the growth and development of bitter gourd grown under two conditions viz. organic and conventional are presented below.

4.1.1.1 Fruit length

Mean fruit length was found increasing from eighth day (15.69 cm) to 17th day (24.68) after flower opening irrespective of growing conditions (Table 1). Organic and conventional bitter gourd recorded a length of 22.96 cm and 24.26 cm respectively after 14th day of flower opening after which the increase was non significant.

Significant interaction effects were observed between two growing conditions at all the stages of maturity. On eighth day of maturity, fruit length was 15.04 cm under organic (G_1) condition and 16.34 cm for conventionally (G_2) grown bitter gourd and on 17th day it was 24.06 cm and 25.30 cm respectively.

Table 1 Change in fruit length (cm) during growth and development of bitter gourd fruits as influenced by growing conditions

Days of maturity (D)	Fruit length (cm)		Mean
	Organic (G_1)	Conventional (G_2)	
8	15.04	16.34	15.69
9	16.26	18.70	17.48
10	17.32	19.56	18.44
11	18.28	20.68	19.48
12	19.70	22.74	21.22
13	21.60	23.56	22.58
14	22.96	24.26	23.61
15	23.56	24.82	24.19
16	23.94	25.10	24.52
17	24.06	25.30	24.68

Treatment effects	SE	CD (0.05)
D	0.209	0.59
D X G	0.296	0.83

Table 2 Change in fruit girth (cm) during growth and development of bitter gourd fruits as influenced by growing conditions

Days of maturity (D)	Fruit girth (cm)		Mean
	Organic (G_1)	Conventional (G_2)	
8	10.14	12.02	11.08
9	11.84	13.86	12.85
10	13.74	14.74	14.24
11	14.68	15.92	15.30
12	15.96	17.10	16.53
13	16.96	18.06	17.51
14	18.36	19.28	18.82
15	19.10	20.96	20.03
16	19.54	21.14	20.34
17	19.76	21.28	20.52

Treatment effects	SE	CD (0.05)
D	0.169	0.48
D X G	0.240	0.68

4.1.1.2 Fruit girth

An increasing trend was shown in fruit girth from eighth day to 17th day after flower opening (Table 2). At eighth day of growth, mean fruit girth was 11.08 cm and on 17th day it was 20.52 cm. Fruit girth was 19.10 cm was recorded for organic and 20.96 cm for conventional on 15th day of maturity after which increase was non significant.

Interaction effects between growing conditions and all stages of maturity showed significant difference. On eighth day of maturity, fruit girth was 10.14 cm for organic (G_1) and 12.02 cm for conventionally (G_2) grown bitter gourd and on 17th day it was 19.76 cm and 21.28 cm respectively.

4.1.1.3 Fruit weight

Fruit weight increased during growth and development of bitter gourd with the mean fruit weight of 82.84 g on eighth day to 206.06 g on 17th day of maturity (Table 3). Change in fruit weight was also influenced by growing conditions and days of maturity. Fruit weight at different stages of maturity differed significantly between organic (G_1) and conventionally (G_2) grown bitter gourd fruits. Organic and conventional fruits recorded an average weight of 182.84 g and 203.15 g respectively at 15th day of harvest after which the percentage increase was less.

4.1.1.4 Fruit colour

Fruit colour change during growth and development of bitter gourd fruits from to growing conditions were scored and given as mean score value (Table 4). Colour of the fruits changed gradually from green colour (1.00) at eight days of maturity to light green and greenish white (3.00) towards the later stages of maturity irrespective of growing conditions.

Table 3 Change in fruit weight (g) during growth and development of bitter gourd fruits as influenced by growing conditions

Days of maturity (D)	Fruit weight (g)		Mean
	Organic (G_1)	Conventional (G_2)	
8	74.66	91.01	82.84
9	94.48	110.96	102.72
10	114.85	129.76	122.30
11	128.38	143.33	135.85
12	142.04	160.56	150.80
13	154.56	177.09	165.82
14	166.96	191.52	179.24
15	182.84	203.15	192.99
16	189.49	211.35	200.42
17	194.23	217.16	206.06
Treatment effects	SE		CD (0.05)
D	1.224		3.46
D X G	1.732		4.89

Table 4 Colour change in bitter gourd fruits during growth and development

Days of maturity (D)	Fruit colour	
	Mean score	
	G_1	G_2
8	1.00	1.00
9	1.20	1.20
10	1.40	1.40
11	1.60	1.60
12	2.00	2.00
13	2.2	2.2
14	2.40	2.40
15	2.60	2.80
16	2.80	3.00
17	3.00	3.00

Score

1-Green colour 2-Light green 3-Greenishwhite

4.1.2 Internal characters

Results of internal characters of fruits recorded during the growth and development of bitter gourd grown under two conditions viz. organic and conventional are presented below.

4.1.2.1 Flesh thickness

An increasing trend in flesh thickness was observed during the development of bitter gourd fruits (Table 5). On eighth day of maturity it was 1.95 cm and increased to 2.55 cm at 17th day which was on par with the thickness at 15th and 16th days of maturity. Flesh thickness for fruits of two growing conditions showed significant difference upto 11th day of maturity and after that it was on par till 17th day of maturity.

4.1.2.2 Flesh colour

Flesh colour change was similar to that of fruit colour which changed from green to greenish white (Table 6) in both organically and conventionally grown bitter gourd.

4.1.2.3 Placenta colour

Placenta colour of bitter gourd fruits changed from white (1.00) on eighth day of maturity to pink colour (3.90) on 17th day of maturity irrespective of growing conditions (Table 7). The colour started changing to pinkish shade after 15th day of maturity and reached maximum score on 17th day of maturity.

4.1.2.4 Seed number and weight

Seed characters *viz.* seed number and seed weight (10 seed on fresh weight basis) recorded periodically are depicted in Table 8. Seeds were developed only after 10 days of flower opening in both growing conditions (G_1 and G_2). Seed number showed no significant difference during various stages of development for both growing conditions. But significant difference was observed between two growing conditions of which G_2 (conventional) recorded higher average seed

Table 5 Change in flesh thickness (cm) during growth and development of bitter gourd fruits as influenced by growing conditions

Days of maturity (D)	Flesh thickness (cm)		Mean
	Organic (G_1)	Conventional (G_2)	
8	1.87	2.03	1.95
9	1.91	2.07	1.99
10	1.94	2.13	2.03
11	1.97	2.18	2.08
12	2.14	2.28	2.21
13	2.23	2.36	2.30
14	2.34	2.47	2.40
15	2.41	2.54	2.47
16	2.46	2.59	2.53
17	2.49	2.62	2.55

Treatment effects	SE	CD (0.05)
D	0.034	0.09
D X G	0.048	0.14

Table 6 Change in flesh colour of bitter gourd fruits during growth and development

Days of maturity (D)	Flesh colour	
	Mean score	
	G_1	G_2
8	1.00	1.00
9	1.20	1.20
10	1.40	1.40
11	1.60	1.60
12	2.00	2.00
13	2.2	2.2
14	2.40	2.40
15	2.60	2.80
16	2.80	3.00
17	3.00	3.00

Score
1-Green colour 2-Light green 3-Greenishwhite

Table 7 Changes in placenta colour of bitter gourd fruits during growth and development

Days of maturity (D)	Placenta colour Mean score	
	G_1	G_2
8	1.00	1.00
9	1.00	1.00
10	1.20	1.20
11	1.40	1.40
12	1.60	1.60
13	2.00	2.00
14	2.60	2.60
15	2.80	2.80
16	3.10	3.10
17	3.30	3.30

Score

1-White 2- Cream 3- Light pink 4- Pink

Table 8 Seed characters during growth and development of bitter gourd fruits as influenced by growing conditions

Days of maturity (D)	Seed number			Seed weight (g)		
	Organic (G_1)	Conventional (G_2)	Mean	Organic (G_1)	Conventional (G_2)	Mean
8	ND	ND	ND	ND	ND	ND
9	ND	ND	ND	ND	ND	ND
10	30.40	36.00	33.20	3.08	3.10	3.09
11	29.40	35.00	32.20	3.22	3.23	3.22
12	28.60	35.80	32.20	3.54	3.55	3.54
13	31.20	36.00	33.60	3.84	3.85	3.84
14	32.20	35.20	33.70	4.07	4.08	4.08
15	31.40	36.00	33.70	4.10	4.11	4.10
16	30.80	35.00	31.90	4.27	4.28	4.28
17	30.00	35.40	32.20	4.44	4.45	4.44
Treatment effects	SE		CD (0.05)	Treatment effects	SE	CD (0.05)
D	1.030		NS	D	0.089	0.25
D x G	1.457		4.12	D x G	0.126	0.36

ND- seeds not developed

number (35.55) than G_1 (30.50) at different stages of maturity. Seed weight increased during growth and development and reached maximum of 4.44 g and did not show any significant difference between two growing conditions.

4.1.2.5 Seed colour

In both organic and conventional bitter gourd, seed colour changed gradually from whitish yellow on 10^{th} day of maturity (1.00) to brownish (3.80) at 17 days of maturity (Table 9). Seed colour was changing to light brown after 14 days of maturity

Considering both external and internal fruit characters during growth and development, two harvest maturities, viz. 14 and 15 days after flower opening were selected for further postharvest studies in both organic and conventional bitter gourd.

4.2 PRECOOLING TREATMENTS

Bitter gourd fruits (var. Preethi) of two harvest maturity (14 days and 15 days) grown under two conditions (organic and conventional) were subjected to hydrocooling containing sodium hypochlorite at different concentrations. Precooled fruits were stored at room temperature and physiological loss in weight, visual and physical observations were recorded daily. Results of precooling experiments are presented in this session.

4.2.1. Physiological loss in weight (PLW)

Physiological loss in weight (%) during storage of bitter gourd is depicted in Table 10 (10.1-10.5). During all the stages of observation, significant difference was recorded for precooling treatments, maturity and growing conditions. All interaction effects were found non significant.

After first day storage of precooled bitter gourd, lowest PLW was observed in T_2 (2.61) which was superior over all other treatments (Table 10.1). The highest weight loss (2.68) was recorded in T_5 (control).

Table 9 Change in seed colour of bitter gourd fruits during growth and development

Days of maturity (D)	Mean score	
	G_1	G_2
8	ND	ND
9	ND	ND
10	1.00	1.00
11	1.40	1.40
12	1.80	1.80
13	2.30	2.30
14	2.50	2.50
15	3.20	3.20
16	3.60	3.60
17	3.80	3.80

ND- Seeds Not Developed

Score
1 - Whitish yellow 2 – Creamy 3 - Light brown 4 – Brown

Table 10.1 Effect of precooling treatments on PLW (%) of bitter gourd after first day of storage

Treatments	G_1		G_2		Mean- T
	M_1	M_2	M_1	M_2	
T_1	2.61	2.65	2.63	2.66	2.64
T_2	2.59	2.61	2.62	2.64	2.61
T_3	2.62	2.64	2.64	2.66	2.64
T_4	2.63	2.66	2.65	2.67	2.65
T_5	2.66	2.68	2.67	2.69	2.68

Mean	I	II
G	2.63	2.65
M	2.63	2.65

	SE	CD (0.05)		SE	CD (0.05)
T	0.012	0.02	T X G	0.012	NS
M	0.002	0.01	M X G	0.011	NS
G	0.001	0.01	T X M X G	0.010	NS
T X M	0.011	NS			

The weight loss was less in T_4 (2.65) as compared to T_5 and the treatments T_1 and T_3 were on par. Physiological loss in weight was significant for harvest maturity and growing conditions. PLW was highest for M_2 (2.65) than M_1 (2.63) and G_2 (2.65) than G_1 (2.63).

After second day of storage (Table 10.2), lowest PLW was observed in T_2 (2.58) which was superior to other sanitizing treatments. Highest weight loss was noted in T_5 (2.65) which differed significantly from others. T_4 recorded less weight loss (2.63) than T5 and T_1 and T_3 were on par. PLW was significant for harvest maturity and growing condition. Highest PLW was found in M_2 (2.63) and G_2 (2.62).

Lowest PLW (%) was recorded in T_2 (2.55) which was superior to other treatments after third day of storage (Table 10.3). Highest weight loss was occurred in T_5 (2.61) and T_1 and T_3 were on par. Harvest maturity M_1 recorded lowest PLW of 2.56 per cent and growing condition G_1 recorded 2.57 per cent of weight loss.

After fourth day of storage (Table 10.4) PLW recorded was minimum in T_2 (2.52 per cent) and maximum in T_5 (2.58 per cent). The treatment T_4 showed less weight loss (2.56) than T5 and treatments T3 and T1 were on par. Harvest maturity and growing conditions had significant influence on PLW. Lowest weight loss was with M_1 (2.54) and G_1 (2.54).

Lowest PLW was observed in T_2 (2.48) which was superior to other treatments after fifth day of storage (Table 10.5). Highest percent weight loss occurred in T_5 (2.57) which differed significantly from other treatments. Lowest PLW was recorded in harvest maturity M_1 (2.49) and growing condition G_1 (2.50).

4.2.2 Visual and physical characters

Visual and physical characters of precooled and sanitized fruits stored at room temperature were scored and depicted in Table 11. Fruits were of good quality up to five days in T_2 (150 ppm) for 14 days maturity (M_1) grown organically (G_1) where as control (T_5) was good only up to three days. Fruits with

Table 10.2 Effect of precooling treatments on PLW (%) of bitter gourd after second day of storage

Treatments	G_1		G_2		Mean- T
	M_1	M_2	M_1	M_2	
T_1	2.59	2.62	2.60	2.63	2.61
T_2	2.56	2.59	2.58	2.60	2.58
T_3	2.59	2.63	2.61	2.64	2.62
T_4	2.59	2.63	2.63	2.65	2.63
T_5	2.63	2.65	2.64	2.67	2.65

Mean	I	II
G	2.60	2.62
M	2.60	2.63

	SE	CD (0.05)		SE	CD (0.05)
T	0.012	0.01	T X G	0.011	NS
M	0.001	0.01	M X G	0.012	NS
G	0.001	0.01	T X M X G	0.013	NS
T X M	0.013	NS			

Table 10.3 Effect of precooling treatments on PLW (%) of bitter gourd after third day of storage

Treatments	G_1		G_2		Mean- T
	M1	M2	M1	M2	
T_1	2.54	2.59	2.56	2.60	2.57
T_2	2.52	2.55	2.54	2.57	2.55
T_3	2.55	2.59	2.57	2.61	2.58
T_4	2.56	2.60	2.57	2.61	2.59
T_5	2.58	2.61	2.61	2.62	2.61

Mean	I	II
G	2.57	2.59
M	2.56	2.59

	SE	CD (0.05)		SE	CD (0.05)
T	0.012	0.01	T X G	0.011	NS
M	0.001	0.01	M X G	0.010	NS
G	0.002	0.01	T X M X G	0.014	NS
T X M	0.011	NS			

Table 10.4 Effect of precooling treatments on PLW (%) of bitter gourd after fourth day of storage

Treatments	G_1		G_2		Mean- T
	M_1	M_2	M_1	M_2	
T_1	2.49	2.54	2.54	2.56	2.54
T_2	2.49	2.52	2.52	2.54	2.52
T_3	2.54	2.55	2.55	2.57	2.55
T_4	2.55	2.56	2.56	2.57	2.56
T_5	2.56	2.57	2.57	2.61	2.58

Mean	I	II
G	2.54	2.56
M	2.54	2.56

	SE	CD (0.05)		SE	CD (0.05)
T	0.012	0.01	T X G	0.012	NS
M	0.011	0.01	M X G	0.013	NS
G	0.012	0.01	T X M X G	0.021	NS
T X M	0.011	NS			

Table 10.5 Effect of precooling treatments on PLW (%) of bitter gourd after fifth day of storage

Treatments	G_1		G_2		Mean- T
	M_1	M_2	M_1	M_2	
T_1	2.47	2.50	2.49	2.56	2.51
T_2	2.44	2.49	2.46	2.51	2.48
T_3	2.49	2.53	2.49	2.55	2.52
T_4	2.52	2.55	2.54	2.56	2.54
T_5	2.53	2.57	2.57	2.59	2.57

Mean	I	II
G	2.50	2.52
M	2.49	2.54

	SE	CD (0.05)		SE	CD (0.05)
T	0.011	0.02	T X G	0.011	NS
M	0.010	0.01	M X G	0.010	NS
G	0.010	0.01	T X M X G	0.012	NS
T X M	0.012	NS			

Table 11 Effect of precooling treatments on visual and physical characters (mean score) of bitter gourd during storage

Days of storage	M1 (14 days)									
	G1(Organic)					G2(Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
1	9	9	9	9	9	9	9	9	9	9
2	9	9	8	8	7	9	9	8	7	7
3	7	8	7	6	5	6	8	6	5	3
4	6	7	5	3	3	5	6	4	3	2
5	4	5	3	2	1	2	3	1	1	1
	M2 (15 days)									
Days of storage	G1(Organic)					G2(Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
1	9	9	9	9	9	9	9	9	9	9
2	9	9	8	7	7	8	8	8	7	6
3	7	8	6	5	5	6	7	5	4	3
4	5	7	4	3	2	4	5	3	3	2
5	3	4	3	1	1	1	2	`1	1	1

Visual and physical quality scored on a scale of 9 to 1 where

9 - Excellent visual quality, colour, fresh, firm

7 - Good visual quality, colour, turning soft

5 - Fair (suitable) visual quality,yellowing, soft

3 - Poor (edible) visual quality,yellowing, soft

1 - Inedible, poor visual quality, shriveled, decayed

Table 12 Effect of precooling treatments on Microbial spoilage (mean score) of bitter gourd during storage

Days of storage	M_1 (14 days)									
	G_1(Organic)					G_2(Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	1	0	0	0	1	2
4	0	0	0	1	2	1	0	1	2	4
5	1	0	1	2	4	2	1	2	3	5
	M_2 (15 days)									
	G_1(Organic)					G_2(Conventional)				
Days of storage	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	1
3	0	0	0	0	1	1	0	1	1	2
4	1	0	1	2	3	2	1	2	2	3
5	2	1	2	3	5	3	2	3	4	4

0 - Fruit not showing any decay

1 - Slight decay, up to 1% of the total surface area of fruit rotted

2 - 1-5 % of total surface exhibiting rotting

3 -1- 10% of total surface showing rotting

4 - Above 10% of total surface rotted showing deterioration

14 days maturity (M_1) and grown conventionally (G_2) remained good up to four days in T_2 and control were of poor quality on third day of storage. Organic fruits (G_1) of 15 days maturity (M_2) were found excellent up to fourth day of storage (T_2) and of fair quality on fifth day and in control (T_5) fruit quality deteriorated after third day of storage. For conventionally grown (G_2) fruits of 15 days (M_2) maturity fruits were of good quality up to three days in T_2 and in control (T_5) on third day itself fruits were of poor quality.

4.2.3 Microbial spoilage

Fruits precooled with water containing sodium hypochlorite recorded less incidence of spoilage irrespective of the harvest maturity and growing conditions. The treatment T_2 recorded less incidence of rotting when compared to all other treatments (Table 12). In the treatment T_5 (control) rotting started three days after storage and in T_4 spoilage was after four days for both harvest maturities and growing conditions.

4.3 PREPACKAGING AND STORAGE

Bitter gourd fruits harvested at different maturity (14 days and 15 days) for both organic and conventional growing conditions were precooled with water containing 150 ppm sodium hypochlorite. The precooled fruits were packaged with different prepackaging materials and stored at room temperature and refrigerated condition. Physiological and biochemical changes of bitter gourd in different packages during storage were analysed and described in this section.

4.3.1 Physiological loss in weight

Physiological loss in weight (per cent) during storage of prepackaged fruits were analysed periodically and given in Table 13(13.1-13.7). PLW in different packages at the time of storage was zero as there was no loss in weight at the time of storage.

On second day of storage (Table 13.1), significant difference was observed among prepackaging treatments. PLW was minimum (0.20) for the treatment T_1

Table 13.1 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the second day of storage

Treatments	M_1	M_2	Mean	G_1	G_2	S_1	S_2
T_1	0.15 (1.09)	0.25 (1.12)	0.20 (1.09)	0.18 (1.08)	0.22 (1.10)	0.29 (1.14)	0.11 (1.05)
T_2	0.19 (1.09)	0.31 (1.14)	0.25 (1.12)	0.22 (1.10)	0.28 (1.13)	0.35 (1.16)	0.15 (1.07)
T_3	0.81 (1.35)	0.93 (1.39)	0.87 (1.37)	0.79 (1.34)	0.95 (1.40)	1.19 (1.48)	0.57 (1.25)
T_4	1.37 (1.54)	1.49 (1.68)	1.43 (1.56)	1.35 (1.53)	1.51 (1.58)	1.56 (1.60)	1.30 (1.52)
T_5	2.70 (1.92)	2.81 (1.95)	2.76 (1.94)	2.67 (1.91)	2.84 (1.96)	3.87 (2.21)	1.79 (1.67)
Mean	0.94 (1.39)	1.06 (1.44)		0.95 (1.40)	1.06 (1.43)	1.30 (1.52)	0.72 (1.31)
	M_1	M_2	G_1	G_2		G_1	G_2
S_1	1.20 (1.48)	1.40 (1.55)	1.22 (1.49)	1.38 (1.54)	M_1	0.88 (1.37)	1.01 (1.42)
S_2	0.70 (1.30)	0.75 (1.32)	0.69 (1.30)	0.76 (1.33)	M_2	1.01 (1.42)	1.11 (1.45)

	SE	CD (0.05)		SE	CD (0.05)
T	0.001	0.01	T X S	0.012	0.01
S	0.001	0.004	M x G	0.001	0.01
M	0.001	0.004	S x M	0.001	0.01
G	0.001	0.004	S x G	0.001	0.01
T X M	0.001	0.01	T x G	0.000	0.01

(Transformed values ($\sqrt{x} + 1$) are given in parentheses)

(PE) followed by T_2 (PP) (0.25) and was maximum for T_5 (2.76). All the pre packaging treatments were superior over the control (T_5).

The two storage conditions showed significant influence on PLW. Prepackaged fruits stored at S_2 (refrigerated) were found superior with lowest PLW (0.72 per cent) to S_1 (room temperature) which recorded a loss of 1.30 per cent. Bitter gourd grown under G_1 (organic) recorded a PLW of 0.95 per cent which was significantly lower than G_2 (1.06). Fruits with harvest maturity M_1 (14 days) recorded least PLW (0.94) as compared to M_2 (1.06).

Among T x M interactions, T_1M_1 (PE – 14 days) recorded the lowest PLW (0.15 per cent) which was on par with T_2M_1 and superior to other treatment interactions. T_5M_2 (control- 15 days) recorded the highest weight loss of 2.81 per cent. In T x G interactions, lowest weight loss (0.18) was for T_1G_1 (PE- organic) and highest (2.84) for T_5G_2 (control- conventional). In T x S interactions, T_1S_2 (PE- refrigerated) recorded the minimum weight loss of 0.11 per cent and maximum (3.87) was for T_5S_1 (control- room temperature). Among S x M interactions, lowest PLW (0.70 per cent) was observed in S_2M_1 (refrigerated – 14 days) and highest (1.40) in S_1M_2. With S x G interactions, minimum weight loss (0.69) was noticed in S_2G_1 (refrigerated – organic) and maximum (1.38) for S_1G_2 (room temperature - conventional). In M x G interactions, M_1G_1 (14 days-organic) recorded the lowest weight loss of 0.88 per cent and highest weight loss (1.11) for M_2G_2 (14 days- conventional).

During fourth day of storage (Table 13.2), prepackaged bitter gourd had lowest weight loss in T_1 (0.17 per cent) which was superior to the other treatments and highest weight loss observed in T_5 (2.55 per cent). Maturity had found significant influence in PLW with lowest weight loss occurred in M_1 (0.88 per cent) than M_2 (0.99). Growing condition and storage condition had significant influence, lowest PLW was recorded in G_1 (0.88 per cent) than G_2 and S_2 (0.69) than S_1 (1.19 per cent).

In T x M interactions, T_1M_1 (PE- 14 days) recorded the lowest PLW (0.14 per cent) which was on par with T_2M_1 and superior to all other interactions. T_5M_2 (control- 15 days) recorded the highest weight loss of 2.61 per cent. In T x G

Table 13.2 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the fourth day of storage

Treatments	M_1	M_2	Mean	G_1	G_2	S_1	S_2
T_1	0.14 (1.07)	0.21 (1.10)	0.17 (1.08)	0.16 (1.08)	0.18 (1.09)	0.25 (1.12)	0.10 (1.05)
T_2	0.16 (1.08)	0.25 (1.12)	0.21 (1.10)	0.18 (1.09)	0.23 (1.11)	0.29 (1.14)	0.13 (1.06)
T_3	0.73 (1.32)	0.89 (1.37)	0.81 (1.34)	0.74 (1.32)	0.88 (1.37)	1.11 (1.45)	0.52 (1.23)
T_4	1.33 (1.52)	1.44 (1.56)	1.38 (1.54)	1.30 (1.52)	1.46 (1.57)	1.51 (1.58)	1.25 (1.50)
T_5	2.50 (1.87)	2.61 (1.90)	2.55 (1.89)	2.46 (1.86)	2.65 (1.91)	3.47 (2.11)	1.75 (1.66)
Mean	0.88 (1.37)	0.99 (1.41)		0.88 (1.37)	0.99 (1.41)	1.19 (1.48)	0.69 (1.30)
	M_1	M_2	G_1	G_2		G_1	G_2
S_1	1.10 (1.45)	1.29 (1.51)	1.12 (1.46)	1.26 (1.50)	M_1	0.82 (1.35)	0.94 (1.39)
S_2	0.67 (1.29)	0.71 (1.31)	0.66 (1.29)	0.73 (1.31)	M_2	0.95 (1.39)	1.03 (1.43)

	SE	CD (0.05)		SE	CD (0.05)
T	0.001	0.01	M x G	0.002	0.01
S	0.001	0.01	M X S	0.001	0.01
M	0.001	0.01	S x G	0.001	0.01
G	0.002	0.01	T x G	0.002	0.01
T X M	0.001	0.01	T X S	0.002	0.01

(Transformed values ($\sqrt{x}+1$) are given in parentheses) interactions, lowest weight loss (0.16) was for T_1G_1 (PE- organic) which was on par with T_2G_1 and highest (2.65) for T_5G_2 (control- conventional). In T x S interactions, T_1S_2 (PE- refrigerated) recorded the minimum weight loss of 0.10 per cent which was on par with T_2S_2 and maximum (3.47) was for T_5S_1 (control- room temperature). Among S x M interactions, lowest PLW (0.67 per cent) was observed in S_2M_1 (refrigerated – 14 days) and highest (1.29) in S_1M_2. With S x G interactions, minimum weight loss (0.66) was noticed in S_2G_1 (refrigerated – organic) and maximum (1.26) for S_1G_2 (room temperature - conventional). In M x G interactions, M_1G_1 (14 days- organic) recorded the lowest weight loss of 0.82 per cent and highest weight loss (1.03) for M_2G_2 (14 days- conventional).

During sixth day of storage (Table13.3), lowest PLW was recorded in prepackaging treatment T_1 (0.15 per cent) which was superior to other treatments. Highest PLW was recorded in T_5 (2.10 per cent). Minimum weight loss was observed with maturity M_1 (0.78), growing condition G_1 (0.79) and storage condition S_2 (0.65 per cent).

Among the T x M interactions, T_1M_1 (PE- 14 days) recorded the lowest PLW (0.11 per cent) which was on par with T_2M_1 and superior to other treatments and T_5M_2 (control- 15 days) recorded the highest weight loss of 2.13 per cent. The interaction effects T_1M_2 and T_2M_2 were on par. In T x G interactions, lowest weight loss (0.14 percent) was for T_1G_1 (PE- organic) which was on par with T_1G_2 and T_2G_1. The highest weight loss was (2.13) for T_5G_2 (control- conventional). The interaction effects T_2G_1 and T_2G_2 were on par. In T x S interactions, T_1S_2 (PE- refrigerated) and T_2S_2 recorded the minimum weight loss of 0.09 per cent and maximum (2.54) was for T_5S_1 (control- room temperature). Among S x M interactions, lowest PLW (0.63 per cent) was observed in S_2M_1 (refrigerated – 14 days) which was on par with S_2M_2 and highest (1.08) in S_1M_2. With S x G interactions, minimum weight loss (0.63) was noticed in S_2G_1 (refrigerated – organic) and maximum (1.03) for S_1G_2 (room temperature - conventional). In M x G interactions, M_1G_1 (14 days- organic) recorded the lowest weight loss of 0.75 per cent and highest weight loss (0.91) for M_2G_2 (14 days- conventional).

Table 13.3 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the sixth day of storage

Treatments	M_1	M_2	Mean	G_1	G_2	S_1	S_2
T_1	0.11 (1.06)	0.18 (1.09)	0.15 (1.07)	0.14 (1.07)	0.15 (1.07)	0.21 (1.10)	0.09 (1.04)
T_2	0.14 (1.07)	0.22 (1.10)	0.18 (1.09)	0.17 (1.08)	0.19 (1.09)	0.26 (1.12)	0.10 (1.05)
T_3	0.63 (1.28)	0.82 (1.35)	0.73 (1.31)	0.67 (1.29)	0.79 (1.34)	1.01 (1.42)	0.47 (1.21)
T_4	1.25 (1.50)	1.36 (1.54)	1.31 (1.52)	1.26 (1.53)	1.35 (1.53)	1.40 (1.55)	1.21 (1.49)
T_5	2.10 (1.76)	2.13 (1.77)	2.10 (1.76)	2.07 (1.75)	2.13 (1.77)	2.54 (1.88)	1.69 (1.64)
Mean	0.78 (1.33)	0.87 (1.37)		0.79 (1.34)	0.85 (1.36)	1.00 (1.41)	0.65 (1.29)
	M_1	M_2	G_1	G_2		G_1	G_2
S_1	0.92 (1.39)	1.08 (1.44)	0.97 (1.41)	1.03 (1.43)	M_1	0.75 (1.32)	0.80 (1.34)
S_2	0.63 (1.28)	0.68 (1.29)	0.63 (1.28)	0.68 (1.30)	M_2	0.84 (1.36)	0.91 (1.38)

	SE	CD (0.05)		SE	CD (0.05)
T	0.001	0.010	T X S	0.002	0.01
S	0.001	0.004	M x G	0.002	NS
M	0.001	0.004	M X S	0.001	0.01
G	0.001	0.004	S x G	0.001	NS
T X M	0.001	0.010	T x G	0.002	0.01

(Transformed values ($\sqrt{x} + 1$) are given in parentheses)

On sixth day of storage, fruits stored at room temperature were found of very poor quality and acceptance and were discarded.

During eighth day of refrigerated storage (Table13.4), minimum weight loss was found in T_1 (0.08) which was superior to other treatments. Maximum loss was observed in T_5 (1.64 per cent). Maturity and growing conditions had shown significant difference in PLW. In case of maturity, lowest PLW was recorded in M_1 (0.60 per cent) than M_2 (0.64) and G_1 (organic) had lowest PLW (0.60 per cent) than G_2 (0.64).

Lowest weight loss was recorded in T_1M_1 (0.08 per cent) which was on par with T_1M_2 and T_2M_1 and highest was found in T_5M_2 (1.66 per cent). In T x G interactions, minimum PLW was recorded in T_1G_1 (0.08 percent) which was on par with T_1G_2 and T_2G_1 and maximum PLW was in T_5G_2 (1.66 per cent).

During 10[th] day of refrigerated storage (Table 13.5), minimum weight loss occurred in treatments T_1 (0.08) which was superior to other treatments. Highest weight loss was observed in T_5 (1.60 per cent). Lowest PLW was recorded in maturity M_1 (0.56 per cent) than M_2 (0.61) and growing condition G_1 (0.56 per cent) than G_2 (0.61).

Among the interactions, lowest weight loss was recorded in T_1M_1 (0.07 per cent) which was on par with T_1M_2 and T_2M_1. Highest weight loss was recorded in T_5M_2 (1.60 per cent). In T x G interactions, minimum PLW was recorded in T_1G_1 (0.07 per cent) which was on par with T_1G_2 and T_2G_1. Maximum weight loss was in T_5G_2 (1.60 per cent). Other interactions did not show any significant difference.

On 12[th] day of storage lowest weight loss was observed in T_1 (0.07 per cent) which was on par with T_2 and superior to other treatments. Highest PLW was recorded in T_5 (1.52 per cent). In maturity, lowest weight loss was recorded in M_1 (0.52) than M_2 (0.56 per cent). In case of growing conditions lowest PLW was observed in G_1 (0.51) than G_2 (0.58 per cent).

Lowest weight loss recorded in T_1M_1 (0.07 per cent) which was on par with T_1M_2, T_2M_1 and T_2M_2. Highest weight loss was in T_5M_2 (1.54 per cent). In T

Table 13.4 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the eighth day of storage

Treatments	M_1	M_2	Mean	G_1	G_2
T_1	0.08 (1.04)	0.09 (1.05)	0.08 (1.04)	0.08 (1.04)	0.09 (1.05)
T_2	0.09 (1.05)	0.11 (1.07)	0.11 (1.07)	0.09 (1.05)	0.11 (1.07)
T_3	0.37 (1.17)	0.46 (1.21)	0.42 (1.19)	0.37 (1.17)	0.47 (1.21)
T_3	1.10 (1.45)	1.20 (1.48)	1.15 (1.47)	1.10 (1.45)	1.20 (1.48)
T_5	1.62 (1.62)	1.66 (1.63)	1.64 (1.62)	1.61 (1.62)	1.66 (1.63)
Mean	0.60 (1.26)	0.64 (1.28)		0.60 (1.26)	0.64 (1.28)

	SE	CD (0.05)
T	0.001	0.01
M	0.002	0.01
T X M	0.004	0.01
G	0.001	0.01
T X G	0.001	0.01
M X G	0.001	NS

(Transformed values ($\sqrt{x} + 1$) are given in parentheses)

Table 13.5 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the 10th day of storage

Treatments	M_1	M_2	Mean	G_1	G_2
T_1	0.07 (1.03)	0.08 (1.04)	0.08 (1.04)	0.07 (1.03)	0.08 (1.04)
T_2	0.08 (1.04)	0.10 (1.06)	0.10 (1.06)	0.08 (1.04)	0.10 (1.06)
T_3	0.32 (1.15)	0.41 (1.19)	0.42 (1.19)	0.32 (1.15)	0.42 (1.19)
T_4	1.04 (1.43)	1.14 (1.46)	1.13 (1.46)	1.04 (1.43)	1.13 (1.46)
T_5	1.55 (1.60)	1.60 (1.61)	1.60 (1.61)	1.55 (1.60)	1.60 (1.61)
Mean	0.56 (1.25)	0.61 (1.27)		0.56 (1.25)	0.61 (1.27)

	SE	CD (0.05)
T	0.001	0.01
M	0.002	0.01
T X M	0.001	0.01
G	0.001	0.01
T X G	0.002	0.01
M X G	0.001	NS

(Transformed values ($\sqrt{x}+1$) are given in parentheses)

Table 13.6 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the 12th day of storage

Treatments	M_1	M_2	Mean	G_1	G_2
T_1	0.07 (1.03)	0.07 (1.04)	0.07 (1.03)	0.06 (1.03)	0.07 (1.04)
T_2	0.08 (1.04)	0.08 (1.04)	0.08 (1.04)	0.07 (1.04)	0.08 (1.04)
T_3	0.24 (1.11)	0.35 (1.16)	0.29 (1.14)	0.22 (1.11)	0.36 (1.17)
T_4	0.96 (1.40)	1.03 (1.43)	1.00 (1.41)	0.92 (1.39)	1.08 (1.44)
T_5	1.49 (1.58)	1.54 (1.59)	1.52 (1.59)	1.49 (1.58)	1.54 (1.59)
Mean	0.52 (1.23)	0.56 (1.25)		0.51 (1.23)	0.58 (1.26)

	SE	CD (0.05)
T	0.001	0.01
M	0.001	0.01
T X M	0.012	0.02
G	0.002	0.01
T X G	0.011	0.02
M X G	0.001	NS

(Transformed values ($\sqrt{x}+1$) are given in parentheses)

x G, interactions of T_1 and T_2 with G_1 and G_2 recorded minimum PLW of 0.06 per cent. Maximum weight loss was in T_5G_2 (1.54 per cent).

Similar trend was seen in 14th day of storage of prepackaged bitter gourd fruits in refrigerated condition. Lowest weight loss was recorded in T_1 (0.06 per cent) which was on par with T_2 and highest was in T_5 (1.44). In case of growing conditions, G_1 (0.46) had lowest PLW than G_2 (0.53 per cent). The harvest maturity M_1 had minimum weight losses (0.48) than M_2 (0.51 per cent). T x G interactions, were of similar trend as in 12th day of storage with maximum weight loss recorded in T_5G_2 (1.48).

4.3.2Visual and physical characters

Visual and physical characters of prepackaged fruits stored at room temperature and refrigerated temperature were scored and depicted in Table 14. Fruits were of good quality up to six days in T_1 (micro ventilated polyethylene) for 14 and 15 days maturity (M_1) grown organically (G_1) in room temperature (S_1) where as control (T_5) up to four days in good quality. Organic fruits (G_1) of 15 days maturity were found excellent up to sixth day of storage but 15 days fruit recorded less score (6.00) than 14 days of maturity (6.5). For conventionally grown (G_2) fruits of 15 day (M_2) maturity was good quality up to five days in (T_1) but score recorded less than 14 days of maturity. In case of refrigerated storage organic fruit with 14 and 15 days maturity were of acceptable quality up to 14 days of storage in the treatment T_1. Where as conventional fruits of 14 and 15 days of maturity recorded shelf life of 12 days in T_1. Organic and conventional fruits (G_1 and G_2) of both maturity (M_1 and M_2) were of acceptable quality up to 8 and 6 days of storage respectively. Prepackaging treatments T_2 and T_3 are found of better quality than T_4 and T_5 (control).

4.3.3 Microbial spoilage

Fruits prepackaged with plastic films recorded less incidence of spoilage irrespective of the harvest maturity, growing conditions and storage temperature. The treatment T_1 (micro ventilated polyethylene) recorded less incidence of

Table 13.7 Effect of prepackaging, maturity, growing conditions and storage on PLW (%) of bitter gourd on the 14th day of storage

Treatments	M_1	M_2	Mean	G_1	G_2
T_1	0.06 (1.03)	0.06 (1.03)	0.06 (1.03)	0.06 (1.03)	0.07 (1.03)
T_2	0.07 (1.03)	0.07 (1.04)	0.07 (1.04)	0.07 (1.03)	0.08 (1.04)
T_3	0.19 (1.09)	0.26 (1.12)	0.23 (1.11)	0.15 (1.07)	0.31 (1.14)
T_4	0.89 (1.38)	0.92 (1.38)	0.90 (1.38)	0.84 (1.36)	0.97 (1.40)
T_5	1.42 (1.56)	1.46 (1.57)	1.44 (1.56)	1.41 (1.55)	1.48 (1.57)
Mean	0.48 (1.22)	0.51 (1.23)		0.46 (1.21)	0.53 (1.24)

	SE	CD (0.05)
T	0.001	0.01
M	0.002	0.01
T X M	0.011	NS
G	0.002	0.01
T X G	0.012	0.18
M X G	0.001	NS

(Transformed values ($\sqrt{x}+1$) are given in parentheses)

Table 14 Effect of prepackaging treatments on visual and physical characters (mean score) of bitter gourd during storage

Days	M_1 (14 days) S_1 (Room temperature)										Days	M_2 (15 days) S_1 (Room temperature)									
	G_1 (Organic)					G_2 (Conventional)						G_1 (Organic)					G_2 (Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5		T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
2	9	9	9	9	9	9	9	9	9	9	2	9	9	9	9	9	9	9	9	9	8
4	8	7.75	7.50	7.25	7	7.50	7	6.75	6.50	6	4	7.75	7.50	7.25	7	6.75	6.75	6.50	6.25	6	5
6	6.5	5.5	4.5	3	2	3	2.5	2	1.5	1	6	6	5	4	3	1.5	2.5	2	1	1	1

Days	M_1 (14 days) S_2 (Refrigerated)										Days	M_2 (15 days) S_2 (Refrigerated)									
	G_1 (Organic)					G_2 (Conventional)						G_1 (Organic)					G_2 (Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5		T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
2	9	9	9	9	9	9	9	9	9	9	2	9	9	9	9	9	9	9	9	9	9
4	9	9	9	8.75	8	8.75	8.75	8.75	8	6.50	4	9	9	9	8.50	7.50	8.75	8.75	8.75	7.75	6
6	8.75	8.5	8	7	6	8.50	8.25	7.75	7	5	6	8.50	8.25	7.75	6.75	5.50	8.25	8	7.50	6.5	4
8	8.5	8	7.75	6.5	4	8	7.75	7.25	6	1	8	8	7.75	7	6	3.50	7.75	7.25	7	5.5	1
10	8	7.75	7	6	1	7.50	7	6.5	5.5	1	10	7.50	7	6.5	5.75	1	7	6.5	6	4.5	1
12	7.50	7	6.5	5.5	1	6	5.5	5	4.5	1	12	6.5	6	5	4.5	1	5.5	5	4.5	3.5	1
14	6.5	5.5	5	3	1	3	2.75	2.5	2	1	14	6	5	4.5	2.5	1	2.5	2.25	2	1	1

Visual and physical quality scored on a scale of 9 to 1 where

9 - Excellent visual quality, colour, fresh, firm
7 - Good visual quality, colour, turning soft
5 - Fair (suitable) visual quality, yellowing, soft
3 - Poor (edible) visual quality, yellowing, soft
1 - Inedible, poor visual quality, shriveled, decayed

Table 15 Effect of prepackaging treatments on microbial spoilage (mean score) of bitter gourd during storage

Days	M_1 (14 days) S_1 (Room temperature)										Days	M_2 (15 days) S_1 (Room temperature)									
	G_1 (Organic)					G_2 (Conventional)						G_1 (Organic)					G_2 (Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5		T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	1	1	4	0	0	0	0	0	0	0	0	0	1
6	0	1	1	2	3	1	2	2	3	4	6	0	1	2	2	3	1	2	2	3	4
	M_1 (14 days) S_2 (Refrigerated)											M_2 (15 days) S_2 (Refrigerated)									
Days	G_1 (Organic)					G_2 (Conventional)					Days	G_1 (Organic)					G_2 (Conventional)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5		T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	1	8	0	0	0	0	1	0	0	0	1	1
10	0	0	0	0	1	1	1	1	2	2	10	0	0	0	1	2	1	1	1	2	2
12	1	1	1	1	2	2	2	3	3	3	12	1	1	1	2	3	2	2	3	3	3
14	2	2	3	3	3	3	3	4	4	4	14	2	2	3	3	4	3	3	4	4	4

0 - Fruit not showing any decay

1 - Slight decay, up to 1% of the total surface area of fruit rotted   2 - 1-5 % of total surface exhibiting rotting

3 -1- 10% of total surface showing rotting   4 - Above 10% of total surface rotted showing deterioration

spoilage when compared to all other treatments (Table 15). Minimum incidence of microbial spoilage was observed in organic (G_1) fruits than conventional (G_2) in all prepackaging and storage conditions. Fruits stored at refrigerated condition (G_2) recorded less incidence of microbial spoilage than room temperature (S_1).Organic fruits of 14 and 15 days maturity prepackaged in T_1 and stored at room temperature (S_1) did not show any signs of microbial spoilage on sixth day of storage but for conventional (G_2) fruits rotting started from fourth day of storage.

Refrigerated storage of organic fruits (G_1) of both maturity (M_1 and M_2) prepackaged in T_1 showed negligible symptoms of spoilage after 12 days of storage and were acceptable up to 14 days of storage. Conventional fruits (G_2) of both maturity (M_1 and M_2) prepackaged in T_1 showed symptoms of spoilage after 10 days of storage and were acceptable up to 12 days.

4.3.4 Nutritional changes

Nutritional qualities of bitter gourd grown under both organic and conventional conditions with 14 and 15 days maturity were analysed before storage (Table 16) and also at the end of shelf life (Table 17) of prepackaged and stored bitter gourd fruits.

4.3.4.1 Acidity

Acidity (%) of fruits before storage was analysed and no significant difference was found between the harvest maturity and growing conditions. The value ranged from 0.25 to 0.27 per cent in all the treatments. Percentage reduction in acidity at the end of shelf life of fruits is depicted in Table 17. Prepackaging treatments, growing conditions and storage temperature showed significant influence on acidity during storage. Fruits prepackaged in T_1 recorded the lowest reduction (24.45 per cent) which was superior over other treatments. The highest reduction (50.17) was noticed in T_5 (control). Organically grown fruits (G_1) recorded lowest reduction (35.74) as compared to conventionally (G_2) cultivated (40.62). The percentage reduction in acidity was 45.37 in S_2 (refrigerated) at the end of shelf life which was 14 days and in S_1 it was 35.74 after 6 days of storage. Shelf life of fruits stored at room temperature was less as compared to fruits stored under refrigerated condition.

4.3.4.2 Crude protein

Crude protein (%) content of fruits showed no significant difference except for growing conditions before storage. Fruits grown conventionally (G_2) recorded highest crude protein (25.33) as compared to G_1 (organic fruits). During storage, crude protein content reduced irrespective of the treatments and percentage reduction was lowest (17.61) in T_1 and highest in T_5 (37.72) which was on par with T_4. When growing conditions are compared, the percentage reduction was lowest in G_1 (25.74) as compared to G_2 (31.15). In storage conditions S_2, recorded the lowest reduction of 33.77 and for S_1 it was 23.12. In the interaction effects (Table 17), T_1G_1 recorded the lowest reduction of 12.53 where T_1G_2 recorded 22.68. Highest reduction of 39.74 per cent was observed in T_5G_2.

4.3.4.3 Crude fibre

Crude fibre content of fruits before storage showed significant difference only between two growing conditions. High fibre content of 4.24 per cent was observed in organically (G_1) grown fruits than G_2 (conventional) which recorded 3.77 per cent. During storage T_1 recorded lowest increase (10.47) and highest by T_5 (24.29) which was on par with T_4. Minimum percentage of increase was seen in growing condition G_1 (14.44) as compared to G_2 (22.11). In storage conditions, S_2 recorded the lowest increase of 14.61 per cent and in S_1 it was 21.94 per cent. In T X G interactions (Table 18) lowest percentage of increase (8.90) was observed in T_1G_1 which was on par with T_1G_2 and T_2G_1. Highest percentage of increase (30.56 per cent) was observed in T_5G_2.

Table 16 Nutritional qualities of bitter gourd before storage

	Acidity (%)	Crude protein (%DW)	Crude fibre (% DW)	Calcium (mg/ 100 g DW)	Magnesium (mg/ 100 g DW)	Iron (mg/ 100 g DW)	Ascorbic acid (mg/ 100 g)
G_1	0.25	20.42	4.24	4.04	0.31	5.53	100.68
G_2	0.27	25.33	3.77	3.81	0.23	4.04	95.15
SE	0.15	0.15	0.02	0.01	0.01	0.03	0.17
CD (0.05)	NS	0.43	0.06	0.02	0.02	0.07	0.46

Table 17 Effect of prepackaging and storage on nutritional qualities of bitter gourd as percentage reduction

Treatments	Acidity (% decrease)	Crude protein (% decrease)	Crude fibre (% increase)	Ascorbic acid (% decrease)
T_1	24.45	17.61	+10.47	6.56
T_2	33.20	23.25	+15.78	8.32
T_3	38.77	28.29	+19.12	10.03
T_4	44.45	35.34	+21.71	11.22
T_5	50.17	37.72	+24.29	12.89
SE	1.96	0.92	+1.21	0.31
CD (0.05)	5.47	2.59	+3.40	0.87
G_1	35.74	25.74	+14.44	8.03
G_2	40.62	31.15	+22.11	11.58
SE	1.24	0.58	+0.77	0.20
CD (0.05)	3.46	1.64	+2.15	0.55
S_1	31.05	23.12	+21.94	7.53
S_2	45.37	33.77	+14.61	12.08
SE	1.24	0.58	+0.77	0.20
CD (0.05)	3.46	1.64	+2.15	0.55

4.3.4.4 Calcium

Before storage, there was no significant difference in calcium content of fruits except for growing conditions. Higher calcium content (4.04 mg/100g) was observed with organically grown fruits (G_1) than G_2 which was 3.81 per cent on dry weight basis for both 14 and 15 days maturity. During storage there was no reduction in calcium content of fruits in all the treatments and their interactions.

4.3.4.5 Magnesium

Magnesium content of fruits showed significant difference for growing conditions after harvest. Higher magnesium content (0.31 mg/100g) was observed with organically grown fruits (G_1) than in G_2 it was 0.23 mg/100g on dry weight basis for both days of maturity. During storage there was no reduction in magnesium content of fruits in all treatments and their interactions.

4.3.4.6 Iron

Iron content recorded significant difference only for growing conditions. Higher iron content (5.53 mg/100g) was recorded with organically grown fruits (G_1) than G_2 which was 4.04 mg/100g on dry weight basis irrespective of maturity at harvest. There was no reduction in iron content of fruits in all treatments and their interactions during storage.

4.3.4.7 Ascorbic acid (Vitamin C)

Ascorbic acid content of bitter gourd before storage showed significant difference only for growing conditions. Highest amount of ascorbic acid was recorded in G_1 (100.68 mg/100g) than G_2 (95.15 mg / 100g). Harvest maturity did not show any significant difference in ascorbic acid content.

Ascorbic acid content of fruits decreased during storage. Prepackaging and storage conditions influenced the reduction for both organic and conventional bitter gourd. The percentage reduction was lowest (6.56) for prepackaging treatment T_1 and highest reduction of 12.89 per cent was recorded with T_5. Reduction was less in G_1 (organic) fruits (8.03) as compared to G_2 (11.58).

Table 18 Interaction effects between prepackaging and growing conditions on nutritional qualities of bitter gourd during storage as percentage reduction

Treatments	Crude protein (% decrease)		Crude fibre (% increase)	
	G_1	G_2	G_1	G_2
T_1	12.53	22.68	+8.90	+12.03
T_2	19.24	27.26	+13.22	+18.35
T_3	26.26	30.33	+15.48	+22.77
T_4	34.97	35.71	+16.57	+26.85
T_5	35.69	39.74	+18.03	+30.56
SE	1.31		1.72	
CD (0.05)	3.66		4.80	

Storage conditions S_1 recorded a reduction of 7.53 per cent after 6 days of storage and S_2 recorded 12.08 percentage reduction after 14 days of storage. The interaction effects were found non significant.

DISCUSSION

5. DISCUSSION

Bitter gourd is an important cucurbitaceous vegetable widely cultivated throughout the tropics. The immature fruits are good source of iron, calcium, vitamin and inexpensive source of minerals and protein (Dey *et al.*, 2006). It is well known for antidiabetic property and recently for its antiviral, antibacterial and prevention of cancer (Kumar *et al.,* 2000). There has been a rapid change in dietary habits owing to increased income which has accelerated the demand of horticultural produce. Therefore organic and conventional bitter gourd has great demand in both domestic and international market. But about 30 to 35 per cent of India's total vegetable production is lost due to poor post harvest practices (Ahsan, 2006).

In order to reduce the postharvest losses in quantity and quality, care should be taken from the harvesting itself. Bitter gourd variety Preethi, which is of national attention, is an important variety of south Kerala. It is high yielding with medium size greenish white fruits and has high demand in market. Hence the present study "Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage" was conducted with the objective to determine the stage of harvest maturity and its influence on postharvest life along with prepackaging and storage condition for organic and conventional bitter gourd (var. Preethi) and to develop a postharvest package for extended shelf life with minimum nutritional loss. Results of the experiment conducted are discussed in this chapter.

5.1 DETERMINATION OF HARVEST MATURITY

Growth and development studies for both organic and conventional bitter gourd (var. Preethi) were conducted to determine the optimum stage of harvest maturity. Kanellis *et al.* (1986) and Zong *et al.* (1995) reported that stage of development at harvest is important in determining postharvest quality of bitter gourd and cucumbers. Asian Productivity Organization emphasised the need for development of maturity indices for reducing postharvest losses in vegetables. Commercial maturity in bitter gourd is very hard to judge from the outward appearance of the fruit but external fruit colour of the whole fruit can be used. This needs to be complimented with seed coat colour which is a better indicator of maturity (Morgan and Midmore, 2002).

Hence in the present study, physical and visual observations of fruit external and internal characters of bitter gourd were recorded during development. Fruit external characters like fruit length (Fig. 1), girth (Fig. 2) and weight (Fig. 3) increased periodically during growth and development of bitter gourd in both growing conditions. All these characters recorded higher values for fruits grown under conventional condition than that of organic fruits. Fruit external growth parameters are affected by nutrition. Gosbee and Marte (2010) also had reported similar findings. Conventional fruits recorded a maximum fruit length of 25.30 cm, girth 21.28 cm and weight 217.60 g at 17^{th} day of maturity where as organic fruits recorded 24.06 cm, 19.76 cm and 194.23 g respectively. Percentage of increase in fruit length, girth and weight was maximum between 11 and 13 days in organic and between 11 and 12 days in conventional fruits.

Yadav *et al.* (2008) recorded 15.67 cm fruit length, 4.83 cm width and 118.33 g weight for the variety preethi and Reshmi (2009) recorded an average fruit length of 24.56 cm, 16.90 cm girth, and 189.95 g fruit weight. Bitter gourd harvested at 15 to 16 days after flowering recorded 23 cm fruit length, 6 cm diameter and 276 g weight (Gosbee and Marte 2010). Thangamani *et al.* (2011) reported average fruit length for Preethi as 17.92 cm, girth 14.39 cm and weight (110.66 g) at harvest. Studies revealed that fruit growth characters are influenced by variety, climate and growing conditions.

Katyal (1977), Thomas (1984) and Jayasree (2005) reported increased mean length of bitter gourd fruits by the combined application of organic and inorganic fertilizers than organic alone.

In bitter gourd, principal external index of harvest maturity is fruit size and it depends on the use and the cultivar. Skin colour is another widely used index of assessing fruit maturity (Traynor, 2005). The present investigation revealed that increase in fruit length and girth was found negligible after 15^{th} day of harvest

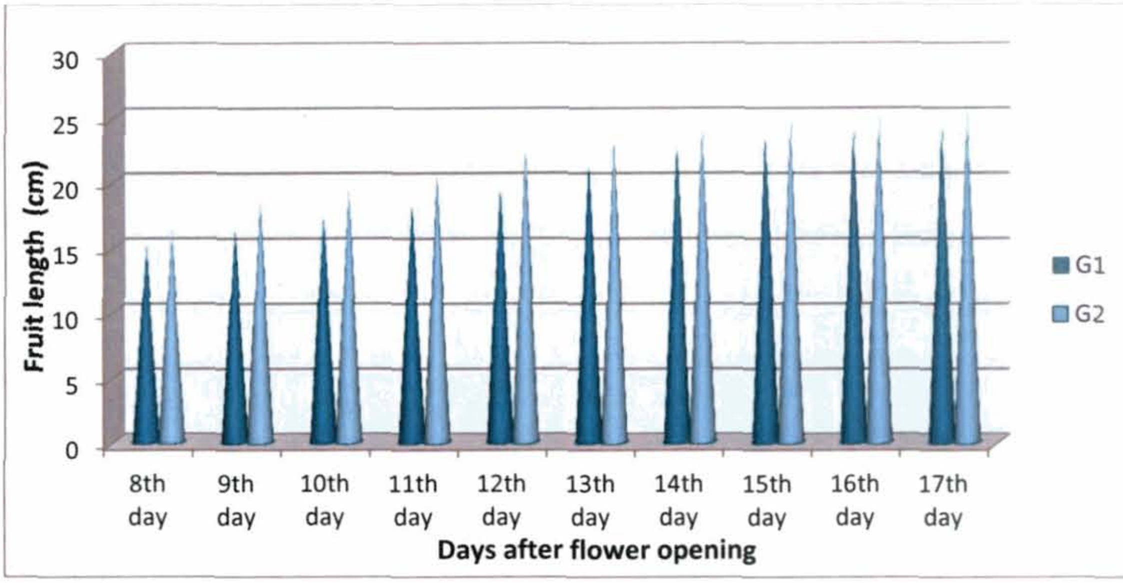


Fig. 1. Change in fruit length (cm) during growth and development of bitter gourd fruits as influenced by growing conditions

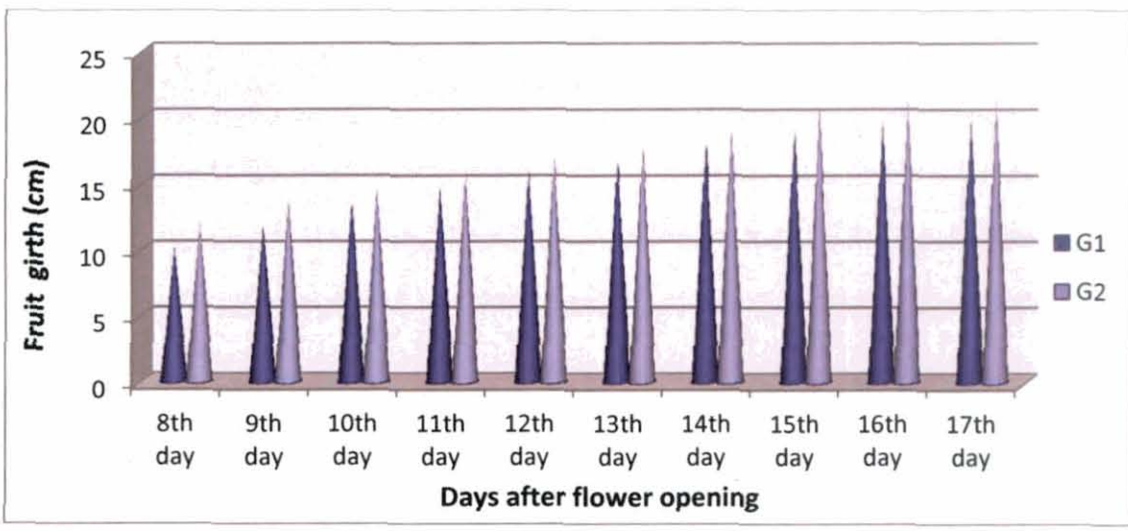


Fig. 2. Change in fruit girth (cm) during growth and development of bitter gourd fruits as influenced by growing conditions

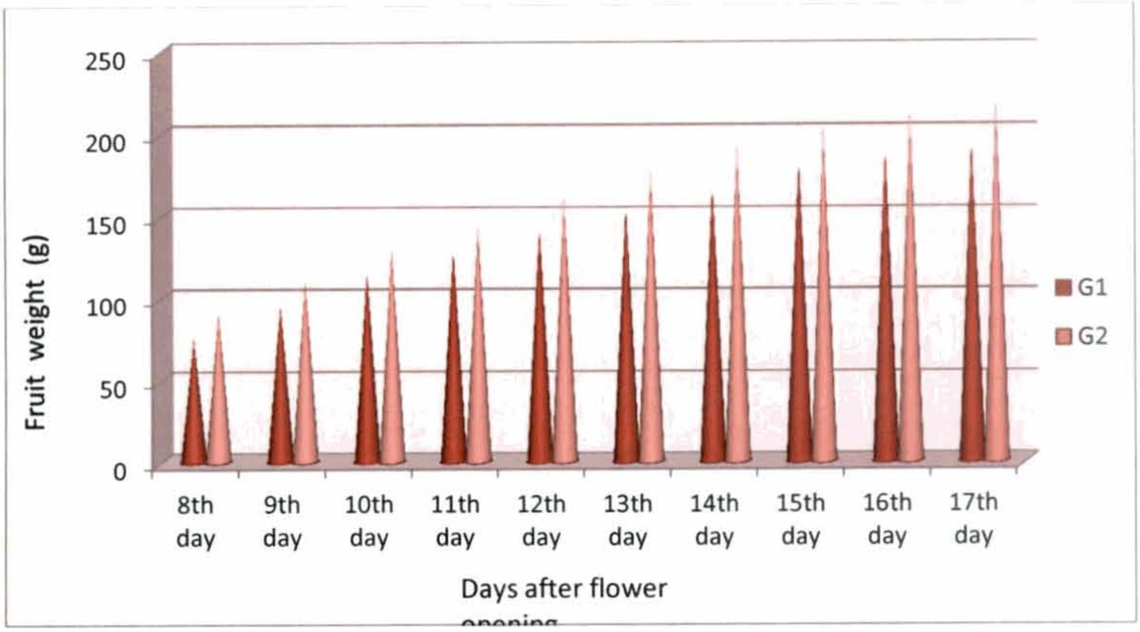


Fig. 3. Change in fruit weight (g) during growth and development of bitter gourd fruits as influenced by growing conditions

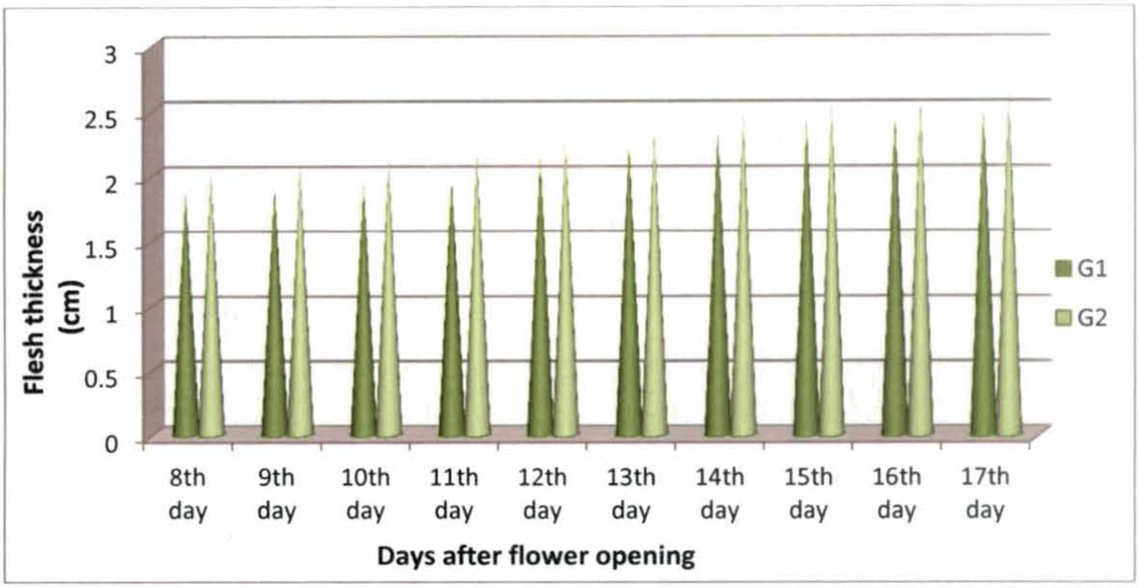


Fig. 4. Change in flesh thickness (cm) during growth and development of bitter gourd fruits as influenced by growing conditions

maturity and percentage of fruit weight increase was also less after fifteen days for both growing conditions. Fruit colour changed gradually from green to greenish white towards the end of maturity irrespective of growing conditions (Plate 2 and 3).

Fruit internal characters viz. flesh thickness, flesh colour, placenta colour, seed number, seed weight and seed colour were recorded during the growth and development of bitter gourd grown under two conditions. Flesh thickness showed (Fig.4) no significant difference between two growing conditions and also for maturity after 14 days. Flesh colour change was similar to that of fruit colour which changed from green to greenish white in both growing conditions. Placenta colour was white during early stages of maturity that changed to pink on 17^{th} day of maturity irrespective of growing conditions. The colour started changing to pinkish shade after 15^{th} day of maturity. A cross sectional slice obtained from the centre of the fruit is also taken to assess internal fruit maturity.

According to Morgan and Midmore (2002), Traynor (2005) and Behera *et al.* (2010) harvesting in bitter gourd should be done before onset of ripening or before the seed cavity shows any pink or red colour.

Seed development in bitter gourd started only after 10 days of flower opening in both growing conditions. Seed number showed no significant difference during various stages of development for both growing conditions. But seed number recorded was higher in conventional bitter gourd (35.55) than organic (30.50). This might be due to the increased fruit size of conventional fruits. Seed weight increased during growth and development and did not show any difference between two growing conditions. In both organic and conventional bitter gourd, seed colour changed gradually from whitish yellow to brownish during development. Seed colour was changing to light brown after 14 days of maturity.

Reshmi (2009) reported 20 to 45 seeds per fruit of bitter gourd var. Preethi and 100- seed weight as 20.15 g at harvest. Bitter gourd fruits should be light green, thick and juicy (Lim, 1998) and the seeds should be soft and white (Huyskens *et al.* 1992) creamy to pale green brown (Vujovic *et al.* 2000) at

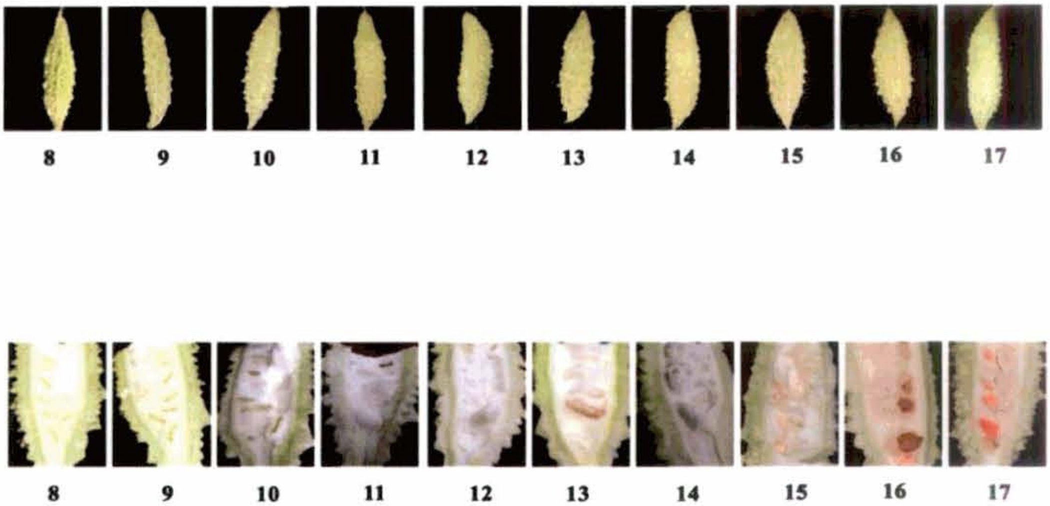


Plate 2.1. Growth and development of organic bitter gourd

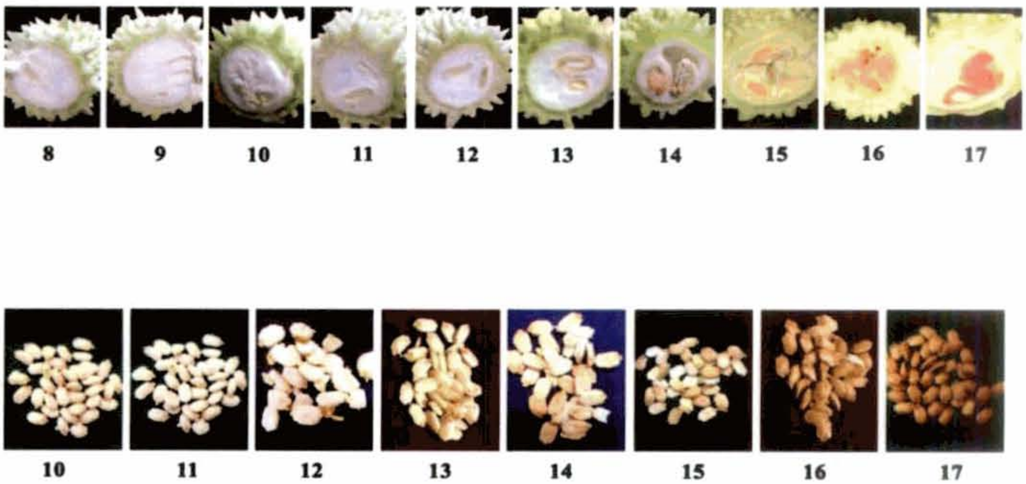


Plate 2.2. Growth and development of organic bitter gourd

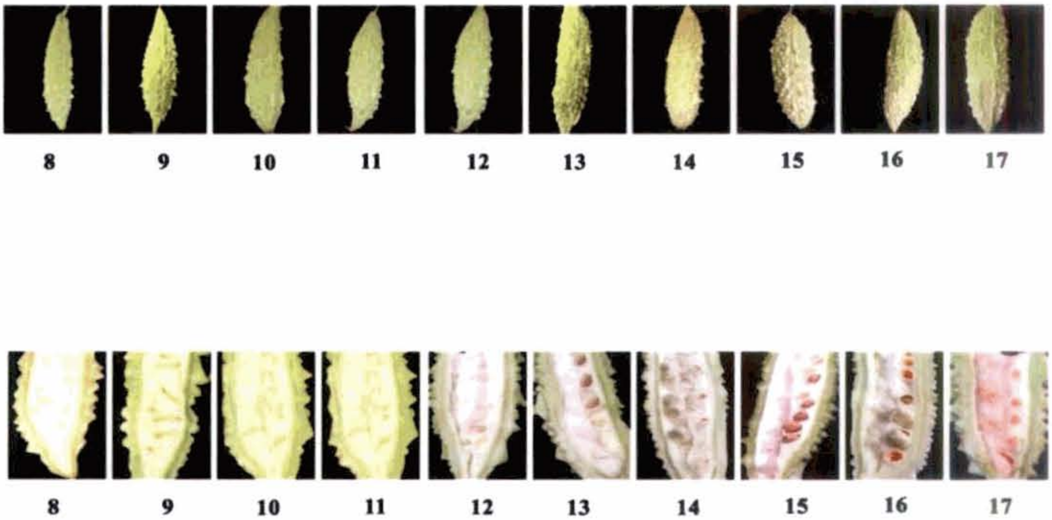


Plate 3.1. Growth and development of conventional bitter gourd

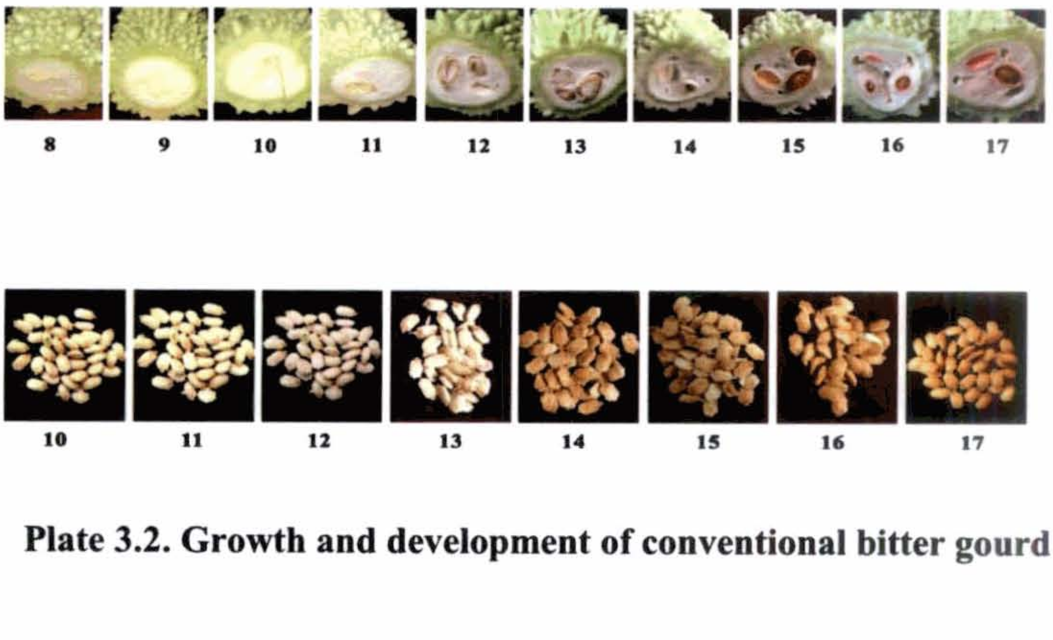


Plate 3.2. Growth and development of conventional bitter gourd

harvest. Behera *et al.* (2010) and Mohammed (2010) reported that seed coat colour is a good indicator of optimal harvest maturity which changes from creamy or pale green-brown to pink colouration with over maturity.

Findings of investigations on growth and development studies in bitter gourd reveal that fruits attain full harvest maturity at 15 days after flower opening after which the placenta colour and other internal characters show the symptoms of over maturity or ripening for both organic and conventional growing conditions. As there was negligible increase in growth characters like fruit length, girth and less percentage of increase in weight between 14 and 15 days, fruits can be harvested at 14 days after flower opening for extending shelf life and reducing postharvest losses during long distance transport and 15 days maturity for domestic market.

Morgan and Midmore (2002) reported that since bitter gourd fruit continues to mature after harvest, fruit for immediate sale in local markets should be harvested mature (still physiologically immature) and fruit for long distance transport (interstate or export) when immature. It typically takes about 15 to 20 days after fruit set to reach marketable age (Reyes *et al.* 1994 and Palada and chang, 2003) but can be harvested at any stage before, depending on the market. Bitter gourd grows rapidly under high temperatures and took 12 to16 days for harvest in hot growth season and 20 to 22 days under lower temperatures (Chang *et al.* 2000). Pal *et al.* (2005) found that harvesting of 'Pusa Hybrid-1' bitter gourd can be extended upto 12 days after fruit set for better nutritional quality and marketability.

5.2 PRECOOLING TREATMENTS

Bitter gourd has a relatively high respiration rate and therefore prompt removal of the field heat via hydrocooling or room cooling is recommended (Gopalakrishnan, 2007; Morgan and Midmore, 2002 and Mohammed, 2010). Fresh produce can be microbiologically contaminated at any point along the farm – to – table food chain. Sanitation practices during production, harvest, sorting, packing and transport play a critical role in minimizing the potential for microbial contamination of fresh produce. Clean water containing an appropriate concentration of sanitizers is required in order to minimize the potential transmission of pathogens from water to produce, from healthy to infected produce within a single lot and from one lot of produce to another over time. The concentration of sanitizer is important so that it should kill the microbes but should not affect the quality of the produce.

Bitter gourd fruits (var. Preethi) of two harvest maturity (14 days and 15 days) grown under two conditions (organic and conventional) were subjected to hydrocooling containing sodium hypochlorite at different concentrations. Precooled fruits were stored at room temperature and results on physiological loss in weight, visual and physical observations revealed that hydro cooling with 150 ppm sodium hypochlorite as the best treatment for maintaining the postharvest quality for both harvest maturities and growing conditions. Physiological loss in weight, highest mean score for physical and visual parameters and less microbial decay were observed in this treatment (Fig.5). Mohammed and Wickham (1993) reported that postharvest dip treatment with 500 mg/l NaClO solution at 10°C for 45 min removed field heat and eliminated surface pathogens in bitter gourd. Liu *et al* (2007) recorded lower PLW in NaClO treated tomato fruits. Sodium hypochlorite was found as effective sanitizer in pointed gourd (Koley *et al.*, 2009).

Postharvest quality deterioration was less with fruits of 14 days maturity as compared to 15 days. Organic bitter gourd maintained the quality longer than conventional fruits. Fruits were of acceptable quality up to five days in the treatment hydrocooling with 150 ppm sodium hypochlorite for 14 days and 15 days harvest maturity in organic fruits. Conventional fruits of 14 and 15 days maturity recorded a shelf life of four and three days respectively. Earlier works had revealed that organic manuring has a positive effect on shelf life of perishable commodities (Joseph and Pillai, 1985 and Rajasree 1999).

Precooling with water alone was found better than fruits stored without any precooling. This may be due to removal of field heat which reduced the rate of physiological process and helped in reducing postharvest deterioration. Fruits

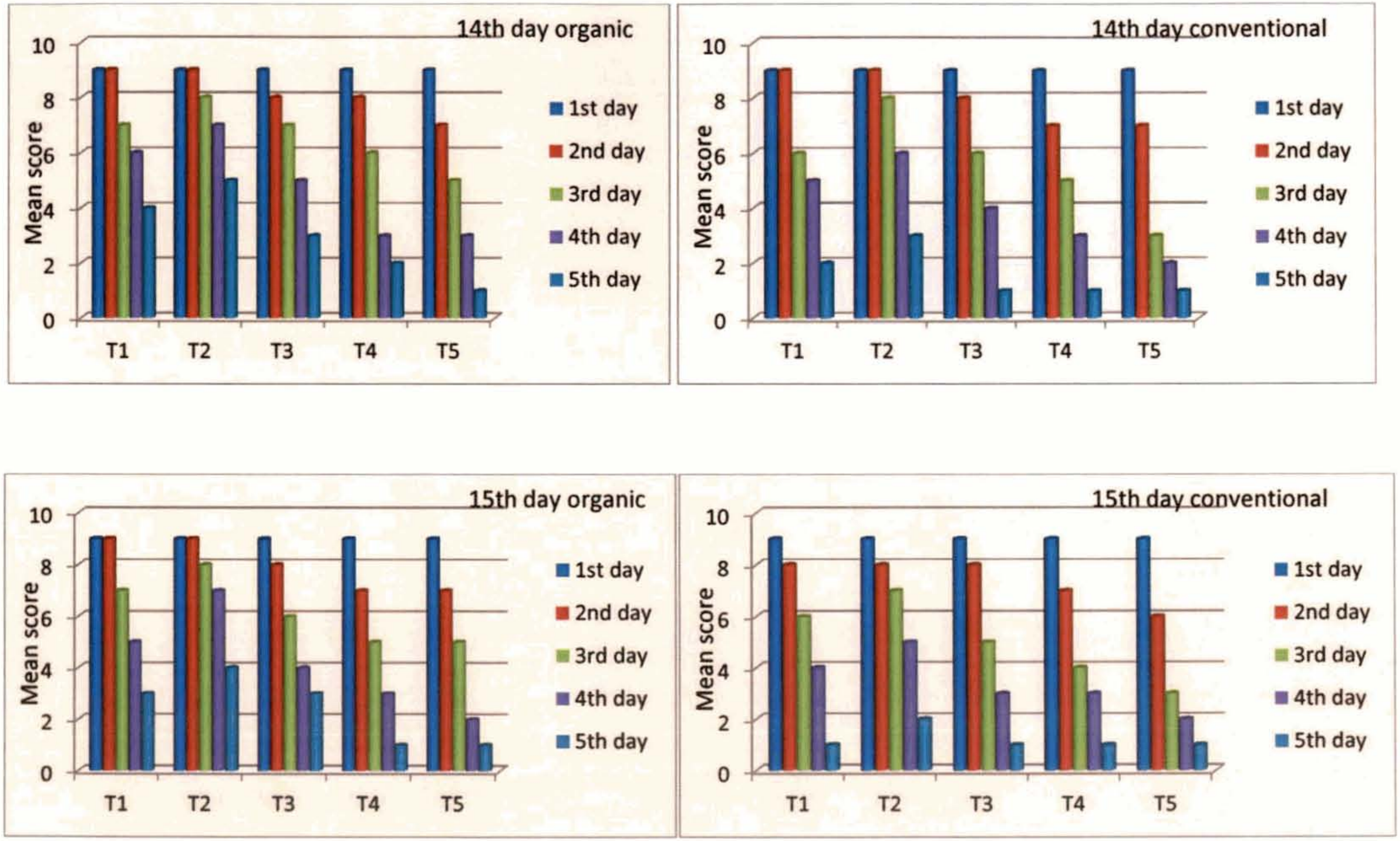


Fig. 5. Effect of precooling treatments on visual and physical characters (mean score) of bitter gourd during storage

precooled with water containing sodium hypochlorite recorded less incidence of microbial spoilage irrespective of the harvest maturity and growing conditions. Addition of sanitizing agent (NaClO) reduced the microbial contamination and increased the shelf life. Bitter gourd having more spines and natural plant surface contours, natural openings, harvest and trimming wounds can provide points of entry as well as safe harbour for microbes. Sodium hypochlorite at 150 ppm was found as the effective sanitizer concentration which is sufficient to kill microbes before they attach or become internalized in produce. Acedo and Weinberger (2010) opined that washing of egg fruits in 100-200 ppm sodium hypochlorite solution is useful for sanitizing to minimize microbial decay during storage.

5.3 PREPACKAGING AND STORAGE

Modified atmosphere packaging is known to extend the shelf life of produce by retarding the physiological metabolism leading to senescence by the increased CO_2 and decreased O_2 concentration in the storage atmosphere. The creation of an appropriate gaseous atmosphere around a commodity is done by use of selectively permeable polymeric films. This atmosphere modification slowed down the rate of respiration, rate of ethylene biosynthesis and its action that subsequently helped in decreasing microbial contamination. It also created high humidity inside the package, which resulted in reduced moisture loss and prevented the shrivelling of fruits during storage thus retaining the quality for a longer period.

Respiration of product and permeability of prepackaging film are influenced by storage temperature. Even though plastic films can reduce water loss from the stored fresh produce, condensation of water may occur inside the package which leads to microbial spoilage. Therefore micro ventilated plastic films were used. Islam *et al.* (2008) reported that perforated film may offer a simple solution for to the water condensation problems while packaging of fresh produce.

Prepackaging of bitter gourd reduced the PLW during storage as compared to fruits without any packaging. Among the treatments, micro ventilated polyethylene recorded the lowest weight loss. Prepackaging with micro ventilated polypropylene and cling film also reduced PLW than that of control. Visual and physical observations and microbial spoilage scores revealed that fruits with micro ventilated polyethylene prepackaging increased the shelf life (Fig. 6). Thus the polyethylene packaged fruits reduced PLW and extended the shelf life. The lowest PLW is due to high humidity created within the packages by respiring fruits and low water vapour transmission rate of packaging material used. These findings are in conformity with earlier workers Talukder *et al.* (2004). Mohammed (2010) found that individually wrapped bitter gourd fruits stored at 5-7°C were marketable up to 21 days. Gosbee and Marte (2010) reported that bitter gourd stored in perforated polyethylene bags were of superior quality and extended the shelf life. Perforated films can prevent anaerobic conditions, reduces water loss and let excess water to leave the package without dehydrating the product (Islam *et al.*, 2008). High wilting, softening, shrivelling and loss of quality was observed in control due to water loss and high rate of respiration. Similar observations were recorded by Hardenburg *et al.* (1986), Kader (1991) and Mitchell (1991).

Storage at low temperature also reduced PLW. Bitter gourd stored at refrigerated condition (10 to 12°C) recorded the lowest PLW in all the prepackaging treatments and micro ventilated polyethylene was superior. Organic fruits prepackaged in micro ventilated polyethylene were found acceptable up to six days at room temperature and 14 days under refrigerated storage. Refrigerated storage was superior to room temperature storage in reducing the microbial spoilage, delayed pattern of colour change and extended over all acceptability. Mohammed and Wickham (1993) reported that bitter gourd could be stored for 21 days at 5 – 7°C without chilling symptoms if the fruits were protected with polythene film wrap. Zong *et al.* (1995) found that storage of bitter gourd below 10°C showed chilling symptoms and fruits can be stored for 10 to 14 days at 10 - 12.5°C. Refrigerated storage decreased the rate of respiration resulting in reduction of build up of respiration heat, thermal decomposition and microbial spoilage and helped in retention of quality and freshness for a long period was

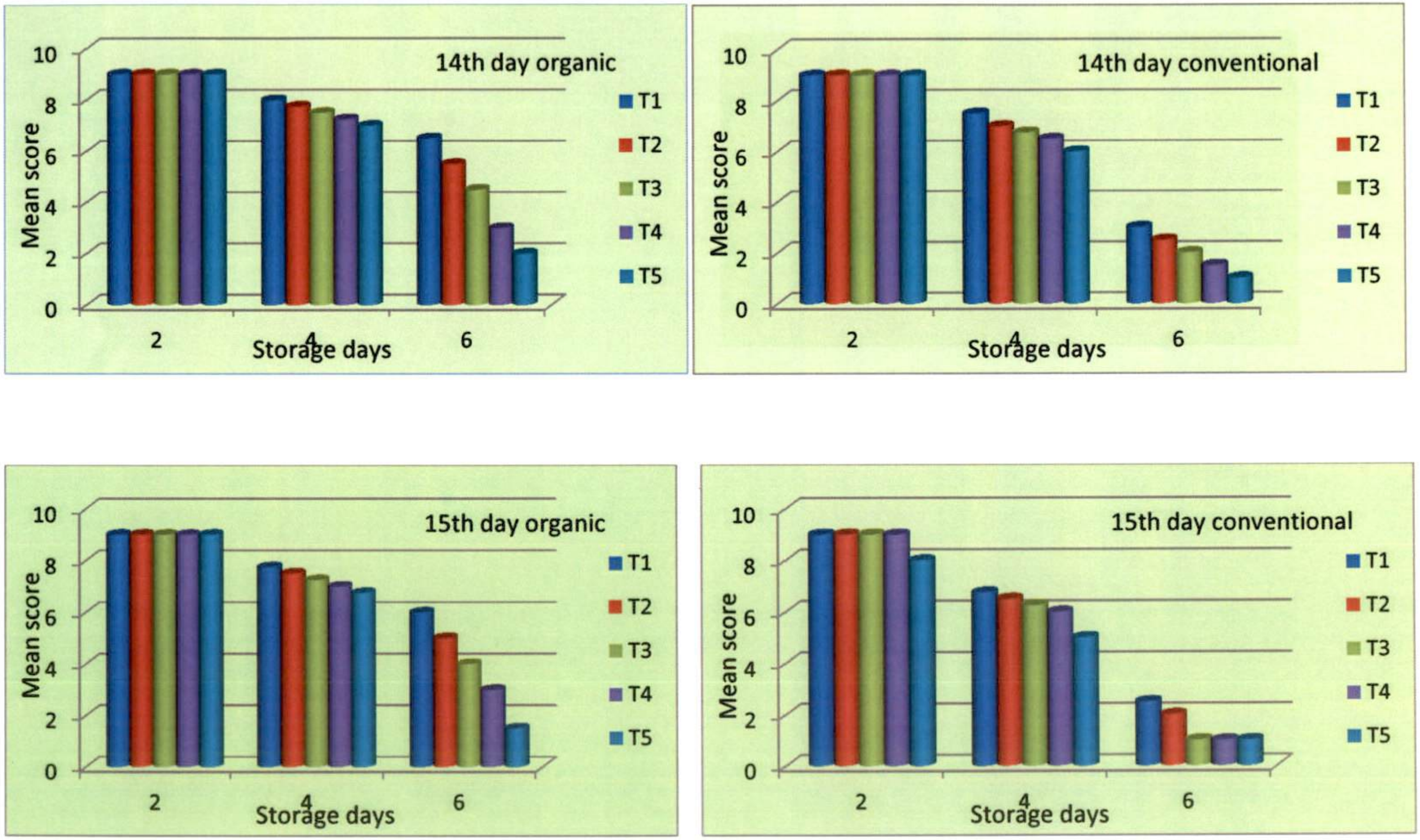


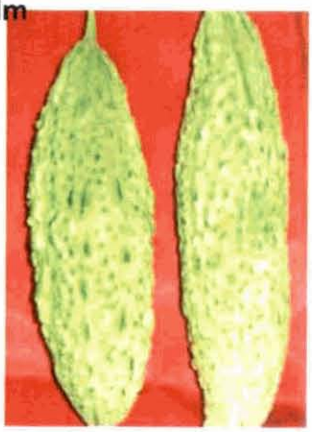
Fig. 6. Effect of prepackaging treatments on visual and physical characters (mean score) of bitter gourd during room temperature

T1 Micro ventilated polyethylene

T2 Micro ventilated polypropylene

T3 Wrapping with cling film

T4 Butter paper



T5 Control

Plate 4. Prepackaged biter gourd fruits

reported by Prasad and Singh (1996) and Wills *et al.* (1998). Similar results were reported by Gosbee and Marte (2010) and Mohammed (2010) in bitter gourd.

Fruits stored at room temperature continued to develop during storage showing undesirable changes of yellowing, seed development and fruit splitting. Similar observations were recorded by Mohammed (2010).

Refrigerated storage of organic fruits of both maturities prepackaged in micro ventilated polyethylene showed negligible symptoms of spoilage after 12 days of storage and were acceptable up to 14 days of storage. Conventional fruits of both maturities with micro ventilated polyethylene prepackaging showed symptoms of spoilage after 10 days of storage and were acceptable up to 12 days.

Desai *et al.* (1986) reported that the rate of respiration and multiplication of decay organisms is higher at high temperature. This is in accordance with the present finding that at room temperature fruits deteriorated at a faster rate. Beuchat and Brackett (1990); Nguyen and Carlin (1994) stated that mesophilic microorganisms can be significantly reduced with decreasing storage temperature.

Stage of harvest maturity also influenced the physiological loss in weight. Fruits harvested at 14 days maturity recorded lowest PLW than of 15. This finding is in conformity with Zong *et al.* (1995). Gosbee and Marte (2010) also reported less PLW and extended shelf life for bitter gourd of 15 -16 days maturity than 18 to 19 days.

Organic bitter gourd had less weight loss during storage than conventional fruits. Visual and physical score and microbial spoilage scores showed increased shelf life for harvest at 14 days maturity and organic fruits.

Similar results were obtained by Nair and Peter (1990) in green chilli. Rajasree (1999) reported that shelf life of fruits under room temperature was more for bitter gourd (4 days) when nitrogen nutrition was given through organic manures. Kays and Hayes (1978) and Zheng (1986) reported that bitter gourd fruits exhibited high respiration and ethylene production rates during ripening which indicate a climacteric behaviour and the rate is higher than other cucurbits. The matured fruits during storage at room temperature had high rate of respiration and reduced shelf life (Mohammed and Wickham, 1993). Krishna (2005) found out that shelf life of cowpea was significantly influenced by the different sources of nutrition and lower shelf life was observed for inorganic cowpea. Mohammed (2010) reported that immature bitter gourd fruit maintained postharvest quality better than fruit harvested at fully developed green stage.

Organic fruits of 14 days maturity and prepackaged in micro ventilated polyethylene had a shelf life of six days at room temperature and 14 days under refrigerated storage. Conventional fruits prepackaged in micro ventilated polyethylene recorded a shelf life of five days at room temperature and 12 days at refrigerated condition. Prepackaging and low temperature storage has been shown to increase shelf life by slowing down the growth of microbes as reported by Hussein *et al.* (2000).

Compared to other cucurbits, bitter gourd is considered as nutrition rich vegetable. Nutritional qualities analysed after the harvest (before storage) of bitter gourd for both maturity and growing conditions revealed that there was no difference in nutritional qualities of bitter gourd harvested at 14 and 15 days of maturity. Zong *et al.* (1995) reported that there was no quality difference in bitter gourd fruits of two developmental maturities at harvest. Horax *et al.* (2010) stated that crude protein, ascorbic acid and minerals did not show any significant difference between mature and ripe stages of bitter gourd.

Bitter gourd is a good source of minerals. Minerals like calcium, magnesium, iron and ascorbic acid were highest in organic bitter gourd as compared to conventional. Crude fibre content was also high in organic fruits. Crude protein content was high in conventional fruits and no difference in acidity was seen between growing conditions. Thus organic bitter gourd had high nutritional quality than conventional fruits.

Kulkarni *et al.* (2005) reported that titratable acidity of fresh bitter gourd of fruits ranged between were 0.08 – 0.21%. Alabi and Odubeney (2001) observed higher vitamin C content cowpea grown on organic waste as compared to those grown with NPK. Nair (2003) reported that quality attributes like ascorbic acid and iron content were highest in organic products. Akanni and

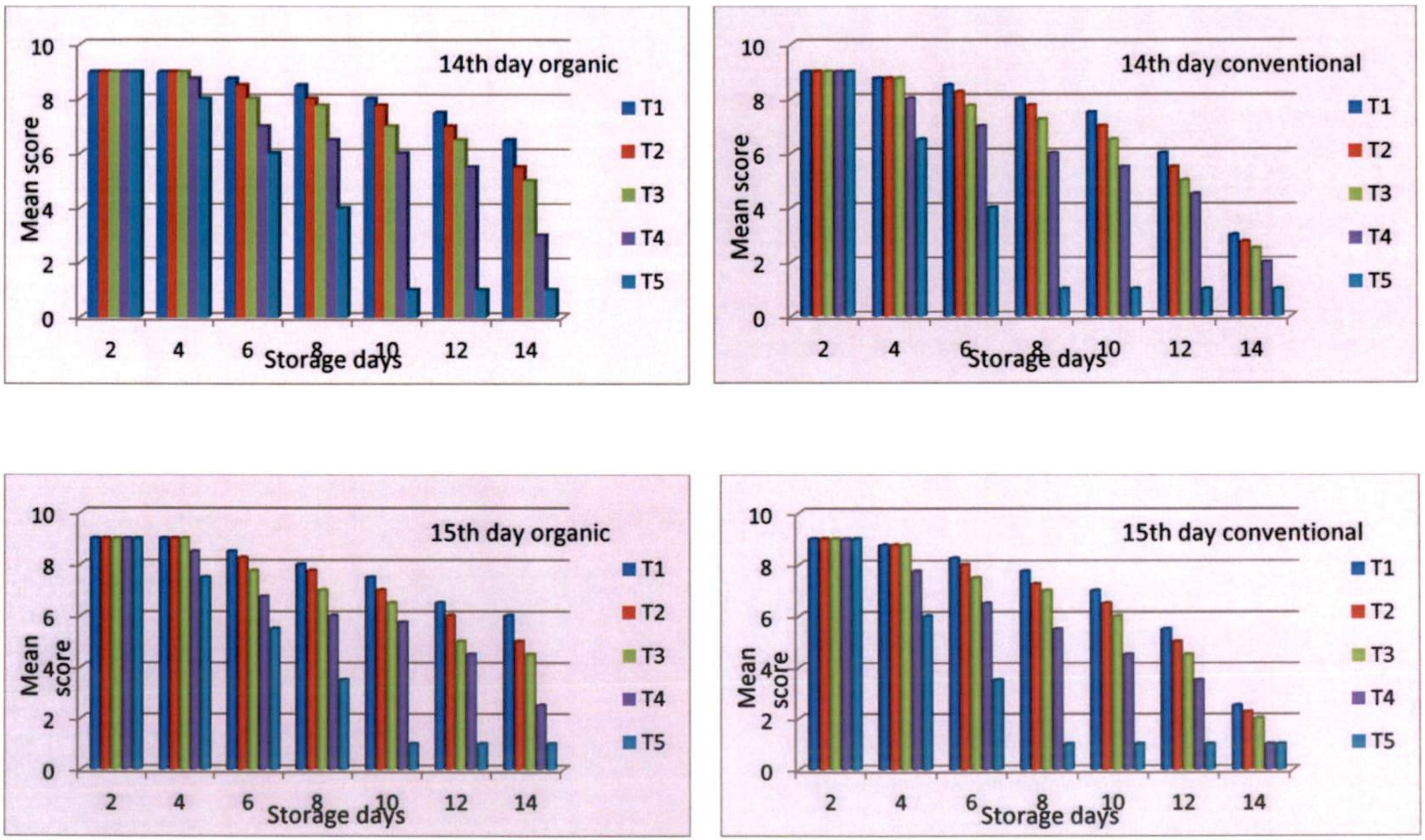


Fig. 7. Effect of prepackaging treatments on visual and physical characters (mean score) of bitter gourd during refrigerated temperature

Ojeniyi (2008) reported higher vitamin C levels in amaranthus grown with goat and poultry manures.

However Kumar (2000) observed significantly high fibre content in organically cultivated amaranth. Krishna (2002) noticed that inorganic treatments resulted in high fibre content. Neelam *et al.* (2009) revealed higher fibre content in organically grown brinjal.

Ahenkora *et al.* (1998) observed higher mineral content in organically cultivated cowpea. Comparative studies of organic and conventional produce by Worthington (2001) revealed that organic crops contained significantly high vitamin C, iron magnesium and other minerals and stated that a non significant trend in protein content was seen with less protein but of good quality in organic products. This is in confirmation to the present findings. Rajasree and Pillai (2012) reported high mineral and ascorbic acid content in bitter gourd with organic nutrition. Probably this may due to the difference in uptake of nutrients among the organic and conventional growing conditions. Organically grown vegetables are recorded with high root spread and application of organic manure lead to higher mineral levels.

Nutritional qualities of fruits and vegetables deteriorate during storage. Postharvest handling practices aim not only to reduce postharvest losses but also to maintain quality and safety of the produce so that nutritional loss is less. Fruits prepackaged in micro ventilated polyethylene recorded lowest percentage reduction in acidity, crude protein, ascorbic acid and lowest percentage increase in crude fibre in both storage temperatures. Similarly the reduction was less with organic fruits. Minerals did not show any change during storage. Similar results were documented by Islam *et al.* (2008) in various bitter gourd genotypes.

The acidity was found decreased during storage of bitter gourd fruits (Aminah and Anna, 2011). Similar results of decreasing acidity were reported by Illeperuma and Jayasooriya (2002) and Fisk *et al.* (2006) in refrigerated mangoes and kiwi fruits.

Storage temperature had significant effect on nutritional changes. Refrigerated storage of bitter gourd fruits had reduced the nutritional loss.

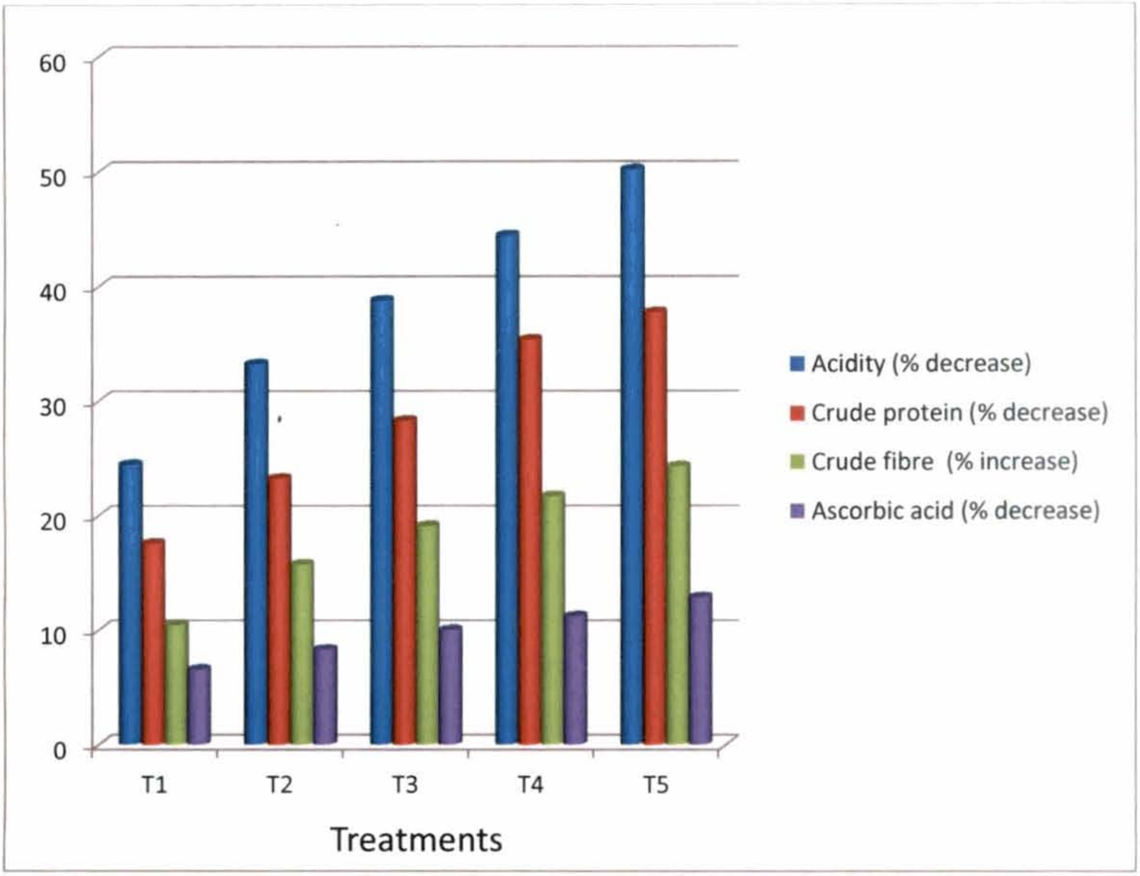


Fig. 8. Effect of prepackaging and storage on nutritional qualities of bitter gourd as percentage reduction

Percentage reduction of acidity, crude protein and ascorbic acid was less in low temperature storage. This indicates the low respiration and enzyme activity at refrigerated storage which extended the shelf life and nutritional quality. Wills *et al.* (1989) also reported similar findings.

Crude protein content reduced during storage in both storage conditions with less percentage reduction in refrigerated storage. Fruits prepackaged in micro ventilated polyethylene recorded lowest reduction in both storage conditions. The finding is supported by Xie *et al.* (2004) and Islam *et al.* (2008). The reduction might be due to hydrolysis of protein during storage (Islam *et al.*, 2008). Ascorbic acid content decreased during storage and prepackaging and storage temperature influenced the reduction. The reduction was found less in micro ventilated polyethylene stored at refrigerated temperature. This is supported by the studies of Wang (2001), Xie *et al.* (2004) and Islam *et al.* (2008). Mineral content of fruits did not show any significant difference in during storage. Prepackaging of bitter gourd in micro ventilated polyethylene extended the shelf life with minimum nutritional loss.

Future line of work

Vegetables play an important role in food and nutritional security. The perishable nature of vegetables necessitates its proper postharvest handling and storage. Tropical vegetables are highly perishable than others and need special care right from preharvest, harvest and postharvest stages. Therefore studies regarding determination of optimum harvest maturity and postharvest handling of tropical vegetables can be undertaken to reduce the postharvest losses with more marketability. As demand of organic fresh produce is in high momentum, special emphasis can be given for organic vegetables.

SUMMARY

6. SUMMARY

The present investigation on "Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage" was undertaken at Department of Processing Technology, College of Agriculture, Vellayani during 2011-2013, with the objective to determine the stage of harvest maturity and its influence on postharvest life along with prepackaging and storage condition for organically and conventionally grown bitter gourd (var. Preethi) and to develop a postharvest package for extended shelf life with minimum nutritional loss. The experiment was conducted in the three continues phases viz. determination of harvest maturity, precooling treatments and prepackaging and storage. The results obtained are summarized in this chapter.

Growth and development studies for both organic and conventional bitter gourd (var. Preethi) were conducted to determine the optimum stage of harvest maturity. Fruit external and internal characters of bitter gourd recorded during development had shown that external characters like fruit length, girth and weight increased periodically in both growing conditions. But conventional fruits recorded higher values for all these physical characters. Percentage of increase in fruit length, girth and weight was negligible 15 days after flower opening. Fruit colour and flesh colour changed gradually from green to greenish white towards the end of maturity irrespective of the growing conditions.

Flesh thickness did not observe any significant difference between two growing conditions and also for maturity after 14 days. Placenta colour was white during early stages of maturity and changed to pink on 17th day of maturity irrespective of growing conditions. The colour started changing to pinkish shade after 15th day of maturity.

Seed development in bitter gourd started only after 10 days of flower opening in both growing conditions. Seed number showed no significant difference during various stages of development for both growing conditions. But highest seed number was recorded for conventional bitter gourd than organic. Seed weight increased during growth and development and did not show any difference between two growing conditions. In both organic and conventional bitter gourd, seed colour changed gradually from whitish yellow to brownish during development. Seed colour had started changing to light brown after 14 days of maturity.

Considering both external and internal fruit characters during growth and development, two harvest maturities, 14 and 15 days after flower opening were selected for further postharvest studies in both organic and conventional bitter gourd.

Fruits harvested at 14 and 15 days maturity for both organic and conventional growing conditions were hydrocooled containing sodium hypochlorite as sanitizing agent. Precooled fruits were stored at room temperature and results on physiological loss in weight, observations on visual and physical parameters and microbial spoilage revealed that hydrocooling with 150 ppm sodium hypochlorite as the best sanitizing treatment for maintaining the postharvest quality for both harvest maturities and growing conditions. Precooling with water alone was found better than fruits stored without any precooling for reducing the postharvest losses.

Prepackaging of bitter gourd with polymeric films which created a modified atmospheric packaging increased the shelf life as compared to fruits without any packaging. Among the prepackaging treatments micro ventilated polyethylene was found superior.

Bitter gourd with 14 days maturity recorded a slow rate of physiological processes than 15 days maturity in both organic and conventional growing conditions which extended the acceptability.

Refrigerated storage (10 to 12°C) had reduced the postharvest losses and extended the shelf life. Prepackaging and refrigerated storage was found promising. Shelf life of organic bitter gourd was more than that of conventional in both room temperature and refrigerated storage.

Nutritional quality analysis revealed that there is no difference in nutritional parameters between 14 and 15 days of harvest maturity.

Organic bitter gourd was of high nutritional quality which recorded a higher amount of crude fibre, ascorbic acid and minerals like calcium, magnesium and iron.

Prepackaging of fruits with micro ventilated polyethylene and refrigerated storage helped in maximum nutrient retention in both organic and conventional bitter gourd.

Organic fruits of 14 days maturity and prepackaged in micro ventilated polyethylene had a shelf life of six days at room temperature and 14 days under refrigerated storage. Conventional fruits prepackaged in micro ventilated polyethylene recorded a shelf life of five days at room temperature and 12 days at refrigerated condition with minimum nutritional loss.

Thus it can be concluded that bitter gourd fruits (var.Preethi) (organic and conventional) can be harvested at 14 and 15 days after flower opening without any economic loss to farmers. There was no nutritional difference observed between the two harvest maturities. Postharvest physiological changes were at a slower rate in 14 days maturity than 15 days. Fruits can be harvested at 14 days maturity for long distance market and export and 15 days maturity for domestic market in order to reduce the postharvest losses in bitter gourd.

Sanitization using 150 ppm sodium hypochlorite along with hydrocooling and prepackaging of bitter gourd in micro ventilated polyethylene stored under refrigerated temperature can extend the shelf life with minimum loss in nutritional quality. Organic fruits had better shelf life and high nutritional quality than conventional bitter gourd.

A postharvest package for organic and conventional bitter gourd (var.Preethi) can be developed as harvesting at optimum maturity (14 and 15 days after flower opening) followed by hydrocooling with 150 ppm sodium hypochlorite, prepackaging in micro ventilated polyethylene and refrigerated storage for reducing postharvest losses and extended shelf life with minimum nutritional loss .

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ABSTRACT

POSTHARVEST EVALUATION OF BITTER GOURD AS INFLUENCED BY GROWING CONDITION, HARVEST MATURITY, PREPACKAGING AND STORAGE

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ABSTRACT

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ABSTRACT

The present investigation on "Postharvest evaluation of bitter gourd as influenced by growing condition, harvest maturity, prepackaging and storage" was carried out at the Department of Processing Technology, College of Agriculture, Vellayani during 2011-2013, with the objective to determine the stage of harvest maturity and its influence on postharvest life along with prepackaging and storage condition for organically and conventionally grown bitter gourd (var. Preethi) and to develop a postharvest package for extended shelf life with minimum nutritional loss.

The experiment was conducted in three continuous phases such as determination of harvest maturity, precooling treatments, prepackaging and storage. Growth and development studies conducted for determining harvest maturity revealed that fruit length, width, weight and flesh thickness increased periodically till 15 days of flowering and percentage of increase was negligible 15 days after flower opening. But conventional fruits recorded higher values for all these physical characters at all the stages of maturity. Considering the development of both external and internal fruit characters, 14 and 15 days after flower opening were selected as optimum harvest maturity for further postharvest studies.

Hydrocooling of harvested fruits with 150 ppm sodium hypochlorite was found as the best sanitizing treatment for maintaining the postharvest quality and increased shelf life for both harvest maturities (14 and 15 days) and growing conditions (organic and conventional).

Prepackaging and storage trials revealed that prepackaging treatments, growing conditions and storage temperature had significant influence on shelf life and nutritional qualities of fruits. Fruits with 14 days maturity, grown organically,

prepackaged in micro ventilated polyethylene and stored under refrigerated condition had resulted in lowest PLW.

Nutritional parameters of fruits viz, protein, acidity, fibre, calcium, magnesium, iron and ascorbic acid were analysed before storage and at the end of shelf life. Before storage, none of the factors except growing conditions had significantly influenced the nutritional parameters. Fruits grown conventionally had higher protein and organic fruits exhibited high fibre, Ca, Mg, Fe and ascorbic acid content. Storage studies revealed that refrigerated storage after prepackaging in micro ventilated PE had lower nutritional and physiological changes during storage.

From the study it can be concluded that bitter gourd (var. Preethi) fruits can be harvested at 14 days maturity for export and long distance market and 15 days for domestic market grown under both organic and conventional system in order to reduce the postharvest losses. Harvested fruits precooled with water containing 150 ppm sodium hypochlorite, prepackaged in micro ventilated polyethylene and stored under refrigerated condition was effective for extending the shelf life with minimum nutritional loss.