EFFECTS OF HYDROCOOLING, PACKAGE MODIFICATION AND STORAGE TEMPERATURE ON POST-HARVEST QUALITY OF FRESH *AKABARE* CHILLI (*CAPSICUM CHINESE*)

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Effects of Hydrocooling, Package Modification and Storage Temperature on Post-Harvest Quality of Fresh *Akabare* Chilli (*Capsicum Chinese*)

A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology

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Approval Letter

This *dissertation* entitled *Effects of Hydrocooling, Package Modification and Storage Temperature on Post-Harvest Quality of Fresh Akabare Chilli (Capsicum chinese)* presented by Ruchita Bhattarai has been accepted as the partial fulfillment of the requirement for the B. Tech. degree in Food Technology

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Abstract

Akabare chilli (*Capsicum chinese*) is High Value Crops (HVC) in eastern hills of Nepal. *Akabare* growers faced the problem of its value decrement during transportation and marketing because of immediate post-harvest loss. This study was targeted for finding a cheap postharvest treatment to extend freshness and shelf life of fresh *akabare*. Effect of hydrocooling, package modification [use of perforated (2.5 mm diameter) and unperforated polypropylene bag] and storage temperature [low temperature (8-10ºC) and room temperature, (25-27°C)] on chemical qualities (moisture, vitamin C and total chlorophyll content) and visual appearance of fresh *Akabare* were studied on regular interval of 4 days. 51 ± 3 g of sample was packed in 12 cm×12 cm of packaging material for study. All data were statistically analyzed using Analysis of Variance (ANOVA) at 5 % level of significance.

Samples without any treatment remained fresh only for 2 days regarding Vitamin C, total chlorophyll, moisture content and visual appearance. Sample only hydrocooled retained chlorophyll, vitamin C, moisture and visual appearance significantly higher than untreated, in both of the storage temperatures. None of samples stored at room temperature retained freshness beyond 4 days. It was seen that hydrocooled sample packaged in polypropylene bags of 4 and 6 perforations followed by low temperature storage showed no visual spoilage till 23 days and 21 days respectively and gave best results regarding Vitamin C, total chlorophyll content, moisture content and visual appearance. Hence, they were the best treatments. At 20^{th} day of storage moisture (%, wb), vitamin C (mg/100 g, wb) and total chlorophyll (mg/g, wb) of samples hydrocooled and stored in low temperature (8-10ºC) and packaged with 6 perforations were 68.65 ± 0.7709^{b}, 65.46 ± 0.4300^{b}, 21.09 ± 0.3090^{b} respectively whereas in package with 4 perforations were 76.85 ± 0.4771^{a}, 73.04 ± 0.6842^{a}, 18.94 ± 0.3704^{a} respectively. Thus, hydrocooling followed by packaging in perforated polypropylene bag (4 perforations per bag) and the storage at low temperature (8-10°C) can be considered the best post-harvest treatment for *akabare* chilli because it incurs the least change in colour, crispiness, vitamin C, moisture and chlorophyll.

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List of Abbreviations

Abbreviation	Full form
APP	Agriculture Perspective Plan
CFTRI	Central Food Technological Research Institute
DHA	Dehydroascorbic acid
HVCs	High value crops
LSD	Least Significant Difference
MAP	Modified Atmosphere Packaging
PP	Polypropylene
RDA	Recommended Daily Allowance
RH	Relative Humidity
SHU	Scoville heat unit

List of color plates

Part I

Introduction

1.1 General introduction

There are 22-25 species of *Capsicum* out of which only five species are cultivated for use in food (Basu and De, 2003). Among these five, *Capsicum annuum* is the most commonly cultivated species for pungent (hot pepper) and non-pungent (sweet pepper/bell pepper) fruits and has worldwide commercial distribution. The hot pepper fruits are consumed in fresh-, dried-, or processed forms (e.g., after pickling in salt and vinegar). Fruit carotenoids, capsaicinoids and flavor extracts are used in food, feed, medicine and the cosmetic industries (Kumar *et al.*, 2006).

Some varieties of *Capsicum annuum* (syn *chinense Jacqs*) are highly prized for their noted hotness. One such variety, called *akabare khursani* or *dale khursani* in Nepalese language, is taken to be one of the hottest chilli peppers (with Scoville heat units ratings in the range of 100,000-350,000). A variant grown in Nagaland (India), called king chilli, has an exceptionally high Scoville rating of 330,000-1,000,000 (Bhutia *et al.*, 2016).The peculiar pungency and fiery hotness of *akabare* increases appetite when taken as a meal adjunct (Rai, 2017). *Akabare* is grown in Sikkim, Nepal, Darjeeling and the surrounding regions (Bhutia *et al.*, 2016).

Akabare has already become a High Value Crops (HVCs) in eastern hills of Nepal (Tehrathum, Dhankuta, Panchthar and Ilam), the fresh fruit easily fetching NRs 400-1,600 per kg, in the peak and off season, respectively. Consequently, several farmers are involved in its cultivation (Shrestha, 2018).

The shelf-life of fresh green chillies is reported to be only three days at room conditions and 9-10 days in low storage conditions (Pruthi, 2003), and *akabare* is no exception. As with any perishable fruits and vegetables, losses (quantitative as well as qualitative) also occur throughout the harvesting, packaging, transportation and storage sequence. In the Nepalese rural setting/context, the losses can be much higher than generalized in the literature.

Akabare is a very prized pepper among the Nepalese. It is also exported to India, Pakistan, Bangladesh and China. Its production has therefore become a very remunerative activity in the rural hills of eastern Nepal. *Akabare* production, however, also has its own postharvest problems, which stem mainly from the lack of technical knowledge for minimizing losses

during handling, packaging, transportation and storage. *Akabare* loses moisture very rapidly. This causes not only weight loss (quantitative loss) but also shriveling (qualitative loss), both to the detriment of the producer. The pepper is also very prone to microbial (mold and bacteria) decays (Khanal, 2009).

Agriculture provides employment opportunities to 66 percent of the total population and contributes about 36 percent in the gross domestic product in Nepal. *Akabare* is becoming a High Value Crops (HVCs) in eastern hilly region of Nepal (Tehrathum, Dhankuta, Panchthar and Illam). Several farmers are involved in its cultivation. This crop has got high market price in fresh and unprocessed condition (NRs. 400 per kg in peak season and NRs. 1600 per kg in off season). Its cultivation is going to be professionals because of high selling cost (Shrestha, 2018).

The success in the production of any crop depends on the appropriate post-harvest technology applied. Several studies revealed that post-harvest management and marketing problems in the high value crop have endangered the agriculture sector which has direct negative impact on the livelihood of the farmers (Anon., 2014) .

As of now, several proven techniques have evolved for minimizing postharvest losses in pepper (Bosland and Votava, 2012; Raghavan, 2007; Thompson *et al.*, 1998) but these largely apply to commercially important varieties. However, literature on appropriate technology for the postharvest handling of locally grown peppers in general and *akabare* in particular, is relatively scarce. To this end, any effort expended on the development of relatively simple methods, utilizing readily available local resources, is therefore more than justified.

1.2 Statement of the problems

Because of perishable nature, *akabare* requires constant post-harvest care and attention. It is available only for short period during the month of Bhadra to Kartik. After harvesting it has to be transferred over long distances for market access. The containers during transportation are of traditional types. During long transportation, there is onset of spoilage. The produce becomes unacceptable and finally there is a loss. As a result, the farmers do not get the proper price; traders bear a part of loss and the consumers have to pay more for remaining of it (Anon., 2014). These biochemical and microbial changes can be delayed by application of post-harvest treatment. If this period can be extended it would be the boon for all farmers, traders and consumer (Khanal, 2009). Due to the large distances that the product generally must travel

between the location of production and the shelf of the consumer, the demand for postharvest techniques to maintain the quality of the fresh product for longer periods of time has grown (Wills *et al.*, 1989).

1.3 Objectives

Several simple techniques allow the quality of the fresh produce to be maintained for a longer period at a reasonable cost. No question, these techniques are also applicable in case of *akabare*.

1.3.1 General objectives

The objective of this study is to assess the effects of hydrocooling, packaging technology, (use of perforated and unperforated plastic) and storage temperature on the postharvest quality (moisture and weight loss, vitamin C and chlorophyll) and visual appearance of *akabare khursani*.

1.3.2 Specific objectives

1. To study the effect of hydrocooling on chemical (moisture and weight loss, Vitamin C, chlorophyll) quality and visual appearance of *akabare*.
2. To study the effect of perforation and intensity of perforation on chemical (moisture and weight loss, Vitamin C, chlorophyll) quality and visual appearance of *akabare.*
3. To study the effect of storage temperature i.e. low temperature (8-10°C) temperature and room temperature (25-27°C) on chemical (moisture and weight loss, Vitamin C, and chlorophyll) quality and visual appearance of *akabare*.

1.4 Significance of study

This research work will address the problem faced by *akabare* chilli (*akabare khursani)* growers due to immediate post-harvest losses of *akabare* after harvesting. The research will be advantageous for the people who are involved in collection, transportation and trading. Finding of this work will be helpful for bulk storage of *akabare*. Technologically the research will be more advantageous for keeping the *akabare* unchanged with respect to its sensory characteristics that is colour texture and flavour.

1.5 Limitations and delimitations

The limitations of the research are:

1. Change in oleoresin could not be observed on a daily basis.
2. The chilli was collected only from selected parts of Eastern Nepal (Hile, Dhankuta).
3. The texture of the chillies collected could not be studied owing to lack of texturometer.
4. The delimitation of the research is that all the causes of the post harvest loss could not be measured.
5. Only the bright green chillies were studied for convenience in laboratory work.

PART II

Literature review

2.1 Capsicum

2.1.1 History

Capsicum are indigenous to central and south America; there is prehistoric evidence of Capsicums in Peru and it is thought that capsicums were cultivated as early as 7,000 BC in the America. Capsicums were being widely cultivated when the Portugese and Spanish began to colonize South America. Capsicums are known to have been introduced to Europe by Columbus in 1493. Europeans initially used dried, crushed capsicums as a substitute for peppercorns (*Piper nigrum*). The Portuguese introduced capsicums to their colonies in Asia in the 16th century, where it was widely adopted into Asian cooking (largely because it was easier than Piper *nigrum* to grow) (Mason, 2014). Chillies dominate the flavors of many cultures south Indians, Sri Lankans, Southeast Asians, Latin Americans, and the Caribbean islanders (Raghavan, 2007).

Chillies were historically known to be used to impart flavor and hotness to food. Many civilizations were known to use this species, especially the Mayans and the Aztecs. The very foundation of Mexican food is based on the essence of chillies (De, 2003a). The sophisticated use of different chillies that began with the ancient Mayans and Aztecs continues around the world today (Raghavan, 2007).

2.1.2 Genus capsicum

Capsicum species are members of the Solanaceae, a large tropical family that includes tomato, potato, tobacco and petunia (Bosland and Votava, 2012). The genus *Capsicum* perhaps comes from the Latin word ‘capsa’, meaning chest or box because of the shape of fruits, which enclose seeds very neatly, as in a box. The capsicum encompasses a diverse group of plants producing pungent or non-pungent fruits (Kumar *et al.*, 2006).

At present, it is widely accepted that the genus consists of approximately 25 wild and five cultivated species. Among the cultivated species, viz, *C. annuum, C. frutescens, C. chinense, C. baccatum (var. baccatum), C. pubescens.* The *Capsicum* species that we cultivate most widely around the world *is Capsicum annuum*. All the five cultivated species of capsicum are represented by genotypes with pungent (hot pepper) or non-pungent (sweet pepper)

fruits. Furthermore, these species have huge variability for fruit size/shape and pungency and often genotype with similar fruit morphology exist across the species (Kumar *et al.*, 2006).

The word 'chili' is the common name for any capsicum species in Mexico, Central America and Southwestern U.S.A. In Asia, the spelling 'chilli' is more common and is always associated with highly pungent varieties of *C. annum* and *C. frutescens*, while the non-pungent sweet bell peppers are referred to as 'capsicums'. Pungent fruits of all cultivated capsicum species as a collective class are called 'chillies' in the Food and Agriculture Organization (FAO) Yearbook (Berke and Shieh, 2001).

Capsicums are also known by the common names of pepper or chilli (Mason, 2014).The high nutritive and culinary value of pepper gives them a high demand in the market. Capsicum are used fresh or dried, whole or ground into powder and alone or in combination with other flavoring agents (Premavalli and Amrinder, 2010).

The scientific classification of the chilli as given by Mason (2014) is as follows:

Kingdom: Plantae

Division: Angiosperm

Class: Magnoliopsida

Sub-class: Asteridae

Order: Solanales

Genus: *Capsicum*

Common name: Chilli, Cili, Cabai

2.1.3 *Capsicum Chinese-Habanero*

Akabare chilli (habanero chilli-*Capsicum chinese*), also known as *Dalle khursani*,is mostly grown in Sikkim and its surrounding regions; Nepal and Darjeeling. It is one of the hottest chilli pepper with a Scoville rating of 100,000 to 350,000 SHU (for comparison Naga King chilli has Scoville rating of 330,000-1,000,000 SHU, Tabasco red pepper sauces has rating of 2500-5000 SHU and pure capsaicin has Scoville rating of 16,000,000 SHU) (Bhutia *et al.*, 2016). The *akabare* chilli (habanero chilli-*Capsicum Chinese*) is one of the most intensely spicy species of chilli peppers of *Capsicum* genus. It is very hot and highly valued chilly which is highly

perishable and is available only for short period of time, from Bhadra to Kartik especially in the Eastern part of Nepal (Bokhim, 2007).

It is cherry like oval shaped fruit with a deep red skin color when matured and green when immature. Other colors like brown, white, pink are also seen. The average physical dimension of *akabare khursani* was found 3.11 (cm), 2.21 (cm), and 3.76 (g) for length, breadth and weight respectively. Similarly, weight of seeds in a fruit is 2.28 (g). Total flesh weight per fruit is 1.46 (g) and number of seeds per fruit is 31-35 (Khanal, 2009). *Akabare khursani* is widely cultivated and consumed in Nepal. It is used to make fresh or fermented pickle and spice up curry, *daal* or soup. It is popular during low winter months as its heat keeps the body warm. It can be pickled on either simply in vinegar or with spices is the most popular and can be jarred for several months, and consumed alongside with *daal, bhaat, tarkari*. It has peculiar pungency and hotness which increases the appetite of meal (Rai, 2017).

2.1.4 Classification

The scientific classification of Habanero chilli (*akabare*) as referred to Manju and Sreelathakumary (2002), is given as follow:

Kingdom: Plantae

Division: Angiosperm

Order: Solanales

Family: Solanaceae

Genus: *Capsicum*

Species: *chinese*

Binomial name: Capsicum chinense Jacq

2.1.5 Production

Capsicum is grown in the world on an area of 1.5 million hectare with the production of 10.60 million tons (Bhutia *et al.*, 2016). Though there are no official figures for the production of chillies worldwide, it is estimated that India tops the list with 8,50,000 tonnes, followed by China with 4,00,000 tonnes, Pakistan 3,00,000 tonnes , South Korea 1,50,000 tonnes, Mexico 3,00,000 tonnes , Bangladesh 1,00,000 tonnes and other countries combining

to produce 4,00,000 tonnes (De, 2003a). The data of chilli production in Nepal in year 2014 is given in Table 2.1.

Table 2.1 Data of chilli production in Nepal

Region	Area (Hectare)	Production (Metric tons)	Yield (Metric tons/ha)
Eastern	1152	3767	3.27
Central	1856	6741	3.63
Western	572	2456	4.29
Mid-Western	1150	4995	4.34
Far Western	1422	5854	4.12
Nepal	6152	23813	3.87

Source: Islama (2014)

Ilam is leading in the production of *akabare* with existing area being involved as 145 ha land with the production of 550 metric ton every year. The area of production is being expanded every year to other eastern district of Nepal, such as Taplejung, Panchthar, Tehrathum, Bhojpur and Dhankuta district. In recent years akabare is cultivated as commercial farming in these hilly areas. *Akabare* chilli is an important Highly Value Crops (HVCs) for cash generation in eastern hilly region of Nepal. Nepal government has launched 20 years Agriculture Perspective Plan (APP) from 1995 to assist the nation by increasing the research and development (R&D) work in agriculture sector. Agriculture provides employment opportunities to 68 % of the total population and contributes about 25-28% in the gross domestic product in Nepal (Islama, 2014). According to APP, the annual growth rate of HVC crops is assumed to accelerate from 4.8% during the year of 1995 to 5.8% during the end period (2014), with corresponding increase in agriculture GDP from 13% to 15%. The success in the promotion if these crops in hills are dependent on the basic infrastructure and appropriate post-harvest technology applied (Bhurtel *et al.*, 1996).

2.1.6 Favorable climate and geography

Typically, commercially grown peppers may take between 65 and 80 days from planting the plants, to when you harvest the first peppers. Sweet peppers (i.e. 'bell pepper 'cultivars) grow best at temperatures between 21-24°C (70-75°F). Hot peppers (chilli types) include cultivars that grow well in warmer conditions. The optimum temperature range for hot peppers is 21-29°C (i.e. 70-85°F). Rh is one of the most important factor for growth of capsicum. The plant can exhibit an under-supply of water, even when moisture levels in the soil are adequate especially if there is low humidity and high temperatures. This can result in water transpiring from the plant faster than it can be taken up through the roots, and when this happens water deficit can occur and that in turn results in abscission (i.e. dropping) of buds flowers and small fruits (Mason, 2014).

The ease with which nutrients are able to enter a plant is greatly affected by pH. Extremely acid or alkaline soils can often stop the nutrients present being absorbed and used by the plant. The plant will suffer a nutrient deficiency, not because the required nutrient is not in the soil, but because the plant cannot get it (i.e. it is not available). The ideal pH for nutrient availability is different for each nutrient. A pH that makes iron very available will make calcium much less available. The only answer is to compromise - go for a pH in the middle, where no element is so available that it become toxic. The ideal pH for growing Capsicums is 6 to 6.5; on acidic soils lime is often applied to raise the pH. Dolomite lime, which also contains calcium, is generally preferred (Mason, 2014).

2.1.7 Harvesting of capsicum

The first fruits are harvested 8 to 16 weeks (or sooner) after planting the young plants; depending upon where they are grown and the cultural techniques used. Bell capsicums are either harvested when fruits are still green; or just beginning to turn red. Red fruit often bring a higher price; but take longer to produce. Fruits should be plucked by snapping off the stem, being careful to not detach too close to the fruit. If too little, or no stem is left on a fruit, it will deteriorate faster after harvest. Fruit that is harvested in heavy rain periods can rot faster. Water can even be contained inside the fruit cavity, further increasing the rate of rotting (Mason, 2014). After harvesting, fruits should be gently cooled to between 5°C and 10°C to optimize quality and shelf life. The best way of cooling large quantities commercially is with forced air fans in a room at between 5° and 10°C. If necessary, fruits may be stored in a cool room at 7-

10 °C for up to 3 weeks. Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently (EI-Ramaday *et al.*, 2015).

2.2 Nutritional value of capsicum

Nutritional compositions of pepper fruits depend on the genotype and fruit maturity stage. In general, 100 g of green fruits contain 85.7 g moisture, 2.9 g protein, 0.6 g fat, 1.0 g minerals, 6.8 g fibers, 3.0 g carbohydrates, 30 mg calcium, 24 mg magnesium, 0.39 mg riboflavin, 67 mg oxalic acid, 0.9 mg nicotinic acid, 80 mg phosphorus, 1.2 mg iron, 6.5 mg sodium, 217 mg potassium, 1.55 copper mg, 34 mg Sulphur, 15 mg chlorine, 0.19 mg thiamine, 292 IU vitamin A and 111 mg vitamin C (Mason, 2014). Similarly, According to Litoriya *et al.* (2014) 100 gram of Capsicum contain 85.7% moisture, 0.88% protein, 92.8 mg/100 g of ascorbic acid, 10.09 mg/g of chlorophyll content, and 0.424% capsaicin.

Green fruits of hot and sweet peppers are one of the richest sources of antioxidant vitamins such as vitamins A, C and E, mineral salts and the antibiotic capsaicin. Sweet peppers are generally higher in vitamins than hot peppers or chillies. In fact, vitamin C was first purified from Capsicum fruits in 1928 by Hungarian biochemist Albert Szent Gyorgyi, which helped him to receive the Nobel Prize in physiology and medicine during 1937 (Kumar *et al.*, 2006).

The antioxidant vitamins C, E and provitamin A are present in high concentrations in various pepper types. Peppers are also good sources of carotenoids and xanthophylls and may contain high amounts of vitamins P (citrin), B_1 (thiamine), B_2 (riboflavin), and B_3 (niacin). Peppers are richer in vitamins C and A than the usually recommended food sources (Bosland and Votava, 2012). Vitamin levels drop dramatically when peppers are cooked or canned; or if they get too ripe.

- 1 ounce of sweet pepper (approx. 28,000 mg) contains 40 mg of vitamin C.
- 1.5 ounces (42 gm) of sweet pepper can supply the recommended daily intake of vitamin C for an average person.

Considerable research has focused on antioxidants in foods, as protection against cancer, anemia, diabetes and cardiovascular diseases. As an excellent source of these antioxidants, which counter the oxidation of lipids via scavenging oxygen free radicals, a great deal of attention has been paid to peppers (Bosland and Votava, 2012).

One medium green bell pepper (weighing 148 g) has 30 calories, 7 g total carbohydrates (i.e. 2% of the recommended daily allowance (RDA) for adults), 2 g dietary fiber (8% of the adult RDA), 4 g sugar and 1 g protein, plus, respectively, 8%, 180%, 2%, and 2% of the adult RDA for vitamin A, vitamin C, calcium and iron (Bosland and Votava, 2012).

2.2.1 Vitamin C in capsicum

Vitamin C is one of the most important nutritional quality factors in many horticultural crops and has many biological activities in the human body. It is present in plant tissues undergoing active growth and development, and the amount of vitamin C varies among species and cultivars (Kader, 2000). Peppers are among the richest known plant sources of vitamin C (ascorbic acid). Vitamin C was in fact first purified from peppers in 1928 by the Hungarian biochemist Albert Szent-Gyorgyi who went on to win the Nobel Prize in Physiology and Medicine for his work on the vitamin. A pepper pod can contain six times as much vitamin C as an orange. Pepper pods from the green to the succulent red stage each contain enough vitamin C to meet or exceed the adult RDA. Fresh peppers are excellent sources of ascorbic acid ,which participates in several antioxidant processes in plants besides acting in the prevention of human chronic diseases, including certain types of cancer, coronary disorder, arteriosclerosis and cataracts (Howard *et al.*, 2000)

Fresh fruits may contain up to 340 mg vitamin C per 100 g but vitamin-C content falls by about 30% after canning or cooking and becomes negligible after drying (Bosland and Votava, 2012). However, vitamin C content is affected by cultivar, with black, purple, and white peppers having lower ascorbic acid levels than green, yellow, red, brown, and orange peppers. Differences in vitamin C content among cultivars is due to variations in the moisture content of the fruits, since vitamin is a water-soluble compound (Bosland and Votava, 2012).

2.2.2 Color pigments

Fruit color is due to the presence of various plant color pigments. Some of these pigments, including anthocyanins and carotenoids, are believed to have important health benefits. The numerous shades of peppers are due to the variations in carotenoid pigments produced by peppers as they ripen. More than 30 different pigments, including the green pigments chlorophylls a and b; the yellow-orange pigments lutein, zeaxanthin, violaxanthin, antheraxanthin, beta-cryptoxanthin and beta-carotene; and the red pigments capsanthin,

capsorubin and cryptocapsin have been identified in pepper fruits (Bosland and Votava, 2012).

Peppers are rich in phytochemicals, which give them a diverse range of colors consisting of red, yellow, orange, purple, and brown. The pigments include three classes of phytochemicals: chlorophyll, carotenoids, and anthocyanins. The range of pepper fruit color is due to the accumulation of one or more of these pigments. Pigments are photosynthetic compounds involved in many plant functions (DellaPenna and Pogson, 2006).

2.2.2.1 Chlorophyll

Chlorophylls are hydrophobic compounds made of four modified pyrole rings with an Mg atom and an attached long C20 hydrocarbon tail. In pepper, unripe fruit colors can vary from ivory, green, or yellow. The green color is accumulation of chlorophyll in the chloroplast while ivory indicates chlorophyll degradation as the fruit ripens (Wang *et al.*, 2005).

Chlorophylls are responsible for green color in peppers and during ripening, it disappears and red, orange or yellow color develop as consequence of carotenoid synthesis. The color change that occurs with the ripening of pepper fruits is due to a change in pigment content. During the conversion process chlorophyll begins to disappear and the synthesis of carotenoids increases (Camara and Moneger, 1978).

2.2.3 Capsicum as medicine

Chilli fruits have a variety of medicinal uses: stimulant, digestive, bacteriostatic properties; unlike some other types of stimulants, capsicum has no narcotic affect (Mason, 2014). According to Mason (2014) , uses of chilli as medicine are:

- As a stimulant, chilli may increase heart rate; pumping the blood faster, and increasing sweating. This helps may help cool the body faster; which may be partially why chilli is more widely used in tropical climates than very low climates.
- Used externally as rubefacients. If used in excess, capsicum can damage the mucous tissues in the mouth and tissues in the digestive and renal systems.
- Oil derived from capsicum when dissolved in ether, is said to be effective as a rub to relieve rheumatism.

- Chilli peppers are sometimes taken in moderate quantity to stimulate slow digestion. Recipes containing chilli are sometimes found in homeopathy and herbal medicine, as a treatment for slow digestion.

- There are suggestions that eating chilli peppers can lower blood cholesterol, though substantiated proof cannot be found.

2.2.4 Uses of capsicum in food processing

Pepper is a most popular and widely used condiment all over the world. Fruits are consumed in fresh, dried or processed forms, as table vegetable or spice. Fruits are extensively pickled in salt and vinegar. Fruit carotenoids (colour), capsaicinoids and flavor extracts are used in food, feed, medicine and the cosmetic industries. Sweet peppers are widely used at green-immature or mature stage as a vegetable. The fruits of the genus *Capsicum* have many versatile and innovative uses and diversity (Kumar *et al.*, 2006).

2.2.5 Post harvest handling of capsicum

Postharvest handling is the stage of crop production immediately following harvest, including cooling, cleaning, sorting and packing. The instant a crop is removed from the ground, or separated from its parent plant, it begins to deteriorate. Postharvest treatment largely determines final quality, whether a crop is sold for fresh consumption, or used as an ingredient in a processed food product. Postharvest handling is the final stage in the process of producing high quality fresh produce. Being able to maintain a level of freshness from the field to the dinner table presents many challenges (EI-Ramaday *et al.*, 2015).

2.3 Fresh peppers

Fresh fruits and vegetables must have an attractive appearance, acceptable flavor, appropriate texture, and a positive nutritional image to attract initial and continued purchases by consumers. The primary indicators of pod freshness are firmness and degree of dehydration. The US Food and Drug Administration's (FDAs) nutrient-content descriptions for fresh peppers include 'fat-free, saturated-fat free, very low sodium, cholesterol-free, low in calories, high in vitamin A, and high in vitamin C. A good quality mature fresh green pepper is firm, bright in appearance, thick-fleshed and with a fresh, green calyx. Immature peppers are usually soft, pliable, thin-fleshed and pale green in color (Seigge *et al*., 2001). Fresh peppers are also excellent sources of ascorbic acid (vitamin C), which participates in several antioxidant

processes in plants besides acting in the prevention of human chronic diseases, including certain types of cancer, coronary disorder, arteriosclerosis and cataracts (Howard and Hernandez, 1997).

Fresh green pepper loses water very quickly after harvest and begins to shrivel and turn color within a few days if unrefrigerated. If stems remain they should be firm and green. Darkening, shriveling or rotting of stems indicates that the pepper was not harvested recently. To ensure a pepper fruit of high quality, the fruit must have quick and proper cooling. All pepper types but especially New Mexican green pepper are highly susceptible to water loss, sunscald and heat damage. These problems are likely to occur if peppers are allowed to sit for more than 1 h in direct sunlight (Bosland and Votava, 2012).

2.3.1 Sensory characteristics of fresh peppers

Fresh fruits and vegetables must have an attractive appearance, acceptable flavor, appropriate texture, and a positive nutritional image to attract initial and continued purchases by consumers. Quality can be viewed from either a product or a consumer orientation. A consumer orientation views the product through the sensory perspective of the consumer at the points of purchase and consumption (Shewfelt, 1993). Consumers often buy the first time based on appearance, but repeat purchases are driven by expected quality factors determined by flavor compounds and texture (Waldron *et al.*, 2003).

2.3.1.1 Colour and appearance

Color and appearance is the initial quality attributes that attract us to a fruit or vegetable product (Yamaguchi and Ninomiya, 2000). The colour and texture are affected by many factors such as temperature, relative humidity and other atmospheric conditions. Color and appearance attract the consumer to a product and can help in impulse purchases. At the point of purchase the consumer uses appearance factors to provide an indication of freshness and flavor quality (Shewfelt, 1993).

Appearance is determined by physical factors including the size, the shape, the wholeness, the presence of defects (blemishes, bruises, spots, etc.), finish or gloss, and consistency. Size and shape may be influenced by cultivar. Gloss on the outside of whole fruits tends to be a desirable attribute for whole fruits. The wholeness and absence of defects will be affected by exposure to disease and insects during the growing period and postharvest handling operations.

Fruit and vegetable gloss are related to the ability of a surface to reflect light and freshly harvested products are often more glossy. Gloss and shine is affected by moisture content, wax deposition on the surface, and handling practices postharvest. Fresh fruits and vegetables must appear to be fresh, generally indicated by the brightness of color and the absence of visual defects. The visual characteristics that prevent *akabare* from being sold are, presence of withering, wilting and loss of shine and gloss of original chili (Mitcham *et al.*, 1996). The colour and texture are affected by many factors such as temperature, relative humidity and other atmospheric conditions.

2.3.1.2 Texture

Consumers have clear expectations for the texture of fresh vegetables and fruits. Fresh pepper should be crisp and crunchy. While consumers generally cite flavor as the most important quality attribute for fruits and vegetables, textural defects and the interaction of flavor and texture are more likely to cause rejection of a fresh product (Harker *et al.*, 2003). Textural parameters of fruits and vegetables are perceived with the sense of touch, either when the product is picked up by hand or placed in the mouth and chewed (Waldron *et al.*, 2003). According to Bourne (1982), the textural properties of a food are the group of physical characteristics that arise from the structural elements of the food, are sensed by the feeling of touch.

2.3.1.3 Pungency and aroma

Pungency is produced by the capsaicinoids, a group of alkaloid compounds that are found only in the plant genus, *Capsicum*. The nature of the pungency has been established as a mixture of seven homologous branched-chain alkyl vanillyl amides. They are often called capsaicin after the most prevalent compound. Capsaicin is a powerful and stable alkaloid that can be detected by human taste buds in solutions of ten parts per million (Zachariah and Gobinath, 2008).

2.3.1.4 Nutritional value

Consumers expect fresh fruits and vegetables to be good sources of dietary fiber and many vitamins and minerals. During storage little change occurs in dietary fiber and mineral content, but the vitamins are lost. Increase in respiration and senescence during storage leads to more

rapid loss of certain vitamins. Vitamin C is the vitamin that usually degrades most rapidly and can be used as an index of freshness (Howard and Hernandez, 1997).

2.4 Purpose and principle of postharvest management

Quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and RH of the storage conditions. Quality factors for fruits include the following: maturity, firmness, the uniformity of size and shape, the absence of defects, skin and flesh color (Perez *et al.*, 2003). Hardenburg *et al.* (2016) mentioned that storage under low temperature is the most efficient method to maintain quality of fruits and vegetables due to its effects on reducing respiration rate, ethylene production, ripening, senescence, and rot development. High temperature increases the vapor pressure difference between the fruit and the surrounding, which is the driving potential for faster moisture transfer from the fruit to the surrounding air (Hardenburg *et al.*, 2016).

Postharvest management is a set of post-production practices that includes: cleaning, washing, selection, grading, disinfection, drying, packing and storage. These eliminate undesirable elements and improve product appearance, as well as ensuring that the product complies with established quality standards for fresh and processed products. Postharvest practices include the management and control of variables such as temperature and relative humidity, the selection and use of packaging, and the application of such supplementary treatments such as fungicides (EI-Ramaday *et al.*, 2015).

Kader (2002) in his research found out that the magnitude of postharvest losses in fresh fruits and vegetables is estimated to be 5 to 25% in developed countries and 20 to 50% in developing countries, depending upon the commodity, cultivar, and handling conditions. To reduce these losses, producers and handlers must first understand the biological and environmental factors involved in deterioration, and second, use postharvest techniques that delay senescence and maintain the best possible quality. The post-harvest treatments play an important role in extending the storage and marketable life of horticultural perishables.

Disease and oversupply contribute to this losses, but there are many other reasons for the losses. Postharvest management can influence all of them, with the two most important areas being temperature management and packaging (EI-Ramaday *et al.*, 2015) **.** The purpose of postharvest handling system is to deliver appealing and nutritious food to consumer in an economical manner (Seigge *et al.*, 2001). Handler and consumer attach a lot to retention of fruit

colour, freshness and firmness. In addition absence of defect due to bruises mechanical damages and rot rate are also considered in extension of shelf life of pepper fruit (Jobling, 2001).

2.5 Methods of post harvest treatment in agriculture produce

Following methods have been seen to have been used as post harvest treatments.

2.5.1 Pre-cooling of horticulture produce

Pre-cooling of the produce soon after their harvest is one of the important components of the cool chain, which ultimately affect the shelf life of the produce. The main purpose of precooling is to immediately remove the field heat from the produce. Generally it is a separate operation requiring special facilities, but complementary to low temperature storage**.** As deterioration is proportional to the time produce is exposed to high temperatures, precooling is beneficial even when produce is later returned to ambient conditions (EI-Ramaday *et al.*, 2015). For most of the highly perishable horticultural products, including leafy and flowering vegetables, the rate of deterioration is accelerated when the field heat has not been removed before being put into low storage (Brosnan and Sun, 2001).

Freshly harvested fruits must be rapidly cooled by removing field heat with a compatible cooling method. Excess heat causes fruits and vegetables to have higher respiration rates, ultimately resulting in a faster deterioration of their quality. The rate of cooling is directly related to the temperature difference between the cooling medium and the product (Thompson, 2014). However, in order for cooling to be effective, at least 7/8 of the field heat should be rapidly removed from the harvested crop. The time it takes to remove this amount of heat is known as the "7/8 Cooling Time" (Thompson *et al.*, 1998).

Temperature of the surrounding air and produce can be reduced by forced air cooling, hydro cooling, vacuum cooling, ice cooling and adiabatic cooling (Thompson *et al.*, 1998). However, most of these cooling methods are unaffordable by the small-scale peasant farmers, retailers and wholesalers, as they require high initial cost and power sources (Wills *et al.*, 1989).One of the easiest way of precooling is hydrocooling. The use of low water is an old and effective cooling method used for quickly cooling a wide range of fruits and vegetables before packaging. Hydrocooling removes heat at faster rate than forced air cooling (Sargent *et al.*, 1995). This method of cooling not only avoids water loss but may even add water to the commodity. The hydro cooler normally used are of two types: shower and immersion type. Because of its higher

capacity to absorb heat, it is faster than forced-air cooling. Among the different methods used for cooling vegetables, hydrocooling with low water is one the most efficient due to the direct contact of the low water with the product. In addition, it is relatively cheap compared to forced air or vacuum cooling systems (Gast and Flores, 1991; Wills *et al.*, 1989). Furthermore, by submerging the product in low water, there is no water loss, which happens when the product is cooled with low air or a vacuum (Brosnan and Sun, 2001). Alvares (2007) in his research found that the hydrocooling was able to prevent the loss of water and also allowed some water uptake by the commodity, as was observed by the higher content of water detected once the pre-cooling had ended. This system cannot be used for crops that do not tolerate wetting, chlorine and water infiltration. Chlorination of water (150–200 ppm) can be done to prevent the accumulation of pathogens (EI-Ramaday *et al.*, 2015).

2.5.2. Packaging

Product damage is usually caused by either climatic conditions or physical environments (Paine and Paine, 1992a). Knowing which product group spoils easiest, at what point along the chain they spoil the most, what brings about the food loss and last but not the least, can losses be avoided or not, are specific concerns along the value chain, with high implications on packaging (Manalili and Dorado, 2003).

Some commodities are very sensitive to ethylene gas and need to avoid gas build-up during transit to avoid premature ripening whereas some are sensitive to moisture loss. Fresh fruit and vegetables (FFV) are the most perishable food items. Thus, Packaging must protect from moisture loss and against bruising which can occur if the product is handled or packaged incorrectly (Paine and Paine, 1992a). As for form, packaging can either be flexible or rigid , owing to cost and flexibility advantage (Manalili and Dorado, 2003).

Moving of fresh fruits and vegetables from the production site to the table in the desired state of freshness poses the biggest challenge to the packaging sector. Knowing when and where the losses occur in the commodity chain helps to pinpoint, not only the food loss hot spots, but also their probable causes, which in turn will be crucial in determining the extent to which they can be avoided or not, and the packaging solutions to best address them (Manalili and Dorado, 2003). Prepackaging in polymeric film or paper bags or plastic bags improves the storage life and retains the freshness of chillies (De, 2003a).

Plastics exhibit outstanding usage properties, so they are used preferentially for packaging foodstuffs. Plastic packages are capable of retarding and sometimes preventing detrimental changes in the packed material due to external influences such as oxygen, light, and microorganisms. Plastics are also able to reduce to a great extent, the loss of components such as water or flavour in the packed material. Resulting from this protection, plastic packages enable the consumer to use foodstuffs in perfectly hygienic conditions, and to store them without loss in quality over an extended period of time (Vergnaud and Rosca, 2006).

2.5.3 Perforated packaging

Products such as fresh vegetables that require complete ventilation in transport and storage needs to be packed in open mesh bags or packages. At first these open mesh bags were first made in hessian with a very open weave, and then were produced in yarn twisted from special kraft paper, but now most are made with tough resilient plastics. In smaller quantities, up to about 3 kg weight, polyethylene film bags with perforations may be used for the same produce, but above this weight film bags are not so good (Paine and Paine, 1992b)

Prepackaging of the fruits in perforated polyethylene packages has been shown to reduce water loss rates by 20 times or more. Prepackaging also reduces colour development (red colour) across cultivars on storage (De, 2003b).

The benefits offered by perforation are high rate of gas transmission. Drilling holes in the plastic films can achieve the required degree of perforation : macro perforation greater than 300 μ m in diameter and micro perforation of 5–300 μ m in diameter. The gas transmission depends on hole size and perforation number, and can be estimated using several mathematical models (Mir, 2009). The diffusion rates of CO_2 and O_2 through perforated and non-perforated polymeric films differ significantly (Mir and Beaudry, 2004). A large number of small holes is better able to provide a consistent O_2 transmission rate than a small number of large holes. The O_2 and CO_2 transmission contributed by the plastic film layer and by air due to perforations can help to create the optimal modified atmosphere for produce with high respiration rates. Perforation can be achieved in a number of ways. Mechanical puncturing using a low or hot needle has been practiced for some time and is commonly used for making macro perforations (Yam and Lee, 2012).

Temperature abuse during transportation, storage, and marketing of fresh produce is a primary concern in MAP for fresh produce. With an increase in temperature, the O_2 level in the

package decreases and CO_2 level increases: this is because the temperature increase does not cause the permeability of the package film to the O_2 and CO_2 gases to increase to the same extent as the respiration rate of the produce. The low O_2 concentration and high CO_2 concentration are detrimental to fresh produce, causing physiological damage and off- flavors (Yam and Lee, 2012).

The gas permeability of a perforated film is controlled by the number and dimensions of the perforations. Macro perforated films have higher permeability rate than those of micro perforated materials. Such films are used for commodities tolerating simultaneously low O_2 and high CO_2. The package headspace dynamics vary with the number of macro perforations. This technique is simple and involves only the punching of desired macro perforations in the ordinary film package to affect higher gaseous diffusion across the film packages. However, the attainment of ideal steady-state headspace partial pressures of O_2 and CO_2 under any type of MAP is still a difficult task in the design of MAP and often requires repetitive experimentation; which increases the cost of experiment levels such as fresh-cut products and commodities having high respiration rate. In the perforation-mediated packaging system the regulation of the gas exchange is achieved by single or multiple tubes that perforate an otherwise impermeable packaging material. From an engineering point of view, the transport of gases through perforations is a complex phenomenon that involves diffusion gradients together with co-current transport of multiple species, with oxygen entering the package and carbon dioxide leaving it. It is also a good solution for packing high-respiring products, due to the high gas exchange rates and low permeability coefficients achieved (Soltani *et al.*, 2015).

2.5.4 Storage temperature

In an excellent review on pre harvest and postharvest factors influencing vitamin C content, Lee and Kader (2000) found that postharvest temperature management was the most important tool for the extension of shelf-life and maintenance of fresh fruit and vegetable quality. They state that delays between harvesting and cooling may result in direct losses due to water loss and decay and indirect losses in flavor and nutritional quality.

Temperature is one of the major factors affecting shelf life of fresh produce and needs to be positively controlled during handling and marketing of such commodities. Respiration of raw fruits and vegetables increases 2- to 3-fold for every 10°C rise in temperature within the range of temperature usually encountered in the distribution and marketing chain (4–30°C). By

decreasing temperature, the rate of enzymatic reactions and respiration is reduced according to the Arrhenius relationship (Brecht *et al.*, 2003). The recommended refrigerated temperature for storage of pepper is given as 7–10°C and 85–90% RH for 8–10 days (J. Thompson, 2003).

However , bell peppers are susceptible to chilling injury at temperatures below 7°C Chilling injury (De, 2003b). Packaging peppers with polyethylene bags at low temperature (7.5˚C) reduced the water loss by 40-50% and maintained the fruit quality. The use of packaging films has been shown to increase the shelf-life of perishable produce establishing a beneficial in package atmosphere containing low O_2 and high CO_2 and reduced water loss (Sharma *et al.*, 2018).

2.6 Postharvest losses in capsicum

In general, fruits and vegetables are bulky, easily damaged mechanically, consist largely of water which is readily lost, and, above all, are living and must be kept so. This means that they are sensitive to their environment, their rate of metabolism is temperature dependent, and they may be damaged by heat or low. They are affected by the levels of oxygen and carbon dioxide, ethylene and other volatiles in the atmosphere. When fresh fruits and vegetables respire, they take in oxygen and give out carbon dioxide, heat and water vapour (Paine and Paine, 1992a).

Peppers are highly perishable vegetable and needs appropriate handling and adequate care to maintain shelf-life and quality. The storage life of pepper fruit is limited by pathological deterioration , rapid water loss during prolonged storage and susceptibility to chilling injury (Hughes *et al.*, 1981). Main factors of quality degradation of sweet pepper during storage include decay development, susceptibility to chilling injury and shriveling associated to rapid water loss (Sharma *et al.*, 2018).

2.6.1 Moisture loss

They lose moisture (wilt) rather rapidly by evaporation (Paine and Paine 1992). The harvest interrupts the fruit water supply and the subsequent loss of water is responsible for the qualitative and quantitative losses (Ramalho do Rego *et al.*, 2016). While attached to the plant, the losses due to these processes are replaced by the flow of sap, but after harvest respiration and water loss continue and the plants are dependent entirely on the food reserves and moisture they contain; losses are not replaced, deterioration begins and they

eventually perish (Paine and Paine, 1992a). Harvested produce remains fresh only as long as it retains water. Transpiration is one of the main processes that affect commercial and physiological deterioration. It induces wilting, shriveling, and loss of firmness, crispness, and succulence, all components of freshness (Ben-yehoshua and Rodov, 2002).

Excessive loss of water results on less shiny skin and shrunken fruits, but the amount of water necessary to cause these problems depends on the variety and environmental conditions of storage. In addition to the above symptoms , the fruits are more susceptible to deterioration, including an increase in oxidative reactions, degradation of chlorophyll, and elevation of ethylene synthesis and action (Ramalho do Rego *et al.*, 2016).

The maximum acceptable loss of water from peppers is only 10% of the original fresh weight (Kays, 1997). As fruits and vegetables contain over 90% water, a loss of 5% or more water is visually noticeable, lowering the grade of the produce and resulting in a decrease in its commercial value. Major effects of water loss are a reduction in weight and a wilted appearance; there is also a reduction in nutritional value as the amount of water-soluble components decreases when water is released, a loss in aroma and flavor, and an enhanced sensitivity to chilling injuries (Robertson, 2010). Packaging of fruits and vegetables in plastic films is common for reducing excessive water loss that aids in prolonging the postharvest life of fresh produce. Low O_2 and elevated CO_2 concentrations in the modified atmosphere (MA) of the package reduce the respiration rate and hence improve storage life. Alleviation of water stress is the main factor extending postharvest life of pepper sealed in plastic film (Hughes *et al.*, 1981). However, excessive relative humidity (RH) and consequent water condensation may increase the risk of fruit decay as excessive in-package humidity may stimulate microbial pathogen development. Therefore, the ranges of O_2 , CO_2 and water vapor levels must be chosen for each produce, and the MA packaging must be designed to provide optimal storage conditions (Brecht *et al.*, 2003). The use of perforated films was recommended for mango and peppers fruit by Ben-Yehoshua (1985), later was tested under experimental conditions . Due to their brittle structure, peppers should be handled with care. Transpiration losses in peppers are very high, limiting their storage life (De, 2003b).

2.6.2 Vitamin C Loss

Many pre- and postharvest factors influence the vitamin C content of horticultural crops. Vitamin C is most sensitive to destruction when the commodity is subjected to adverse handling

and storage conditions. Losses are enhanced by extended storage, higher temperatures, low relative humidity, physical damage, and chilling injury (Kader, 2000). In general, freshly harvested fruits and vegetables contain more vitamin C than those held in storage. Generally, fruits and vegetables show a gradual decrease in Vitamin C content as the storage temperature or duration increases (Adisa, 1986). Ascorbic acid is usually degraded by oxidative process, which is stimulated in the presence of light, oxygen, heat, peroxides and enzymes, such as ascorbate oxidase or peroxidase (Plaza *et al.*, 2006). Chilling injury causes accelerated losses in Vitamin C content of chilling sensitive crops. Destruction of ascorbic acid can occur before any visible symptoms of chilling. Low humidity and/or rapid air movement often result in rapid wilting and make the produce less attractive. Also, wilting plasmolysis might hasten oxidation of the cell constituents and result in an adverse effect on the vitamin C content (Miller and Heilman, 1952). High O_2 and low CO_2 concentration cause oxidation of ascorbic acid into dehydroascorbic acid (DHA) leading to subsequent decrease in ascorbic acid (Mahajan *et al.*, 2014). Also, high CO_2 concentration stimulates degradation of ascorbic acid due to its high stimulating effects on the oxidation of ascorbic acid and/or inhibition of DHA reduction to ascorbic acid compared to the equivalent O_2 concentration (Agar *et al.*, 1999; Lee and Kader, 2000).

2.6.3 Chlorophyll loss

One of the symptoms of senescence in harvested horticultural crops is the loss of greenness that comes with the degradation of chlorophyll. Manolopoulou *et al.* (2010) demonstrated that postharvest color development in peppers is inhibited by refrigeration. As storage time increases, slight ripening occurs. The ripening process induces color change, which concomitantly promotes carotenoids biosynthesis and chlorophylls degradation. The red color in peppers is caused by the concomitant biosynthesis of some carotenoids during ripening, e.g., capsanthin, capsanthin 5, 6-epoxide. Carotenoids biosynthesis in fruits and vegetables depends on the storage temperature (Yahia and Ornelas-Paz, 2010). On the other hand, chlorophyllase activity has been related to chlorophyll degradation during ripening in several pepper genotypes; however, other enzymes could also be involved in such degradative processes. The maximum chlorophyllase activity is achieved at temperatures from 20 to 30°C, whereas the minimum activity of these enzymes is observed at 0°C.The activity of chlorophyll-degrading enzymes is low during refrigerated storage (Hornero and Minguez, 2002).

The chlorophyll degradation during curing, processing or during aging of plant tissues results in a colour change. The factors that affect the degradation of chlorophyll are: water stress, light, temperature, ethylene or their combination (Yang *et al.*, 2009). Cantwell *et al.* (1998) report that temperature is one of the major factors that determine the postharvest quality of the green vegetables. High temperature of preservation accelerates deterioration and reduces storage time whereas low temperature increases shelf life of most fresh vegetables delaying degradation of chlorophyll. The reduction of the intensity of green color in vegetables is associated with aging, the reduction in the nutritional value and in general their quality (Yang *et al.*, 2009).

It is known that the temperature plays an important role in the degradation of chlorophyll. Generally, the high temperature stimulates the enzymatic degradation whereas the low temperature delays it (Yang *et al.*, 2009). The characteristic green color of immature fruit is due to the presence of chlorophylls and carotenoids (Pogson and Morris, 1997).

2.6.4 Loss of flavors and oleoresins

Flavor is typically described by aroma (odor) and taste. Aroma compounds are volatile. They are perceived primarily with the nose, while taste receptors exist in the mouth and are impacted when the food is chewed. The flavor has the largest impact on acceptability and desire to consume any product (Yamaguchi and Ninomiya, 2000).

The total flavor extracts prepared by solvent extraction of the ground spices are known as Oleoresins. It is a viscous liquid derived by polar solvent extraction from ground powder of any Capsicum species. It is also called as concentrated liquid form of the spice. It has the aroma of the spice and possess the attribute to taste such as pungency. It is naturally occurring flavoring and colouring substances. It is found in ground fruit pods, with or without the seeds (Mini *et al.*, 1998). Capsicum oleoresins contain a complex mixture of essential oils, waxes, coloured materials (mainly capsanthin, capsorubin, zeaxanthin, cryptoxanthin and lutein), and several capsaicinoids. It also consists pharmaceutical ingredients (Hui Yiu and Barta, 2006).With increase in storage days and temperature there is development of off-flavours .These off-flavours may be produced through the action of enzymes such as lipoxygenase or peroxidase, which form reactive free radicals and hydro peroxides that may catalyze the oxidation of lipid compounds (Harker *et al.*, 2003).

Part III

Materials and methods

3.1 Materials

3.1.1 Procurement of *Akabare* chilli

Fresh green *Akabare* (immediately after harvest) was collected from Hiley, Pakhribas, a hilly place situated in eastern part of Nepal. The a*kabare* used for the whole experiment was of same variety (Habanero), same maturity (65 days from plantation). The hand plucked *akabare* chillies were brought to Central Campus of Technology (CCT), Dharan in a loosely packed polyethylene. The time lag between harvesting and actual commencement of the experiment was kept minimum.

3.1.2 Preparation of packaging structures

The films that are traditionally used for MAP are patented and generally too costly to be used for horticultural commodities. So, for economical convenience, polypropylene plastic bags (PP) of dimensions 12 cm × 12 cm were brought from local market and then perforated at level 2, 4, 6 with the help of punching machine of 2.5 mm diameter. Each sample was subdivided into sachets of 51 ± 3 g which contained 15-16 chillies.

For convenience and easy accessibility during the whole work, storage environment of low store was recreated in laboratory refrigerator (Model: LG-GL-V292RVBN). Maintenance of thesis conditions throughout the storage period was confirmed with the use of thermometer. Humidity of 85-90% was maintained using saturated sodium chloride solution (36 g of NaCl in 100 g of water at 20°C) (Anonymous). Maintenance of Rh condition throughout the storage period was confirmed with the use of hygrometer (Model: J412CTH).

3.1.3 Chemicals required and apparatus required

General laboratory apparatus and equipments like Spectrophotometer, Glass wares, Weighing balance, Mortar and pestle, Soxhlet apparatus, Thermometer, Gas burner, Petri Plates, Autoclave, etc. and chemicals like acetone, ether, 6-Dichlorophenolindophenol, HPO_3, DPPH, was be made available in and through the laboratory of Central Campus of Technology, Dharan-14.

3.2 Experimental design

Firstly, *Akabare* chillies were brought and moisture adhered on the surface of the chilli was absorbed by clean blotting paper and experimental setup was performed. Two experiments were conducted to determine best storage condition for fresh *akabare*: storage at room temperature (25-27°C) was considered as experiment I and at refrigeration (8-10°C as Experiment II. Then following treatments were applied:

Treatment 1: No any treatment at all for the control sample (NT)

Treatment 2: Only hydrocooled and no packaging (OH)

Treatment 3: Hydrocooling of *akabare* + unperforated plastic packaging (HUP)

Treatment 4: No Hydrocooling of *akabare* +unperforated plastic packaging (NHUP)

Treatment 5: Hydrocooling of *akabare*+ two perforations plastic packaging (P2)

Treatment 6: Hydrocooling of *akabare* + four perforations plastic packaging (P4)

Treatment 7: Hydrocooling of *akabare* + six perforations plastic packaging (P6)

For perforated and unperforated treatments, polypropylene (PP) packaging plastic bags were brought from local market then perforations at several levels/intensity (with each of 2, 4, 6 holes of 2.5 mm diameter) were made.

For hydrocooling, freshly harvested chillies were immersed in water at 5-10°C for 10 minutes. The chillies, packaged/ unpackaged with different treatments were kept on a lab bench at room temperature (25-27°C) for Experiment I and in Refrigerator (8-10°C) for Experiment II. Maintenance of the refrigerated condition and RH throughout the period was confirmed using thermometer and hygrometer regularly.

The methodological approach used were pre- and post-treatment i.e. the chilli was analyzed before, during and after treatments.

Before commencement of the experiment, analyses were carried out for moisture content, oleoresin, chlorophyll, vitamin C, and visual appearance. During Storage period, visual analysis was carried out on each days of storage whereas chemical analysis (moisture content, weight loss, change in vitamin C, and change in chlorophyll) was carried out in each 4 days up to the

end of the experiment. The total loss in the sensory and chemical quality was observed. Seven samples from each experimental group were removed on interval of each 4 days from storage and evaluated for quality (loss of moisture, vitamin C and chlorophyll). Firmness was measured in descriptive way i.e. textural changes were detected by touch.

3.3 Analysis of chilli

3.3.1 Analysis of physical parameter

The physical parameters of *akabare* such as, length, breadth and weight per ball were recorded with the help of electronic balance and vernier calipers.

3.3.2 Appearance

Based on visual observations on shrinkage, presence of withering, wilting, loss of shine and gloss of original chilli, freshness and color changes, appearance was recorded (Mitcham *et al.*, 1996).

3.3.3 Firmness

Firmness changes rapidly during storage and become softer. Excessive loss of moisture affect the texture of crops. These textural changes were detected by touch. Textural measurements were performed on harvest day and during postharvest storage (Bourne, 1982).

3.3.4 Analysis of moisture content

Moisture content was determined following the method reported by Singh et al. (2000) by drying sample in an air oven at 100±3°C till constant mass was obtained (Turhan *et al*., 1997).

3.3.5 Analysis of vitamin C (ascorbic acid)

Ascorbic acid was measured as per the method described by Ranganna (1986). 10 g of sample was macerated using 3% meta-phosphoric acid and volume was made up to 100 ml with meta-phosphoric acid. An aliquot of 5 ml of the extract was taken and titrated with the standard dye (2, 6-dichlorophenol indophenol) till pale pink end-point was observed which persisted for 15–20 s.

3.3.6 Analysis of oleoresin

The oleoresin content was determined by using Soxhlet apparatus (Ranganna, 1986). 10 g of capsicum were taken and then ground to required mesh size. Then extraction was undertaken with the help of ether as a solvent. Extraction was done by percolation of solvent at room temperature through bed of ground spices and then dark viscous extract was drawn off and distilled to remove excess solvent.

3.3.7 Analysis of chlorophyll content

Chlorophyll content in chillies were measured following the method reported by Yoshida *et al.* (1972). One gram sample was taken and ground into fine pulp in mortar and pestle with about 10ml of 80% acetone. The pulp was centrifuged for 5 min. it was extracted with 80%acetone till no perceptible green colour in residue was seen. The absorbance of the extracts was read in spectrophotometer at 663 and 645 nm using 80% acetone as blank. Using the absorption coefficients, the amount of chlorophyll is calculated using the empirical formula

$$\text{Chlorophyll a (mg/g)} = \frac{12.7\times A663+2.69\times A645}{1000\times W}\times V$$

$$\text{Chlorophyll b (mg/g))} = \frac{22.9\times A645+4.68\times A663}{1000\times W}\times V$$

Total chlorophyll (mg/g) = chlorophyll a (mg/g) + chlorophyll b (mg/g)

3.3.8 Determination of moisture loss

The total moisture loss was calculated by subtracting the final moisture content from the initial moisture content (Ranganna, 1986)

Total loss due to moisture changes (%) = initial moisture content (%) - final moisture content (%)

3.3.9 Statistical Analysis

Statistical Calculations and data analysis were performed using Microsoft Excel 2013 and GENSTAT v.12; based on the type of results obtained.

Part IV

Results and discussion

A study was conducted to increase the shelf life of fresh *akabare* chillies by applying postharvest treatments like hydrocooling, low temperature storage, perforation mediated plastic packaging. Accordingly, seven treatments were applied. Firstly, fresh *akabare* before storage was chemically analyzed. During the storage period; changes in moisture, vitamin C, and chlorophyll were measured and compared.

4.1 Physical parameters of fresh *akabare*

The average length of *akabare* was found to be 2.7 (0.02) cm, breadth as 2.35 (0.02) cm, and weight as 3.45 (0.08) g. The values are an average of decupliate values taken. The results obtained were similar to that obtained by Khanal (2009).

4.2 Analysis of fresh *akabare* before storage

Fresh green *akabare* were analyzed before storage for moisture content, vitamin C, oleoresin, and chlorophyll content and results obtained has been mentioned in Table 4.1.

Table 4.1 Chemical parameters of *akabare* before storage

Parameters	Value (wb)
Moisture Content (%)	86.67 (0.1)
Vitamin C (mg/100 g)	85.03 (0.1)
Chlorophyll Content (mg/g)	14.81 (0.12)
Oleoresin (%)	1.51 (0.012)

The values are the means of triplicate. Numbers in the parentheses are standard deviation of the values. The chemical composition of chilli is influenced by many factors such as genotype and fruit maturity stage, place, cultivar, etc. (Bosland and Votava, 2012; Mason, 2014). Thus, the chemical composition has very wide range. The above obtained value were closer to those obtained for hot peppers by Litoriya *et al.* (2014). The oleoresin content obtained were closer to those obtained by Rai (2017).

4.3 Visual Inspection for spoilage of chillies during storage

Appearance of a commodity has profound impact on its sensory characteristics and acceptance. At the point of purchase the consumer uses appearance factors to provide an indication of freshness and flavor quality (Shewfelt, 1993). The visual characteristics that prevent *akabare* from being sold are, presence of withering, wilting and loss of shine and gloss of original chilli (Mitcham *et al.*, 1996). Hence, *akabare* chilies under various treatment and storage conditions were inspected for their visual characteristics such as presence of withering, wilting, loss of shine/gloss and decaying. Thus, being based on these characteristics, actual storage lives of *akabare* chilies based on treatments were studied and has been summarized in Table 4.2.

Table 4.2 Effect of treatments (hydrocooling, packaging and storage temperature) on visual quality and storage life of *akabare.*

Temperature of Storage	Treatments Done	Days until visual spoilage was seen
Low Temperature (8-10°C)	No Treatment (NT)	4
	Only Hydro cooled and no packaging (OH)	5
	Hydrocooled Unperforated Packaging (HUP)	8
	Not Hydrocooled and Unperforated Packaging (NHUP)	10
	Hydrocooled + two perforations packaging (P2)	16
	Hydrocooled + four perforations packaging (P4)	23
	Hydrocooled + six perforations packaging (P6)	21
Room Temperature (25-27°C)	No Treatment (NT)	2
	Only Hydro cooled and no packaging (OH)	3
	Hydrocooled Unperforated packaging (HUP)	4
	Not Hydrocooled and Unperforated Packaging (NHUP)	4
	Hydrocooled + two perforations packaging (P2)	6
	Hydrocooled + four perforations packaging (P4)	7
	Hydrocooled + six perforations packaging (P6)	6

It was seen that unpackaged pepper (no any treatment, NT) had the shortest storage life. There was rapid water loss and, consequently wilting/withering was easily seen. The original shine that appeared in freshly procured chilies also easily faded in sample NT. It was therefore shrunken more as compared to others, in case of both storage temperatures.

In case of Hydrocooled and not hydrocooled (both in case of unperforated packaged and no packaged), hydrocooled had better moisture retention that that of non hydrocooled but had higher incidence of rots during subsequent storage than those that were not hydrocooled. The moisture retention in hydrocooled sample was more as compared to those not hydrocooled due to water being trapped between the fruit and the calyx (Hughes *et al.*, 1981).

But in both the unperforated packages (HUP and NHUP) rot was seen. However, the unperforated packaging helped in moisture retention than those that were not packaged. Packaging that reduces desiccation encourage water condensation, but in turn encourages microbial rot and pathogen development. This result may be due to the eventual condensation and water accumulation on the inside of package, which created an atmosphere with a high level of moisture (Ben-Yehoshua, 1985).

Perforations were installed to reduce the condensation of water droplets and control the rate of moisture loss. It was seen from Table 4.2 that Polypropylene Packaging (PP) with four perforations was the most suitable treatment for storage of *akabare* chilli, in either of storage temperatures.

4.4 Effects of temperature on storage stability of *akabare* (based on visual appearance)

Graphical Comparison of storage lives of chilies due to storage temperatures have been given in Fig. 4.1. Comparisons on maximum days that the samples could be stored, under various treatments have also been shown. Two bars with different alphabets at the top mean that the values are significantly different from each other. We can easily infer that every value is significantly different from each other. The values obtained have been given in Appendix C.

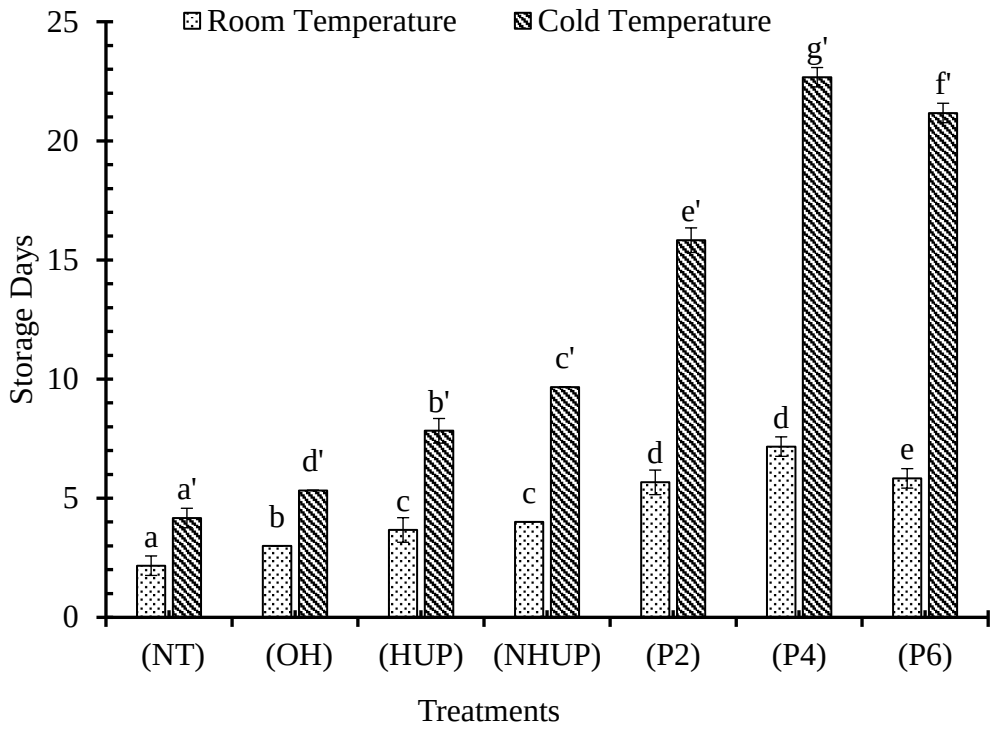

Fig. 4.1 Effect of storage temperature on storage time of *akabare* chili

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference.

In the Fig. 4.1 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

4.4.1 Storage stability of *akabare* at room temperature (25-27°C)

From Fig. 4.1, it can be seen that at room temperature (25-27°C) sample NT (no treatment) was acceptable only for 2.17 ± 0.4082^{a} days and OH (only hydrocooled) for 3^{b} days. Withering and wilting was easily seen along with loss of original shine. The storage life of HUP (hydrocooled, packaged but unperforated) was 3.67 ± 0.5164^{c} days and that of NHUP (not hydrocooled, packaged but not perforated) was 4^{c} days; after which excessive rotting was seen. This might be due to moisture condensation inside the package. Ben Yehoshua and Rodov (1998) also found similar result in his experiment in which bell pepper in non-perforated plastic film promoted decay when water droplets condensed inside the package. In case of P6 (packaged, 6 perforations), the storage life was 5.83 ± 0.4082^{d} days after which marked shrinkage a well as

rot as seen. Perforated packages P4 and P2 had a storage stability up to 7.17 ± 0.4082^{e} and 5.67 ± 0.5164^{d} days. After that, they also showed rotting, and yellowing which made them visually unacceptable. Thus, storage at room temperature was clearly a bad choice. The result agrees with the previous work done by Ornelas-Paz and Castenada Jiminez (2015). At 8^{th} day, nearly all pepper fruits stored at ambient condition were unmarketable in terms of color, shape, moisture content, chlorophyll content, Vitamin C. However, during storage at room temperature, it was observed that treatment P4 was the most effective against spoilage.

4.4.2 Storage stability of *akabare* at low temperature (8-10℃)

The results seen at low temperatures were further studied for finding out the optimum storage temperature. Fig. 4.1 shows that it at low temperature (8-10℃), sample NT (no treatment) had storage life of only $4.17\pm0.4082^{a'}$ days. The samples seemed to fade, and there was marked loss of original shine after 4.17 days. After this, wilting and withering was also seen. Thus it was visually unacceptable and rejected. In case of OH (only hydrocooled), the storage life was $5.33\pm0.5164^{b'}$ days, after which, the sample seemed to fade and wither. In case of HUP (hydrocooled, packaged but unperforated) and NHUP (not hydrocooled, packaged but unperforated), it was observed that there was accumulation of water droplets inside the package. These samples had a storage life of $7.83\pm0.4082^{c'}$ and $9.67\pm0.5164^{d'}$ days respectively after which they seemed to rot. Sample HUP and NHUP was visually unacceptable in terms of higher numbers of rots. HUP had more rots that NHUP which might be due to water being trapped between fruit and calyx during hydrocooling (Hughes *et al.*, 1981) and this might be due to the reason that since there was no way out for water and eventual condensation and water accumulation on the inside of package thereby creating an atmosphere with high moisture level that favoured rotting and decaying. The development of elevated relative humidity inside a package due to respiration of products or use of materials having low permeability to water vapor can cause condensation, which can then lead to reduced quality and safety of the produce due to microbial proliferation (Ben-Yehoshua, 1985). Now, in case perforated packages, it was seen that sample P2 (packaged, 2 perforations), P4 (packaged, 4 perforations) and P6 (packaged, 6 perforations) prevented spoilage for $15.83\pm0.4082^{e'}$, $22.67\pm0.5164^{g'}$ and $21.17\pm0.4082^{f'}$ days respectively after which, rotting, slight yellowing and change in colour and loss of crispy and crunchy texture was observed.

Once the spoilage was seen, the samples were considered unacceptable. Then, chemical analysis of such unacceptable samples would be meaningless. It was therefore seen that use of

low temperature had significant effect on delaying the spoilage. Based on the results obtained from this visual inspection; physiochemical analyses were carried out on frequent interval of each 4 days and evaluated for their moisture, Vitamin C, chlorophyll contents.

The specific advantage of hydrocooling and packaging conditions on acceptance of chilies were confirmed using statistical analysis where three parameters were studied, viz. vitamin C content, moisture content, and chlorophyll content. Out of these parameters, vitamin C and moisture content truly represented freshness and chlorophyll content represented stage of ripening and quality of the chillies.

4.5 Effects of low temperature (8-10ºC) on chemical characteristics (moisture content, chlorophyll, and vitamin C) during storage

4.5.1 Effects on moisture content

The pattern in which average moisture in *akabare* under various treatments has changed during storage time is shown in Fig. 4.2.

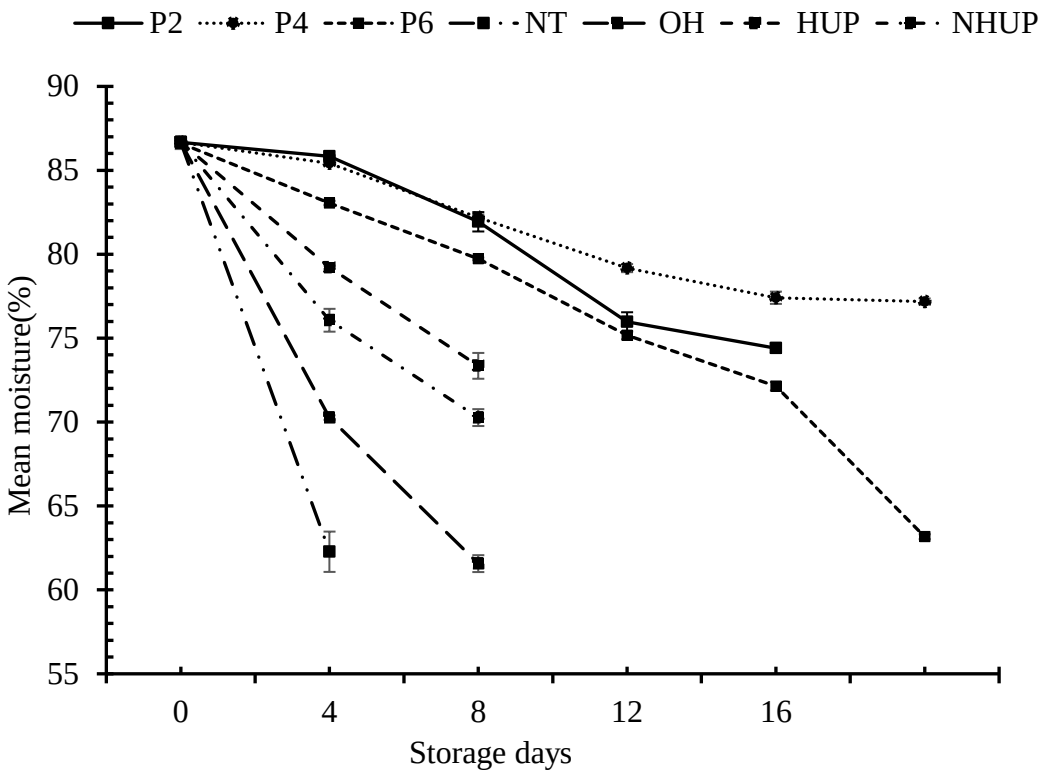

Fig. 4.2 Pattern of change in moisture during storage at low temperature

Vertical error bars represent standard deviation of values from mean. In the figures, P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

The effects of hydrocooling and packaging methods (i.e. perforations) on moisture retention of *akabare* chilies have been graphically represented in Fig. 4.2 to Fig. 4.7. Fig. 4.3 shows average moisture contents of *akabare* under various treatments, measured on 4th day.

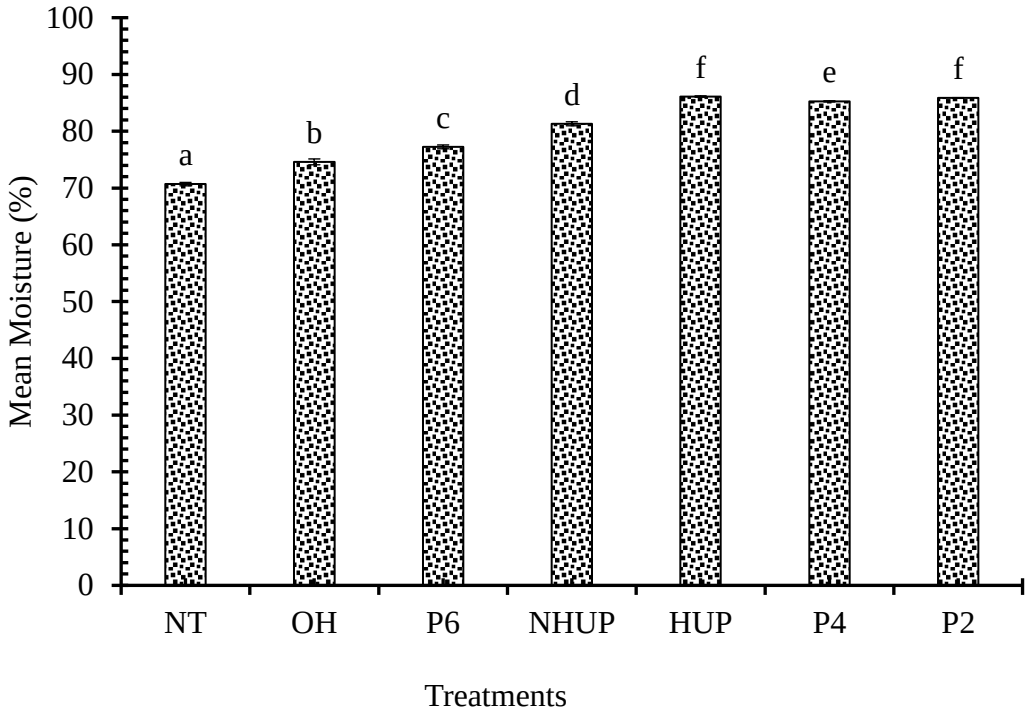

Fig. 4.3 Mean moisture content at 4th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig.4.3 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

Fig. 4.4 represents average moisture contents of *akabare* under various treatments, measured on 8th day.

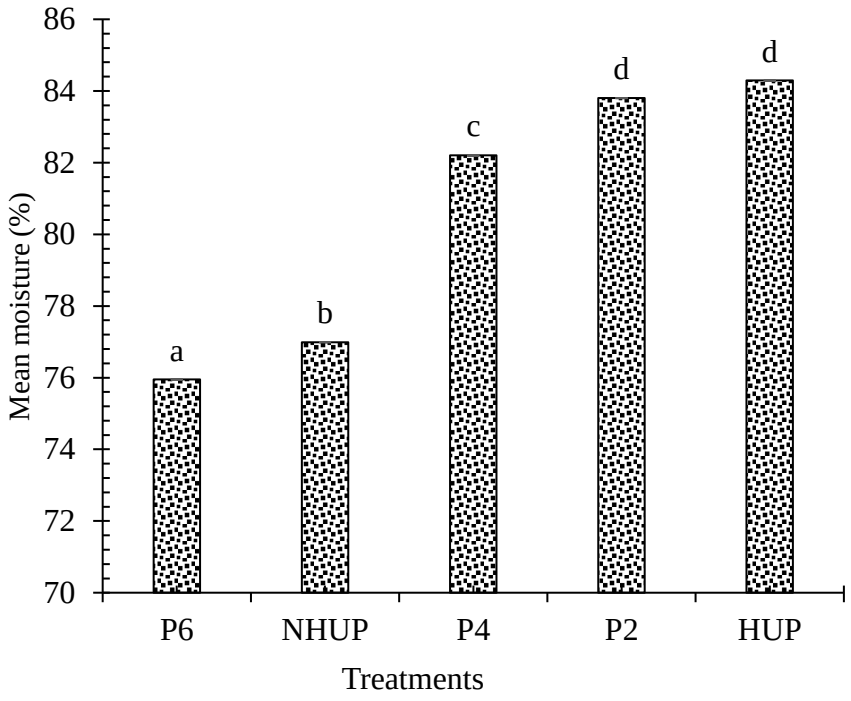

Fig. 4.4 Mean moisture at 8th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.4 P2, P4, P6, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

Fig. 4.5 represents average moisture contents of *akabare* under various treatments, measured on 12th day.

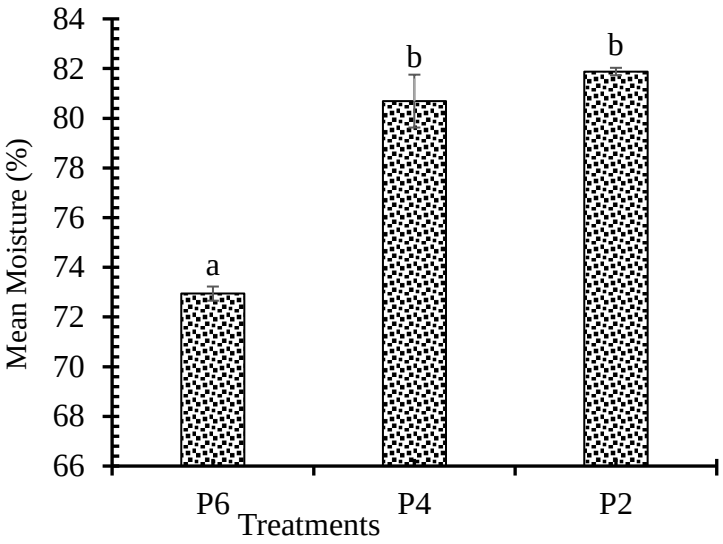

Fig. 4.5 Mean moisture at 12th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.5 P2, P4, P6 denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

Fig. 4.6 shows average moisture contents of *akabare* under various treatments, measured on 16th day.

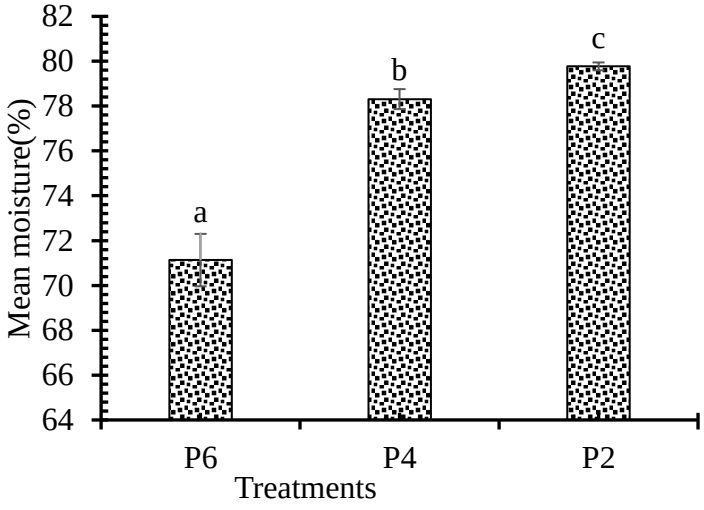

Fig. 4.6 Mean moisture at 16th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.6 P2, P4, P6 denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

Fig. 4.7 represents average moisture contents of *akabare* under various treatments, measured on 20th day.

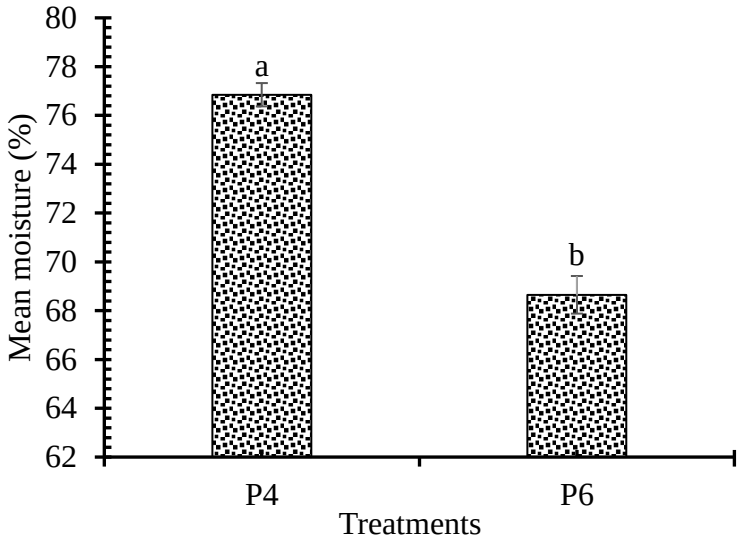

Fig. 4.7 Mean moisture at 20th day of low storage (t-test)

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.7 P4, P6 denotes (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

From Appendix Fig. A.1 it was seen that the values for moisture on day 4, under treatments NT, OH, P6, NHUP, P4 P2 and HUP are 70.68±0.3055^{a} %, 74.6±0.5141^{b} %, 77.24%± 0.3372^{c} %, 81.31±0.3550^{d} %, 85.26±0.1040^{e} %, 85.86±0.0611^{f} % and 86.11±0.1205^{f} % respectively. Similarly, values of moisture on day 8, under treatments P6, NHUP, P4, P2 and HUP were 75.95±0.2165^{a} %, 76.99±0.7663^{b} %, 82.2±0.1950^{c} %, 83.8±0.7409^{d} % and 84.29±0.1767^{d} % respectively. On day 12, values of moisture under treatments P6, P4 and P2 were 72.94± 0.2857^{a} %, 80.69±1.6401^{b} % and 81.88±0.1501^{b} % respectively. On 16th day, values of moisture under treatments P6, P4 and P2 were 71.13±1.1676^{a} %, 78.31±0.4464^{b} % and 79.77±0.1761^{c} % respectively. Lastly, the values of moisture on 20th day, under treatments P4 and P6 were 76.85± 0.4771^{a} % and 68.65±0.7709^{b} % respectively**.**

Fig. 4.2 to Fig. 4.7 show that during the storage time of 23 days, most effective treatments were P4 (packaged with 4 perforations) and P6 (packaged with 6 perforations). The samples under various other treatments besides P4 and P6 have gradually spoilt. From Fig. 4.3 and Fig. 4.4, it can be seen that the samples with treatments NT and OH became unacceptable after 4 days of storage period and had the least storage life. Moreover, their moisture loss was greater than 10% of the original fresh weight on 4^{th} day itself. So, it can be concluded that these treatments are not effective for preserving freshness of chilies for more than 4 days (Kays, 1997). On 4^{th} day, however, the moisture content of OH (74.6 ± 0.5142^{b}) was greater than NT (70.68 ± 0.305^{a}) which could be because of absorption of water by calyx of chilies on hydrocooling (Hughes *et al.*, 1981). EI-Ramaday *et al.* (2015) reported that hydrocooling not only removes field heat but also adds water to the commodity. This means that only hydrocooling also helps in retention of moisture of fresh chilies (compared to nothing) although the retention is insignificant to preserve freshness.

On 8^{th} day of storage, it was seen that packaged sample were unspoilt. The only difference between NT and NHUP is that, NT was unpackaged, and NHUP was packaged. It should be noted here, that the moisture of NHUP on 8^{th} day of storage is 76.99% and that of NT on 4^{th} day of storage is only 70.68%. So, only packaging and storing in low temperatures is also a good way of retaining moisture of *akabare* chilies (De, 2003b). The studies carried out at the Central Food Technological Research Institute (CFTRI), Mysore, India also gave similar result where prepackaging in polymeric film or paper bags improved the storage life and retained the freshness of chillies (De, 2003b). But, again, this retention was effective only up to 8 days and not beyond that. After 8 days NHUP and NT faced excessive rotting due to development of elevated relative humidity inside a package due to respiration which causes condensation of water inside the packages resulting in microbial rotting and decaying. Similar results were found during research at CFTRI where decay in stored fresh chillies were reported to be hastened by high in-package relative humidity (De, 2003b)

Similarly, the only difference between treatment OH and treatment HUP is that OH is hydrocooled but not packaged whereas HUP is hydrocooled and packaged. Fig. 4.3 and Fig. 4.4 suggests that hydrocooling and packaging has significant effect in moisture retention. Samples with treatments OH had a moisture content of 74.6% on 4^{th} day itself whereas samples with treatment HUP had moisture content of 84.29% on 8^{th} day. This means that hydrocooling

combined with packaging can retain original moisture for 8 days compared to only hydrocooling and no packaging (OH).

Moreover, If NHUP and HUP are compared on 8th day, from the Appendix Fig. A.1 it was observed that HUP had significantly greater moisture than NHUP. This also suggests that hydrocooling can significantly retain moisture content compared to samples which are not hydrocooled.

But, packaging and hydrocooling also could not prevent spoilage after 8days of storage time. It was observed after 8 days, the sample with highest moisture, i.e. HUP developed rot. On the other hand, NHUP which had far lesser moisture than HUP and other treatments, also developed rot. This could be due to the fact that water droplets were seen to accumulate in samples packaged with no perforations, thereby facilitating microbial rot (Ben-Yehoshua, 1985). It is a well-known fact that plants transpire by releasing water vapor to their surroundings. This transpiration depends on humidity of surrounding air as well as other factors such as, area of transpiring surface. Whatever be the conditions, water vapor released from chilies could not find a way to escape to the outer air and got accumulated in the inner surface of the package. This accumulation was enough to cause significant microbial growth and subsequent microbial rot (Mir, 2009; Mir and Beaudry, 2004).

This reason is justified by the fact that the samples with perforated packaging prevented rot as well as spoilage for longer period than unperforated packages. De (2003b) reported that prepackaging of fresh fruits in perforated polyethylene packages showed reduction in water loss rates by 20 times as well as low microbial rot. For 16 days of storage period, these three treatments, i.e. P4, P6 and P2 well retained the moisture of chilies. However, although the moisture of P6 was far below acceptable range, no spoilage was seen until 20th day. It was found on 20th day that that the treatments P6 and P4 prevented spoilage significantly compared to P2, which could again be attributed to the fact that P2 had higher moisture inside the package (i.e.in package humidity) and thereby caused microbial rot easily.

However, comparing the initial moisture content (86.67±0.1%) with the final moisture content, it was seen that on 20th day of storage, the moisture content of P4 was 76.85±0.4771 % and P6 was 68.65±0.7709 %. These values are significantly different from each other. It was observed that it was only the treatment P4 that prevented moisture loss below 10% of original

fresh weight. Thus, only the sample with treatment P4 can be considered as 'fresh' at the end of 20th day (Kays, 1997).

4.5.1.1 Effects of hydrocooling

To study effect of hydrocooling, samples that differ from each other only on the basis of presence or absence of hydrocooling are compared. Such samples are NT and OH, NHUP and HUP. While samples P2, P4 and P6 are also hydrocooled, they have been studied from the perspective of "effects of perforations" in packaging systems which has been explained in subsequent sections.

In Fig. 4.3 and Fig. 4.4 it can be observed that the samples with treatments NT and OH became unacceptable after 4 days of storage period and had the least storage life. Moreover, their moisture loss was greater than 10% on 4th day itself. So, it can be concluded that these treatments are not effective for preserving freshness of chilies for more than 4 days. On 4th day, however, the moisture content (%) of OH (74.6 ± 0.5142^{b}) was greater than NT (70.68 ± 0.305^{a}) which could be because of absorption of water by calyx of chilies on hydrocooling. This means that only hydrocooling helps in retention of moisture of fresh chilies (compared to nothing) although the retention is insignificant to preserve freshness.

Moreover, If NHUP and HUP are compared on 8th day, it can be seen that HUP has significantly greater moisture than NHUP. This also suggests that hydrocooling can significantly retain moisture content compared to samples which are not hydrocooled. But, after 8th day both NHUP and HUP got rot. However, the degree of rotting was more in HUP than in NHUP. Hughes *et al.* (1981) also found that Capsicums that were hydrocooled had a higher incidence of rot during subsequent storage than those that were not, even when chlorine was added to the water.

4.5.1.2 Effects of packaging

For the study on effect of packaging, the samples that differ from each other only on the basis of presence or absence of packaging have been compared. In this case, one of such pairs of samples happen to be NT (no treatment, no packaging) and NHUP (no hydrocooling, packaged). The other pair happen to be OH (hydrocooled, no packaging) and HUP (hydrocooled, packaged).

On 8th day of storage, it was seen that packaged sample were unspoilt compared to unpackaged samples. The only difference between NT and NHUP is that, NT was unpackaged, and NHUP was packaged. It should be noted here, that sample NT has a moisture content of 70.68% on 4th day and NHUP has a moisture content of 81.31% on 4th day and 76.99% on 8th day. These values are significantly different from each other. Samples with treatments OH had a moisture content of 74.6% on 4th day itself whereas samples with treatment HUP had moisture content of 86.11% on 4th day and 84.29% on 8th day. These values are also significantly different from each other. So, only packaging and storing in low temperatures is also a good way of retaining moisture of *akabare* chilies. Plastic film and bags to create a modified atmosphere have also been used in Capsicum storage. Anandswamy *et al.* (1959) found that the storage life of Capsicum and green chilli peppers could be almost doubled in plastic film bags. Bussel and Kenigsberger (1975) reported that the main benefit of packing capsicum in plastic film was a reduction in water loss but they also found that condensation on the fruit gave rise to decay by micro-organisms.

But, again, this retention was effective only up to 8 days and not beyond that. After 8 days yellowing, rotting and decaying was observed. This result may be due to the eventual condensation and water accumulation on the inside of the package, which creates an atmosphere with a high level of moisture. Alvares (2007) also found excessive water accumulation on the inside of the packages and attributed it to high levels of transpiration and similar decaying of commodities.

4.5.1.3 Effects of hydrocooling and packaging, combined

HUP, P2, P4 and P6 are samples that have been hydrocooled as well as packaged. However, due to perforations, P2, P4 and P6 have been studied under separate sections. Here, in this section HUP has been compared with NT, OH and NHUP.

In Fig. 4.3 and Fig. 4.4 it can be seen that hydrocooling and packaging had significant effect in moisture retention. Although hydrocooled, OH easily spoilt after 4 days. Also, values of moisture for HUP on 4th day and 8th day are significantly higher than that seen in OH on 4th day. Moreover, NT and OH spoiled after 4 days of storage making packaged samples superior to unpackaged samples. This means that hydrocooling combined with packaging can retain original moisture for 8 days compared to only hydrocooling.

But, packaging and hydrocooling also could not prevent spoilage after 8days of storage time. It was observed after 8 days that the sample with highest moisture, i.e. HUP developed rot. On the other hand, NHUP which had far lesser moisture than HUP and other treatments, also developed rot. This could be due to the fact that water droplets were seen to accumulate in samples packaged with no perforations, thereby facilitating microbial rot. It is a well-known fact that plants transpire by releasing water vapor to their surroundings. This transpiration depends on humidity of surrounding air as well as other factors such as, area of transpiring surface. Whatever be the conditions, water vapor released from chilies could not find a way to escape to the outer air and got accumulated in the inner surface of the package. This accumulation was enough to cause significant microbial growth and subsequent microbial rot (Mir, 2009).

4.5.1.4 Effects of perforations in packaging

Effect of perforations was studied by comparing hydrocooled and packaged, but unperforated samples (i.e. HUP) with P2, P4 and P6.

The fact that accumulation of water droplets leads to spoilage is justified by the fact that the samples with perforated packaging prevented rot as well as spoilage for longer period than unperforated packages. If we see closely, the sample with no perforations (HUP) had higher moisture content than the perforated samples until 8^{th} day of storage. But the same moisture became cause of rot in HUP. Whereas in perforated packages, it was observed that perforations significantly reduced the extent of decay. So, perforations had an advantage over unperforated packages to extend the shelf life. Ben Yehoshua and Rodov (1998) from his experiment also suggested that changing the perforations per package in effect changes the transmission capability thereby reducing the water condensation and decay. It was clearly observed that along with prevention of spoilage, these three treatments, i.e. P4, P6 and P2 well retained the moisture of chilies for 16 days of storage period. But, the moisture of P6 was far below acceptable range despite the fact that no spoilage was seen until 20^{th} day. It was found on 20^{th} day that that the treatments P6 and P4 prevented spoilage significantly compared to P2, which could again be attributed to the fact that P2 had higher moisture and thereby caused microbial rot easily.

However, from Appendix Fig. A.1 comparing the initial moisture content (86.67 ± 0.1%) with the final moisture content, it was seen that on 20^{th} day of storage, the moisture content of

P4 was 76.85±0.4771 % and P6 was 68.65±0.7709 %. These values are significantly different from each other. It was observed that it was only the treatment P4 that prevented moisture loss below 10% of initial weight. Thus, only the sample with treatment P4 can be considered as 'fresh' at the end of 20th day.P2, on the other hand preserved freshness for 16 days, after which rotting was observed eventually.

4.5.2 Effects on vitamin C content

Fig. 4.8 shows the pattern in which average vitamin C in *akabare* under various treatments has changed during storage time.

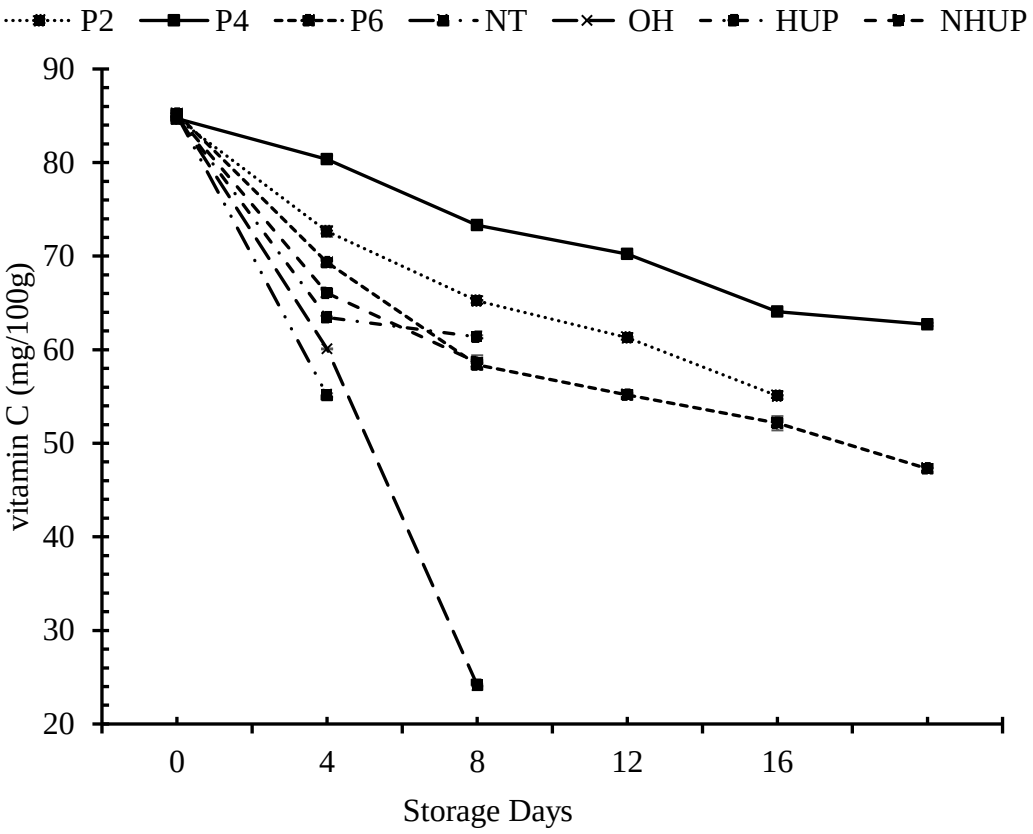

Fig. 4.8 Pattern of change in vitamin C during storage at low temperature

Vertical error bars represent standard deviation of values from mean. In the Fig. 4.8 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

The effects of hydrocooling and packaging methods (i.e. perforations) on vitamin C retention by *akabare* chilies have been graphically represented in Fig. 4.8 to Fig. 4.13.

Fig. 4.9 shows average vitamin C contents of *akabare* under various treatments, measured on 4th day.

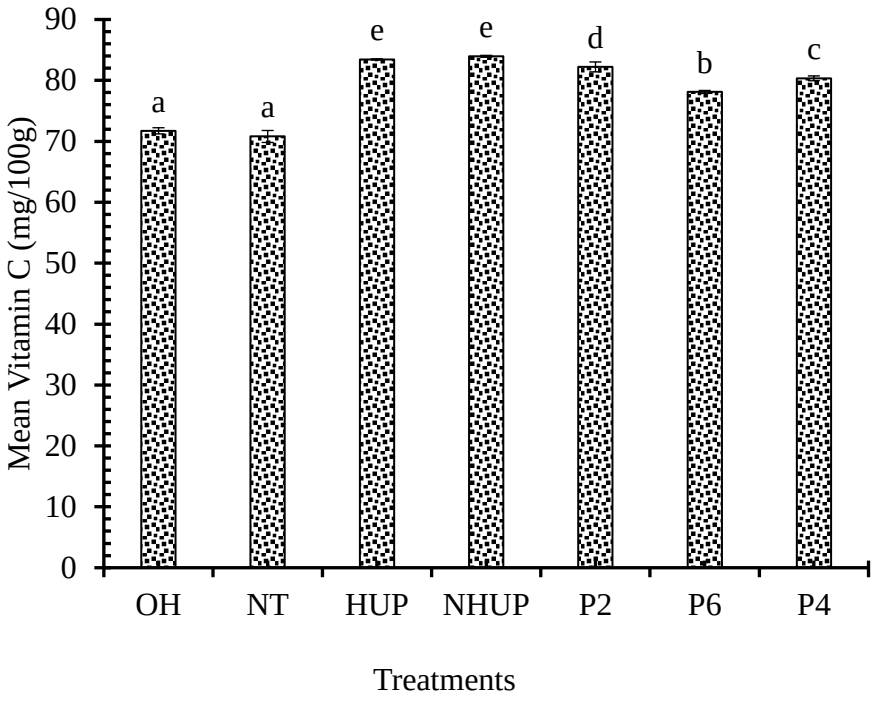

Fig. 4.9 Mean vitamin C at 4th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.9, P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

Fig. 4.10 shows average vitamin C contents of *akabare* under various treatments, measured on 8th day.

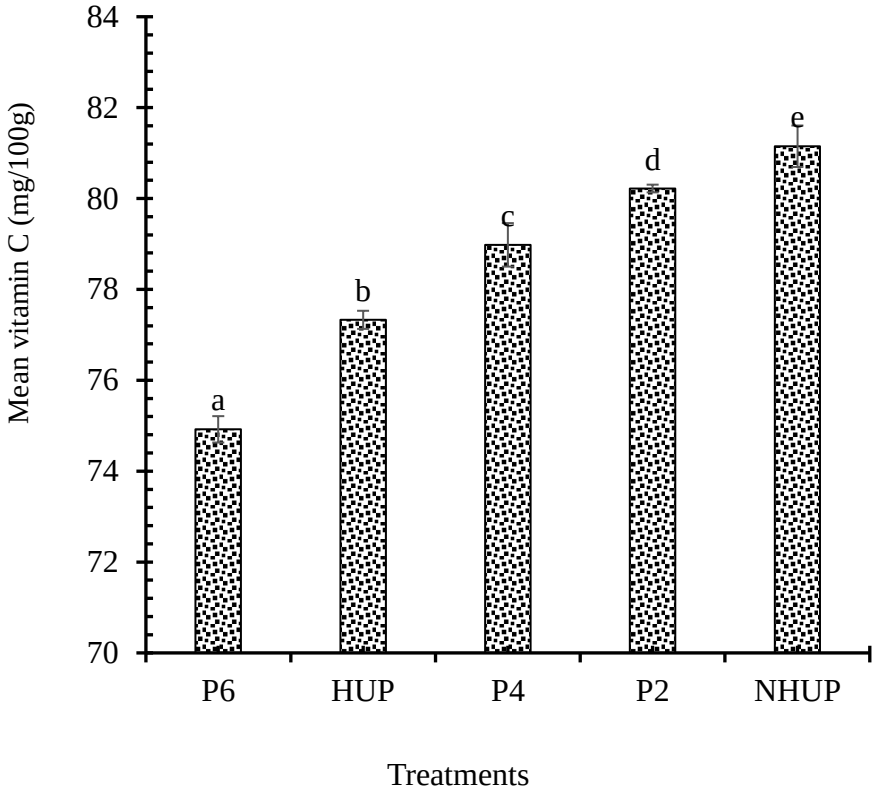

Fig. 4.10 Mean vitamin C at 8th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig 4.10 P2, P4, P6, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

Average vitamin C contents of *akabare* under various treatments, measured on 12th day has been shown in Fig. 4.11.

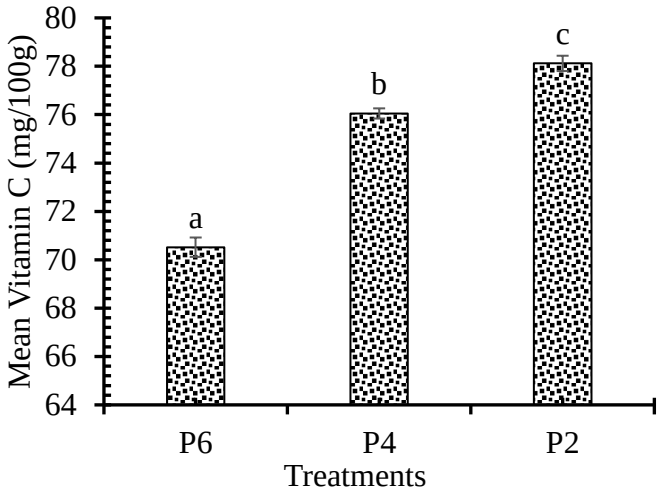

Fig. 4.11 Mean vitamin C at 12th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.11 P2, P4, P6 denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

Fig. 4.12 shows average vitamin C contents of *akabare* under various treatments, measured on 16th day.

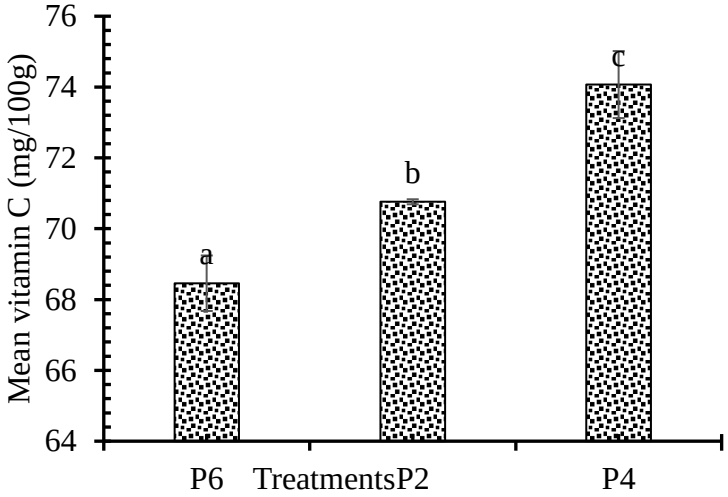

Fig. 4.12 Mean vitamin C at 16th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.12 P2, P4, P6 denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

Fig. 4.13 shows average vitamin C contents of *akabare* under various treatments, measured on 20th day

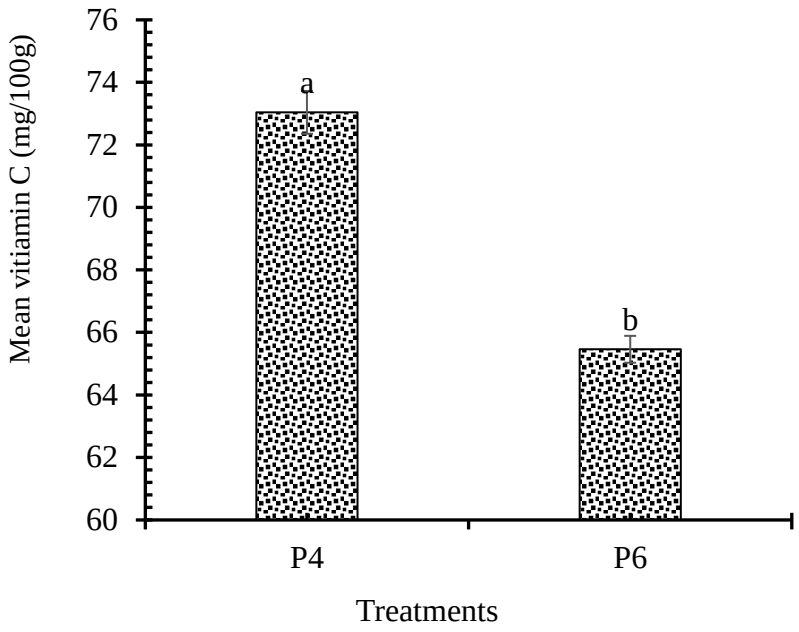

Fig. 4.13 Mean vitamin C at 20th day of low storage (t-test)

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.13 P4, P6 denote (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

It was seen that the values for vitamin C on day 4, under treatments NT, OH, P6, P4, P2, HUP and NHUP are 70.80± 0.9874^{a} mg/100 g, 71.72±0.5084^{a} mg/100 g, 78.11±0.2463^{b} mg/100 g, 80.34±0.3955^{c} mg/100 g, 82.21±0.8127^{d} mg/100 g, 83.45±0.0971^{e} mg/100 g and 83.96±0.1562^{e} mg/100 g respectively. Similarly, values of vitamin C on day 8, under treatments P6, HUP, P4, P2 and NHUP were 74.92±0.2901^{a} mg/100 g, 77.33±0.1992^{b}) mg/100 g, 78.98 ±0.4784^{c} mg/100 g, 80.22±0.8505^{d} mg/100 g and 81.15±0.4565^{e} mg/100 g respectively. On day 12, values of vitamin C under treatments P6, P4 and P2 were 70.52±0.400042^{a} mg/100 g, 76.05±0.2098^{b} mg/100 g and 78.12±0.3164^{c} mg/100 g respectively. On 16th day, values of

vitamin C under treatments P6, P2 and P4 were 68.46±0.7860[a] mg/100 g, 70.76±0.0709[b] mg/100 g and 74.07±0.9459[c] mg/100 g respectively. Lastly, the values of vitamin C on 20th day, under treatments P4 and P6 were 73.04±0.6842[a] mg/100 g and 65.46±0.4300[b] mg/100 g respectively.

Vitamin C is most sensitive to destruction when the commodity is subjected to extended storage, higher temperatures, low relative humidity, physical damage, and chilling injury (Kader, 2002). So was seen in the experiment.

In Fig. 4.8 to Fig. 4.13 it can be seen that during the storage time of 23 days, most effective treatments were P4 (packaged with 4 perforations) and P6 (packaged with 6 perforations). The samples under various other treatments besides P4 and P6 have gradually spoilt. From Fig. 4.9 and Fig 4.10, it can be seen that the samples with treatments NT and OH became unacceptable after 4 days of storage period and had the least storage life. All the samples besides P4 and P6 have gradually spoilt and become unacceptable before 20th day of storage.

From Fig. 4.8, it can be seen that the ascorbic acid had shown a decreasing trend in all the samples during storage. If looked at the decrement pattern of vitamin C contents of various treatments in Fig. 4.8, we see that P4 has the least slope and the highest slope was seen in NT.

On 4th day of storage, on comparing the NT and OH we see that the values of vitamin C are 70.8 mg/100 g and 71.71 mg/100 g respectively. These values are insignificant from each other although the hydrocooled sample had higher vitamin C contents. No conclusive information can be drawn being based on this information. Again, HUP and NHUP also seem to have no significant effects on 4th day itself. However, it can be easily observed that packaging had significant effect on retention of vitamin C on 4th day even when hydrocooling showed no effect. P6 had least value of vitamin C on 4th day than P4, P2, HUP and NHUP possibly because of greater number of pores that caused vitamin C to destroy easily. The reason for decrement in ascorbic acid content as number of pores increased might be attributed to high O_2 and low CO_2 concentration in P2, P4 and P6 packages that may have caused oxidation of ascorbic acid into dehydroascorbic acid (DHA) leading to subsequent decrease in ascorbic acid (Mahajan *et al.*, 2014). Opara *et al.* (2016) observed similar significant decrease in ascorbic acid toward end of 15 days of low storage (4ºC) of minimally processed pomegranate packaged in perforated plastic packaging. Hence, vitamin C was least in samples with highest no of pores. In case of unperforated samples, therefore, the vitamin were found to be highest.

On 8th day of storage, since NT and OH spoilt completely, they were discarded and only remaining samples were studied. It was found that, NHUP had highest vitamin C content and P6 had the lowest. This is also logical because, P6, due to greater number of pores, facilitated highest rate of destruction of the vitamin, thereby significantly destroying vitamin C in it. One anomaly was seen in case of HUP and NHUP in which HUP had reduced vitamin C levels. HUP had vitamin C content less than P4 and greater than P6. It was also observed during this time that rotting started. Rotting significantly causes the original texture of the fruit to degenerate and release the sap inside it. The sap is largely water, in chili. When this sap was released, vitamin C also started to come out along with this sap since vitamin C is soluble in water. Miller and Heilman (1952) suggested that plasmolysis might hasten oxidation of the cell constituents and result in an adverse effect on the vitamin C content. The reason might be same for decrement of Vitamin C content when the sample rotted.

On 12th day of storage, similar pattern of vitamin C reduction was seen, i.e. more the number of pores in a package, more the reduction of vitamin C. Hence, P2 had highest vitamin C retention and P6 had lowest retention. By this day, samples HUP and NHUP had already rotten due to water condensation and subsequent microbial rot as explained in Section 4.5.2.

However, on 16th day of storage, it was observed that P4 had highest vitamin C retention, and P6 had the least. This could be because rotting had possibly started in sample P2 causing vitamin C to come out along with the sap.

On 20th day of storage, it was observed that P4 had better vitamin C retention than P6. Thus P4 was considered the best treatment.

4.5.2.1 Effects of hydrocooling

For studying effect of hydrocooling, samples that differ from each other, only on basis of presence or absence of hydrocooling, are compared. Such samples are NT and OH, NHUP and HUP. While samples P2, P4 and P6 are also hydrocooled, they have been studied from the perspective of "effects of perforations" in packaging systems which has been explained in subsequent sections.

On 4th day of storage, on comparing the NT and OH, the values of vitamin C are 70.8 mg/100 g and 71.71 mg/100 g respectively. From Fig. 4.9 and Appendix Fig. A.1 it can be seen that these values are insignificant from each other although the hydrocooled sample had higher

vitamin C contents. Again, HUP and NHUP also seem to have no significant effects on 4th day itself. It was observed that NHUP had slightly greater vitamin C than HUP although the differences in values were highly insignificant. No conclusive information that hydrocooling has significant effects in vitamin C, can be drawn being based on this information.

On 8th day, however, samples NHUP and HUP seem to have significant differences in values of vitamin C. But, since hydrocooled sample has significantly lower vitamin C content than non-hydrocooled sample, it can be said that, hydrocooling had negative effects in retention of vitamin C content. However, this negative effect in packaged (unperforated) samples is not only due to hydrocooling since packaging has also been done in both the cases.

4.5.2.2 Effects of packaging

For the study on effect of packaging, the samples that differ from each other only on the basis of presence or absence of packaging have to be compared. In our case, one of such pairs of samples happen to be NT (no treatment, no packaging) and NHUP (no hydrocooling, packaged). The other pair happen to be OH (hydrocooled, no packaging) and HUP (hydrocooled, packaged). It was clearly seen that values of vitamin C for NT on 4th day is far lower than value of vitamin C for NHUP on 4th day. Again, comparing OH and HUP, we see that values of vitamin C for OH on 4th day is also far lower than value of vitamin C for HUP on 4th day. Here, packaging worked as a barrier to chilling injury for HUP and NHUP whereas NT and OH were unpacked and thus exposed to oxygen more and were more susceptible to chilling injury than HUP and NHUP. This might be the reason for lesser vitamin C content in NT and OH as. According to Kader (2000) vitamin C losses are enhanced by chilling injury and exposure to oxygen. Thus we can clearly conclude that packaging has significant effect in retention of vitamin C. Besides HUP and NHUP, other samples (i.e. P2, P4 and P6 also had significantly higher values of vitamin C when compared to NT and OH. Moreover, samples OH and NT could not prevent spoilage for more than 4 days even at low temperature making them bad choices for retention of vitamin C.

4.5.2.3 Effects of packaging and hydrocooling, combined

The samples that are hydrocooled as well as packaged, are HUP, P2, P4 and P6. However, due to perforations, P2, P4 and P6 have been studied under separate sections. Here, in this section HUP has been compared with NT, OH and NHUP.

Comparing the values of vitamin C in these samples, we see that HUP is clearly a good choice when compared to NT and OH. However, from Appendix Fig. A.1, NHUP seems to be better (although insignificant) for vitamin C retention than HUP as NHUP has higher values of vitamin C than HUP, on 4^{th} day of storage as well as 8^{th} day of storage.

But, packaging and hydrocooling also could not prevent spoilage after 8days of storage time. It was observed after 8 days that the sample with highest moisture, i.e. HUP developed rot. On the other hand, NHUP which had far lesser moisture than HUP and other treatments, also developed rot. So, either of these treatments were acceptable only for 8 days of storage time in low storage.

Although vitamin C were lesser in amounts in samples with perforated packaging, they prevented spoilage for prolonged period compared to samples with unperforated packaging.

4.5.2.4 Effects of perforations in packaging

Effect of perforations was studied by comparing hydrocooled and packaged, but unperforated samples (i.e. HUP) with P2, P4 and P6.

It was clearly seen that HUP had higher vitamin C contents than P4, P2 and P6 on 4^{th} day of storage whereas lesser vitamin C than P4 and P2 on 8^{th} day of storage period. However, this sample rotted easily and could not prevent spoilage until 12^{th} day of storage. Hence, although HUP had higher vitamin C content, it was considered inferior to perforated samples owing to spoilage observed. As, mentioned earlier, this rotting was mainly due to water accumulation. On observing for 16 days of storage period, vitamin C retention clearly depended upon the number of perforations. Ascorbic acid is usually degraded by oxidative process, which is stimulated in the presence of light, oxygen, heat, peroxides and enzymes, such as ascorbate oxidase or peroxidase (Plaza *et al.*, 2006). The perforations aided in exposure of Capsicum to oxygen. It was seen that higher number of perforations caused higher loss of vitamin C until 16^{th} day of storage. But, on 20^{th} day of storage, it was seen that vitamin C reduced significantly in sample P2 compared to P4. This can be attributed to the fact that P2 started to rot after that. On 20^{th} day, only samples P4 and P6 remained unspoilt. P4, then significantly had higher vitamin C content than sample P6. Hence, P4 and P6 are both good for retaining vitamin C i.e. 73.036 (0.6841^{a}) and 65.46 (0.43^{b}) but P4 is superior to P6. In the case of P2, it was a good choice only until 16^{th} day of storage. Thus, in case of P4 there was minimal changes in vitamin C content. This result agrees with the previous report by Koide and Shi (2007) in which minimal

minor changes in Vitamin C was observed in intact green peppers that had been packed in perforated plastics and refrigerated.

Being based on moisture content as well as vitamin C content, we can conclude that P4 is the best treatment method.

4.5.3 Effects on chlorophyll content

Fig. 4.14 shows the pattern in which, average total chlorophyll in *akabare* under various treatments, has changed during storage time.

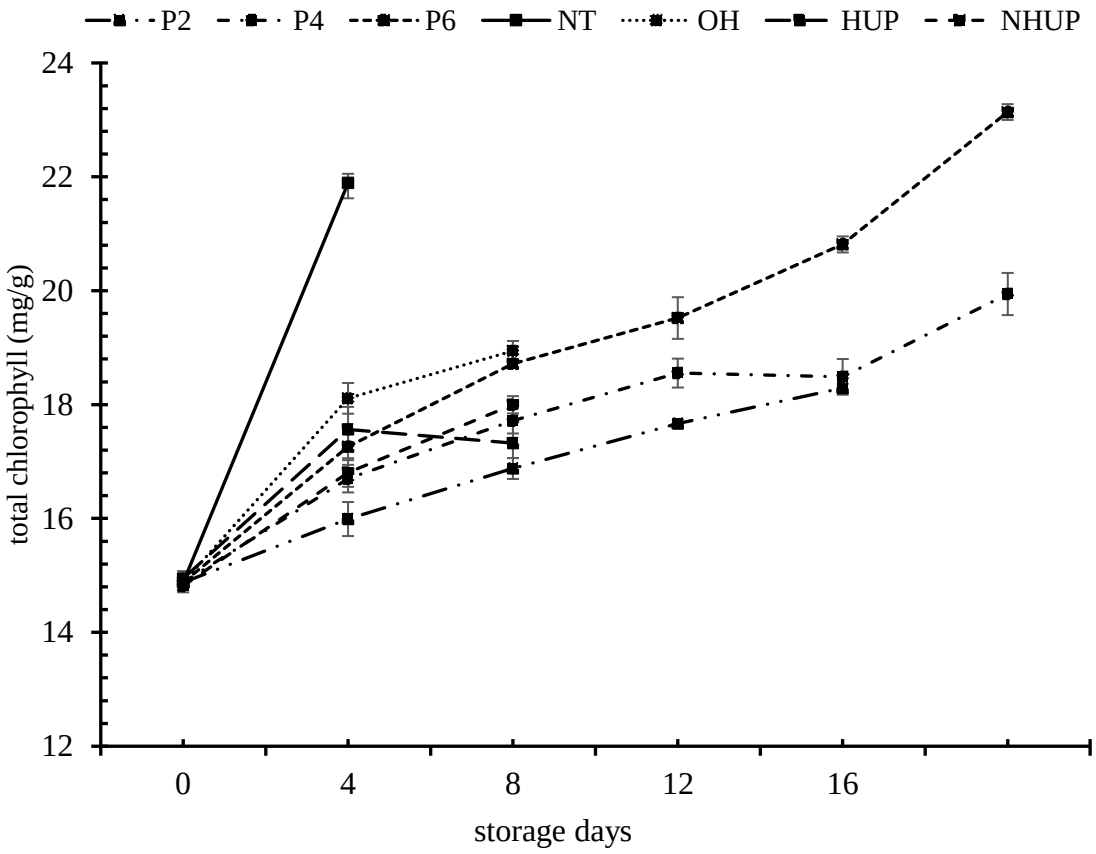

Fig. 4.14 Pattern of change in total chlorophyll during storage at low temperature

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference.

In the Fig. 4.14 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP

packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

The effects of hydrocooling and packaging methods (i.e. perforations) on total chlorophyll retention by *akabare* chilies have been graphically represented in Fig.4.14 to Fig. 4.19. Fig. 4.15 represents average total chlorophyll contents of *akabare* under various treatments, measured on a 4th day.

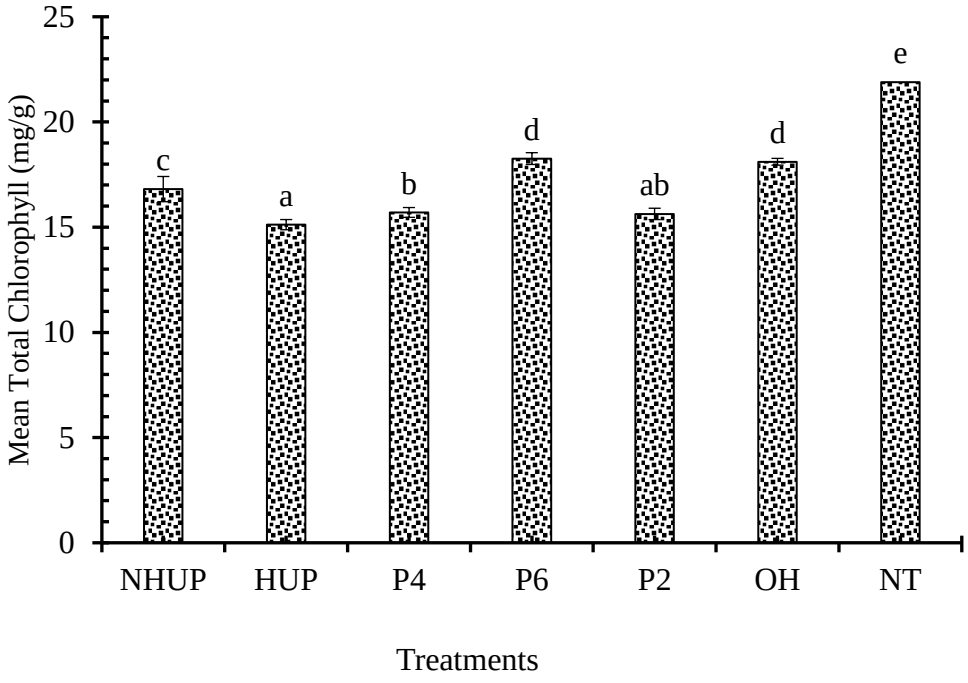

Fig. 4.15 Mean total chlorophyll at 4th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.15 P2, P4, P6, NT, OH, HUP and NHUP denotes (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

Fig 4.16 represents average total chlorophyll contents of *akabare* under various treatments, measured on 8^{th} day.

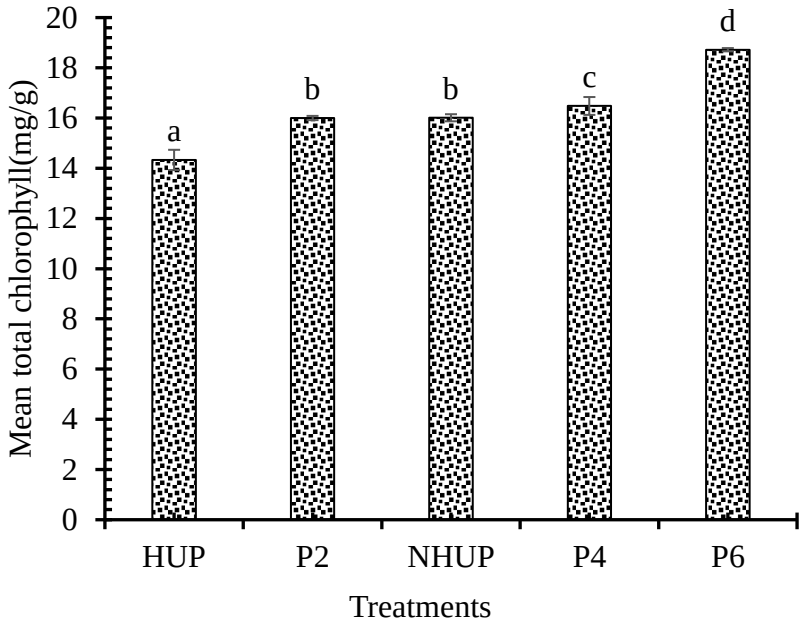

Fig. 4.16 Mean total chlorophyll at 8th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.16 P2, P4, P6, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

Fig. 4.17 represents average total chlorophyll contents of *akabare* under various treatments, measured on a 12th day.

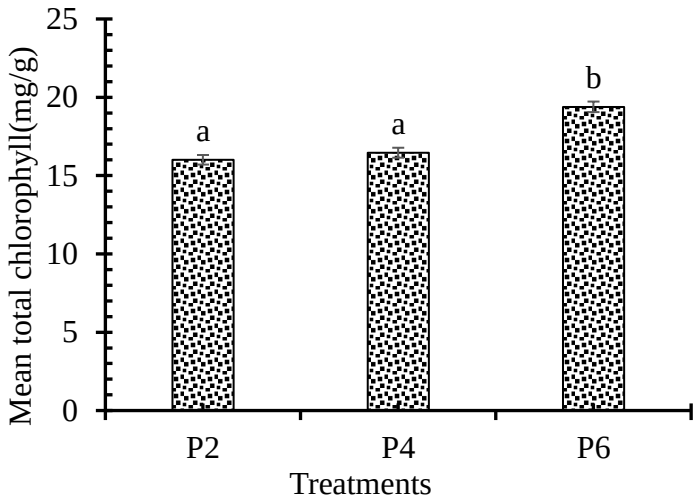

Fig. 4.17 Mean total chlorophyll at 12th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.17 P2, P4, P6 denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

Fig. 4.18 represents average total chlorophyll contents of *akabare* under various treatments, measured on a 16th day.

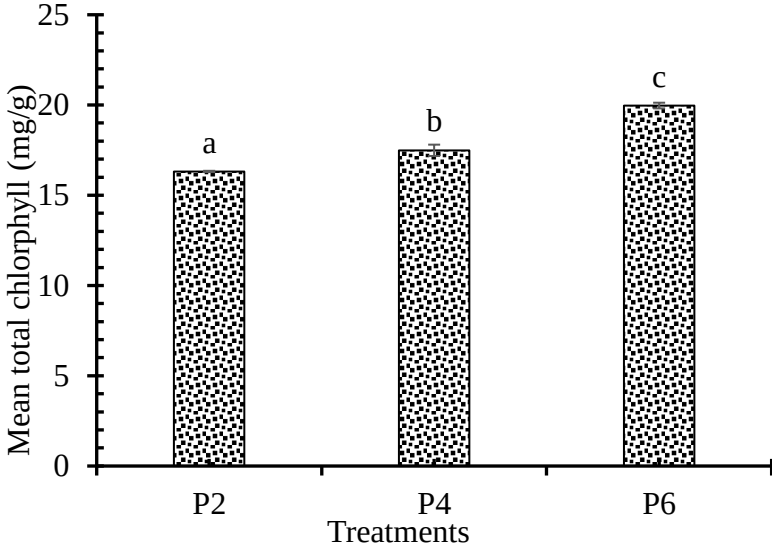

Fig. 4.18 Mean total chlorophyll at 16th day of low storage

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.18 P2, P4, P6 denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

Fig. 4.19 represents average total chlorophyll contents of *akabare* under various treatments, measured on a 20th day.

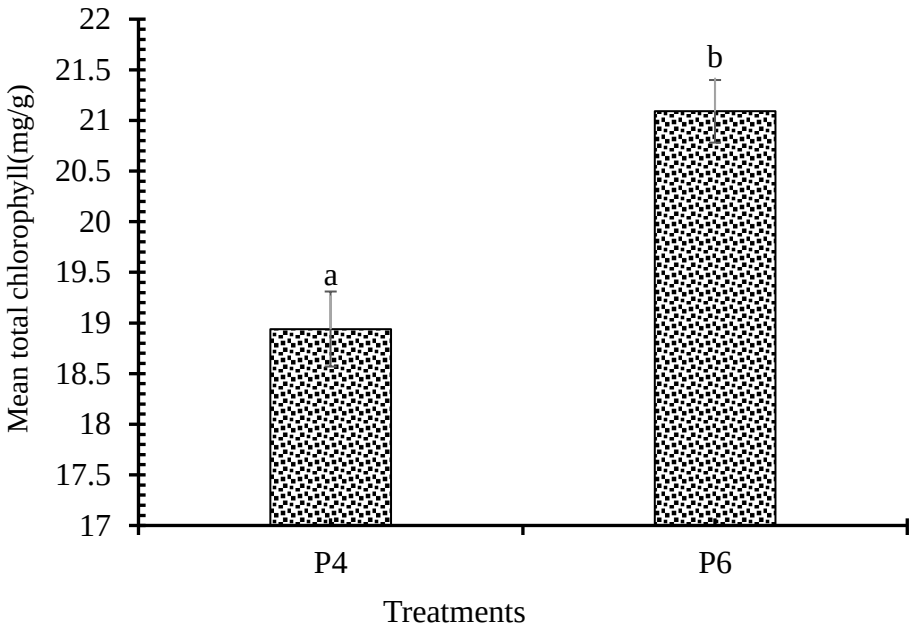

Fig. 4.19 Mean total chlorophyll at 20th day of low storage (t-test)

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.19 P4, P6 denotes (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), conditions respectively.

It was seen that the values for total chlorophyll on day 4, under treatments HUP, P2, P4, NHUP, OH, P6 and NT are 15.12±0.5991^{a}) mg/g, 15.63±0.28^{ab} mg/g, 15.7±0.2424^{b} mg/g, 16.81±0.2510^{c} mg/g, 18.11±0.2700^{d} mg/g, 18.26±0.2328^{d} mg/g and 21.89±0.1601^{e} mg/g respectively. Similarly, values of total chlorophyll on day 8, under treatments HUP, P2, NHUP, P4 and P6 were 14.33±0.4041^{a} mg/g, 16±0.0838^{b} mg/g, 16.01±0.8386^{b} mg/g, 16.48±0.3557^{c} mg/g and 18.72±0.0655^{d} mg/g respectively. On day 12, values of total chlorophyll under treatments P2, P4 and P6 were 16.01±0.3051^{a} mg/g, 16.46±0.3174^{a} mg/g and 19.39±0.3360^{b} mg/g respectively. On 16th day, values of total chlorophyll under treatments P2, P4 and P6 were

16.32± 0.0346[a] mg/g, 17.49± 0.3137[b] mg/g and 19.97±0.1575[c] mg/g respectively. Lastly, the values of total chlorophyll on 20th day, under treatments P4 and P6 were 18.94±0.3704[a] mg/g and 21.09±0.3090[b] mg/g respectively**.**

From Fig. 4.15 to Fig. 4.19 it can be seen that chlorophyll content has increased over the storage period in all treatment conditions except HUP. This could be attributed to loss of moisture content and subsequent increment in dry mass of chilies under study. In actual there was no increment in chlorophyll content. The increment shown might be due to loss of water. So, it can be inferred that this increase was caused by postharvest dehydration.

Fig. 4.16 suggests that the chlorophyll content at 8th day has increased than the previous day data for all due to loss in moisture content caused increment in concentration of chlorophyll pigments. But in case of HUP, lowering of chlorophyll content than that of 4th day i.e. 15.1233 (0.59919[a]) can be seen in 8th day i.e. 14.326 (0.40416[a])analysis that is because in case of this unperforated hydrocooled (HUP), the chillies were seen rotted and yellow color development was evident. Slight yellowing, also known as loss of green color and an indicator of decreased quality, was observed in HUP on 8th day. But in case of others there was increment in chlorophyll content. Chlorophyll content was 14.33 mg/g, 16 mg/g, 16.01 mg/g, 16.48 mg/g, and 18.72 mg/g for HUP, P2, NHUP, P4, and P6 respectively. This shows that at 8th day of analysis, the highest chlorophyll content was in sample P6 i.e.18.72 mg/g and least was in sample HUP i.e. 14.33 mg/g.

From Fig. 4.17 and Appendix Fig. A.1 it can be seen that at 12th day of analysis P2 and P4 are not significantly different to each other in terms of chlorophyll content. However p6 is significantly different. P2 has total chlorophyll content of 16.01 mg/g, P4 has total chlorophyll content of 16.46 mg/g and P6 has total chlorophyll content of has 19.39 mg/g.

From Fig. 4.18 and Appendix Fig. A.1 it can be seen that the chlorophyll content for P2, P4, and P6 on 16th day of storage was 16.32 mg/g, 17.49 mg/g and 19.97 mg/g respectively. The chlorophyll content of P6 was significantly maximum which can be justified by low moisture content as shown by Fig. 4.6.

From Fig. 4.19, it can be seen that P4 has a total chlorophyll content of 18.94 mg/g and p6 has a total chlorophyll content of 21.09 mg/g. These results could be explained by the decreased in water loss in P4, which concentrates the pigments in the chillies.

4.5.3.1 Effects of hydrocooling

For studying effect of hydrocooling, samples that differ from each other, only on basis of presence or absence of hydrocooling are compared, while other treatments remain same. Such samples are NT and OH, NHUP and HUP. While samples P2, P4 and P6 are also hydrocooled, they have been studied from the perspective of "effects of perforations" in packaging systems which has been explained in subsequent sections.

It was seen during the storage that chlorophyll content was dependent on the moisture content of samples rather than hydrocooling. Higher the moisture content, lower was the chlorophyll content. With time, and eventual evaporation of moisture from samples, chlorophyll seemed to increase gradually in pattern reverse to the pattern of moisture loss. This happened, because wet mass of the sample decreased due loss of moisture thereby increasing the mass of chlorophyll. This was evident on 8^{th} day of storage time. But in case of HUP, lowering of chlorophyll content was observed that is because in case of HUP the chillies were seen rotted and yellow color development was evident.

4.5.4.2 Effects of packaging

For the study on effect of packaging, the samples that differ from each other only on the basis of presence or absence of packaging were compared. In our case, one of such pairs of samples happen to be NT (no treatment, no packaging) and NHUP (no hydrocooling, packaged). The other pair happen to be OH (hydrocooled, no packaging) and HUP (hydrocooled, packaged).

It was seen that packaged sample NHUP had lower chlorophyll content compared to unpackaged sample (NT) on 4^{th} day of storage because in NHUP, there was higher moisture than NT. On, 8^{th} day, the value of chlorophyll of sample HUP have also decreased on 8^{th} day. Along with that, rotting and yellowing was also seen. So, it can be inferred that it was rotting and yellowing, that caused the chlorophyll content to decrease in this cases. In other packaged samples however, there was rise in chlorophyll contents which can be attributed to moisture loss.

4.5.4.3 Effects of packaging and hydrocooling, combined

The samples that are hydrocooled as well as packaged, were HUP, P2, P4 and P6. However, due to perforations, P2, P4 and P6 have been studied under separate sections. Here, in this section, HUP has been compared with NT, OH and NHUP. It was seen that, HUP had lowest

chlorophyll content compared to other samples. Also, the presence of high moisture caused microbial rot easily. Hence, HUP is a bad choice compared to other samples. On 8th day of storage, it was seen that sample P6 was most effective in chlorophyll retention. However, considering loss of moisture, P6 was unable to preserve freshness when compared to P4. P4 on the other hand, had lower chlorophyll content than P6 and higher chlorophyll than other samples. Also, the change in chlorophyll content in P4 from initial value (14.88 mg/g) to 20th day value (18.942 mg/g) was less as compared to change in value for P6 in 20th day i.e. 21.088 mg/g. The increment in chlorophyll content can be attributed to loss of moisture as storage period increased. This, also justifies that P6 lost more moisture than P4. Moreover, there was not rot or withering seen in P4 possibly due to optimum moisture content. Hence, P4 was considered superior.

4.5.4.4 Effects of perforations in packaging

Effect of perforations was studied by comparing hydrocooled and packaged, but unperforated samples (i.e. HUP) with P2, P4 and P6.

It can be easily concluded that samples with perforated packaging were superior to samples with unperforated packaging.

It was seen that, P6 had highest chlorophyll content and P2 had lowest chlorophyll content on both 12th and 16th day. But, P2 spoilt after that. Consequently, on 20th day of storage period, it was observed that only unspoilt sample remaining was P4 and P6. P6 although had higher chlorophyll content was seen to have shriveled, possibly due to excessive loss of moisture. P4, on the other hand, had clearly, good amount of moisture content as well as increased chlorophyll content compared to fresh sample. Thus, P4 was best among all the perforations.

Thus, it was seen that chlorophyll content was not affected by packaging or hydrocooling. The only change in chlorophyll content was due to moisture loss. On the other hand, chlorophyllase is only active at temperatures from 10 to 75°C; therefore, we infer that the activity of chlorophyll-degrading enzymes was low or nonexistent in refrigerated peppers, favoring the stability of the green color (Arkus *et al.*, 2005). Here, the increment of chlorophyll is only attributed to moisture loss. Similar result was found by Kosson (2003), he did not find color differences between peppers maintained in unperforated bags and perforated bags in refrigeration.

4.6 Effects of room temperature (25-27ºC) on chemical characteristics (moisture content, chlorophyll, and vitamin C) during storage

4.6.1 Change in moisture content during room temperature storage

Fig. 4.20 shows the pattern in which average moisture content in *akabare* under various treatments has changed during storage time at room temperature.

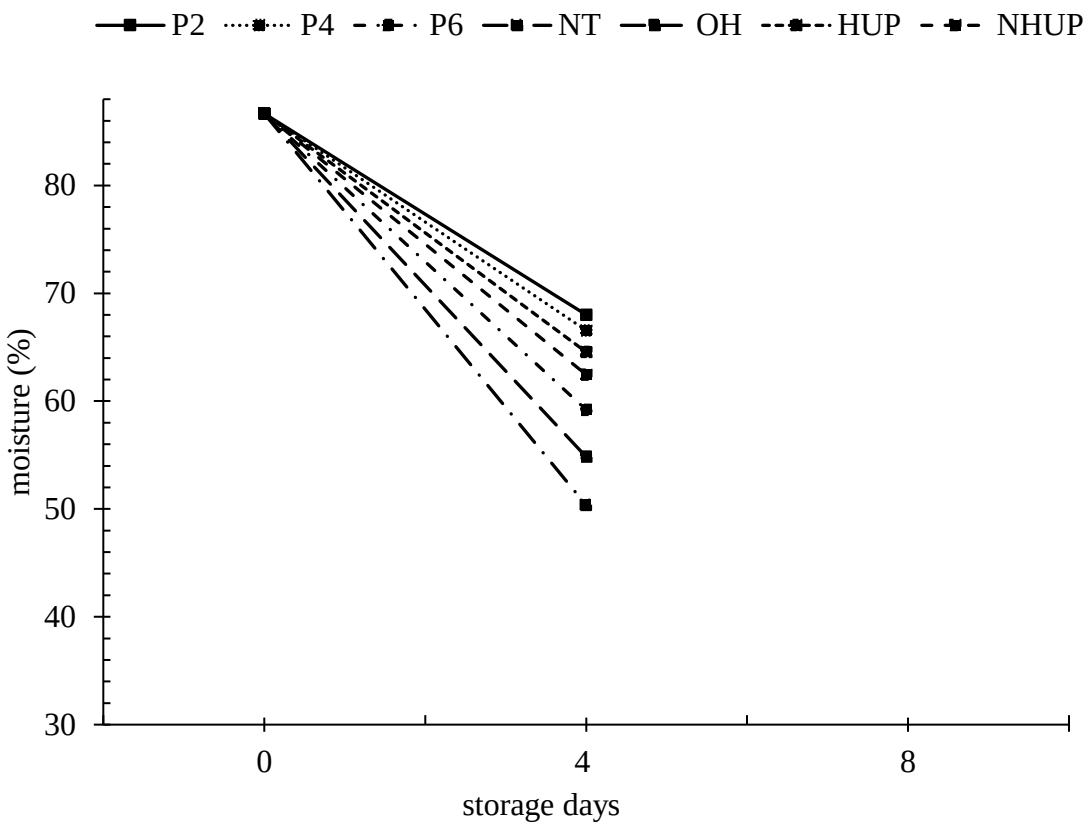

Fig. 4.20 Pattern of change in moisture during storage at room temperature

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.20 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

It was observed that the sample kept at room temperature spoilt before 8 days of storage time. Hence, analytical data of only 4 days could be collected. Also, the loss in moisture and vitamin C was excessive and unacceptable after 4 days of storage at room temperature. It can

be seen in Appendix Fig. A.2 and Fig. 4.20 that on 4th day of storage, the average moisture content was found to be 68.01±0.1401^{g} % , 66.56±0.2587^{f} %, 64.55±0.385^{e} %, 62.46±0.346^{d} %, 59.19±0.0153^{c} %, 54.83±0.122^{b} % and 50.36±0.167^{a} % on samples with treatments, P2, P4, HUP, NHUP, P6, OH and NT respectively. Hence, this suggests that P2 was best treatment in retaining the moisture. But, loss of moisture below 10% of original value is not acceptable (Kays, 1997). Also, all the chillies sample stored at ambient temperature were observed to be excessively withered, wilted and loss of shine, thus making it undesirable and unmarketable (Mitcham *et al.*, 1996). High temperature and low relative humidity might be the reasons for such unacceptable conditions and high temperature is supposed to increase respiration and enzymatic reaction rate by 2-3 fold (Brecht *et al.*, 2003). So, in terms of moisture content, storage at room temperature is unacceptable.

4.6.2 Change in vitamin C content during room temperature storage

Fig. 4.21 shows the pattern in which average vitamin C in *akabare* under various treatments has changed during storage time at room temperature.

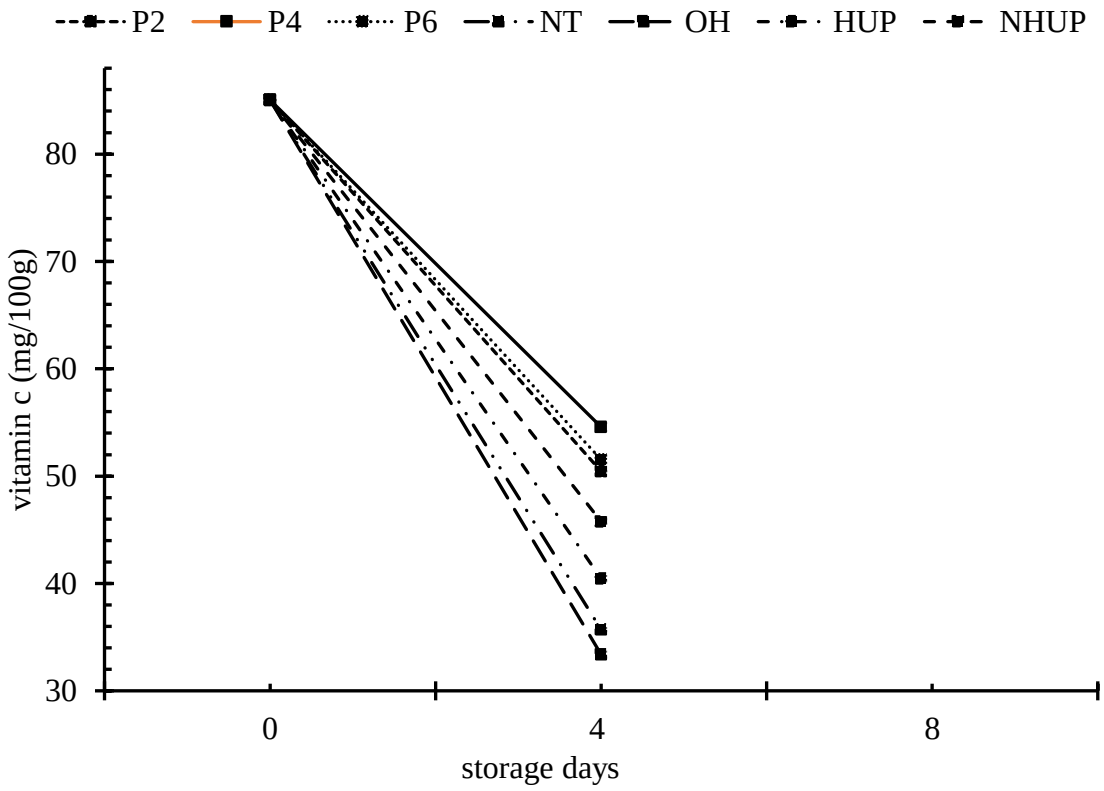

Fig. 4.21 Pattern of change in vitamin C during storage at room temperature

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.21 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

It was observed that the sample kept at room temperature spoilt before 8 days of storage time. Hence, analytical data of only 4 days could be collected. It can be seen in Fig 4.21 and Appendix Fig. A.2 and that on 4th day of storage, the vitamin C content was found to be 54.57 (0.365^{g}) mg/100 g, 51.53 (0.3308^{f}) mg/100 g, 50.45 (0.02^{e}) mg/100 g, 45.76 (0.2201^{d}) mg/100 g, 40.45 (0.2516^{c}) mg/100 g, 35.71 (0.2768^{a}) mg/100 g and 33.37 (0.148^{b}) mg/100 g on samples with treatments P4, P6, P2, NHUP, HUP, OH and NT respectively. Hence, this suggests that P4 was best treatment in retaining vitamin C. However, referring to Fig 4.20 we can say that freshness has already lost due to reduction of moisture below 10% of original content. Hence, storage at room temperature presents no significance although vitamin C seems to retain most in sample with P4 treatment.

4.6.3 Change in total chlorophyll content during room temperature storage

Fig. 4.8 shows the pattern in which average total chlorophyll content in *akabare* under various treatments has changed during storage time at room temperature.

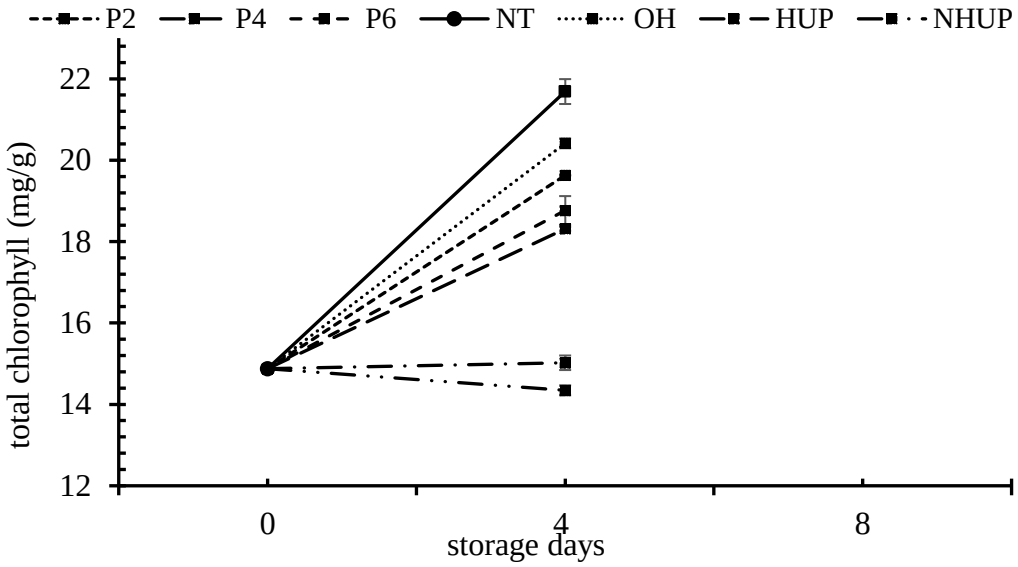

Fig. 4.22 Pattern of change in total chlorophyll during storage at room temperature

Vertical error bars represent standard deviation of values from mean. The same letters signify no significant difference. In the Fig. 4.22 P2, P4, P6, NT, OH, HUP and NHUP denote (hydrocooled, PP packaged with 2 perforations), (hydrocooled, PP packaged with 4 perforations), (hydrocooled, PP packaged with 6 perforations), no any treatment, only hydrocooled, (hydrocooled, packaged but not perforated) and (not hydrocooled, packaged but not perforated) conditions respectively.

In general, increment in chlorophyll content was seen during storage of *akabare* at room temperature. The values of total chlorophyll contents for treatments NT, OH, P2, P6, P4, HUP and NHUP were 21.69 ± 0.0827^{g} mg/g, 20.41 ± 0.0901^{f} mg/g, 19.63 ± 0.001^{e} mg/g, 18.76 ± 0.3545^{d} mg/g, 18.31 ± 0.025^{c} mg/g, 15.022 ± 0.0702^{b} mg/g and 14.35 ± 0.0666^{a} mg/g respectively at 4 days analysis. Chlorophyll content might have increased to reduction in weight of sample due to moisture loss.

Thus, based on visual inspection and chemical analysis the chillies stored at room temperature were considered unacceptable and storage of chillies at room temperature for longer period of time is not advised. We observed rapid water loss and, consequently, wilting, a symptom that prevents the plants from being sold.

Part V

Conclusions and recommendations

5.1 Conclusions

As per the objectives, methodologies as mentioned was followed and based on the result and discussions of research followed, following conclusions were made.

1. Low storage (8-10ºC) of akabare chilli resulted in best storage temperature as compared to room temperature (25-27ºC) in terms of minimum moisture loss, minimum Vitamin C loss, and minimum change in chlorophyll content.
2. Hydrocooling minimized the moisture loss so was good in case of unpackaged groups, however in case of unperforated packaged, non hydrocooled sample was good as hydrocooled groups suffered for higher degree of rot.
3. Unperforated PP packaging prevented significant water loss but due to condensation of water inside the package, after few days it became the reason for rotting and decaying.
4. The installation of perforations gave many good results of unperforated packaging i.e. reduction in moisture loss and less shriveling along with preventing off flavours, decay and rotting, and preventing water condensation inside the package.
5. Hydrocooled and 4 perforations at 8-10°C were the most effective method on quality (freshness) maintenance and retained significantly more percentage acceptable and marketable fruits throughout the storage period compared to other.
6. Perforation induced MAP inhibited loss of weight, moisture, vitamin c and chlorophyll.
7. Thus, storage of *akabare* in perforated low cost plastic bags at low temperature appears to require much less investments and permits the cost effective preservation of quality peppers.

5.2 Recommendations

1. One can test migration of compounds in between packaging materials and peppers.
2. Farmers and traders can use this techniques during long transportation of *akabare* chilli to market access.
3. Analysis of oleoresins and other bioactive agents (phenols, β -carotene, and capsaicinoids) can be carried out on each sampling day for other quality assessment.
4. All the causes of the post-harvest loss could be measured.
5. Use of texturometer for actual analysis of texture can be done

Part VI

Summary

Problems faced by fresh *akabare* (*Capsicum chinese*-var. habanero*)* production mainly occurs due to lack of technical knowledge for minimizing losses during post harvest handling. Several techniques have evolved for minimizing such postharvest losses. However, farmers and peasants cannot afford these high costly remedies. This research will address the problem faced by *Akabare* chilli growers and traders due to immediate post harvest losses of *Akabare* after harvesting. The purpose of this study was to assess the effects of hydrocooling and polypropylene perforated and non-perforated packaging on post-harvest quality of pepper stored at low temperature(8-10°C) and room temperature (25-27°C).

Understanding the effects of hydrocooling, storage temperature and packaging on postharvest water loss and storage quality of pungent pepper cultivars provide a basis for optimizing postharvest storage techniques. For this, *Akabare khursani* was brought and two experiments were conducted to determine best storage condition for fresh *akabare*: storage at room temperature (25-27°C) and at refrigeration (8-10°C). The chillies, packaged/ unpackaged (perforated and unperforated) with different treatments were stored on a lab bench for Experiment I and in Refrigerator for Experiment II. For packaging polypropylene (PP) from local market was brought and perforations at several levels/intensity (with each of 2, 4, 6 holes of 2.5 mm diameter) were made. Thus resulting in 7 different treatments in each storage temperatures.

Water loss influences postharvest longevity. Placing pepper fruit in perforated polypropylene packages reduced water loss rates and showed less rotting and spoilage so that water loss no longer limited postharvest storage. Storage at ambient conditions resulted in high weight loss and rapid deterioration in vitamin C and chlorophyll change as compared to low temperature (8-10°C). The best modified atmosphere was obtained with four perforations polypropylene packages at low storage temperature (8-10°C) that facilitated storage of pepper up to 23 days without visual spoilage. The moisture content, Ascorbic acid content, chlorophyll content of P4 were 76.84%, 73.03667 mg/100 g and 18.942 mg/g respectively at the end of storage days. Significant loss of weight and firmness were prevented by packaging. The tested bags represent a cost-effective alternative to preserve the quality of intact peppers for small scale peasant farmers.

References

Adisa, V. A. (1986). The influence of molds and some storage factors on the ascorbic acid content of orange and pineapple fruits. *Food Chem.* **22**, 139-146.

Agar, I. T., Massantini, R., Hess-pierce, B. and Kader, A. A. (1999). Postharvest CO_2 and ethylene production and quality maintenance of fresh-cut kiwifruit slices. *J. Food Sci.*, 433-440.

Alvares, V. S. (2007). Effect of precooling on the postharvest of parsley leaves. *J. Food, Agric. and Environ.* **5**, 31-34.

Anandswamy, B., Murthy, H. B. N. and Iyengar, N. V. R. (1959). Prepackaging studies on fresh produce: *Capsicum grossum* Sendt and *Capsicum acuminatum*. *J. Sci. Ind. Res.*

Anon. (2014). Terms of Reference to Assess Harvest and Postharvest Practices to Reduce Postharvest Loss [Report]. Nepal Market Developer Programme. Nepal.

Anonymous. Retrieved from https://www.scribd.com/document/56050035/Saturated-Salt-Solutions-and-RH. [Accessed 11 March, 2018].

Arkus, K. A. J., Cahoon, E. B. and Jez, J. M. (2005). Mechanistic analysis of wheat chlorophyllase. *Arch. Biochem. Biophy.*, 146-155.

Basu, S. K. and De, A. K. (2003). Capsicum: historical and botanical perspective. *In:* "Capsicum – The Genus Capsicum". (A. K. De, Ed.). pp. 1-13. London. Taylor and Francis Group.

Ben-Yehoshua, S. (1985). Individual seal packaging of fruits and vegetables in plastic flims-new post harvest technique. *Hortsci.* **20**, 32-37.

Ben-yehoshua, S. and Rodov, V. (2002). Transpiration and water stress. *In:* "Postharvest Physiology and Pathology of Vegetables" (2nd ed.). (J. A. Bartz and J. K. Brech, Eds.). pp. 111-159. CRC press.

Ben Yehoshua, S. and Rodov, V. (1998). Modified atmosphere packaging of fruits and vegetables : reducing of water in bell peppers and mangoes. *Acta Horticulturae*.

Berke, T. G. and Shieh, S. C. (2001). Capsicum, chillies, paprika, bird's eye chilli *In:* "Handbook of Herbs and Spicies ". (K. V. Peter, Ed.). pp. 127-139. Cambridge, England. Woodhead Publishing Ltd.

Bhurtel, P. R., Regmi, K. R. and Sapkota, R. P. (1996). Horticulture Reasearch in NARC: Status and Prospectus

Bhutia, K. L., Tombisana Meetei, N. G. and Khanna, V. K. (2016). In vitro regeneration of *dalle khursani*, an important chilli cultivar of Sikkim, using various explants. *Agrotechnol.* **5** (1), 1-4. [doi: 10.4172/2168-9881.1000142].

Bokhim, H. (2007). Study on Post Harvest Loss of *Akabare* [Report]. Vol. 17. Ministry of Agriculture and Cooperative, Department of Food Technology and Quality Control Nepal

Bosland, P. W. and Votava, E. J. (2012). Introduction. *In:* "Peppers: Vegetable and Spice Capsicum" (2nd ed.). (S. Hulbert, Ed.). pp. 1-12. [ISBN 978-1-84593-82-5-3].

Bourne, M. C. (1982). "Food Texture and Viscosity" (2 ed.). Academic Press. New York. [ISBN 9780080491332].

Brecht, J. K., Chau, K. V., Fonseca, S. C., Oliveira, F. A. R., Silva, F. M., Nunes, M. C. N. and Bender, R. J. (2003). Maintaining optimal atmosphere conditions for fruits and vegetables throughout the postharvest handling chain. *In:* "Postharvest Biology and Technology" (Vol. 27).). pp. 87-101.

Brosnan, T. and Sun, D. W. (2001). Precooling techniques and applications for horticultural products. *Int. J. Refrigeration*. 54-170.

Bussel, J. and Kenigsberger, Z. (1975). Packaging green bell peppers in selected permeability films. *J. Food Sci.* **40**, 1300-1303. [doi:10.1111/j.1365-2621.1975. tb01077.x].

Camara, B. and Moneger, R. (1978). Free and esterified carotenoids in green and red fruits of *Capsicum annuum J. Phytochem.*, 91-93.

Cantwell, M. J., Rovelo, X. N. and Rubatzky, V. (1998). Specialty salad greens: postharvest physiology and shelf-life. *Acta Horticulturae*. 371-377.

De, A. K. (2003a). A glimpse of the world trade in Capsicum *In:* "Capsicum- The Genus Capsicum". (P. S. S. Thampi, Ed.). pp. 16-24. London. Taylor and Francis Group.

De, A. K. (2003b). Post-harvest handling and processing of Capsicums *In:* "Capsicum-The Genus Capsicum". (V. Prakash and W. E. Eipeson, Eds.). pp. 161-174. London Taylor and Francis group.

DellaPenna, D. and Pogson, B. J. (2006). Vitamin synthesis in plants: tocopherols and carotenoids. *In:* "Annual Review of Plant Biology " (Vol. 57).). pp. 711–738.

EI-Ramaday, H. R., Domokos-Szabolcsy, E., Abdalla, N. A. and Taha, H. S. (2015). Postharvest management of fruits and vegetables storage *J. Sustainable Agric. Rev.* **15**, 65-152. [doi: 10.1007/978-3-319-09132-72].

Gast, K. L. B. and Flores, R. (1991). Postharvest Management of Commercial Horticultural Crops: Precooling Produce [Press release]. Cooperative Extension Service, Manhattan State University, Kansas. Retrieved from https://bit.ly/2XtzAco. [Accessed 30 September, 2018].

Hardenburg, R. E., Watad, A. E. and Wang, C. Y. (2016). Fruits abd vegetables. *In:* "The Commercial Storage of Fruits, Vegetables, Florist, and Nursery Stocks". (K. C. Cross and C. Y. Wang, Eds.). pp. 481-484. Washington. USDA.

Harker, F. R., Gunson, F. A. and Jaeger, S. R. (2003). The case for fruit quality:an interpretative review of consumer attitudes, and preferences. *Postharvest Biol. Technol.* (28), 333–347.

Hornero, D. and Minguez, M. I. (2002). Chlorophyll disappearance and chlorophyllase activity during ripening of *Capsicum annuum L* fruits. *J. Sci. Food Agric.* **82**, 1564-1570.

Howard, R. and Hernandez, C. (1997). Antioxidant content and market quality of jalapeno pepper rings as affected by minimal processing and modified atmosphere packaging. *J. Food Qual.*, 317–327.

Howard, R., Talcott, S. T., Brenes, C. H. and Villalon, B. (2000). Changes in phytochemical and antioxidant activity of selected pepper cultivar as influenced by maturity. *J. Agric. Food Chem.* **48**, 1713-1720.

Hughes, P. A., Thompson, A. K., Plumbley, R. A. and Seymour, G. B. (1981). Storage of capsicums: *Capsicum annum L.* Sendt. under controlled atmosphere, modified atmosphere and hypobaric conditions. *J. Horticultural Sci.* **56**, 261-265.

Hui Yiu, H. and Barta, J. (2006). "Handbook of Fruits and Fruits Processing". Blackwell Publishing. USA.

Islama, R. (2014). International Labour Organization ILO Country office for Nepal. Nepal,

Jobling, J. (2001). Modified atmosphere Packaging, Postharvest laboratory information sheet *Good Fruit and Vegetable Magazine*.

Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *In:* "Postharvest Biology and Technology" (Vol. 20). (K. Seung and A. A. Kader, Eds.). pp. 207–220. Division of Plant Science, Seoul National University, Suwon, 441-744, Korea.

Kader, A. A. (2002). Postharvest biology and technology: an overview. *In:* "Post Harvest Technology of Horticulture Crop". (A. A. Kader, Ed.). pp. 39-49. USA. University of California Agriculture and Natural Resources. [ISBN 9781879906518].

Kays, S. J. (1997). "Postharvest Physiology of Perishable Plant Products". Exon Press. Athens, GA.

Khanal, B. (2009). A study on post harvest losses of *akabare* chilli (*Capsicum chinese*) at dharan bazar. Presented at Class Seminar of M. Tech II year. Central Department of Food Technology, Institute of Science and Technology, Tribhuwan University, Hattisar, Dharan Nepal.

Koide, S. and Shi, J. (2007). Microbial and quality evaluation of green peppers stored in biodegradable flim packaging. *Food Control*. 1121-1125.

Kosson, R. (2003). Chlorophyll fluorescence and chilling injury of green pepper as affected by storage conditions. *Acta Horticulture*. 379-385.

Kumar, S., Kumar, R. and Singh, J. (2006). Cayenne/American pepper. *In:* "Handbook of Herbs and Spices" (Vol. 3). (K. V. Peter, Ed.). pp. 299-310. England. Woodhead Publishing Ltd.

Lee, S. K. and Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *J. Postharvest Biol. Technol.* (20), 207–220.

Litoriya, N. S., GandhiI, K. and Talati, J. G. (2014). Nutritional composition of different chilli (*Capsicum annuum L.*) varieties. *Indian J. Agri. Biochem.* **27** (1), 91-92.

Mahajan, B. V. C., Dhillon, W. S., Kumar, M. and Singh, B. (2014). Effect of different packaging films on shelf life and quality of peach under super and ordinary market conditions. *J. Food Sci. Technol.*, 3756-3762.

Manalili, N. M. and Dorado, M. A. (2003). "Appropriate Food Packaging Solutions for Developing Countries". Rome. FAO. pp. 1-38. Retrieved from http://www.fao.org/3/mb061e/mb061e00.pdf. [Accessed 5 June, 2018].

Manju, P. R. and Sreelathakumary, I. (2002). Genetic variability, heritability and genetic advance in hot chilli (*Capsicum chinense Jacq*.). *J. Tropical Agri.* (40), 4-6.

Manolopoulou, H., Xanthopoulos, G., Douros, N. and Lambrinos, G. (2010). Modified atmosphere packaging storage of green bell peppers: quality criteria. *J . Biosystem Eng.*, 535–543.

Mason, J. (2014). History and science. *In:* "Growing and Using Capsicums and Chillies".). pp. 6-10. Queensland, Australia. ACS Distance Education. [ISBN: 978-0-9924429-8-9].

Miller, E. V. and Heilman, A. S. (1952). Ascorbic acid and physiological breakdown in the fruits of the pineapple. *Science*. 505-506.

Mini, C., Vahab, M. A., Augustine, A. and Rajan, S. (1998). Standarisation of sovent for chilli oleoresin extraction. *In:* "South Indian Horticulture" (Vol. 46).). pp. 309-311.

Mir, N. (2009). Film, perforated. *In:* "The Wiley Encyclopedia of Packaging Technology". (K. L. Yam, Ed.). pp. 486-488. Hobokon. John Wiley & Sons.

Mir, N. and Beaudry, R. M. (2004). Modified atmosphere packaging. *In:* "The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks.". (K. C. Gross, C. Y. Wang and M. Saltveit, Eds.). Washington, D. C.

Mitcham, B., Cantwell, M. and Kader, A. (1996). Methods for determining quality of fresh commodities. *Perishables Handling Quarterly*

Opara, U. L., Hussein, Z. and Caleb, O. J. (2016). Phytochemical properties and antioxidant properties of minimally processed "Acco" pomegranate arils as affected by perforation-mediated modified atmosphere packaging. *J. Food Process. Preservation*. [doi:10.1111/jfpp.12948].

Ornelas-Paz, J. J. and Castenada Jiminez, A. C. (2015). Effect of the perforation level of recycled-LDPE bags on the modification of the atmosphere development, bioactive compunds content, and other qualities of Jalapeno peppers during storage. *J. Food Sci. Technol.*, 1-18. [doi: 10.1007/s13197-015-1749-8].

Paine , F. A. and Paine , H. Y. (1992). Fresh fruits and vegetables. *In:* "A Handbook Of Food Packaging" (2nd ed.). (H. Y. Paine and F. A. Paine, Eds.). pp. 231-249. New Delhi. Chapman & Hall. [ISBN 978-1-4613-6214-2].

Paine, F. A. and Paine, H. Y. (1992a). Graphics and package design. *In:* "A Handbook of Food Packaging" (2nd ed.). (F. A. Paine and H. Y. Paine, Eds.). pp. 33-39. New Delhi. Chapman and Hall. [ISBN 978-1-4615-2810-4].

Paine, F. A. and Paine, H. Y. (1992b). Packaging machinery. *In:* "A Handbook Of Food Packaging" (2nd ed.). (F. A. Paine and H. Y. Paine, Eds.). pp. 97-167. New Delhi. Chapman and Hall [ISBN 978-1-4613-6214-2].

Perez, K., Mercado, J. and Soto-Valdez, H. (2003). Effect of storage temperature on the shelf life of Hass avocado (Persea americana). *J. Food Sci. Technol.*, 73-77. [doi: 10.1177/1082013204043763].

Plaza, L., Sanchez-Moreno, C., Elez-Martinez, P., De-Ancos, B. and Marin-Belloso, O. (2006). Effect of refrigerated storage on vitamin C and antioxidant activity of orange juice processed by high-pressure or pulsed electric fields with regard to low pasteurization. *J. Eur. Food Res. Technol.*, 487-493.

Pogson, B. J. and Morris, S. C. (1997). Consequences of cool storage of broccoli on physiological and biochemical changes and subsequent senescence at 20°C. *Horticulture Sci.*, 553-558.

Premavalli, K. S. and Amrinder, S. B. S. (2010). Development of ready to eat appetizers based on pepper and their quality evaluation. *J. Food Sci. Technol.* **47** (6), 305-309. [doi: 10.1007/s13197-010-0105-2].

Pruthi, J. S. (2003). Advances in postharvest processing technologies of Capsicum. *In:* "Capsicum – The Genus Capsicum". (A. K. De, Ed.). p. 129. London. Taylor & Francis Group.

Raghavan, S. (2007). "Handbook of Spices, Seasonings and Flavorings". CRC Press.

Rai, R. (2017). Processing effect on oleoresin retention of *akabare* chilli (*Capsicum chinese*). B.Tech Dissertation. Tribhuvan Univ., Nepal.

Ramalho do Rego, E., Monterio do Rego, M. and Finger, F. L. (2016). Physiology and postharvest of pepper fruits. *In:* "Production and Breeding of Chili Peppers (*Capsicum* spp.)" (Vol. 9). (F. L. Finger and G. M. Pereira, Eds.). pp. 27-40. [ISBN-978-3-319-06531-1].

Ranganna, S. (1986). "Handbook of Analysis and Quality Control for Fruit and Vegetable Products". Tata McGraw-Hill Publishing Company. New Delhi, India. .

Robertson, G. L. (2010). Packaging and shelf life of fresh fruits and vegetables. *In:* "Food Packaging and Shelf Life :A Practical Guide". (G. L. Robertson, Ed.). pp. 297-310. London, New York. Taylor and Francis Group. [ISBN 978-1-4200-7844-2].

Sargent, S. A., Ritenour, M. A., Brecht, J. K. and Bartz, J. A. (1995). Handling, Cooling, and Sanitation Techniques for Maintaining Postharvest Quality. University of Florida. Retrieved from http://irrec.ifas.ufl.edu/postharvest/HOS_5330/Lectures/SP%20170%20Veg%20Prod%20Guide%20PH%20Quality%20cv11500-2007.pdf. (Last update July, 2007). [Accessed 29 March, 2018].

Seigge, G. O., Hansman, C. F. and Joubert. (2001). Effect of packaging materials and methisulphite treatment on the colour of dehydrated green bell pepper (*Capsicum annum L*). *J. Food Qual.*, 24-35.

Sharma, K. D., Cardona, J. A. and Sibomana, M. S. (2018). Quality attributes of modified atmosphere packaged bell pepper (*Capsicum annuum L.*) during storage. *J. Nutr. Food Res. Technol.*, 56-62. [doi:10.30881/jnfrt.00012].

Shewfelt, R. L. (1993). Measuring quality and maturity. *In:* "Postharvest Handling: A Systems Approach". (R. L. Shewfelt and S. E. Prussia, Eds.). pp. 99–124. San Diego. Academic Press.

Shrestha, R. (2018). Personal communication [Interview]. 18 March, 2018.

Singh, M., Shivhare, U. S. and Ahmed, J. (2000). Drying characteristics and product quality of bell pepper. *Int. J. Food Properties*. 249-257. [doi:10.1080/10942910009524631].

Soltani, M., Alimardani, R., Mobli, H. and Mohtasebi, S. S. (2015). Modified atmosphere packaging; a progressive technology for shelf life extension of fruits and vegetables. *J. Appl. Packaging Res.* **7** (3).

Thompson, Mitchell, F. G., Runsey, T. R., Kasmire, R. F. and Crisosto, C. H. (1998). "Commercial Cooling of Fruits Vegetables and Flowers". UC Davis. USA.

Thompson, J. (2003). Postharvest technology of fruit and vegetables. *In:* "Fruits and Vegetables: Harvesting, Handling and Storage" (2nd ed.). (J. Thompson, Ed.). pp. 178-190.

Turhan, M., Turhan, K. N. and Sahbaz, F. (1997). Drying kinetics of red pepper *J. Food Process. Preserv.*, 209-223.

Vergnaud, J. M. and Rosca, I. D. (2006). "Assessing Food Safety of Polymer Packaging ". Smithers Rapra Limited. United Kingdom. [ISBN 098-1-84735-026-8].

Waldron, K. W., Parker, M. L. and Smith, A. C. (2003). Plant cell walls and food quality. *J. Compr. Rev. Food Sci. Food Safety*. 101-111.

Wang, H. C., Huang, X. M., Hu, G. B., Yang, Z. and Huang, H. B. (2005). A comparative study of chlorophyll loss and its related mechanism during fruit maturation in the pericarp of fast and slow degreening litchi pericarp. *Sci. Horticulture*. 247–257.

Wills, R. B. H., McGlasson, W. B., Graham, D., Tlee, H. and Hall, E. G. (1989). "Postharvest: An Introduction to the Physiology and Handling of Fruits and Vegetables". Vol. 3.New York.

Yahia, E. M. and Ornelas-Paz, J. J. (2010). Chemistry, stability and biological actions of carotenoids. *In:* "Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value

and Stability.". (L. D. L. Rosa, P. E. Alvarez and G. A. González, Eds.). pp. 177-222. USA. Blackwell Publishing.

Yam, K. L. and Lee, D. S. (2012). Emerging packaging technologies for fresh produce. *In:* "Emerging Food Packaging Technologies". (M. S. Vakkalanka, T. D'Souza, S. Ray and K. L. Yam, Eds.). pp. 108-132. Cambridge, UK. Woodhead Publishing Limited. [ISBN 978-1-84569-809-6].

Yamaguchi, S. and Ninomiya, K. (2000). Umami and food palatability. *J. Nutr.*, 921-926.

Yang, X., Zhang, Z., Joyce, D., Huang, X., Xu, L. and Pang, X. (2009). Characterization of chlorophyll degradation in banana and plantain during ripening at high temperature. *Food Chem.*, 383-390.

Yoshida, S. D., Forno, J. H. and Gomez, K. H. (1972). "Laboratory Manual for Physiological Studies of Rice" (2 ed.). IARI. Los Bobnos, Philippines.

Zachariah, T. J. and Gobinath, P. (2008). Paprika and Chilli. *In:* "Chemistry of Spices". (V. A. Parthasarathy, B. Chempakam and T. J. Zachariah, Eds.). pp. 69-75. Wallingford, UK. CAB International.

Appendices

Appendix A

Analysis of Variances

Table A.1 Effects of low temperature on storage stability of *akabare*

Temperature of Storage	Treatments Done	Days until visual spoilage was seen
Low Temperature (8-10°C)	NT	4.17 (0.408248[a])
	OH	5.33 (0.516398[b])
	HUP	7.83 (0.408248[c])
	NHUP	9.67 (0.516398[d])
	P2	15.83 (0.408248[e])
	P4	22.67 (0.516398[g])
	P6	21.17 (0.408248[f])

The values are the means of triplicate. Numbers in the parentheses are standard deviation of the data. The same letters in the superscript in a column signify no significant difference between the samples.

Table A.2 Effects of room temperature on storage stability of *akabare*

Temperature of Storage	Treatments Done	Days until visual spoilage was seen
Room Temperature (23-27°C)	NT	2.167 (0.408248[a])
	OH	3[b]
	HUP	3.667 (0.516398[c])
	NHUP	4[c]
	P2	5.667 (0.516398[d])
	P4	7.167 (0.408248[e])
	P6	5.833 (0.408248[d])

The values are the means of triplicate. Numbers in the parentheses are standard deviation of the data. The same letters in the superscript in a column signify no significant difference between the samples.

Appendix B

Low Temperature

Day 4

Analysis of variance

Variate: Moisture Content (%)

Table A.3 ANOVA table for moisture content at day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	6	673.71025	112.28504	1254.45	<.001
Residual	14	1.25313	0.08951		
Total	20	674.96338			

Fisher's protected least significant difference test

Table A.4 Fisher's LSD test table for moisture content at day 4

Treatments	Mean moisture (%)	Significant Difference Indicator
NT	70.68	a
OH	74.60	b
P6	77.24	c
NHUP	81.31	d
P4	85.26	e
P2	85.86	f
HUP	86.11	f

The values are the means of triplicate. The same letters in the superscript in a column signify no significant difference between the samples.

Analysis of variance

Variate: Total Chlorophyll (mg/g)

Table A.5 ANOVA table for total chlorophyll at day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	6	98.9609	16.4935	162.15	<.001
Residual	14	1.4241	0.1017		
Total	20	100.3850			

Fisher's protected least significant difference test

Table A.6 Fisher's LSD test table for total chlorophyll content at day 4

Treatments	Mean Moisture Content (%)	Significant Difference Indicator
HUP	15.12	a
P2	15.63	ab
P4	15.70	b
NHUP	16.81	c
OH	18.11	d
P6	18.26	d
NT	21.89	e

The same letters in the superscript in a column signify no significant difference between the samples.

Analysis of variance

Variate: Vitamin_C_mg_100g

Table A.7 ANOVA table for Vitamin C content at day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	6	530.1903	88.3651	289.23	<.001
Residual	14	4.2772	0.3055		
Total	20	534.4675			

Fisher's protected least significant difference test

Table A.8 Fisher's LSD test table for Vitamin C content at day 4

Treatments	Mean Vitamin C (mg/100g)	Significant Difference Indicator
NT	70.80	a
OH	71.72	a
P6	78.11	b
P4	80.34	c
P2	82.21	d
HUP	83.45	e
NHUP	83.96	e

The same letters in the superscript in a column signify no significant difference between the samples.

Day 8

Analysis of variance

Variate: Moisture Content_%

Table A.9 ANOVA table for moisture content at day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	183.1482	45.7871	182.79	<.001
Residual	10	2.5049	0.2505		
Total	14	185.6531			

Fisher's protected least significant difference test

Table A.10 Fisher's LSD test table for moisture content at day 8

Treatments	Mean moisture Content (%)	Significant Difference Indicator
P6	75.95	a
NHUP	76.99	b
P4	82.20	c
P2	83.80	d
HUP	84.29	d

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Vitamin_C_mg_100g

Table A.11 ANOVA table for Vitamin C content at day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	73.0253	18.2563	160.59	<.001
Residual	10	1.1368	0.1137		
Total	14	74.1621			

Fisher's protected least significant difference test

Table A.12 Fisher's LSD test table for vitamin C content at day 8

Treatments	Mean Vitamin C(mg/100g)	Significant Difference Indicator
P6	74.92	a
HUP	77.33	b
P4	78.98	c
P2	80.22	d
NHUP	81.15	e

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Total_Chlorophyll_mg_g

Table A.13 ANOVA table for total chlorophyll content at day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	29.87379	7.46845	116.27	<.001
Residual	10	0.64234	0.06423		
Total	14	30.51613			

Fisher's protected least significant difference test

Table A.14 Fisher's LSD test table for total chlorophyll content at day 8

Treatments	Mean Total chlorophyll (mg/100g)	Significant Difference Indicator
HUP	14.33	a
P2	16.00	b
NHUP	16.01	b
P4	16.48	c
P6	18.72	d

The same letters in the superscript in a column signify no significant difference between the samples

Day 12

Analysis of variance

Variate: Moisture_Content_%

Table A.15 ANOVA table for moisture content at day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	2	141.4022	70.7011	171.56	<.001
Residual	6	2.4726	0.4121		
Total	8	143.8748			

Fisher's protected least significant difference test

Table A.16 Fisher's LSD test table for moisture content at day 12

Treatments	Mean	Significant Difference Indicator
P6	72.94	a
P4	80.69	b
P2	81.88	b

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Vitamin_C_mg_100g

Table A.17 ANOVA table for Vitamin C content at day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	2	92.4508	46.2254	455.87	<.001
Residual	6	0.6084	0.1014		
Total	8	93.0592			

Fisher's protected least significant difference test

Table A.18 Fisher's LSD test table for Vitamin C content at day 12

Treatments	Mean	Significant Difference Indicator
P6	70.52	a
P4	76.05	b
P2	78.12	c

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Total_Chlorophyll_mg_g

Table A.19 ANOVA table for total chlorophyll content at day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	2	20.2718	10.1359	99.09	<.001
Residual	6	0.6137	0.1023		
Total	8	20.8855			

Fisher's protected least significant difference test

Table A.20 Fisher's LSD test table for total chlorophyll content at day 12

Treatments	Mean	Significant Difference Indicator
P2	16.01	a
P4	16.46	a
P6	19.39	b

The same letters in the superscript in a column signify no significant difference between the samples

Day 16

Analysis of variance

Variate: Moisture_Content_%

Table A.21 ANOVA table for moisture content at day 16

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	2	128.1609	64.0804	120.63	<.001
Residual	6	3.1873	0.5312		
Total	8	131.3482			

Fisher's protected least significant difference test

Table A.22 Fisher's LSD test table for moisture content at day 16

Treatments	Mean	Significant Difference Indicator
P6	71.13	a
P4	78.31	b
P2	79.77	c

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Vitamin_C_mg_100g

Table A.23 ANOVA table for Vitamin C content content at day 16

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	2	47.6723	23.8361	47.23	<.001
Residual	6	3.0279	0.5047		
Total	8	50.7002			

Fisher's protected least significant difference test

Table A.24 Fisher's LSD test table for Vitamin C content at day 16

Treatments	Mean	Significant Difference Indicator
P6	68.46	a
P2	70.76	b
P4	74.07	c

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Total_Chlorophyll_mg_g

Table A.25 ANOVA table for total chlorophyll content at day 16

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	2	20.82836	10.41418	251.04	<.001
Residual	6	0.24890	0.04148		
Total	8	21.07727			

Fisher's protected least significant difference test

Table A.26 Fisher's LSD test table for total chlorophyll content at day 16

Treatments	Mean	Significant Difference Indicator
P2	16.32	a
P4	17.49	b
P6	19.97	c

The same letters in the superscript in a column signify no significant difference between the samples

Day 20

Two-sample t-test for moisture

Variates: P4, P6.

Test for equality of sample variances

Test statistic F = 2.61 on 2 and 2 d.f.

Probability (under null hypothesis of equal variances) = 0.55

Summary

Table A.27 Two sample t-test for moisture

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
P4	3	76.85	0.2276	0.4771	0.2755
P6	3	68.65	0.5943	0.7709	0.4451

Difference of means: 8.197

Standard error of difference: 0.523

95% confidence interval for difference in means: (6.743, 9.650)

Test of null hypothesis that mean of P4 is equal to mean of P6

Test statistic t = 15.66 on 4 d.f.

Probability < 0.001

Two-sample t-test for vitamin C

Variates: P4, P6.

Test for equality of sample variances

Test statistic F = 2.53 on 2 and 2 d.f.

Probability (under null hypothesis of equal variances) = 0.57

Summary

Table A.28 Two-sample t-test for vitamin C

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
P4	3	73.04	0.4681	0.6842	0.3950
P6	3	65.46	0.1849	0.4300	0.2483

Difference of means: 7.577

Standard error of difference: 0.467

95% confidence interval for difference in means: (6.281, 8.872)

Test of null hypothesis that mean of P4 is equal to mean of P6

Test statistic t = 16.24 on 4 d.f.

Probability < 0.001

Two-sample t-test for chlorophyll content

Variates: P4, P6.

Test for equality of sample variances

Test statistic F = 1.44 on 2 and 2 d.f.

Probability (under null hypothesis of equal variances) = 0.82

Summary

Table A.29 Two-sample t-test for chlorophyll content

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
P4	3	18.94	0.1372	0.3704	0.2139
P6	3	21.09	0.0955	0.3090	0.1784

Difference of means: -2.146

Standard error of difference: 0.278

95% confidence interval for difference in means: (-2.919, -1.373)

Test of null hypothesis that mean of P4 is equal to mean of P6

Test statistic t = -7.71 on 4 d.f.

Probability = 0.002

Room Temperature

Day 4

Analysis of variance

Variate: Moisture_Content_%

Table A.30 ANOVA table for moisture content at day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treaments	6	747.47365	124.57894	2193.66	<.001
Residual	14	0.79507	0.05679		
Total	20	748.26871			

Fisher's protected least significant difference test

Table A.31 Fisher's LSD test table for moisture content at day 4

Treatments	**Mean**	**Significant Difference Indicator**
NT	50.36	a
OH	54.84	b
P6	59.20	c
NHUP	62.46	d
HUP	64.55	e
P4	66.56	f
P2	68.01	g

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Vitamin_C_mg_100g

Table A.32 ANOVA table for Vitamin C content at day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatments	6	1216.10986	202.68498	3129.69	<.001
Residual	14	0.90667	0.06476		
Total	20	1217.01652			

Fisher's protected least significant difference test

Table A.33 Fisher's LSD test table for Vitamin C content at day 4

Treatments	**Mean**	**Significant Difference Indicator**
OH	33.38	a
NT	35.71	b
HUP	40.45	c
NHUP	45.77	d
P2	50.45	e
P6	51.54	f
P4	54.57	g

The same letters in the superscript in a column signify no significant difference between the samples

Analysis of variance

Variate: Total_Chlorophyll_mg_g

Table A.35 ANOVA table for total chlorophyll content at day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatments	6	132.87477	22.14579	547.71	<.001
Residual	14	0.56607	0.04043		
Total	20	133.44083			

Fisher's protected least significant difference test

Table A.36 Fisher's LSD test table for chlorophyll at day 4

Treatments	Mean	Significant Difference Indicator
NHUP	14.35	a
HUP	15.02	b
P4	18.31	c
P6	18.76	d
P2	19.63	e
OH	20.41	f
NT	21.69	g

The same letters in the superscript in a column signify no significant difference between the samples

Appendix C

Values of study parameters under storage under various treatments

Low temperature

Days of Storage	Treatment	Moisture (%)	SD Moisture	Vitamin C (Mg/100g)	SD Vitamin C	Total Chlorophyll(mg/g)	SD Total Chlorophyll
4	P2	85.81		81.31		15.43	
4	P2	85.93	0.061101009	82.43	0.812649986	15.51	0.28
4	P2	85.85		82.89		15.95	
4	P4	85.29		80.8		15.96	
4	P4	85.34	0.1040833	80.12	0.39551654	15.48	0.242487113
4	P4	85.14		80.11		15.66	
4	P6	76.95		78.34		18.53	
4	P6	77.61	0.337194306	78.14	0.2463737	18.16	0.232880513
4	P6	77.16		77.85		18.1	
4	NT	70.41		70.13		21.9	
4	NT	71.01	0.305505046	70.34	0.984225584	22.05	0.160104133
4	NT	70.61		71.93		21.73	
4	OH	75.18		71.13		18.11	
4	OH	74.42	0.514198405	72.03	0.508461732	18.38	0.27
4	OH	74.2		71.99		17.84	
4	HUP	86.12		83.47		14.66	
4	HUP	85.98	0.120554275	83.34	0.097125349	15.8	0.599193903
4	HUP	86.22		83.53		14.91	
4	NHUP	80.96		84.04		16.78	
4	NHUP	81.31	0.355011737	84.06	0.156204994	17.07	0.251064401
4	NHUP	81.67		83.78		16.57	
8	P2	83.16		80.13		15.95	
8	P2	84.61	0.740967836	80.3	0.085049005	16.1	0.083864971
8	P2	83.62		80.22		15.96	
8	P4	81.98		79.3		16.73	
8	P4	82.29	0.195021366	79.21	0.478434949	16.07	0.355715242
8	P4	82.34		78.43		16.63	
8	P6	75.72		74.63		18.65	
8	P6	75.98	0.216564078	75.21	0.290057466	18.73	0.065574385
8	P6	76.15		74.93		18.78	
8	HUP	84.38		77.21		14.668	
8	HUP	84.41	0.176729549	77.22	0.199248588	14.43	0.404163333
8	HUP	84.09		77.56		13.88	
8	NHUP	76.29		80.62		15.931	
8	NHUP	77.81	0.766311512	81.43	0.456544996	15.92	0.141269246
8	NHUP	76.88		81.39		16.17	
12	P2	81.89		78.39		15.943	
12	P2	82.03	0.15011107	77.77	0.316438514	16.34	0.305182459
12	P2	81.73		78.19		15.74	
12	P4	80.14		76.21		16.22	
12	P4	81.92	1.064017544	76.12	0.20984121	16.34	0.317490157
12	P4	80.02		75.81		16.82	
12	P6	73.24		70.12		19.32	
12	P6	72.92	0.285715476	70.92	0.400041664	19.1	0.336055551
12	P6	72.67		70.53		19.76	
16	P2	79.57		70.77		16.3	
16	P2	79.82	0.176162803	70.82	0.070945989	16.3	0.034641016
16	P2	79.91		70.68		16.36	
16	P4	78.12		74.12		17.844	
16	P4	78.82	0.446430286	73.1	0.945991543	17.254	0.31374087
16	P4	77.99		74.99		17.364	
16	P6	70.1		68.96		19.943	
16	P6	70.9	1.167618659	67.56	0.783602791	19.825	0.157535181
16	P6	72.4		68.87		20.137	
20	P4	76.32		72.79		19.362	
20	P4	77.25	0.477109352	73.81	0.684202699	18.662	0.370405184
20	P4	76.97		72.51		18.802	
20	P6	68.22		65.89		21.194	
20	P6	69.54	0.770908555	65.46	0.43	20.74	0.308953071
20	P6	68.19		65.03		21.33	

Fig A.1 Variation of study parameters during low storage under various treatments

Room Temperature

Days of storage	Treatments	Moisture (%)	SD Moisture	Vit C (mg/100g)	SD Vit C	TotalChlrophyll (mg/g)	SD Total Chl
4	P2	68.15		50.43		19.626	
4	P2	67.87	0.140118997	50.47	0.02	19.628	0.001154701
4	P2	68.02		50.45		19.626	
4	P4	66.33		54.42		18.355	
4	P4	66.51	0.258650343	54.99	0.365011415	18.261	0.0478992
4	P4	66.84		54.31		18.324	
4	P6	59.21		51.67		18.427	
4	P6	59.18	0.015275252	51.16	0.330807094	19.133	0.354131802
4	P6	59.2		51.78		18.731	
4	NT	50.21		35.88		22.001	
4	NT	50.33	0.167032931	35.61	0.147986486	21.39	0.305942805
4	NT	50.54		35.64		21.667	
4	OH	54.73		33.12		20.324	
4	OH	54.81	0.122202019	33.34	0.276827263	20.55	0.120403488
4	OH	54.97		33.67		20.365	
4	HUP	64.17		40.29		15.226	
4	HUP	64.94	0.385010822	40.74	0.251594913	14.949	0.179033516
4	HUP	64.55		40.32		14.891	
4	NHUP	62.34		45.99		14.218	
4	NHUP	62.85	0.345976878	45.76	0.220075745	14.353	0.123194967
4	NHUP	62.19		45.55		14.464	
8	P2	52.78		30.25		21.477	
8	P2	53.41	0.519262297	30.89	0.375410886	21.971	0.289940224
8	P2	53.81		30.23		21.461	
8	P4	50.12		33.96		19.12	
8	P4	50.33	0.448367409	34.32	0.262106848	19.0366	0.046670333
8	P4	50.98		34.47		19.042	

Fig A.2 Variation of study parameters during room storage under various treatments

Color plates

Plate P.1 Chillies stored at room temperature (2nd day)

Plate P.2. Chillies stored at low temperature (P6- 20th day)

Plate P.3. HUP at low temperature (4th day) (water condensed inside packaged)

Plate P.4. OH at Room temperature (2nd day)

Plate P.5. Chillies stored at low temperature (20th day)

Plate P.6. Spectrophotometric chlorophyll analysis