"EFFECT OF POLYETHYLENE PACKAGING AND LOW TEMPERATURE ON THE SHELF LIFE OF BELL PEPPER (*Capsicum annum* L.) CV. INDRA"

A

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ABSTRACT

"EFFECT OF POLYETHYLENE PACKAGING AND LOW TEMPERATURE ON THE SHELF LIFE OF BELL PEPPER (*Capsicum annum* L.) CV. INDRA"

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ABSTRACT

An experiment entitled "Effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* l.) cv. Indra" was conducted at the Post Graduate Research Laboratory, ASPEE College of Horticulture & Forestry, Navsari Agricultural University, Navsari during November 2010. The experiment comprised of packing bell pepper fruits in polyethylene bags of three different thickness (200, 300 and 400 gauge), with and without perforations and storing them at a temperature of 8^0C and 12^0C. The experiment was evaluated in Completely Randomized Design with Factorial Concept (FCRD).

Packaging and perforation had a significant impact on all parameters included in the study. When considered individually, polyethylene bags of 400 gauge thickness and unperforated bags had significantly the highest chlorophyll and carotenoid content, firmness, bulk density, and ascorbic acid. They also recorded significantly the lowest physiological loss in weight, respiration rate, shrinkage and disease incidence.

Significant differences were observed in physiological parameters, physical parameters, biochemical parameters and pathological disorders due to storage temperature. Between the two temperatures, storage at 8°C temperature resulted in significantly higher chlorophyll and carotenoid content, firmness, bulk density, ascorbic acid and TSS. Physiological loss in weight, respiration rate, shrinkage and disease incidence were significantly lower at 8°C. Chilling injury was not observed at 12°C temperature.

Packing fruits in unperforated polyethylene bags of 400 gauge thickness and storing them at 8°C proved to be the best post harvest treatment combination for extending shelf life and arresting quality deterioration in bell pepper. Under these conditions, fruits could be stored for up to 25 days and had the best visual appearance with lower disease incidence, lower chilling injury and limited physiological loss in weight.

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CERTIFICATE

This is to certify that the thesis entitled "**Effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* L.) cv. Indra**" submitted by **Mr. RAJANKUMAR PANKAJKUMAR PATEL** in partial fulfillment of the requirement for the award of degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE** of Navsari Agricultural University is a record of bona fide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Navsari

Date : 6th September, 2011

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DECLARATION

I hereby declare that the whole of the research work reported in this thesis, in the partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE** is the result of investigation done by me under direct guidance and supervision of **Dr. T. R. Ahlawat,** Associate Professor (Horticulture), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari and no part of the research work has been submitted for any other degree so far.

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ABBREVIATIONS

SR. NO.	ABBREVIATION	MEANING
1.	%	*Per cent*
2.	@	At the rate of
3.	µm	Micro meter
4.	^{0}C	Degree Centigrade
5.	^{0}F	Degree Fahrenheit
6.	C.D.	Critical difference
7.	C.V.	Co-efficient of variance
8.	cm	Centimeter
9.	CO_2	Carbon Dioxide
10.	cv.	Cultivar
11.	*et al.*	And others
12.	Fig.	Figure
13.	FW	Fruit Weight
14.	g	Gram
15.	GA	Gibberellic Acid
16.	ha	Hectare
17.	hr	Hour
18.	*i.e.*	*id est* (That is)
19.	kg	Kilogram
20.	Km	Kilometer
21.	M.T.	Metric Tonnes
22.	MAP	Modified Atmosphere Packaging

23.	MDPE	Medium Density Polyethylene
24.	mg	Mili Gram
25.	ml	Mili Litre
26.	mm	Mili Meter
27.	O_2	Oxygen
28.	OVQ	Overall Visual Quality
29.	PE	Polyethylene
30.	ppm	Parts Per Million
31.	PVC	Polyvinyl Chloride
32.	RH	Relative Humidity
33.	S.Em ±	Standard Error of Mean
34.	TSS	Total Soluble Solids
35.	*viz.,*	*Videlicet* (Namely)
36.	ZECC	Zero Energy Cool Chamber

INTRODUCTION

I. INTRODUCTION

Bell peppers belong to Solanaceae, the potato or nightshade family, a group of flowering plants in the Solanales order. Solanaceae includes some of the most important food and drug producing plants, such as potato, tomato, eggplant, tobacco, chilli pepper and the deadly nightshade. Members of Solanaceae are characterized by five petaled flowers, typically conical or funnelform and alternate or alternate to opposite leaves.

Bell pepper belongs to the genus *Capsicum*. Bell pepper contains approximately 20-27 species (Walsh and Hoot, 2001), five of which are domesticated: *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens* (Heiser and Pickersgill, 1969). Fruits of *Capsicum* can vary tremendously in color, shape and size both between and within species.

A native to Northern-South America, Central America and Mexico, bell peppers are sometimes grouped with less pungent pepper varieties known as "sweet peppers". In 1493 traders carried pepper seeds to Spain and later on they were introduced in other European and Asian countries. Even today, the list of major bell pepper producers is topped by Mexico.

Bell pepper also known as Shimla *mirch* or *Capsicum* (*Capsicum annum* L.) is an important vegetable crop of India. Bell pepper (*Capsicum annum* L.) is a large, crisp, bell shaped fruit of the pepper family. It is consumed in raw as well as in cooked form. Available in different bright colours including red, yellow, green and orange, this sweet fleshed member of the pepper family is also cultivated as an ornamental plant in many parts of the globe.

There are several cultivars of the bell pepper which are widely cultivated across continents. Green peppers are unripe bell peppers, while the others are all ripe, with colour variation based on cultivar selection. Since green peppers are unripe, they are less sweet and slightly bitter compared to other cultivars.

Besides being a rich source of the Vitamin C, bell pepper also contains a small quantity of Vitamin K which is important for bone health. It contains lower concentrations of saturated fat and cholesterol. Bell peppers are also an excellent source of vitamin A and C, two very powerful antioxidants that may help in reducing the risk of cardiovascular diseases and several cancers. The nutritive value of bell pepper as per ICMR, NIN Hyderabad (www.timeswellness.com) is given in appendix-I.

When used as a vegetable, bell pepper adds delicacy to every dish. It is one of the most popular salad ingredients of the world. It also tastes well when cooked with other vegetables. It is an inseparable part of traditional Mexican recipes. In many countries, bell pepper is used to add a distinctive flavour to the dish. In India, they are cooked with potatoes and other vegetables. It not only mixes well with vegetables only but also with meat dishes. Bell pepper chicken, mutton and beef are quite popular in all corners of the globe.

In the world, area and production of bell pepper is merged with that of hot pepper. Hence, the statistics related to pepper/chilli as a whole is given. India accounts for about 1202.94 thousand M.T. from an area of 767.23 thousand hectare. (Anon., 2010a). India is the world's largest producer, consumer and exporter of *Capsicum*. India also has the largest area under *Capsicum* in the world. It is grown nearly in all parts of the country, hills and plains. *Capsicum* production is spread throughout the length and breadth of the country, with almost all the states producing this crop. It can also be grown during the entire year in one or the other part of the country. However, the major arrival season extends from February to April. The planting season starts from August and extends till October. Whereas, harvesting begins from December with 5% of the arrivals usually reported in this month. Peak arrivals are reported from February to March. The market remains active till May. The major producers are Andhra Pradesh, Karnataka, MP, Orissa, Maharashtra and Tamil Nadu. In case of Gujarat, the total area under *Capsicum* is reported to be 34,394 ha with a production of 192469 tonnes during the year 2009-10 (Anon., 2010b). Major *Capsicum* growing districts in Gujarat are Narmada, Gandhinagar, Anand, Rajkot and Baroda.

Post harvest losses in fruits and vegetables vary from 20 to 30 *per cent* before they reach consumers. Fruits and vegetables contain high moisture, ranging from 70 to 95 *per cent*. Under normal atmospheric conditions they dry rapidly, which causes wilting and shriveling as a result of loss in rigidity and shrinkage of cells. The primary objective of packaging fruits and vegetables is to protect them during storage, transportation and distribution from deterioration, which may be physical, chemical or biological.

Post harvest losses in vegetables are estimated to be around 25-30 *per cent*. In capsicum, the post harvest loses vary from 4 to 35 *per cent*. The shelf life of bell pepper is 3-5 days only which is not enough for transporting it to distant markets. Improper post harvest handling often leads to water loss and shriveling, thereby retarding fruit quality. There has been a strong move towards the use of non-chemical methods, such as packaging and right storage temperature in managing post harvest pathogens (Bauchmann and Earles, 2000). Use of polythene as a packaging material in bell pepper can increase the shelf life by creating a micro climate around the fruits.

Packaging is hence provided at the point of production or processing or at distribution centers. Though packaging constitutes the last link in the chain of production, storage marketing and distribution, it still plays an important role in delivering the contents safely to the end consumers. Increase in production can have an impact on the consumer only when good quality produce is available to them at an economical price. As mentioned, about 25 to 40 *per cent* of fruits and vegetables are spoiled or become substandard during storage and distribution. This enormous wastage, which results in product scarcity and higher prices, is attributed mainly to improper handling methods, poor packaging, and inadequate transportation facilities (Chakravarty *et al.*, 2003).

Determining the best packaging material and ideal storage temperature would assist the grower, dealers and consumers in maintaining optimum quality of bell pepper for a longer period of time.

In view of the facts mentioned above, the present investigation entitled "Effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* L.) cv. Indra" was undertaken with following objectives:

1. To find out the ideal thickness of polyethylene bags for extending shelf life of bell pepper and retention of fruit quality.
2. To study the effects of perforation in polyethylene bags on shelf life of bell pepper and retention of fruit quality.
3. To identify a suitable temperature for storage of bell pepper and its effect on fruit quality.
4. To study the interaction effects.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

A brief review of work done in the light of the present investigation, pertaining to the effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* L.) cv. 'Indra' in particular and other vegetable crops in general is presented as under.

Capsicum

Akbudak (2008) studied the effect of polypropylene and polyvinyl chloride film packaging (35 µm thickness) on the quality of long pepper cv. 'Yalova Charleston' during storage. Long pepper packed in polypropylene plastic film (35 µm thickness) and stored at 7±1^{0}C temperature with 90±5% RH gave the best results with respect to acidity, ascorbic acid, chlorophyll content and fruit quality at the end of 30 days. It was also effective in delaying maturity.

Brar *et al.* (2000 a) studied the effect of polythene packaging on the shelf life of chilli cv. 'Pusa Jwala'. They reported the minimum PLW in polythene (100 gauge) packaging and the lowest decay loss in newspaper packaging when stored for 25 days at room temperature.

In a similar study with cling films, they recorded minimum physiological weight loss in chilli cv. 'Pusa Jwala' when wrapped in PVC film. The minimum decay loss was observed in control *i.e.* newspaper packing. The highest vitamin C content was noticed in fruit wrapped with LDPE film for 25 days at ambient temperature (Brar *et al.*, 2000 b).

Deb and Suresh (2008) studied the suitability of some post harvest treatment combinations for better shelf life of green chilli and found that a treatment combination comprising of LDPE packaging (100 gauge with 5% vents) + Cold Storage (6-8^{0}C, 75% RH) + GA_3 (Gibberellic acid @ 150 ppm) was the most effective for increasing the shelf life of chilli and retention of quality in respect to physiological loss in weight, green colour retention and ascorbic acid content up to the 25th day of storage.

Gonzalez-Aguilar and Tiznado (1993) evaluated the effects of individual seal packaging in Low Density Polyethylene (LDPE) films and waxing treatments on the storage quality of bell pepper. Waxed and unwaxed fruits were packaged in two LDPE bags of different thickness and stored at 10^{0}C and 75% relative humidity for up to 40 days. Packaging plus waxing significantly delayed fruit senescence reduced the change of colour, weight loss, firmness and percentage decay with respect to waxed and unwaxed fruits. No abnormal flavors were detected in peppers stored at 10°C for up to 40 days. LDPE bags plus waxing effectively prolonged the shelf life of bell pepper up to 20 days, without significant alteration in post harvest quality of pepper.

Bell pepper cv. 'Kandil' was stored in modified atmosphere condition at 8°C temperature in 85-90% relative humidity packed in perforated and non-perforated bags of polyethylene and polypropylene. Bell pepper packed in polypropylene lasted for four weeks while that packed in perforated polyethylene endured for five weeks in cold storage. Perforated polyethylene offered the best result in terms of weight loss, retention of crispiness, lower incidence of infections and chilling injury symptoms (Halloran *et al.*, 2000).

Manolopoulou *et al.* (2010) investigated the influence of modified atmosphere packaging (MAP) on green bell pepper cv. 'Twingo'. Three packaging films (LDPE 60, MDPE 30 and PVC) and two storage temperatures (5 and 10°C) were tested. The in-package O_2 concentration did not go below the 2% level. The in-package CO_2 concentration ranged between 2 and 5% in polyethylene (PE) packaging. Packaging resulted in limited mass loss and firmness reduction at both storage temperatures. Peppers packaged with the PE films did not exhibit significant changes in ascorbic acid content during the storage period including shelf-life. Peppers packaged in PE films at 5⁰C, showed significantly less chilling injuries compared to unpackaged peppers.

The effect of packaging red bell pepper fruits in various kinds of polyethylene bags, having various percentages of perforation (0.064-0.042%), was examined as a means of reducing water loss in fruits stored at a temperature of 7-8⁰C and at 3⁰C. Polyethylene bag packaging reduced water loss by 40-50% in fruits stored for two weeks at 7.5⁰C, thereby resulting in maintenance of fruit quality. Packaging did not significantly increase rot development in the stored fruits during either storage or shelf-life. Polyethylene bags enabled bell peppers to be stored at a reduced temperature (3⁰C) without the appearance of chilling injury symptoms (Meir *et al.*, 1994).

Nyanjage *et al.* (2005) tested the performance of sweet pepper cv. 'California Wonder' under three different packages (open trays, non-perforated and perforated polyethylene bags) stored at a temperature of 4, 6.5 and 17⁰C for 25 days. They recorded the lowest weight loss at storage temperatures of 4 and 6.5 ⁰C and non-perforated packaging. Colour retention was significantly the highest in fruits held at 4 and 6.5⁰C. The interaction of storage at 6.5⁰C and perforated polyethylene packaging produced the best result.

Rai *et al.* (2008) studied the effect of different packaging materials on shelf life of capsicum cv. 'TMR-23' with 12 treatments *viz.*, low density Polyethylene (PE), 100 gauge; LDPE, 100 gauge, perforated (4 holes of 2mm diameter each); LDPE 150 gauge; LDPE, 150 gauge, perforated (4 holes of 2mm diameter each); Polyethylene Terephthalate (PET), 100 gauge; PET, 100 gauge, perforated; Corrugated Fiber Board (CFB) box, 3 ply; CFB, 3 ply, perforated (4 holes of 2mm diameter each); cloth bag treated with $KMnO_4$ (1000 ppm); cloth bag untreated and control (kept open on the floor). They observed the minimum PLW and decay loss in capsicum fruits cv. 'TMR-23' when packed in polyethylene terephthalate (100 gauge) and stored at ambient temperature during 10 days of storage.

Tano *et al.* (2008) investigated the effect of different storage temperatures (6, 16, 21 and 30±2^{0}C) on the shelf life and quality of bell pepper cv. 'Adjane Gouro'. Fruits were packed in sealed perforated (about 20 holes, each 5mm in diameter) polyethylene bags of 120 gauge thickness. They observed that bell pepper fruits when sealed in perforated polyethylene bags (120 gauge) and stored at 6^{0}C had the lowest weight loss and spoilage after 20 days of storage.

Bottle gourd

Lower weight loss was reported in polythene packaging (200 gauge with 1 % vent) of bottle gourd fruits cv. 'Samrat' and 'MGH-4' as compared to newspaper wrapping. General appearance and consumer acceptability was better in fruits of 'MGH-4' cultivar up to the 6th day of storage (Gadakh *et al.*, 1995).

Bottle gourd cv. 'Pusa Naveen' was stored under three different conditions *viz.*, Zero Energy Cool Chamber (ZECC) at 22-25^{0}C and 93-97% RH, room temperature (27-34^{0}C and 50-74% RH) and basement storage (25-32^{0}C and 52-75% RH). Fruits were packed in polyethylene bags (100 gauge and 2% vents), CFB box, newspaper, polyethylene bags (100 gauge and 2% vents) + CFB box, newspaper + CFB box and control (without packaging). Bottle gourd fruit cv. 'Pusa Naveen' packed in polyethylene + CFB box packaging (100 gauge and 2% vents) and kept in Zero Energy Cool Chamber (ZECC) recorded a shelf life of 14 days with excellent quality (Patil *et al.*, 2010).

Waskar *et al.* (1999) studied the effect of packaging on the storage behavior of bottle gourd cv. 'Samrat' under different storage conditions. Fruits were packed in polyethylene bags of 100 gauge with 2% vents, Corrugated fiber board box, wooden box, polyethylene bags of 100 gauge with 2% vents + corrugated fiber board box and polyethylene bags of 100 gauge with 2% vents + wooden box along with untreated fruits as control. Packed fruits were stored at room temperature (26-30^{0}C temperature with 54-68% RH), and cool chamber (26-21^{0}C temperature with 90-94% RH). They found that fruits packed in polyethylene bags of 100 gauge thickness with 2% vents + CFB box had less physiological loss in weight, TSS, sugar and higher acidity with a shelf life of 28 days when stored in the cool chamber.

Brinjal

Brinjal fruits cv. 'Classic' were packed in unperforated low density polyethylene bags (30 µm thick) and stored at 6, 8 and 12^{0}C with relative humidity of 87-90%. Fruits could be stored for more than three weeks at 8^{0}C without sustaining any chilling injury (Fallik *et al.*, 1995).

Hemalatha *et al.* (2000) stored brinjal fruits of cv. 'KKM-1' in polyethylene bags of four different gauges (100, 200, 300 and 400 gauge) with six different levels of ventilation (0, 0.5, 1.0, 1.5 and 2.5%) at ambient temperature. They found that fruit quality and shelf life (8 days as compared to 3 days for the control) were best in polyethylene bags of 200 gauge with 1 *per cent* ventilation.

Cucumber

Adamicki (1985) found that fruits of cucumber cv. 'Skierniewicki' wrapped in plastic film (polyethylene or polyvinyl chloride) and held at 5, 12.5 and 15°C for 7 and 14 days and subsequently for 2 days at 20°C, showed a significant decrease in weight loss as compared to non wrapped fruits. Wrapping extended the shelf life by over a day and also resulted in a slight improvement in quality over control fruits.

Dhall *et al.* (2008) evaluated the effect of shrink wrapping on shelf life and quality of cucumber cv. 'Padmini' under different storage conditions. Fruits were individually wrapped with Cryovac D955 (60 gauge) and stored at 12±1°C, 90-95% RH as well as under ambient condition (29-33°C, 65-70% RH). They concluded that individually shrink wrapped cucumber fruits can be stored for up to 15 days at 12±1°C, 90-95% RH and for 5 days under ambient condition (29-33°C, 65-70% RH) with maximum retention of green colour, no spoilage, minimum weight loss and firmness loss with very good sensory quality.

Wang and Qi (1997) studied modified atmosphere packaging in cucumber and observed less severe chilling injury in 31.75 µm Low Density Polyethylene (LDPE) bags stored at 5°C and 90-95% relative humidity. The onset of chilling injury was delayed by LDPE packaging as compared to non packaged control. Fruits in sealed bags also had the least decay.

Okra

Anandaswamy *et al.* (1963) studied the packaging of fresh okra using different packaging materials *viz.*, 100 gauge and 200 gauge low density polyethylene and MST (300 gauge) cellulose film bags with and without ventilation under room temperature (22-26°C, 50-78% RH), standard condition (24-26°C, 72-75% RH) and low temperature condition (11-13°C, 85-90% RH). They reported a shelf life of 16-18 days in okra fruits packed in polyethylene films of 200 gauge thickness (without ventilation). This treatment recorded the minimum PLW and the maximum ascorbic acid with no significant change in acidity and reducing sugar as against a shelf life of 10-11 days in unpacked fruits stored at a temperature of 11-13°C with 85-90 % RH.

Fernando *et al.* (2008) investigated the effect of temperature and PVC film on the development of chilling injury and storability in okra cv. 'Amarelinho'. Fruits were wrapped in Polyvinyl Chloride (PVC) over a polystyrene tray and stored at 5, 10 and 25°C temperature. The PVC film was effective in reducing the water loss and maintaining the water content in okra regardless the temperature of storage used. The modified atmosphere induced by the PVC film reduced chilling injury development in fruits stored at a temperature of 5°C. The rate of chlorophyll degradation was diminished by reducing the temperature and by wrapping the fruits with PVC film.

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Freshly harvested three varieties of okra namely 'Punjab-7', 'Punjab Padmini' and 'EMS-8' were assessed for their shelf life under refrigerated temperature (8-10^{0}C, 85-90% RH) and ambient conditions (26-34^{0}C, 65-90% RH) by packing them in perforated and non perforated (12 holes amounting to 0.4% ventilation) polypropylene and low density polyethylene bags of 200 gauge thickness. The shelf life of okra cv. 'Punjab Padmini' could be increased from 3 to 15 days when packed in unventilated polypropylene bags and stored at low temperature (Kalra *et al.*, 1988).

Rai *et al.* (2009) evaluated the qualitative and textural changes in freshly harvested okra pods under modified atmosphere packaging in perforated film packages. Okra pods were packed in 35μm thick polypropylene films and stored at 15^{0}C temperature with 75% relative humidity under a modified atmosphere. A gaseous range of 6.3-8.4% for O_2 and 10.7-11.8% for CO_2 resulted in the maintenance of green colour, β- carotene and ascorbic acid.

Sankaran *et al.* (2005) revealed that okra fruits cv. 'Parbhani Kranti' packed in 5 ply Corrugated Fiber Board (CFB) boxes (1% ventilation) and kept at 10 and 12^{0}C temperature recorded the minimum physiological loss in weight, the maximum ascorbic acid and freshness score when stored for up to 14 days.

Singh and Dhankhar (1980) treated okra cv. 'Pusa Sawani' with GA (100 and 250 ppm) and ascorbic acid (100 and 250 ppm) along with polyethylene packaging (100 gauge). They observed the minimum weight loss and the maximum retention of chlorophyll 'a' and 'b' pigments in packaged fruits dipped in GA@100 ppm and stored at a temperature of 10 + 1^{0}C for 12 days.

Singh *et al.* (1980) evaluated the effect of packaging on okra cv. 'Pusa Sawani' using polyethylene films of varying thickness (400, 300, 200 and 100 gauge bags) stored at room temperature (32 + 2^{0}C). Okra packed in 400 gauge polythene films had a shelf life of 9 days as against 2-3 days in unpacked fruits. Fruits packed in 400 gauge thickness polyethylene films had the minimum PLW and also showed higher retention of chlorophyll 'a' and 'b'.

Wagner *et al.* (2010) evaluated the influence of PVC film and temperature (5 or 10^{0}C) on the postharvest storage life in four cultivars ('Amarelinho', 'Red Velvet', 'Star of David' and 'Mammoth Spinless') of okra. Storage at 10^{0}C and wrapping the fruits in PVC film reduced the loss of fresh mass. The film was more efficient in maintaining higher water content in the pericarp at 5 or 10^{0}C. Fruits stored at 5^{0}C had higher vitamin C content. The development of chilling and browning was higher in fruits without PVC film at 5^{0}C.

Spinach

Pathan (2003) assessed the effect of packaging and storage temperature on the shelf life of spinach. Spinach was packed in polyethylene bags (100, 200 and 300 gauge) with 0.5% perforation and stored at 5, 10, 15^{0}C and ambient temperature. Spinach packed in polyethylene bags (300 gauge) and stored at 5^{0}C maintained its chemical composition, colour and texture for a longer period of time (14 days).

Tomato

A range of plastic films with different permeability properties were tested to study their effect on the changes in post harvest qualities of tomatoes stored at 13^{0}C for 60 days. The film used were 20μ (PE20) and 50μ (PE50) polyethylene, 10μ Polyvinyl Chloride (PVC) and 25μ Polypropylene (PP) compared with unwrapped fruits as control. Tomato fruits cv. 'Liberto' packed in polyethylene (200 gauge) and polypropylene (100 gauge) had the lowest weight loss and decay loss when stored at 13^{0}C for up to 60 days of storage (Batu and Thomson, 1998).

Gopalkrishna (1984) found that tomato fruits harvested at mature green stage could be stored successfully for 4 to 5 weeks at 53-54^{0}F in polyethylene bags of 100 gauge thickness.

Tomato fruits of cultivar 'CLN1462A' were held in five types of commercially available polymeric films: 100 and 200 gauge thick Low Density Polyethylene (LDPE) and Polypropylene (PP); 100 gauge thick High Density Polyethylene (HDPE) films. Fruits were held in MAP for 10 days to stimulate prolonged transport and holding period and then transferred to open condition. Fruits continuously held in the open served as control. Fruits packed in MAP (100 gauge thick LDPE) had higher fruit firmness, TSS, titratable acidity, overall sensory acceptability and minimum weight loss for a period of 10 days (Vanndy *et al.*, 2008).

Other Vegetable Crops

Ben-Yehoshua *et al.* (1980) assessed the effect of seal packaging in plastic films on deterioration in vegetables. They observed a 10 to 30 fold reduction in weight loss of cucumber, brinjal, capsicum, carrot and cauliflower when seal packed in polyethylene films of 40, 80 and 120 gauge thickness over non sealed packages. Sealed packages also retained firmness and quality for a longer period.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The experiment entitled "Effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* L.) cv. Indra" was carried out in the year 2010. The details of the material used, experimental procedures followed and techniques adopted during the course of present investigation are described in this chapter.

3.1 Experimental Location

The experiment was carried out at Post Harvest Technology Laboratory, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. It is situated on the coast of Arabian Sea at 72° 54′ E longitudes, 20°-58′ N latitude with an altitude of 10-12 meters above sea level. It is 13 km away from the seashore.

3.2 Climate and Weather

The Navsari Campus is located in South Gujarat Heavy Rainfall Agro climatic Zone I and is characterized by fairly hot summer, warm and humid monsoon and moderately cold winter.

Monsoon commences form the second week of June and retreats by the end of October. Most of the rainfall is received during the month of July and August. The annual precipitation varies from 1117.3 mm to 2207.0 mm. The winter season sets in by the end of October and continues till the end of February. December and January are the coldest month of winter. The temperature starts rising from February and reaches the maximum in the month of May.

The meteorological data on mean maximum and minimum air temperature, relative humidity and bright sunshine hours for the period of experimentation as recorded at the meteorological observatory of College Farm, Navsari Campus are presented in Appendix-II.

3.3 Experimental details

Bell pepper (*Capsicum annum* L.) cv. Indra was purchased from a farmer residing in Ambheta village of Gandevi taluka under Navsari district. Indra is well suited for cultivation in *kharif* and *rabi* season. Plants are medium tall, bushy having vigorous growth. Fruits are dark green, thick-walled and glossy with an average weight of 150 g, 10-12 cm in length and 10 cm in girth having 3-4 lobes. Fruit setting starts in 50-55 days after transplanting.

Physiologically mature fruits were harvested for the experiment. Harvested fruits were carefully transported to the storage unit. Fruits were sorted based on their size. Those with defects or diseases were discarded.

Method and time of fruit sampling

Five fruits were selected from each lot at a time and used for chemical analysis. Overall Visual Quality (OVQ) was measured from a sample size of ten fruits. All observations except OVQ were recorded immediately after harvest and 5 days interval *i.e.* 5, 10, 15, 20 and 25 days after treatment till the fruits maintained their marketability. OVQ was measured on the 15th day of storage. For chemical analysis, fruit pulp was homogenized in a blender and used for determination of chlorophyll content, carotenoid content and ascorbic acid content.

3.4 Experimental Design and Treatment Details

3.4.1 Experimental Design

The experiment was evaluated in a Completely Randomized Design based on Factorial Concept (FCRD). It comprised of packing fruits in LDPE bags of varying thickness (perforated as well as non-perforated) and storing them at two different temperatures. Treatments were repeated thrice.

3.4.2 Treatment Details

Factor I : LDPE packaging (P)

P_1- 200 gauge thickness

P_2- 300 gauge thickness

P_3- 400 gauge thickness

Factor II : With and without perforation (W)

W_1- Without perforation

W_2- With perforations

(5mm^2 hole per 25cm^2 area)

Factor III : Storage temperature (T)

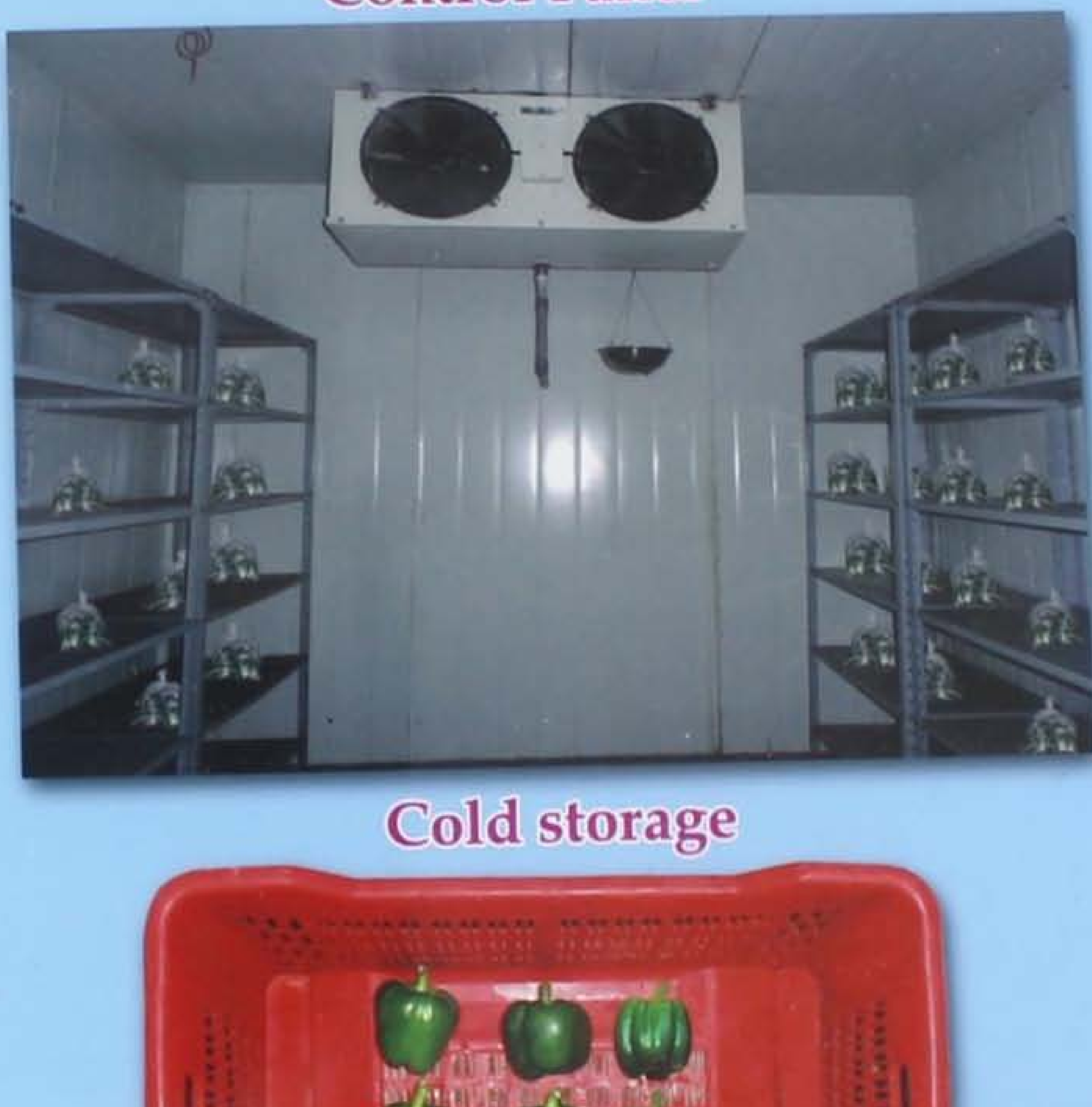
T_1- 8^{0}C with 95% RH

T_2- 12^{0}C with 95% RH

Treatment Combinations

1	$P_1W_1T_1$
2	$P_1W_1T_2$
3	$P_1W_2T_1$
4	$P_1W_2T_2$
5	$P_2W_1T_1$
6	$P_2W_1T_2$
7	$P_2W_2T_1$
8	$P_2W_2T_2$
9	$P_3W_1T_1$
10	$P_3W_1T_2$
11	$P_3W_2T_1$
12	$P_3W_2T_2$
13	**Control I :** Stored at 8^0 C in rigid plastic crates
14	**Control II :** Stored at 12^0 C in rigid plastic crates

Control Panel



Cold storage

Fruits kept in rigid plastic crate

Plate I. General view of experiment

3.5 Packaging Details

Fruits were packed in perforated (about 16 holes, each of 5mm diameter) and non-perforated LDPE bags (30 cm × 25 cm size) of different thickness *viz.*, 200, 300 and 400 gauge thickness. Perforated and unperforated bags were identical in size and weight. About 1 kg fruits were packed in each bag and its mouth tied tightly by means of a rubber band. Samples kept in rigid plastic crates served as control.

3.6 Storage Details

The bell pepper fruits were stored at two different storage temperatures *viz.*, 8^0C and 12^0C. The relative humidity was maintained at 95% during the entire period of experimentation.

3.7 Observations to be recorded

(A) Physiological parameters

1. Physiological loss in weight (%)
2. Chilling injury (%)
3. Total chlorophyll content (mg/100g FW)
4. Carotenoids (mg/100g FW)
5. Rate of respiration (CO_2 mg/kg/hr)

(B) Physical parameters

1. Firmness (kg/cm^2)
2. Shrinkage (%)
3. Bulk density (g/cm^3)

(C) Biochemical parameters

1. Ascorbic acid (mg/100g)
2. TSS (%)

(D) Overall Visual Quality (OVQ) measurement

(Fruit colour, Fruit succulence, General appearance and Fruit odour)

(E) Pathological disorders

1. Disease incidence (%)

3.8 Methodology adopted for preparation of treatments

3.8.1 Physiological loss in weight (%)

For determining the physiological loss in weight, fruits were weighed before imposing the treatment which served as the initial fruit weight. The loss in weight was recorded at 5 days interval until 25 days which served as the final weight. The physiological loss in weight was determined by the following formula and expressed as percentage.

$$\text{PLW (\%)} = \frac{\text{Initial fruit weight} - \text{Fruit weight on the day of observation}}{\text{Initial fruit weight}} \times 100$$

3.8.2 Chilling injury (%)

The incidence of chilling injury was calculated by counting the number of fruits with symptoms as a percentage of the total number of fruits per bag. Incidence of chilling injury was determined at an interval of five days. Symptoms considered for chilling injury were brownish discoloration, pitting and water soaked lesions.

$$\text{Chilling Injury (\%)} = \frac{\text{Number of injured fruits}}{\text{Total number of fruits}} \times 100$$

3.8.3 Total chlorophyll content (mg/100g FW)

The total chlorophyll content in fruit was determined by DMSO (Dimethylsulphoxide) method (Hiscox and Israelstam, 1979). Finely chopped 50 mg peels were weighed in graduated test tube. 10 ml of DMSO was added in each test tube. The tubes were incubated at 65°C for 3 hours. After incubation, the tubes were kept at room temperature and optical density (OD) was recorded at 663 and 645 nm taking DMSO as blank. The amount of chlorophyll present in the sample was calculated using the formula and expressed as mg/100g FW.

$$\text{Total chlorophyll content (mg/100g tissue)} = 22.2\,(\text{OD at } 645) + 8.02\,(\text{OD at } 663) \times \frac{V}{W\,(g)}$$

Where,

V = Final volume of extract in DMSO

W = Fresh weight of tissue extracted (g)

3.8.4 Carotenoids (mg/100g FW)

Carotenoids content was determined using the same extract (used for chlorophyll) and absorbance was recorded at 480 nm. Carotenoid content was calculated using the formula given by Wellburn (1994).

$$\text{Carotenoids } (\mu g\ ml^{-1}) = \frac{(1000\ A480 - 2.14\ Ca - 70.16\ Cb)}{220}$$

(Cx + C)

Where,

Ca = Chlorophyll a = 12.19 A649 - 3.45 A649

Cb = Chlorophyll b = 21.99 A649 - 5.32 A665

$\mu g\ ml^{-1}$ was converted into mg/100g FW by dilution factor.

3.8.5 Rate of respiration (CO_2 mg/kg/hr)

Fruits for measuring respiratory activity were tagged in each lot of treatment. Every fifth day, selected fruits were weighed. Then the fruits were placed in a known volume of polythene bag and sealed. Initial CO_2 concentration was recorded before sealing the polythene bag. After 1 hour, increase in CO_2 concentration was recorded using Infra-Red Gas Analyzer. Respiration rate of fruits was measured by adopting the formula.

$$\text{Respiration rate } (mg\ CO_2/kg/hr) = \frac{CO_2 \text{ concentration change in \%} \times \text{Density of } CO_2 \text{ at temperature} \times (\text{Volume of chamber} - \text{volume of fruit})}{\text{Fruit weight} \times \text{Time}}$$

3.8.6 Firmness (kg/cm^2)

Firmness was measured by using a pocket penetrometer. The penetrometer was adjusted to zero and pierced into the fruit up to the knob. The pressure required to penetrate the penetrometer was recorded in kg/cm^2 provided on the circular disc of the pocket penetrometer. Average firmness from two opposite sides of the same fruit were computed and recorded.

3.8.7 Shrinkage (%)

The volume of selected fruits was measured on the first day of experimentation. Subsequently at 5 days intervals, their volume was recorded and the decrease in volume was expressed as percentage over the initial volume.

$$\text{Shrinkage (\%)} = \frac{\text{(Initial volume - Final volume)}}{\text{Initial volume}} \times 100$$

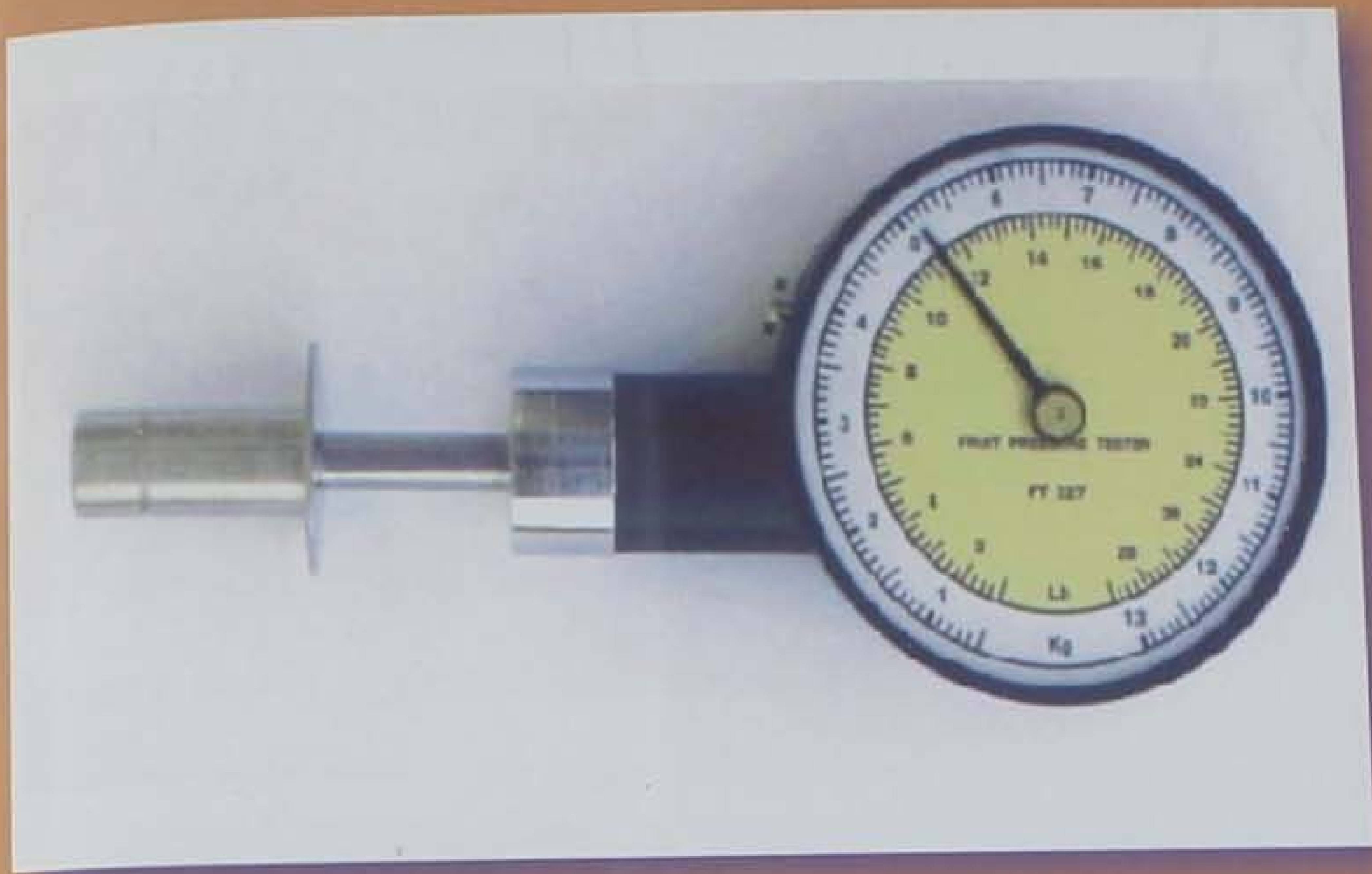
3.8.8 Bulk density (g/cm^3)

Bulk density of fruits was measured by dividing the weight of selected fruits by their volume.

$$\text{Bulk density } (g/cm^3) = \frac{\text{Weight of fruit}}{\text{Volume of fruit}}$$

3.8.9 Ascorbic acid (mg/100g)

Titrimetric method described by Ranganna (1979) was adopted for estimation of the ascorbic acid.



Penetrometer

Refractometer

Plate II. Tools for measuring firmness and TSS

Procedure

Ten grams of the homogenized okra pulp was taken and transferred in 100 ml volumetric flask. The volume was made up with 4 *per cent* oxalic acid solution. After 30 minutes, the suspension was filtered through Whatman No. 1 filter paper. Before titration the 2, 6-Dichlorophenol indophenol (Dye solution) was standardized by titrating against standard ascorbic acid solution and the dye factor was calculated. Five ml of the aliquot was taken from the filtrate and titrated against standardized dye solution through a burette. Titration was continued till light pink colour persisted for 15 seconds. The ascorbic acid content was calculated adopting the following formula and expressed as mg/100g.

$$\text{Ascorbic acid content (mg/100g)} = \frac{\text{Titrate} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Weight or Volume of sample taken for estimation}}$$

3.8.10 TSS (%)

TSS content was determined using a hand refractometer to analyze the juice squeezed from each pepper and the results were reported as percentage.

3.8.11 Overall Visual Quality (OVQ) measurement

The sensory evaluation for assessing the general appearance and off odour was done by a panel of five judges by using the following gradation in each character.

++++	Excellent
+++	Good
++	Acceptable
+	Non acceptable

3.8.12 Disease incidence (%)

Disease incidence was calculated by counting the number of fruits showing symptoms of a particular disease as a percentage of the total number of fruits per bag. Disease incidence was determined at the every fifth day intervals.

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased fruits}}{\text{Total number of fruits}} \times 100$$

3.8.13 Statistical analysis

The data collected were analyzed statistically as per the procedure appropriate for Completely Randomized Design with Factorial Concept (FCRD) and the treatment means were compared by means of critical differences at 5 *per cent* level of probability (Panse and Sukhatme, 1967). The interaction between storage and packaging materials was also worked out. Data was analyzed statistically in the Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of a laboratory experiment entitled "Effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* L.) cv. Indra" conducted during the year 2010-11 at the Post Harvest Technology Laboratory, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari are presented in this chapter with the help of tables and illustrations wherever felt necessary for better understanding of the findings. Observations on various parameters: physiological, physical, biochemical and pathological disorders during storage were recorded and the data thus generated analyzed using standard statistical methods. For the sake of convenience and clarity, the data recorded on 5th and 10th day of this experiment was analyzed in FCRD design and for 15th, 20th and 25th days in simple CRD design. This facilitated a better understanding of individual factors in earlier days and their combinations in later days. The results have been interpreted and presented under the following subheadings.

4.1. Physiological loss in weight (%)

The data pertaining to physiological loss in weight as affected by packaging, perforation and temperature on the 5th, 10th, 15th, 20th and 25th day of the investigation is presented in Tables 4.1 to 4.6 and graphically depicted in Fig. 4.1. It is evident from Table 4.1 that physiological loss in weight increased progressively with extended storage irrespective of treatments.

Table 4.1 : Effect of polyethylene packaging, perforation and temperature on physiological loss in weight (%) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 – 200 gauge thickness	5.60	6.27
P_2 – 300 gauge thickness	4.13	5.07
P_3 – 400 gauge thickness	3.22	4.12
Mean	3.22	4.12
S.Em. ±	0.020	0.010
CD at 5%	0.06	0.03
With and Without Perforation (W)		
W_1 - Without perforation	2.88	3.94
W_2 - With perforations	5.76	6.37
Mean	2.88	3.94
S.Em. ±	0.016	0.009
CD at 5%	0.05	0.02
Temperature (T)		
T_1 - 8°C temperature	3.29	4.30
T_2 - 12°C temperature	5.34	6.00
Mean	3.29	4.30
S.Em. ±	0.016	0.009
CD at 5%	0.05	0.02
CV%	1.41	0.70

* Initial value 0.00 %

4.1.1. Effect of Packaging

There was a significant effect of packaging on the Physiological Loss in Weight (PLW) of bell pepper fruits (Table 4.1). PLW was significantly the lowest in polyethylene bags of 400 gauge thickness on the 5th (3.22%) and 10th day (4.12%) of storage, respectively. Whereas, the highest PLW (5.60 and 6.27%) was noticed in bags of 200 gauge thickness (P_1).

4.1.2. Effect of Perforation

The data furnished in Table 4.1 revealed a significant effect of perforation on PLW of bell pepper fruits. PLW was lower in unperforated bags on the 5th (2.88%) and 10th day (3.94%) of storage, respectively. Higher PLW (5.76 and 6.37%) was observed in perforated bags on the 5th and 10th day of experimentation.

4.1.3. Effect of Low Temperature Storage

The data illustrated a significant effect of storage temperature on PLW of bell pepper fruits (Table 4.1). PLW was lower at 8°C temperature on the 5th (3.29%) and 10th day (4.30%). Whereas, higher PLW (5.34 and 6.00%) was observed at 12°C temperature.

4.1.4. Interaction Effect

The interactions between P x W, P x T, W x T and P x W x T with respect to PLW were found significant on the 5th and 10th day of storage. These interactions are interpreted as under.

4.1.4.1. P x W Interaction

Bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness (P_3W_1) registered significantly the lowest PLW (2.04 and 3.07%) on the 5th and 10th day, respectively (Table 4.2).

Table 4.2 : Interaction effect of polyethylene packaging and perforation on physiological loss in weight (%) of capsicum fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day		10th day	
	W_1	W_2	W_1	W_2
P_1	4.12	7.09	5.05	7.50
P_2	2.47	5.78	3.69	6.45
P_3	2.04	4.40	3.07	5.17
S.Em. ±	0.028		0.015	
CD at 5%	0.08		0.04	

The highest PLW (7.09 and 7.50%) was recorded in bell pepper fruits packed in perforated polyethylene bags of 200 gauge thickness (P_1W_2).

4.1.4.2. P x T Interaction

Fruits packed in polyethylene bags of 400 gauge thickness and stored at 8^0C temperature (P_3T_1) revealed the lowest PLW (2.33 and 3.37%) on the 5th and 10th day of storage (Table 4.3).

Table 4.3 : Interaction effect of polyethylene packaging and temperature on physiological loss in weight (%) of capsicum fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day		10th day	
	T_1	T_2	T_1	T_2
P_1	4.40	6.80	5.37	7.17
P_2	3.12	5.13	4.18	5.97
P_3	2.33	4.11	3.37	4.87
S.Em. ±	0.028		0.015	
CD at 5%	0.08		0.04	

The highest PLW (6.80 and 7.17%) was recorded in bell pepper fruits packed in 200 gauge polyethylene bags and stored at 12⁰C temperature (P_1T_2).

4.1.4.3. W x T Interaction

Fruits packed in unperforated polyethylene bags and stored at 8⁰C temperature (W_1T_1) showed the lowest PLW (1.76 and 2.96%) on the 5th and 10th day (Table 4.4).

Table 4.4 : Interaction effect of perforation and temperature on physiological loss in weight (%) of capsicum fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day		10th day	
	T_1	T_2	T_1	T_2
W_1	1.76	3.99	2.96	4.91
W_2	4.81	6.70	5.65	7.10
S.Em. ±	0.023		0.012	
CD at 5%	0.07		0.04	

The highest PLW (6.70 and 7.10%) was recorded in bell pepper packed in perforated polyethylene bags and stored at 12^0C temperature (W_2T_2).

4.1.4.4. P x W x T Interaction

Bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$) showed the lowest PLW (1.22 and 2.14%) on the 5th and 10th day of storage (Table 4.5).

Table 4.5 : Interaction effect of polyethylene packaging, perforation and temperature on physiological loss in weight (%) of capsicum fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day			10th day		
		T_1	T_2		T_1	T_2
P_1	W_1	2.18	6.05	W_1	3.58	6.51
	W_2	6.62	7.55	W_2	7.16	7.83
P_2	W_1	1.88	3.06	W_1	3.17	4.22
	W_2	4.37	7.20	W_2	5.18	7.71
P_3	W_1	1.22	2.86	W_1	2.14	4.00
	W_2	3.44	5.35	W_2	4.60	5.74
S.Em. ±	0.040			0.021		
CD at 5%	0.12			0.06		

The highest PLW (7.55 and 7.83%) was registered in fruits packed in 200 gauge perforated polyethylene bags and kept at 12^0C temperature ($P_1W_2T_2$).

4.1.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

A close look at Table 4.6 revealed a significant effect of polyethylene packaging, perforation and storage temperature on PLW of bell pepper fruits. The lowest PLW (3.45, 4.11 and 5.14 %) was recorded in fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8⁰C temperature ($P_3W_1T_1$) on the 15th, 20th and 25th day of storage. Whereas, the highest PLW (6.97%) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 200 gauge ($P_1W_1T_2$) stored at 12⁰C on the 15th day and in unperforated polyethylene bags of 300 gauge stored at 12⁰C ($P_2W_1T_2$) on the 20th day (5.89%). On the 25th day of storage, $P_3W_1T_1$ treatment was found superior (5.14 %).

4.1.6. Within Control

The data pertaining to PLW presented in Table 4.6 showed significant results on the 5th day of storage.

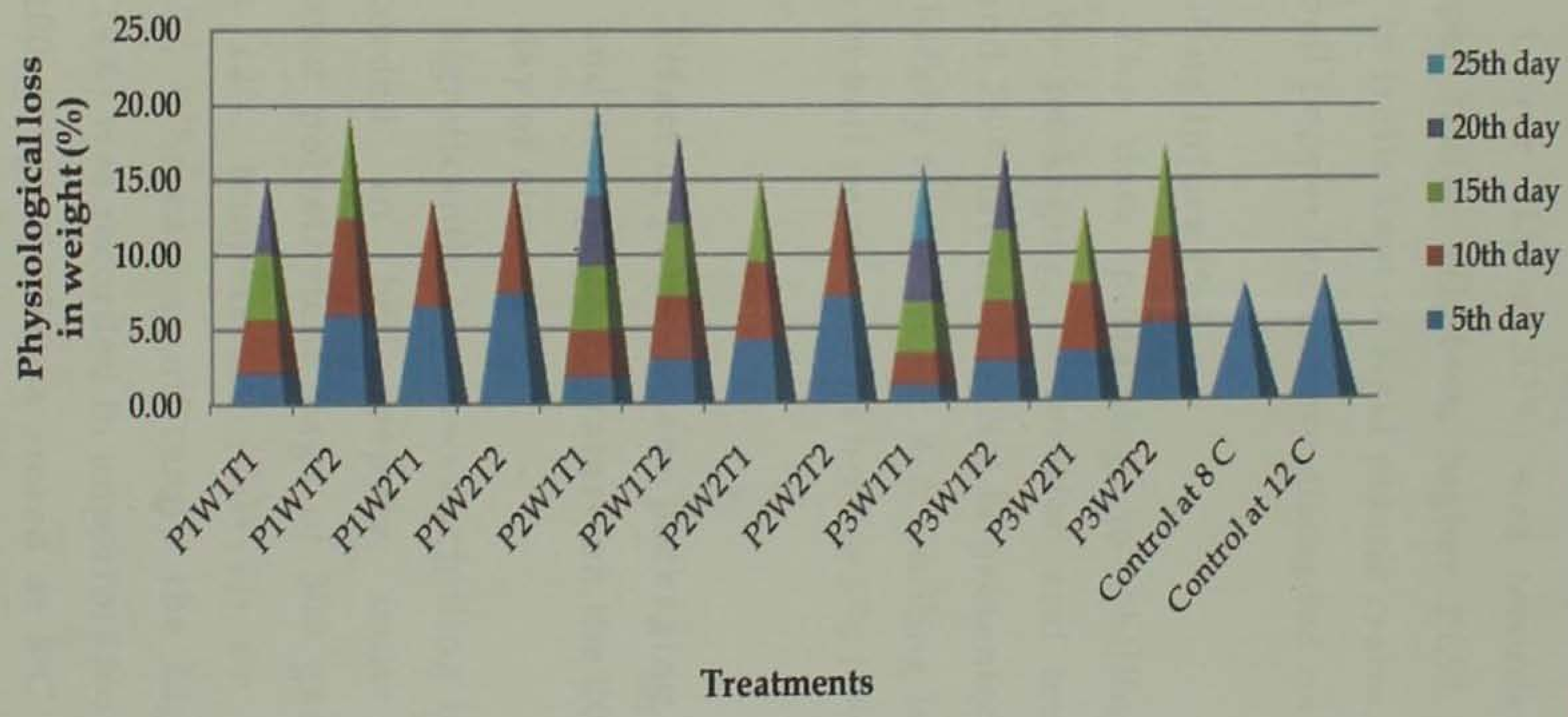
Lower PLW (7.97%) was recorded in bell pepper fruits kept in plastic crates at 8⁰C temperature. Whereas, higher PLW (8.43%) was recorded in fruits stored at 12⁰C temperature.

Table 4.6 : **Effect of polyethylene packaging, perforation and low temperature storage on physiological loss in weight (%) of bell pepper fruits cv. 'Indra'.**

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	2.18	3.58	4.38	5.21	-
$P_1W_1T_2$	6.05	6.51	6.97	-	-
$P_1W_2T_1$	6.62	7.16	-	-	-
$P_1W_2T_2$	7.55	7.83	-	-	-
$P_2W_1T_1$	1.88	3.17	4.26	4.68	6.27
$P_2W_1T_2$	3.06	4.22	4.90	5.89	-
$P_2W_2T_1$	4.37	5.18	5.85	-	-
$P_2W_2T_2$	7.20	7.71	-	-	-
$P_3W_1T_1$	1.22	2.14	3.45	4.11	5.14
$P_3W_1T_2$	2.86	4.00	4.74	5.52	-
$P_3W_2T_1$	3.44	4.60	5.10	-	-
$P_3W_2T_2$	5.35	5.74	6.37	-	-
Mean	4.32	5.15	5.11	5.08	5.71
S.Em. ±	-	-	0.020	0.022	-
CD at 5%	-	-	0.06	0.07	-
Control at 8^{0}C	7.97	-	-	-	-
Control at 12^0 C	8.43	-	-	-	-
Mean	8.20	-	-	-	-
Treated vs. Control					
S.Em. ±	0.021	-	-	-	-
CD at 5%	0.06	-	-	-	-
Within Control					
S.Em. ±	0.040	-	-	-	-
CD at 5%	0.12	-	-	-	-
CV%	1.41	0.70	0.66	0.76	-

* Initial value 0.00 %

Fig. 4.1 Effect of packaging, perforation and low temperature storage on physiological loss in weight (%) of bell pepper cv. 'Indra'



4.1.7. Treated vs. Control

The data for PLW furnished in Table 4.6 showed significant results on the 5th day of storage.

Lower PLW (4.32%) was recorded in treated bell pepper fruits. Whereas, higher PLW (8.20%) was recorded in fruits kept in rigid plastic crates. Due to poor quality, bell pepper fruits were discarded on the 5th day.

4.2. Chilling injury (%)

The data pertaining to chilling injury as affected by packaging, perforation and temperature on the 20th and 25th day of the trial is presented in Table 4.7 and graphically traced in Fig. 4.2. Chilling injury was not observed in bell pepper fruits on the 5th, 10th and 15th day of storage.

4.2.1. Effect of polyethylene packaging, perforation and storage temperature on the 20th and 25th day of storage

Significantly the lowest chilling injury (4.40%) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 300 gauge thickness stored at 12^{0}C temperature ($P_2W_1T_2$) on the 20th day (Table 4.7). Whereas, significantly the highest chilling injury (8.14%) was recorded in unperforated polyethylene bags of 200 gauge thickness stored at 8^{0}C ($P_1W_1T_1$). On the 25th day of storage, minimum chilling injury (6.56 %) was observed in $P_3W_1T_1$ treatment.

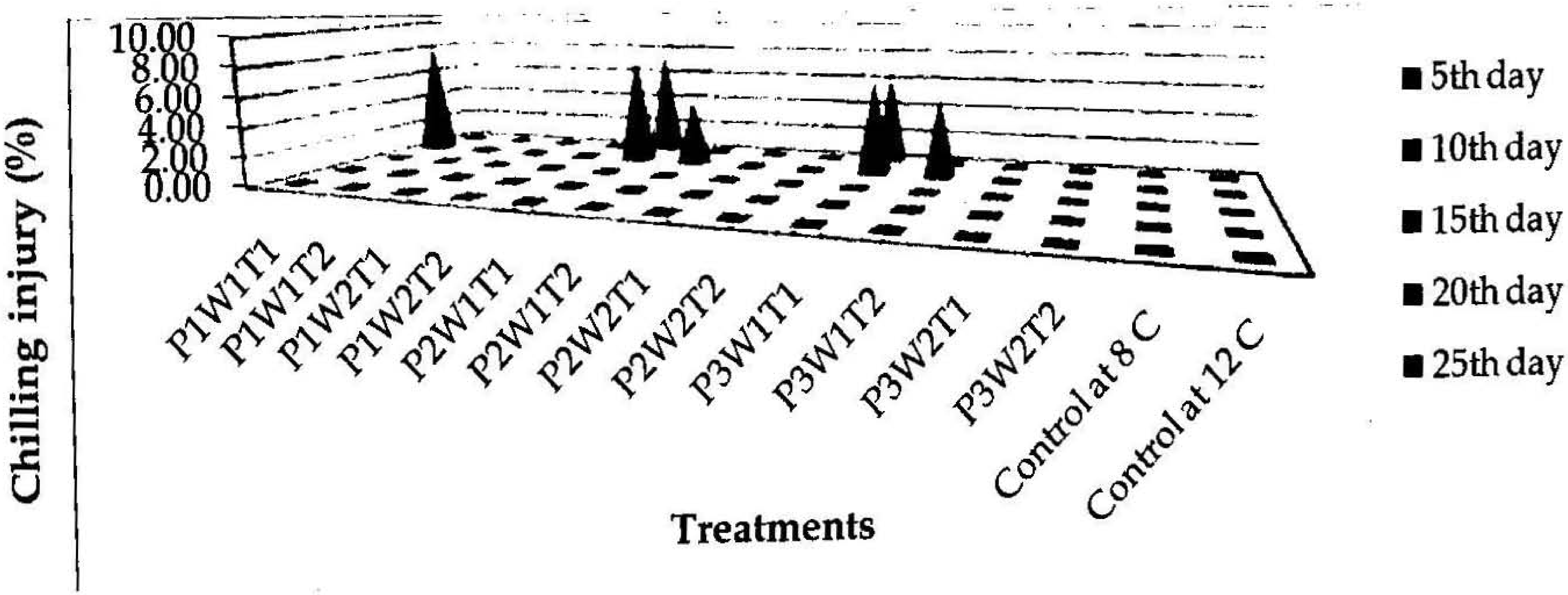
Table 4.7 : **Effect of polyethylene packaging, perforation and low temperature storage on chilling injury (%) of bell pepper fruits cv. 'Indra'.**

Treatments	20th day	25th day
$P_1W_1T_1$	8.14	-
$P_1W_1T_2$	-	-
$P_1W_2T_1$	-	-
$P_1W_2T_2$	-	-
$P_2W_1T_1$	7.46	7.57
$P_2W_1T_2$	4.40	-
$P_2W_2T_1$	-	-
$P_2W_2T_2$	-	-
$P_3W_1T_1$	6.50	6.56
$P_3W_1T_2$	5.37	-
$P_3W_2T_1$	-	-
$P_3W_2T_2$	-	-
Mean	6.38	-
S.Em. ±	0.130	-
CD at 5%	0.41	-
CV%	3.53	-

*Initial value 0.00 %

Note: Chilling injury was not noticed in bell pepper fruits on the 5th, 10th and 15th day of storage, irrespective of treatments

Fig. 4.2 Effect of packaging, perforation and low temperature storage on chilling injury (%) of bell pepper cv. 'Indra'



4.3. Chlorophyll content (mg/100g)

The data pertaining to chlorophyll content as affected by packaging, perforation and low temperature storage on the 5th, 10th, 15th, 20th and 25th day of the investigation is presented in Table 4.8, 4.9 and graphically sketched in Fig. 4.3. There was a gradual reduction in chlorophyll content during the course of this investigation across all treatments.

4.3.1. Effect of Packaging

A perusal of data envisaged in Table 4.8 suggested a significant effect of packaging on chlorophyll content of bell pepper fruits. Chlorophyll content was significantly the highest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness on the 5th (1.88 mg/100g) and 10th day (1.86 mg/100g) of storage, respectively. Whereas, the lowest chlorophyll content (1.78 and 1.76 mg/100g) was noticed in bags of 200 gauge thickness. Due to shrivelling, fruits kept in rigid plastic crates were removed on the 5th day.

4.3.2. Effect of Perforation

The data revealed a significant effect of perforation on chlorophyll content of bell pepper fruits (Table 4.8). The chlorophyll content was higher in bell pepper fruits packed in unperforated bags on the 5th (1.90 mg/100g) and 10th day (1.88 mg/100g) of storage, respectively. Whereas, lower chlorophyll content (1.77 and 1.74 mg/100g) was recorded in perforated bags.

Table 4.8 : Effect of polyethylene packaging, perforation and temperature on chlorophyll content (mg/100g) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	1.78	1.76
P_2 - 300 gauge thickness	1.84	1.82
P_3 - 400 gauge thickness	1.88	1.86
Mean	1.78	1.76
S.Em. ±	0.010	0.012
CD at 5%	0.03	0.03
With and Without Perforation (W)		
W_1 - Without perforation	1.90	1.88
W_2 - With perforations	1.77	1.74
Mean	1.77	1.74
S.Em. ±	0.008	0.009
CD at 5%	0.02	0.03
Temperature (T)		
T_1 - 8°C temperature	1.88	1.86
T_2 - 12°C temperature	1.79	1.76
Mean	1.79	1.76
S.Em. ±	0.008	0.009
CD at 5%	0.02	0.03
CV%	1.86	2.21

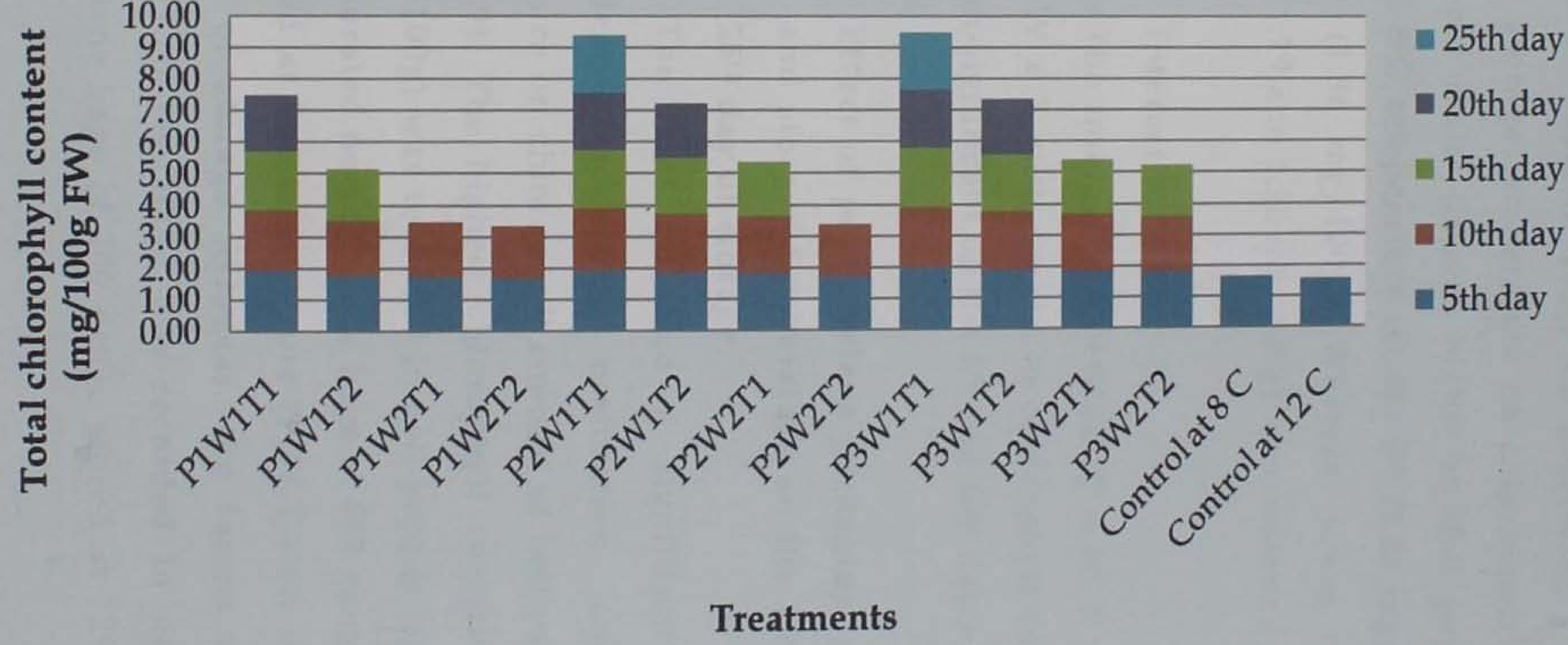
* Initial value 1.99 mg/100g

Table 4.9 : Effect of polyethylene packaging, perforation and low temperature storage on chlorophyll content (mg/100g) of bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	1.93	1.92	1.84	1.81	-
$P_1W_1T_2$	1.77	1.75	1.65	-	-
$P_1W_2T_1$	1.74	1.71	-	-	-
$P_1W_2T_2$	1.67	1.65	-	-	-
$P_2W_1T_1$	1.95	1.93	1.86	1.84	1.80
$P_2W_1T_2$	1.88	1.85	1.78	1.72	-
$P_2W_2T_1$	1.83	1.81	1.72	-	-
$P_2W_2T_2$	1.71	1.68	-	-	-
$P_3W_1T_1$	1.97	1.94	1.88	1.86	1.83
$P_3W_1T_2$	1.90	1.88	1.81	1.77	-
$P_3W_2T_1$	1.85	1.83	1.75	-	-
$P_3W_2T_2$	1.80	1.78	1.68	-	-
Mean	1.83	1.81	1.77	1.80	1.82
S.Em. ±	-	-	0.010	0.010	-
CD at 5%	-	-	0.03	0.03	-
Control at 8ºC	1.63	-	-	-	-
Control at 12ºC	1.56	-	-	-	-
Mean	1.60	-	-	-	-
Treated vs. Control					
S.Em. ±	0.010	-	-	-	-
CD at 5%	0.03	-	-	-	-
Within Control					
S.Em. ±	0.019	-	-	-	-
CD at 5%	0.06	-	-	-	-
CV%	1.86	2.21	0.95	0.93	-

* Initial value 1.99 mg/100g

Fig. 4.3 Effect of packaging, perforation and low temperature storage on total chlorophyll content (mg/100g FW) of bell pepper cv. 'Indra'



4.3.3. Effect of Low Temperature Storage

The data in Table 4.8 illustrated a significant effect of storage temperature on chlorophyll content of bell pepper fruits. It was higher in bell pepper fruits stored at 8^0C temperature on the 5^{th} (1.88 mg/100g) and 10^{th} day (1.86 mg/100g). Whereas, lower chlorophyll content (1.79 and 1.76 mg/100g) was observed at 12^0C.

4.3.4. Interaction Effect

The interactions between P x W, P x T, W x T and P x W x T with regard to chlorophyll content were found non-significant on the 5^{th} and 10^{th} day of storage.

4.3.5. Effect of polyethylene packaging, perforation and storage temperature on the 15^{th}, 20^{th} and 25^{th} day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on chlorophyll content of bell pepper fruits (Table 4.9). The highest chlorophyll content (1.88 and 1.86 mg/100g) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$) on the 15^{th} and 20^{th} day of storage. Whereas, the lowest chlorophyll content (1.65 mg/100g) was recorded in unperforated polyethylene bags of 200 gauge stored at 12^0C ($P_1W_1T_2$)

on the 15th day and in unperforated polyethylene bags of 300 gauge thickness stored at 12^{0}C ($P_2W_1T_2$) on the 20th day (1.72 mg/100g). On the 25th day of storage, $P_3W_1T_1$ treatment emerged superior recording 1.83 mg/100g of chlorophyll content.

4.3.6. Within Control

The data pertaining to chlorophyll content presented in Table 4.9 showed significant results on the 5th day of storage.

Higher chlorophyll content (1.63 mg/100g) was registered in bell pepper fruits kept in plastic crates at 8^{0}C temperature. Whereas, lower chlorophyll content (1.56 mg/100g) was noted at 12^{0}C temperature.

4.3.7. Treated vs. Control

The data on chlorophyll content presented in Table 4.9 also showed significant results on the 5th day of storage.

Higher chlorophyll content (1.83 mg/100g) was recorded in treated bell pepper fruits. Whereas, lower chlorophyll content (1.60 mg/100g) was observed in rigid plastic crates. Due to loss in quality, fruits were discarded on the 5th day.

4.4. Carotenoid content (mg/100g)

The data related to carotenoid content as affected by packaging, perforation and temperature on the 5th, 10th, 15th, 20th and 25th day of experimentation is presented in Table 4.10, Table 4.11 and graphically mapped out in Fig. 4.4. There was a gradual reduction in carotenoid content with an increase in storage period, irrespective of treatments.

4.4.1. Effect of Packaging

There was a significant effect of packaging on carotenoid content of bell pepper fruits (Table 4.10). Carotenoid content was significantly the highest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness on the 5th (1.58 mg/100g) and 10th day (1.54 mg/100g) of storage, respectively. Whereas, the lowest carotenoid content (1.35 and 1.31 mg/100g) was noticed in polyethylene bags of 200 gauge thickness.

4.4.2. Effect of Perforation

An appraisal of data presented in Table 4.10 revealed a significant effect of perforation on carotenoid content of bell pepper fruits. The carotenoid content was higher in bell pepper fruits packed in unperforated polyethylene bags on the 5th (1.62 mg/100g) and on the 10th day (1.58 mg/100g) of storage, respectively. Whereas, lower carotenoid content (1.32 and 1.28mg/100g) was found in perforated polyethylene bags on the 5th and 10th day.

Table 4.10 : **Effect of polyethylene packaging, perforation and temperature on carotenoid content (mg/100g) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.**

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	1.35	1.31
P_2 - 300 gauge thickness	1.48	1.43
P_3 - 400 gauge thickness	1.58	1.54
Mean	1.35	1.31
S.Em. ±	0.027	0.022
CD at 5%	0.08	0.06
With and Without Perforation (W)		
W_1 - Without perforation	1.62	1.58
W_2 - With perforations	1.32	1.28
Mean	1.32	1.28
S.Em. ±	0.022	0.018
CD at 5%	0.06	0.05
Temperature (T)		
T_1 - 8^{0}C temperature	1.57	1.53
T_2 - 12^{0}C temperature	1.37	1.33
Mean	1.37	1.33
S.Em. ±	0.022	0.018
CD at 5%	0.06	0.05
CV%	6.48	5.23

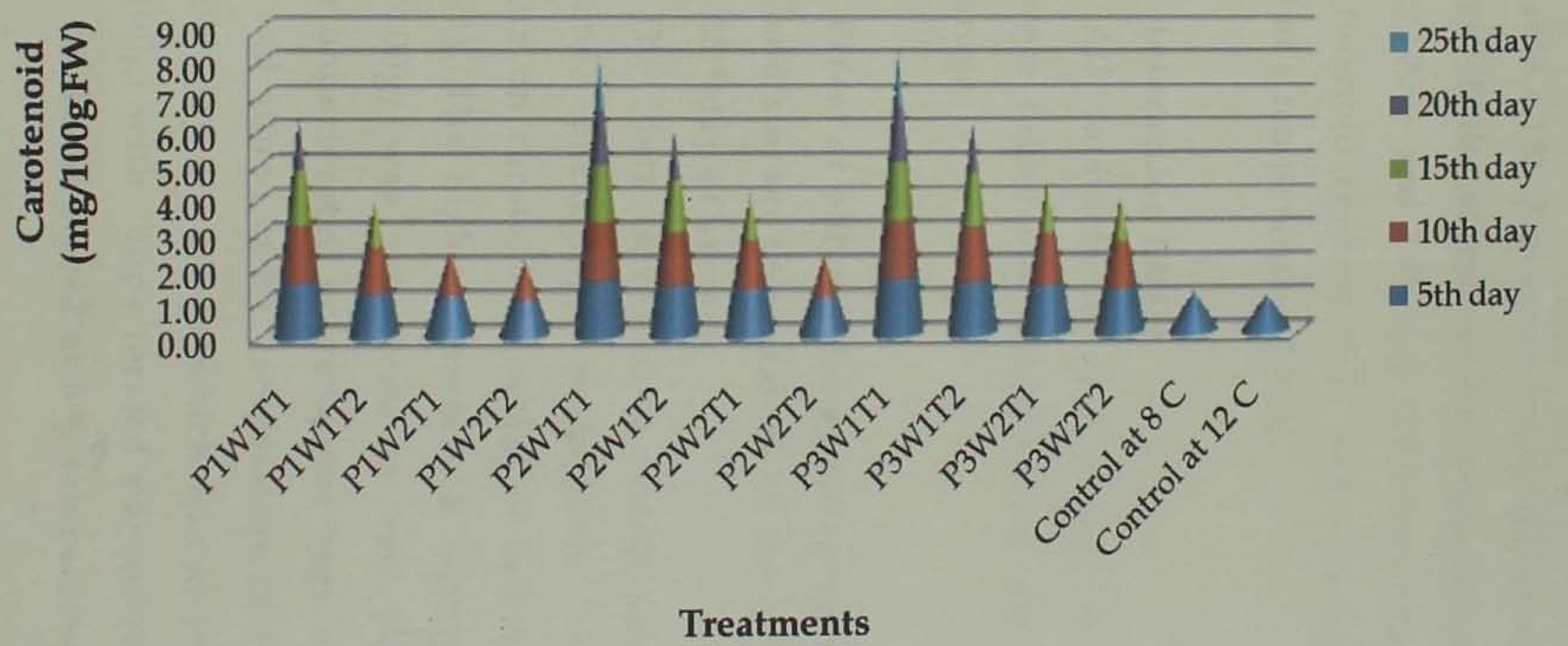
* Initial value 1.79 mg/100g

Table 4.11 : **Effect of polyethylene packaging, perforation and low temperature storage on carotenoid content (mg/100g) of bell pepper fruits cv. 'Indra'.**

Treatments	5^{th} day	10^{th} day	15^{th} day	20^{th} day	25^{th} day
$P_1W_1T_1$	1.67	1.63	1.59	1.54	-
$P_1W_1T_2$	1.34	1.31	1.26	-	-
$P_1W_2T_1$	1.25	1.22	-	-	-
$P_1W_2T_2$	1.12	1.07	-	-	-
$P_2W_1T_1$	1.73	1.69	1.64	1.60	1.52
$P_2W_1T_2$	1.57	1.53	1.48	1.41	-
$P_2W_2T_1$	1.45	1.40	1.34	-	-
$P_2W_2T_2$	1.16	1.11	-	-	-
$P_3W_1T_1$	1.76	1.70	1.66	1.61	1.56
$P_3W_1T_2$	1.64	1.60	1.54	1.47	-
$P_3W_2T_1$	1.53	1.50	1.45	-	-
$P_3W_2T_2$	1.40	1.35	1.31	-	-
Mean	1.47	1.43	1.47	1.53	1.54
S.Em. ±	-	-	0.017	0.016	-
CD at 5%	-	-	0.05	0.05	-
Control at 8ºC	1.19	-	-	-	-
Control at 12ºC	1.06	-	-	-	-
Mean	1.12	-	-	-	-
Treated vs. Control					
S.Em. ±	0.029	-	-	-	-
CD at 5%	0.08	-	-	-	-
Within Control					
S.Em. ±	0.053	-	-	-	-
CD at 5%	NS	-	-	-	-
CV%	6.48	5.23	2.00	1.86	-

* Initial value 1.79 mg/100g

Fig. 4.4 Effect of packaging, perforation and low temperature storage on carotenoid (mg/100g FW) of bell pepper cv. 'Indra'



4.4.3. Effect of Low Temperature Storage

The data illustrated a significant effect of storage temperature on carotenoid content of bell pepper fruits (Table 4.10). The carotenoid content was higher in bell pepper fruits stored at 8^{0}C temperature on the 5th (1.57 mg/100g) and 10th day (1.53 mg/100g). Whereas, lower carotenoid content (1.37 and 1.33 mg/100g) was observed at a temperature of 12^{0}C.

4.4.4. Interaction Effect

All interactions with regard to carotenoid content were found non-significant on the 5th and 10th day of storage.

4.4.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on carotenoid content of bell pepper fruits (Table 4.11). The highest carotenoid content (1.66 and 1.61 mg/100g) was registered in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^{0}C temperature ($P_3W_1T_1$) on the 15th and 20th day of storage which was at par (1.64 and 1.60 mg/100g) with unperforated polyethylene bags of 300 gauge thickness stored at 8^{0}C temperature ($P_2W_1T_1$).

Whereas, the lowest carotenoid content (1.26 mg/100g) was registered in unperforated bags of 200 gauge stored at 12^{0}C ($P_1W_1T_2$) on the 15th day and in unperforated bags of 300 gauge thickness stored at 12^{0}C ($P_2W_1T_2$) on the 20th day (1.41 mg/100g). On the 25th day of storage, $P_3W_1T_1$ treatment recorded higher carotenoid content (1.56 mg/100g).

4.4.6. Within control

The data on carotenoid content presented in Table 4.11 showed significant results on the 5th day of storage.

A higher carotenoid content (1.19 mg/100g) was recorded in bell pepper fruits kept in plastic crates at 8^{0}C temperature. Whereas, lower carotenoid content (1.06 mg/100g) was recorded at 12^{0}C temperature.

4.4.7. Treated vs. Control

The data pertaining to carotenoid content presented in Table 4.11 showed significant results on the 5th day of storage.

Higher carotenoid content (1.47 mg/100g) was recorded in treated bell pepper fruits. Whereas, lower carotenoid content (1.12 mg/100g) was noticed in rigid plastic crates. Owing to inferior quality, bell pepper fruits were discarded on the 5th day.

4.5. Rate of respiration (CO_2 mg/kg/hr)

The data related to rate of respiration as affected by packaging, perforation and temperature on the 5th, 10th, 15th, 20th and 25th day of storage is presented in Table 4.12, Table 4.13 and graphically illustrated in Fig 4.5. The respiration rate gradually increased with storage period and then decreased towards the end of experiment.

4.5.1. Effect of Packaging

A glance at Table 4.12 implicated a significant effect of packaging on the rate of respiration in bell pepper fruits. Rate of respiration was significantly the lowest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness on the 5th (23.11 CO_2 mg/kg/hr) and 10th day (23.95 CO_2 mg/kg/hr) of storage, respectively. Whereas, the highest rate of respiration (26.54 and 27.67 CO_2 mg/kg/hr) was observed in polyethylene bags of 200 gauge thickness.

4.5.2. Effect of Perforation

The data revealed a significant effect of perforation on rate of respiration in bell pepper fruits (Table 4.12). The rate of respiration was lower in fruits kept in unperforated polyethylene bags on the 5th (22.22 CO_2 mg/kg/hr) and 10th day (23.17 CO_2 mg/kg/hr) of experimentation, respectively. Whereas, higher rate of respiration (27.22 and 28.14 CO_2 mg/kg/hr) was noticed in perforated bags.

Table 4.12 : Effect of polyethylene packaging, perforation and temperature on respiration rate (CO_2 mg/kg/hr) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	26.54	27.67
P_2 - 300 gauge thickness	24.51	25.36
P_3 - 400 gauge thickness	23.11	23.95
Mean	23.11	23.95
S.Em. ±	0.406	0.392
CD at 5%	1.18	1.14
With and Without Perforation (W)		
W_1 - Without perforation	22.22	23.17
W_2 - With perforations	27.22	28.14
Mean	22.22	23.17
S.Em. ±	0.332	0.320
CD at 5%	0.96	0.93
Temperature (T)		
T_1 - 8⁰C temperature	23.05	24.02
T_2 - 12⁰C temperature	26.40	27.29
Mean	23.05	24.02
S.Em. ±	0.332	0.320
CD at 5%	0.96	0.93
CV%	5.47	5.29

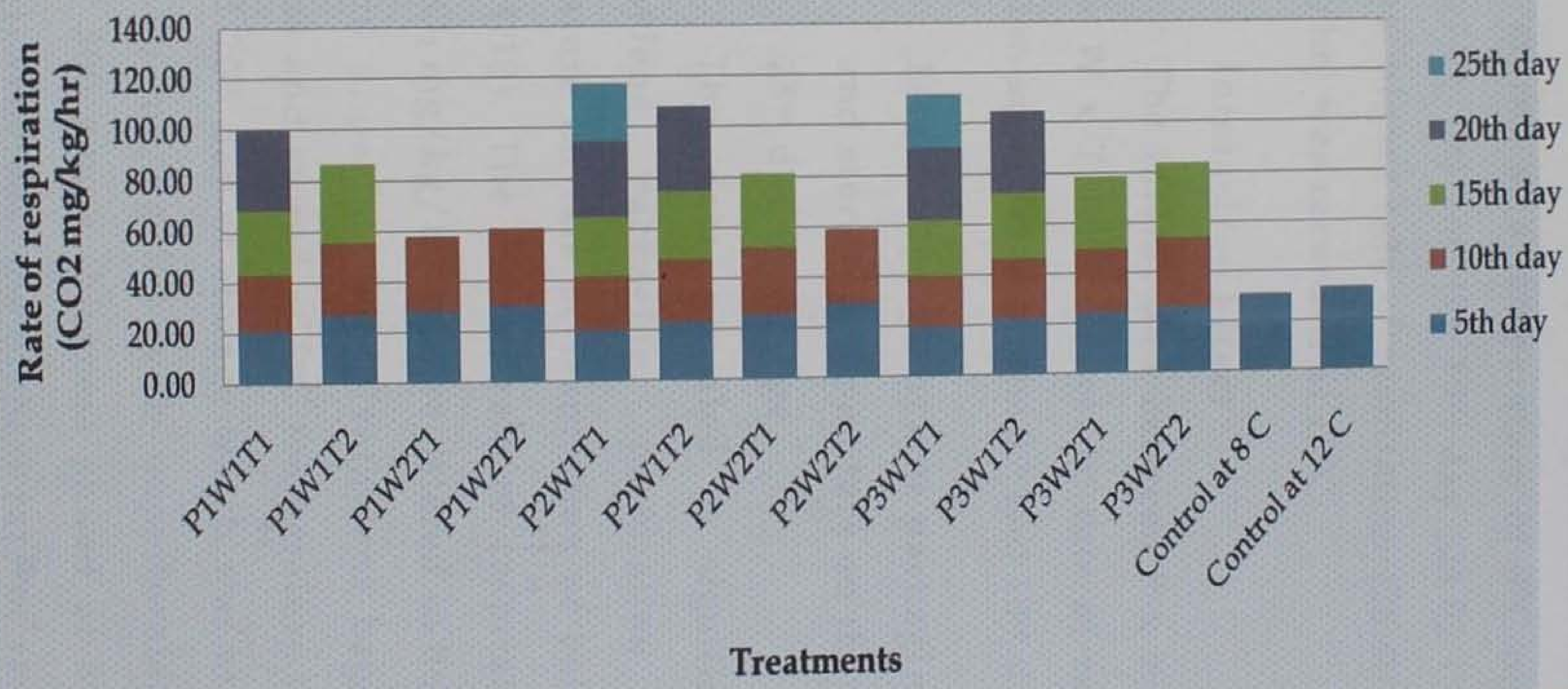
* Initial value 19.84 CO_2 mg/kg/hr

Table 4.13 : Effect of polyethylene packaging, perforation and low temperature storage on respiration rate (CO_2 mg/kg/hr) of bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	20.79	22.26	25.49	31.14	-
$P_1W_1T_2$	27.25	28.17	31.26	-	-
$P_1W_2T_1$	28.26	29.22	-	-	-
$P_1W_2T_2$	29.87	31.03	-	-	-
$P_2W_1T_1$	20.10	21.05	23.32	30.22	22.91
$P_2W_1T_2$	23.32	24.32	27.36	33.07	-
$P_2W_2T_1$	25.34	26.37	29.32	-	-
$P_2W_2T_2$	29.29	29.68	-	-	-
$P_3W_1T_1$	19.43	19.90	22.22	28.98	21.24
$P_3W_1T_2$	22.44	23.31	26.49	32.62	-
$P_3W_2T_1$	24.37	25.34	28.53	-	-
$P_3W_2T_2$	26.21	27.23	30.30	-	-
Mean	24.72	25.66	27.14	31.21	22.08
S.Em. ±	-	-	0.885	0.885	-
CD at 5%	-	-	2.63	2.79	-
Control at 8^{0}C	30.44	-	-	-	-
Control at 12^{0}C	32.89	-	-	-	-
Mean	31.67	-	-	-	-
Treated vs. Control					
S.Em. ±	0.439	-	-	-	-
CD at 5%	1.27	-	-	-	-
Within Control					
S.Em. ±	0.813	-	-	-	-
CD at 5%	2.35	-	-	-	-
CV%	5.47	5.29	5.65	4.91	-

* Initial value 19.84 CO_2 mg/kg/hr

Fig. 4.5 Effect of packaging, perforation and low temperature storage on rate of respiration (CO2 mg/kg/hr) of bell pepper cv. 'Indra'



4.5.3. Effect of Low Temperature Storage

The data in Table 4.12 illustrated a significant effect of storage temperature on rate of respiration in bell pepper fruits. The rate of respiration was lower in bell pepper stored at a temperature of 8^0C on the 5^{th} (23.05 CO_2 mg/kg/hr) and the 10^{th} day (24.02 CO_2 mg/kg/hr). Whereas, higher rate of respiration (26.40 and 27.29 CO_2 mg/kg/hr) was recorded at 12^0C.

4.5.4. Interaction Effect

The interactions between P x W, P x T, W x T and P x W x T with respect to rate of respiration were found non-significant on the 5^{th} and 10^{th} day of storage.

4.5.5. Effect of polyethylene packaging, perforation and storage temperature on the 15^{th}, 20^{th} and 25^{th} day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on rate of respiration of bell pepper fruits (Table 4.13). The lowest rate of respiration (22.22 and 28.98 CO_2 mg/kg/hr) was registered in bell pepper fruits stored in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$) on the 15^{th} and 20^{th} day of storage which was at par (23.32 and 30.22 CO_2 mg/kg/hr) with unperforated polyethylene bags of 300 gauge thickness stored at 8^0C temperature ($P_2W_1T_1$). Whereas, the highest rate of respiration (31.26

CO_2 mg/kg/hr) was registered in bell pepper fruits packed in unperforated polyethylene bags of 200 gauge stored at 12^{0}C ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge thickness stored at 12^{0}C ($P_2W_1T_2$) on the 20th day (33.07 CO_2 mg/kg/hr). On the 25th day of storage, lowest rate of respiration (21.24 CO_2 mg/kg/hr) was recorded in $P_3W_1T_1$ treatment.

4.5.6. Within Control

The data pertaining to rate of respiration presented in Table 4.13 showed significant results on the 5th day of storage.

A lower rate of respiration (30.44 CO_2 mg/kg/hr) was recorded in bell pepper fruits kept in plastic crates at 8^{0}C temperature. Whereas, a higher rate of respiration (32.89 CO_2 mg/kg/hr) was observed at 12^{0}C temperature.

4.5.7. Treated vs. Control

The data for rate of respiration presented in the Table 4.13 showed significant results on the 5th day of storage.

Lower rate of respiration (24.72 CO_2 mg/kg/hr) was recorded in treated bell pepper fruits. Whereas, higher rate of respiration (31.67 CO_2 mg/kg/hr) was recorded in rigid plastic crates. Due to deterioration in quality, bell pepper fruits were discarded on the 5th day.

4.6. Firmness (kg/cm^2)

The data pertaining to firmness as affected by packaging, perforation and temperature on the 5th, 10th, 15th, 20th and 25th day of the investigation is presented in Table 4.14, 4.15 and graphically traced out in Fig. 4.6. Firmness declined progressively under extended storage, irrespective of treatments.

4.6.1. Effect of Packaging

There was a significant effect of packaging on the firmness of bell pepper fruits during the period of investigation (Table 4.14). Firmness was significantly the highest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness on the 5th day (4.87 kg/cm^2) which was at par (4.83 kg/cm^2) with polyethylene bags of 300 gauge thickness. On the 10th day of storage, firmness was significantly the highest (4.18 kg/cm^2) in fruits packed in polyethylene bags of 400 gauge thickness. Whereas, the lowest firmness (4.77 and 3.78 kg/cm^2) was noticed in bags of 200 gauge thickness. Due to shrivelling, fruits kept in rigid plastic crates were removed on the 5th day.

4.6.2. Effect of Perforation

A persual of Table 4.14 suggested a significant effect of perforation on firmness of bell pepper fruits. Firmness was higher in bell pepper fruits packed in unperforated bags on the 5th (4.89 kg/cm^2) and 10th day

Table 4.14 : Effect of polyethylene packaging, perforation and temperature on firmness (kg/cm²) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	4.77	3.78
P_2 - 300 gauge thickness	4.83	4.02
P_3 - 400 gauge thickness	4.87	4.18
Mean	4.77	3.78
S.Em. ±	0.017	0.037
CD at 5%	0.05	0.11
With and Without Perforation (W)		
W_1 - Without perforation	4.89	4.25
W_2 - With perforations	4.76	3.73
Mean	4.76	3.73
S.Em. ±	0.014	0.030
CD at 5%	0.04	0.09
Temperature (T)		
T_1 - 8⁰C temperature	4.87	4.16
T_2 - 12⁰C temperature	4.78	3.82
Mean	4.78	3.82
S.Em. ±	0.014	0.030
CD at 5%	0.04	0.09
CV%	1.29	3.24

* Initial value 5.12 kg/cm²

Table 4.15 : Effect of polyethylene packaging, perforation and low temperature storage on firmness (kg/cm²) of bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	4.92	4.35	3.83	3.42	-
$P_1W_1T_2$	4.77	3.73	3.26	-	-
$P_1W_2T_1$	4.75	3.62	-	-	-
$P_1W_2T_2$	4.65	3.41	-	-	-
$P_2W_1T_1$	4.95	4.46	3.94	3.60	3.14
$P_2W_1T_2$	4.87	4.17	3.66	3.04	-
$P_2W_2T_1$	4.82	3.93	3.42	-	-
$P_2W_2T_2$	4.70	3.50	-	-	-
$P_3W_1T_1$	4.97	4.56	4.13	3.77	3.43
$P_3W_1T_2$	4.89	4.26	3.72	3.22	-
$P_3W_2T_1$	4.84	4.04	3.52	-	-
$P_3W_2T_2$	4.79	3.86	3.36	-	-
Mean	4.83	3.99	3.65	3.41	3.28
S.Em. ±	-	-	0.031	0.029	-
CD at 5%	-	-	0.09	0.09	-
Control at 8⁰C	3.43	-	-	-	-
Control at 12⁰C	2.76	-	-	-	-
Mean	3.09	-	-	-	-
Treated vs. Control					
S.Em. ±	0.018	-	-	-	-
CD at 5%	0.05	-	-	-	-
Within Control					
S.Em. ±	0.034	-	-	-	-
CD at 5%	0.10	-	-	-	-
CV%	1.29	3.24	1.47	1.48	-

* Initial value 5.12 kg/cm²

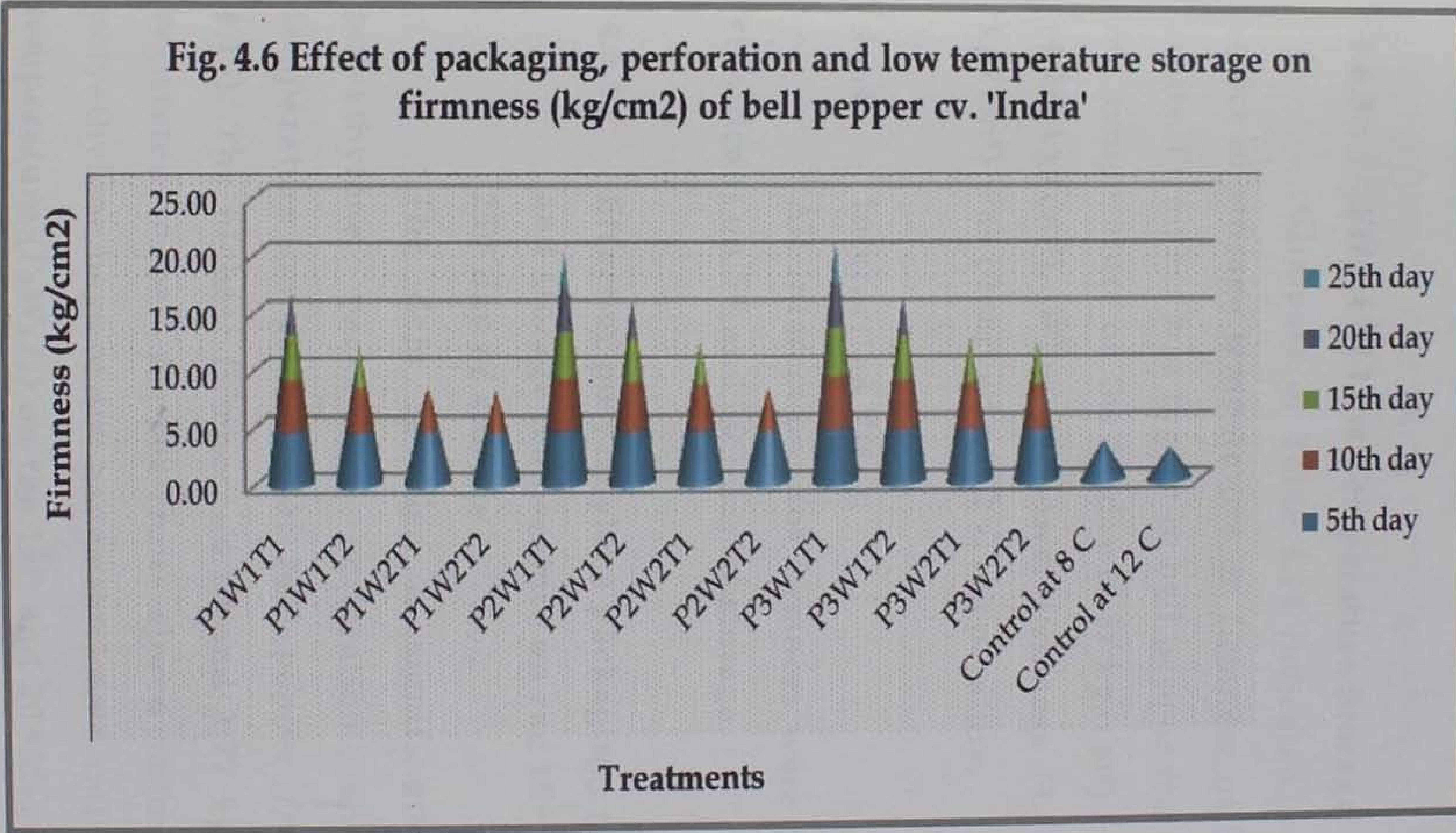


Fig. 4.6 Effect of packaging, perforation and low temperature storage on firmness (kg/cm2) of bell pepper cv. 'Indra'
Firmness (kg/cm2)
25.00
20.00
15.00
10.00
5.00
0.00
P1W1T1
P1W1T2
P1W2T1
P1W2T2
P2W1T1
P2W1T2
P2W2T1
P2W2T2
P3W1T1
P3W1T2
P3W2T1
P3W2T2
Control at 8 C
Control at 12 C
25th day
20th day
15th day
10th day
5th day
Treatments

(4.25 kg/cm^2) of experimentation, respectively. Whereas, lower firmness (4.76 and 3.73 kg/cm^2) was noticed in perforated bags.

4.6.3. Effect of Low Temperature Storage

Glimpses of Table 4.14 indicated a significant effect of storage temperature on firmness of bell pepper fruits. Firmness was higher in bell pepper fruits stored at 8^{0}C temperature on the 5th day (4.87 kg/cm^2) and 10th day (4.16 kg/cm^2). Whereas, lower firmness (4.78 and 3.82 kg/cm^3) was observed at 12^{0}C temperature.

4.6.4. Interaction Effect

All interactions for firmness were found non-significant on 5th and 10th day of storage.

4.6.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on firmness of bell pepper fruits (Table 4.15). The highest firmness (4.13 and 3.77 kg/cm^2) was registered in bell pepper fruits stored in unperforated polyethylene bags of 400 gauge thickness and kept at 8^{0}C temperature ($P_3W_1T_1$) on the 15th and 20th day of storage.

Whereas, the lowest firmness (3.26 kg/cm^2) was registered in bell pepper fruits packed in unperforated polyethylene bags of 200 gauge thickness stored at 12^{0}C ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge stored at 12^{0}C temperature ($P_2W_1T_2$) on the 20th day (3.04 kg/cm^2). On the 25th day of storage, higher firmness (3.43 kg/cm^2) was noticed in $P_3W_1T_1$ treatment.

4.6.6. Within Control

The data on firmness presented in Table 4.15 showed significant results on 5th day of storage.

Higher firmness (3.43 kg/cm^2) was recorded in bell pepper fruits kept in plastic crates at 8^{0}C temperature. Whereas, lower firmness (2.76 kg/cm^2) was recorded at 12^{0}C temperature.

4.6.7. Treated vs. Control

The data related to firmness presented in Table 4.15 showed significant results on 5th day of storage.

Higher firmness (4.83 kg/cm^2) was recorded in treated bell pepper fruits. Whereas, lower firmness (3.09 kg/cm^2) was observed in rigid plastic crates. Due to loss in quality, fruits were discarded on the 5th day.

4.7. Shrinkage (%)

The data pertaining to shrinkage as affected by packaging, perforation and temperature on the 5th, 10th, 15th, 20th and 25th day of the trial is presented in Table 4.16, Table 4.17 and graphically sketched in Fig. 4.7. On the 5th day of storage, shrinkage was not observed in treated fruits. Shrinkage increased progressively with extended storage, regardless of treatments.

4.7.1. Effect of Packaging

A quick look at Table 4.16 divulged that there was a significant effect of packaging on the shrinkage of bell pepper fruits on the 10th day of investigation. Shrinkage was significantly the lowest (0.67%) in fruits packed in polyethylene bags of 400 gauge thickness. Whereas, the highest shrinkage (0.83%) was noticed in polyethylene bags of 200 gauge thickness.

4.7.2. Effect of Perforation

Perforation had a significant effect on shrinkage in bell pepper fruits on the 10th day (Table 4.16). Shrinkage was lower (0.64%) in fruits packed in unperforated bags. Whereas, higher shrinkage (0.85%) was observed in perforated bags (W_2).

Table 4.16 : **Effect of polyethylene packaging, perforation and temperature on shrinkage (%) of bell pepper fruits cv. 'Indra' on the 10th day of storage.**

Treatments	10th day
Polyethylene Packaging (P)	
P_1 – 200 gauge thickness	0.83
P_2 – 300 gauge thickness	0.74
P_3 – 400 gauge thickness	0.67
Mean	0.016
S.Em. ±	0.016
CD at 5%	0.05
With and Without Perforation (W)	
W_1 - Without perforation	0.64
W_2 - With perforations	0.85
Mean	0.013
S.Em. ±	0.013
CD at 5%	0.04
Temperature (T)	
T_1 - 8^0C temperature	0.68
T_2 - 12^0C temperature	0.81
Mean	0.013
S.Em. ±	0.013
CD at 5%	0.04
CV%	7.62

* Initial value 0.00 %

Note: Shrinkage was not observed on the fifth day of storage

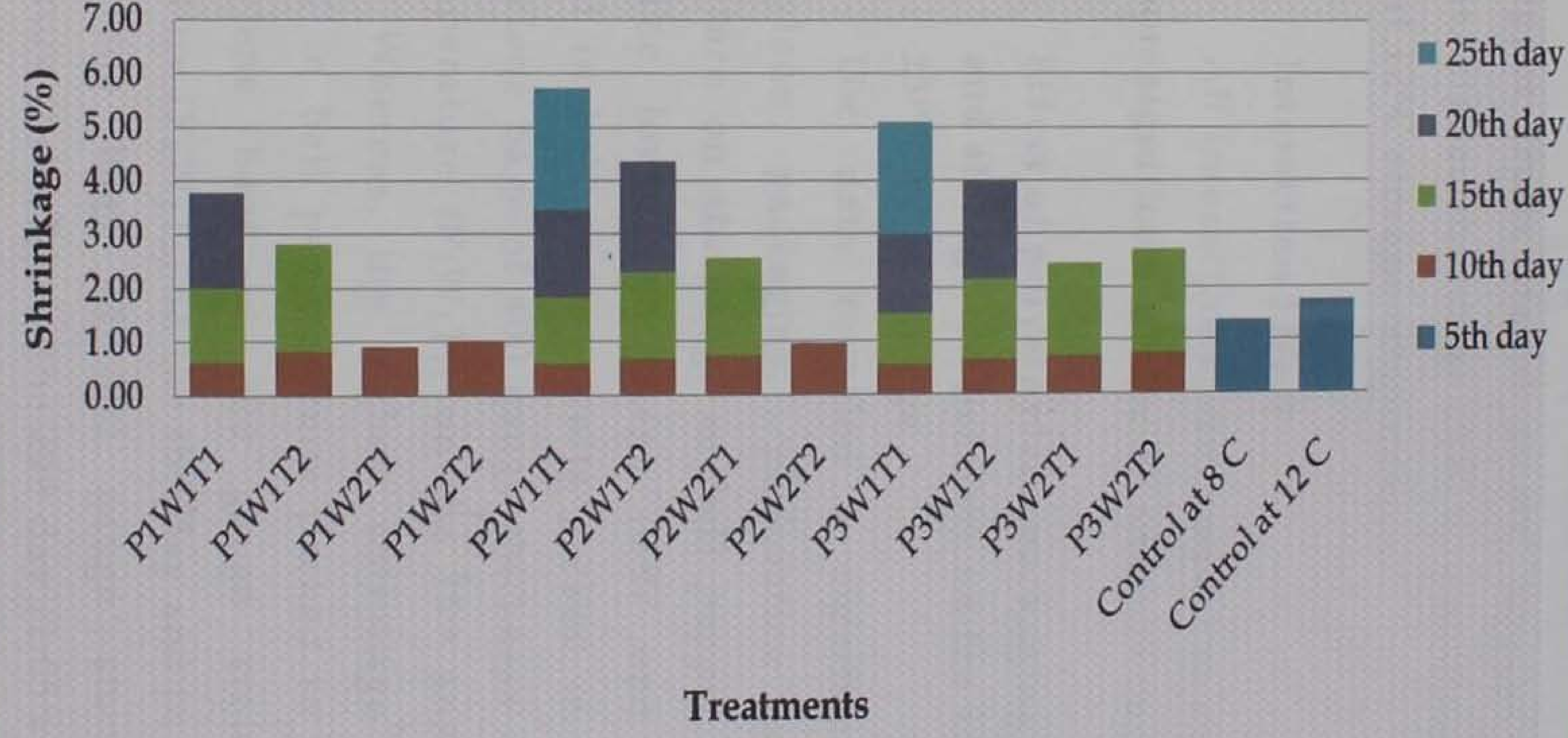
Table 4.17 : **Effect of polyethylene packaging, perforation and low temperature storage on shrinkage (%) of bell pepper fruits cv. 'Indra'.**

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	0.00	0.61	1.39	1.78	-
$P_1W_1T_2$	0.00	0.81	2.02	-	-
$P_1W_2T_1$	0.00	0.89	-	-	-
$P_1W_2T_2$	0.00	1.01	-	-	-
$P_2W_1T_1$	0.00	0.58	1.26	1.62	2.25
$P_2W_1T_2$	0.00	0.67	1.63	2.05	-
$P_2W_2T_1$	0.00	0.73	1.83	-	-
$P_2W_2T_2$	0.00	0.97	-	-	-
$P_3W_1T_1$	0.00	0.55	0.97	1.46	2.10
$P_3W_1T_2$	0.00	0.64	1.51	1.83	-
$P_3W_2T_1$	0.00	0.71	1.74	-	-
$P_3W_2T_2$	0.00	0.77	1.94	-	-
Mean	0.00	0.75	1.59	1.75	2.18
S.Em. ±	-	-	0.029	0.036	-
CD at 5%	-	-	0.09	0.11	-
Control at 8°C	1.38	-	-	-	-
Control at 12°C	1.76	-	-	-	-
Mean	1.57	-	-	-	-
Treated vs. Control					
S.Em. ±	0.012	-	-	-	-
CD at 5%	0.03	-	-	-	-
Within Control					
S.Em. ±	0.022	-	-	-	-
CD at 5%	0.06	-	-	-	-
CV%	5.59	7.62	3.20	3.58	-

* Initial value 0.00 %

Note: Shrinkage was not observed in treated fruits on the 5th day of storage.

Fig. 4.7 Effect of packaging, perforation and low temperature storage on shrinkage (%) of bell pepper cv. 'Indra'



4.7.3. Effect of Low Temperature Storage

A perusal of Table 4.16 showed a significant influence of temperature on shrinkage in bell pepper fruits on the 10th day. Shrinkage was lower (0.68%) in bell pepper fruits stored at 8^0C storage temperature. Whereas, higher shrinkage (0.81%) was observed in fruits stored at 12^0C storage temperature.

4.7.4. Interaction Effect

All interactions with respect to shrinkage were found non-significant on the 5th and 10th day.

4.7.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on shrinkage of bell pepper fruits (Table 4.17). The lowest shrinkage (0.97 and 1.46%) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_1W_1T_1$) on the 15th and 20th day of storage. Whereas, the highest shrinkage (2.02%) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 200 gauge stored at 12^0C temperature ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge stored at 12^0C temperature ($P_2W_1T_2$) on the 20th day (2.05%). On the 25th day of storage, $P_3W_1T_1$ combination resulted in the lowest shrinkage (2.10 %).

4.7.6. Within Control

The data pertaining to shrinkage presented in Table 4.17 indicated significant results on the 5th day of storage.

Lower shrinkage (1.38%) was recorded in bell pepper fruits kept in plastic crates at 8°C temperature. Whereas, higher shrinkage (1.76%) was recorded at 12°C temperature.

4.7.7. Treated vs. Control

The data on shrinkage presented in Table 4.17 revealed significant results on the 5th day of storage.

Shrinkage was not observed in treated bell pepper fruits on the 5th day of storage. Whereas, higher shrinkage (1.57%) was registered in fruits kept in rigid plastic crates. Due to poor quality, bell pepper fruits were discarded on the 5th day.

4.8. Bulk density (g/cm^3)

The data pertaining to bulk density as affected by packaging, perforation and low temperature on the 5th, 10th, 15th, 20th and 25th day of storage is presented in Table 4.18, Table 4.19 and graphically depicted in Fig. 4.8. Bulk density showed a declined trend across all treatments.

Table 4.18 : **Effect of polyethylene packaging, perforation and temperature on bulk density (g/cm³) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.**

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	3.36	2.76
P_2 - 300 gauge thickness	3.47	2.95
P_3 - 400 gauge thickness	3.54	3.07
Mean	3.36	2.76
S.Em. ±	0.018	0.033
CD at 5%	0.05	0.10
With and Without Perforation (W)		
W_1 - Without perforation	3.57	3.13
W_2 - With perforations	3.34	2.72
Mean	3.34	2.72
S.Em. ±	0.015	0.027
CD at 5%	0.04	0.08
Temperature (T)		
T_1 - 8⁰C temperature	3.54	3.06
T_2 - 12⁰C temperature	3.37	2.79
Mean	3.37	2.79
S.Em. ±	0.015	0.027
CD at 5%	0.04	0.08
CV%	1.87	3.94

* Initial value 3.84 g/cm³

Table 4.19 : Effect of polyethylene packaging, perforation and low temperature storage on bulk density (g/cm³) of bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	3.62	3.23	2.71	2.44	-
$P_1W_1T_2$	3.34	2.72	2.08	-	-
$P_1W_2T_1$	3.30	2.64	-	-	-
$P_1W_2T_2$	3.19	2.44	-	-	-
$P_2W_1T_1$	3.67	3.26	2.81	2.56	2.20
$P_2W_1T_2$	3.52	3.08	2.47	2.35	-
$P_2W_2T_1$	3.43	2.91	2.31	-	-
$P_2W_2T_2$	3.25	2.54	-	-	-
$P_3W_1T_1$	3.72	3.34	2.98	2.67	2.39
$P_3W_1T_2$	3.57	3.14	2.61	2.21	-
$P_3W_2T_1$	3.48	2.99	2.44	-	-
$P_3W_2T_2$	3.39	2.81	2.22	-	-
Mean	3.46	2.92	2.51	2.45	2.30
S.Em. ±	-	-	0.030	0.026	-
CD at 5%	-	-	0.09	0.08	-
Control at 8°C	2.78	-	-	-	-
Control at 12°C	2.34	-	-	-	-
Mean	2.56	-	-	-	-
Treated vs. Control					
S.Em. ±	0.019	-	-	-	-
CD at 5%	0.06	-	-	-	-
Within Control					
S.Em. ±	0.036	-	-	-	-
CD at 5%	0.10	-	-	-	-
CV%	1.87	3.94	2.06	1.83	-

* Initial value 3.84 g/cm³

4.8.1. Effect of Packaging

There was a significant effect of packaging on the bulk density of bell pepper fruits (Table 4.18). Bulk density was significantly the highest in bell pepper fruits packed in polyethylene bags of 400 gauge thicknesses on the 5th (3.54 g/cm^3) and 10th day (3.07 g/cm^3) of storage, respectively. Whereas, the lowest bulk density (3.36 and 2.76 g/cm^3) was noticed in polyethylene bags of 200 gauge thickness.

4.8.2. Effect of Perforation

The data furnished in Table 4.18 revealed a significant effect of perforation on bulk density of bell pepper fruits. Bulk density was higher in fruits packed in unperforated polyethylene bags on the 5th day (3.57 g/cm^3) and on the 10th day (3.13 g/cm^3) of storage, respectively. Whereas, lower bulk density (3.34 and 2.72 g/cm^3) was recorded in perforated bags.

4.8.3. Effect of Low Temperature Storage

The data in Table 4.18 illustrated a significant effect of storage temperature on bulk density of bell pepper fruits. Bulk density was higher in bell pepper fruits stored at 8^{0}C temperature on the 5th (3.54 g/cm^3) and 10th day (3.06 g/cm^3). Whereas, lower bulk density (3.37 and 2.79 g/cm^3) was recorded at 12^{0}C.

4.8.4. Interaction Effect

The interactions between P x W, P x T, W x T and P x W x T with regard to bulk density were found non-significant on the 5th and 10th day of storage.

4.8.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on bulk density of bell pepper fruits (Table 4.19). The highest bulk density (2.98 and 2.67 g/cm³) was observed in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8⁰C temperature ($P_3W_1T_1$) on the 15th and 20th day of storage. Whereas, the lowest bulk density (2.08 g/cm³) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 200 gauge stored at 12⁰C temperature ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge thickness stored at 12⁰C temperature ($P_2W_1T_2$) on the 20th day (2.21 g/cm³). On the 25th day of storage, $P_3W_1T_1$ recorded higher bulk density (2.39 g/cm³).

4.8.6. Within Control

The data related to bulk density presented in Table 4.19 showed significant results on the 5th day of storage.

Higher bulk density (2.78 g/cm^3) was registered in bell pepper fruits kept in plastic crates at 8^{0}C temperature. Whereas, lower bulk density (2.34 g/cm^3) was registered at 12^{0}C temperature.

4.8.7. Treated vs. Control

The data pertaining to bulk density presented in the Table 4.19 showed significant results on the 5th day of storage.

Higher bulk density (3.46 g/cm^3) was recorded in treated bell pepper fruits. Whereas, lower bulk density (2.56 g/cm^3) was recorded in rigid plastic crates. Due to inferior quality, bell pepper fruits were discarded on the 5th day.

4.9. Ascorbic acid (mg/100g)

The data related to ascorbic acid as affected by packaging, perforation and low temperature storage on the 5th, 10th, 15th, 20th and 25th day of experimentation is presented in Table 4.20, Table 4.21 and graphically illustrated in Fig. 4.9. Ascorbic acid declined progressively under extended storage, irrespective of treatments.

4.9.1. Effect of Packaging

A perusal of data envisaged in Table 4.20 suggested a significant effect of packaging on the

Table 4.20 : Effect of polyethylene packaging, perforation and temperature on ascorbic acid content (mg/100g) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	72.37	68.61
P_2 - 300 gauge thickness	75.99	73.09
P_3 - 400 gauge thickness	77.96	76.07
Mean	72.37	68.61
S.Em. ±	1.098	1.168
CD at 5%	3.18	3.41
With and Without Perforation (W)		
W_1 - Without perforation	79.62	77.55
W_2 - With perforations	71.26	67.63
Mean	71.26	67.63
S.Em. ±	0.897	0.954
CD at 5%	2.60	2.78
Temperature (T)		
T_1 - 8°C temperature	78.16	75.90
T_2 - 12°C temperature	72.73	69.28
Mean	72.73	69.28
S.Em. ±	0.897	0.954
CD at 5%	2.60	2.78
CV%	5.13	5.57

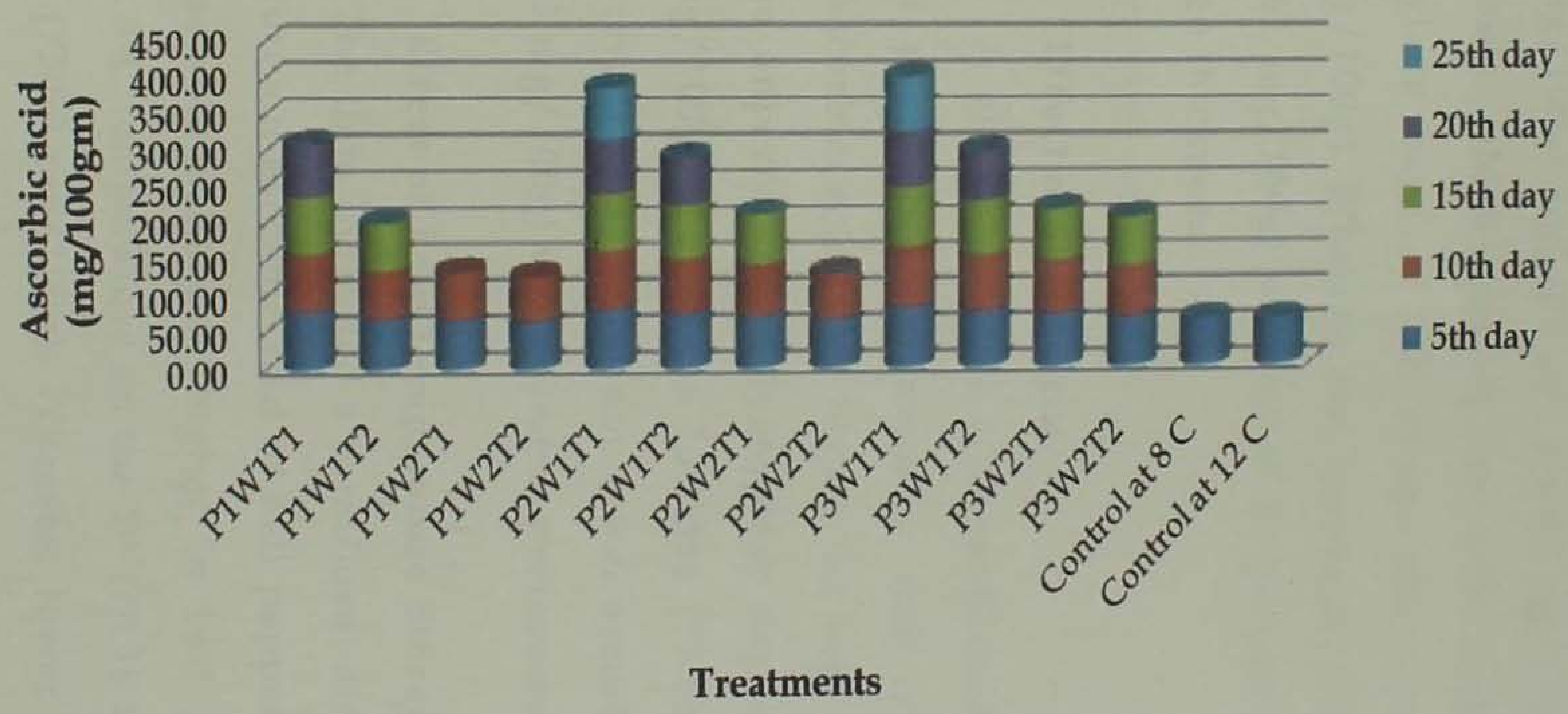
* Initial value 84.46 mg/100g

Table 4.21 : Effect of polyethylene packaging, perforation and low temperature storage on ascorbic acid content (mg/100g) of bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	81.53	79.58	77.61	72.72	-
$P_1W_1T_2$	70.37	67.60	65.72	-	-
$P_1W_2T_1$	70.00	65.68	-	-	-
$P_1W_2T_2$	67.58	61.59	-	-	-
$P_2W_1T_1$	83.34	81.43	77.75	75.25	71.40
$P_2W_1T_2$	77.65	75.60	73.60	66.08	-
$P_2W_2T_1$	73.46	71.67	69.61	-	-
$P_2W_2T_2$	69.52	63.65	-	-	-
$P_3W_1T_1$	85.27	83.46	81.75	78.43	74.47
$P_3W_1T_2$	79.56	77.62	75.49	68.83	-
$P_3W_2T_1$	75.34	73.57	71.70	-	-
$P_3W_2T_2$	71.68	69.63	67.54	-	-
Mean	75.44	72.59	73.42	72.26	72.94
S.Em. ±	-	-	2.221	2.209	-
CD at 5%	-	-	6.60	6.96	-
Control at 8^{0}C	67.12	-	-	-	-
Control at 12^{0}C	66.23	-	-	-	-
Mean	66.68	-	-	-	-
Treated vs. Control					
S.Em. ±	1.186	-	-	-	-
CD at 5%	3.44	-	-	-	-
Within Control					
S.Em. ±	2.197	-	-	-	-
CD at 5%	NS	-	-	-	-
CV%	5.13	5.57	3.48	3.10	-

* Initial value 84.46 mg/100g

Fig. 4.9 Effect of packaging, perforation and low temperature storage on ascorbic acid (mg/100gm) of bell pepper cv. 'Indra'



ascorbic acid of bell pepper fruits. Ascorbic acid was significantly the highest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness on the 5^{th} day (77.96 mg/100g) and 10^{th} day (76.06 mg/100g) of storage, respectively which was at par with fruits packed in polyethylene bags of 300 gauge thickness (75.99 and 73.09 mg/100g). Whereas, the lowest ascorbic acid (72.37 and 68.61 mg/100g) was noted in polyethylene bags of 200 gauge thickness.

4.9.2. Effect of Perforation

A glance at Table 4.20 implicated a significant effect of perforation on ascorbic acid of bell pepper fruits. Ascorbic acid was higher in bell pepper fruits packed in unperforated polyethylene bags on the 5^{th} day (79.62 mg/100g) and on the 10^{th} day (77.55 mg/100g) of storage, respectively. Whereas, lower ascorbic acid (71.26 and 67.63 mg/100g) was found in perforated bags.

4.9.3. Effect of Low Temperature Storage

The data indicated a significant effect of storage temperature on ascorbic acid of bell pepper fruits (Table 4.20). Ascorbic acid was higher in bell pepper fruits stored at $8^{0}C$ temperature on the 5^{th} (78.16 mg/100g) and 10^{th} day (75.90 mg/100g). Whereas, lower ascorbic acid (72.73 and 69.28 mg/100g) was found at $12^{0}C$.

4.9.4. Interaction Effect

All interactions were found non-significant for ascorbic acid on the 5th and 10th day of storage.

4.9.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on ascorbic acid of bell pepper fruits (Table 4.21). The highest ascorbic acid (81.75 and 78.43 mg/100g) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^{0}C temperature ($P_3W_1T_1$) on the 15th and 20th day of storage which was at par with (77.75 and 75.25 mg/100g) unperforated polyethylene bags of 300 gauge thickness and stored at 8^{0}C temperature ($P_2W_1T_1$). Whereas, the lowest ascorbic acid (65.72 mg/100g) was recorded in unperforated polyethylene bags of 200 gauge thickness stored at 12^{0}C ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge stored at 12^{0}C ($P_2W_1T_2$) on the 20th day (66.08 mg/100g). On the 25th day of storage, $P_3W_1T_1$ treatment recorded higher ascorbic acid content (74.47 mg/100g).

4.9.6. Within Control

The data for ascorbic acid presented in Table 4.21 indicated non-significant results on the 5th day of storage.

4.9.7. Treated vs. Control

The data pertaining to ascorbic acid presented in the Table 4.21 showed significant results on the 5th day of storage.

Higher ascorbic acid (75.44 mg/100g) was recorded in treated bell pepper fruits. Whereas, lower ascorbic acid (66.68 mg/100g) was recorded in rigid plastic crates. Due to loss in quality, bell pepper fruits were discarded on the 5th day.

4.10. TSS (%)

The data related to TSS as affected by packaging, perforation and low temperature storage on the 5th, 10th, 15th, 20th and 25th day of the investigation is presented in Table 4.22, Table 4.23 and graphically depicted in Fig. 4.10.

4.10.1. Effect of Packaging

There was a significant effect of packaging on the TSS of bell pepper fruits (Table 4.22). TSS was significantly the highest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness on the 5th day (4.78 %) and on the 10th day (5.60 %) of storage which was at par (4.70 %) with polyethylene bags of 300 gauge thickness on the 5th day of storage. Whereas, the lowest TSS (4.58 and 5.42 %) was noticed in polyethylene bags of 200 gauge thickness.

Table 4.22 : **Effect of polyethylene packaging, perforation and temperature on TSS (%) of bell pepper fruits cv. 'Indra' on the 5th and 10th day of storage.**

Treatments	5th day	10th day
Polyethylene Packaging (P)		
P_1 - 200 gauge thickness	4.58	5.42
P_2 - 300 gauge thickness	4.70	5.53
P_3 - 400 gauge thickness	4.78	5.60
Mean	4.58	5.42
S.Em. ±	0.034	0.016
CD at 5%	0.10	0.05
With and Without Perforation (W)		
W_1 - Without perforation	4.82	5.63
W_2 - With perforations	4.56	5.40
Mean	4.56	5.40
S.Em. ±	0.028	0.013
CD at 5%	0.08	0.04
Temperature (T)		
T_1 - 8^{0}C temperature	4.78	5.59
T_2 - 12^{0}C temperature	4.59	5.43
Mean	4.59	5.43
S.Em. ±	0.028	0.013
CD at 5%	0.08	0.04
CV%	2.56	1.02

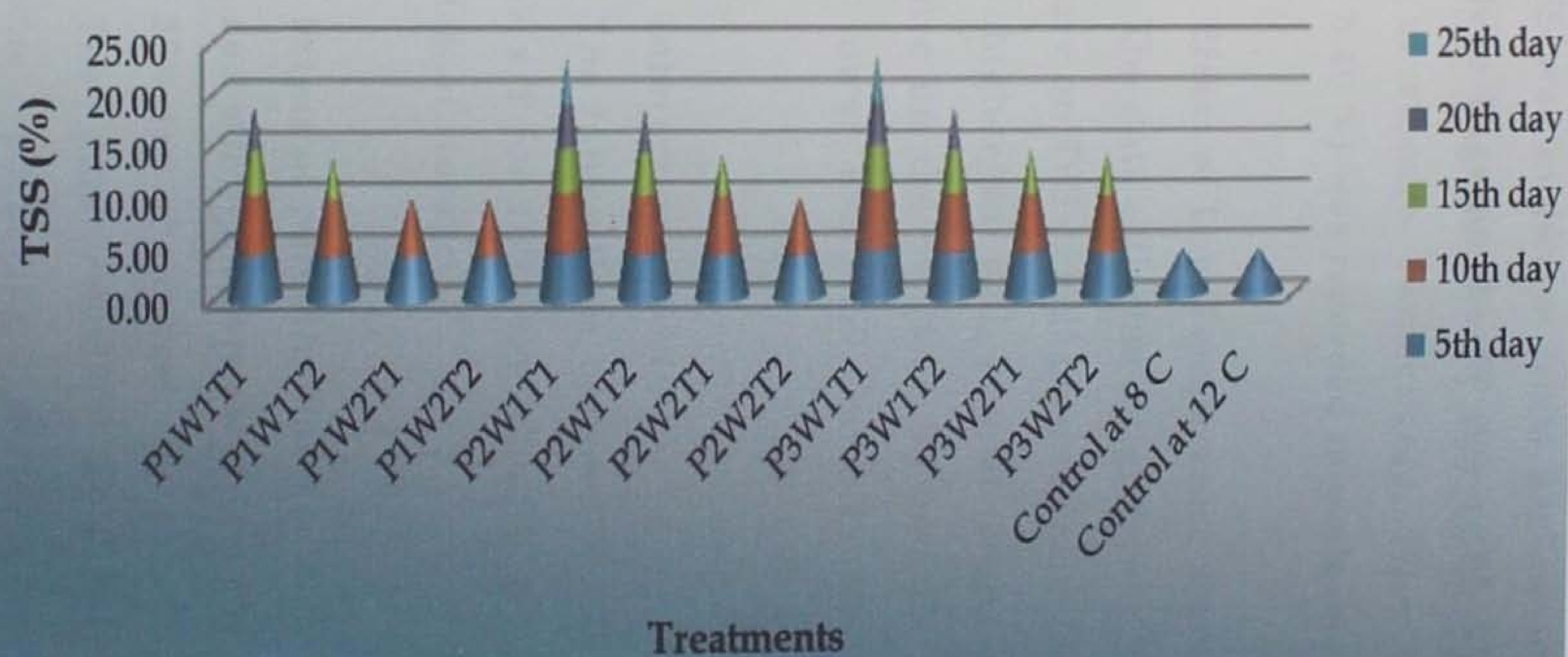
* Initial value 5.28 %

Table 4.23 : Effect of polyethylene packaging, perforation and low temperature storage on TSS (%) of bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	4.83	5.68	4.14	4.10	-
$P_1W_1T_2$	4.55	5.39	3.82	-	-
$P_1W_2T_1$	4.51	5.35	-	-	-
$P_1W_2T_2$	4.44	5.24	-	-	-
$P_2W_1T_1$	4.94	5.72	4.18	4.11	4.39
$P_2W_1T_2$	4.73	5.58	4.05	3.91	-
$P_2W_2T_1$	4.64	5.49	3.94	-	-
$P_2W_2T_2$	4.48	5.31	-	-	-
$P_3W_1T_1$	5.09	5.78	4.22	4.14	4.47
$P_3W_1T_2$	4.78	5.63	4.09	4.00	-
$P_3W_2T_1$	4.68	5.54	4.01	-	-
$P_3W_2T_2$	4.59	5.44	3.89	-	-
Mean	4.69	5.51	4.04	4.05	4.43
S.Em. ±	-	-	0.044	0.041	-
CD at 5%	-	-	0.13	0.13	-
Control at 8°C	4.39	-	-	-	-
Control at 12°C	4.35	-	-	-	-
Mean	4.37	-	-	-	-
Treated vs. Control					
S.Em. ±	0.037	-	-	-	-
CD at 5%	0.11	-	-	-	-
Within Control					
S.Em. ±	0.069	-	-	-	-
CD at 5%	NS	-	-	-	-
CV%	2.56	1.02	1.90	1.76	-

* Initial value 5.28 %

Fig. 4.10 Effect of packaging, perforation and low temperature storage on TSS (%) of bell pepper cv. 'Indra'



4.10.2. Effect of Perforation

A quick look at Table 4.22 revealed a significant effect of perforation on TSS of bell pepper fruits. TSS was higher in fruits packed in unperforated polyethylene bags on the 5th day (4.82 %) and 10th day (5.63 %) of storage, respectively. Whereas, lower TSS (4.56 and 5.40 %) was recorded in perforated bags.

4.10.3. Effect of Low Temperature Storage

The data reflected a significant effect of storage temperature on TSS of bell pepper fruits (Table 4.22). The TSS was higher in bell pepper fruits stored at 8^{0}C temperature on the 5th (4.78 %) and 10th day (5.59 %). Whereas, lower TSS (4.59 and 5.43 %) was noticed at 12^{0}C.

4.10.4. Interaction Effect

The interactions between P x W, P x T, W x T and P x W x T for TSS were found non-significant on 5th and 10th day of storage.

4.10.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on TSS of bell pepper fruits (Table 4.23). The highest TSS (4.22 and 4.14 %) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8⁰C temperature ($P_3W_1T_1$) on the 15th and 20th day of storage which was at par (4.18 and 4.11 %) unperforated polyethylene bags of 300 gauge thickness and stored at 8⁰C temperature ($P_2W_1T_1$). Whereas, the lowest TSS (3.82%) was recorded in unperforated polyethylene bags of 200 gauge thickness stored at 12⁰C ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge stored at 12⁰C ($P_2W_1T_2$) on the 20th day (3.91 %). On the 25th day of storage $P_3W_1T_1$ treatment recorded highest TSS (4.47 %).

4.10.6. Within Control

The data pertaining to TSS presented in the Table 4.23 showed non-significant results on the 5th day of storage.

4.10.7. Treated vs. Control

The data pertaining to TSS presented in Table 4.23 revealed significant results on the 5th day of storage.

A higher TSS (4.69 %) was recorded in treated bell pepper fruits. Whereas, lower TSS (4.37 %) was recorded in rigid plastic crates. Due to loss in quality, bell pepper fruits were discarded on the 5th day.

4.11. Overall Visual Quality (OVQ) measurement

The qualitative parameters of fruits were visually examined. OVQ scores for fruit colour, fruit succulence, general appearance and fruit odour are displayed in Table 4.24.

Maximum retention of green colour (++++) was observed in fruits under $P_1W_1T_1$, $P_2W_1T_1$, $P_2W_1T_2$, $P_3W_1T_1$ and $P_3W_1T_2$ combinations. Whereas, fruits under $P_1W_1T_2$ and $P_3W_2T_2$ treatments were slightly yellow (++).

Bell pepper fruits packed in unperforated polyethylene bags of 200, 300 and 400 gauge thickness and stored at 8^0C were very succulent (++++). However, partially shrivelled (++) fruits were observed in $P_1W_1T_2$ and $P_3W_2T_2$ treatments.

The highest OVQ scores (++++) for general appearance were recorded in bell pepper fruits packed in unperforated polyethylene bags (200, 300 and 400 gauge thickness) and stored at 8^0C. Bell pepper fruits in $P_1W_1T_2$ and $P_3W_2T_2$ treatments were found to be of acceptable quality (++).

Higher scores (++++) for odour were observed in $P_1W_1T_1$, $P_2W_1T_1$, $P_2W_1T_2$, $P_3W_1T_1$ and $P_3W_1T_2$ treatments. Even in the remaining treatment combinations, fruit odour was found to be good (+++).

Table 4.24 : Effect of polyethylene packaging, perforation and temperature on Overall Visual Quality (OVQ) of bell pepper fruits cv. 'Indra' on the 15th day of storage.

Treatments	Fruit colour	Fruit succulence	General appearance	Fruit odour
$P_1W_1T_1$	+ + + +	+ + +	+ + + +	+ + + +
$P_1W_1T_2$	+ +	+ +	+ +	+ + +
$P_2W_1T_1$	+ + + +	+ + + +	+ + + +	+ + + +
$P_2W_1T_2$	+ + + +	+ + +	+ + +	+ + + +
$P_2W_2T_1$	+ + +	+ + +	+ + +	+ + +
$P_3W_1T_1$	+ + + +	+ + + +	+ + + +	+ + + +
$P_3W_1T_2$	+ + + +	+ + +	+ + +	+ + + +
$P_3W_2T_1$	+ + +	+ + +	+ + +	+ + +
$P_3W_2T_2$	+ +	+ +	+ +	+ + +

Scale	Fruit colour	Fruit succulence	General appearance	Fruit odour
+ + + +	Dark green	Very succulent	Excellent	Excellent
+ + +	Light green	Succulent	Good	Good
+ +	Slightly yellow	Partially shriveled	Acceptable	Acceptable
+	Completely yellow	Completely shriveled	Non acceptable	Non acceptable

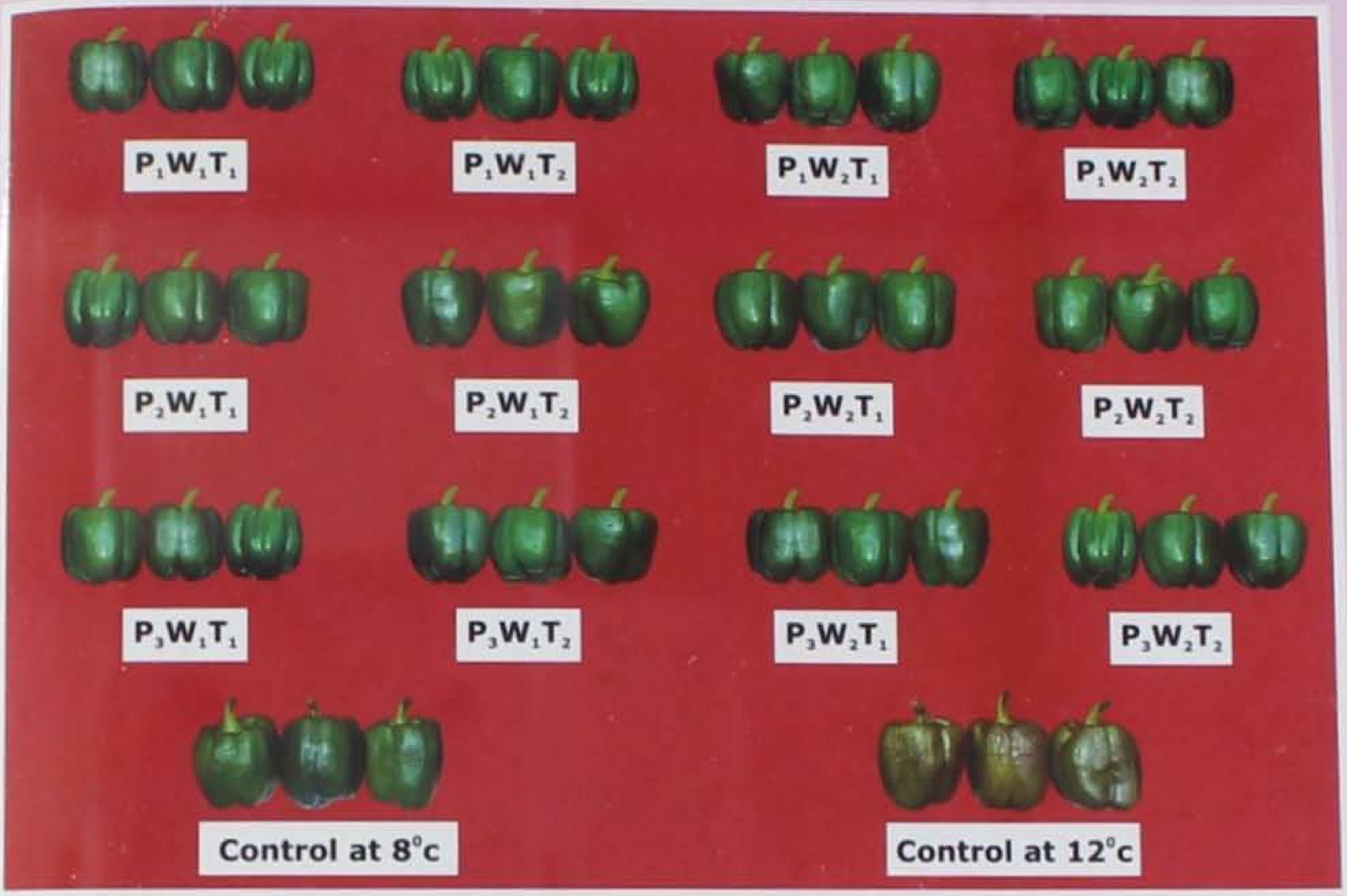


Plate III. Effect of packaging, perforation and low temperature on bell pepper cv. 'Indra' after 5 days of storage.

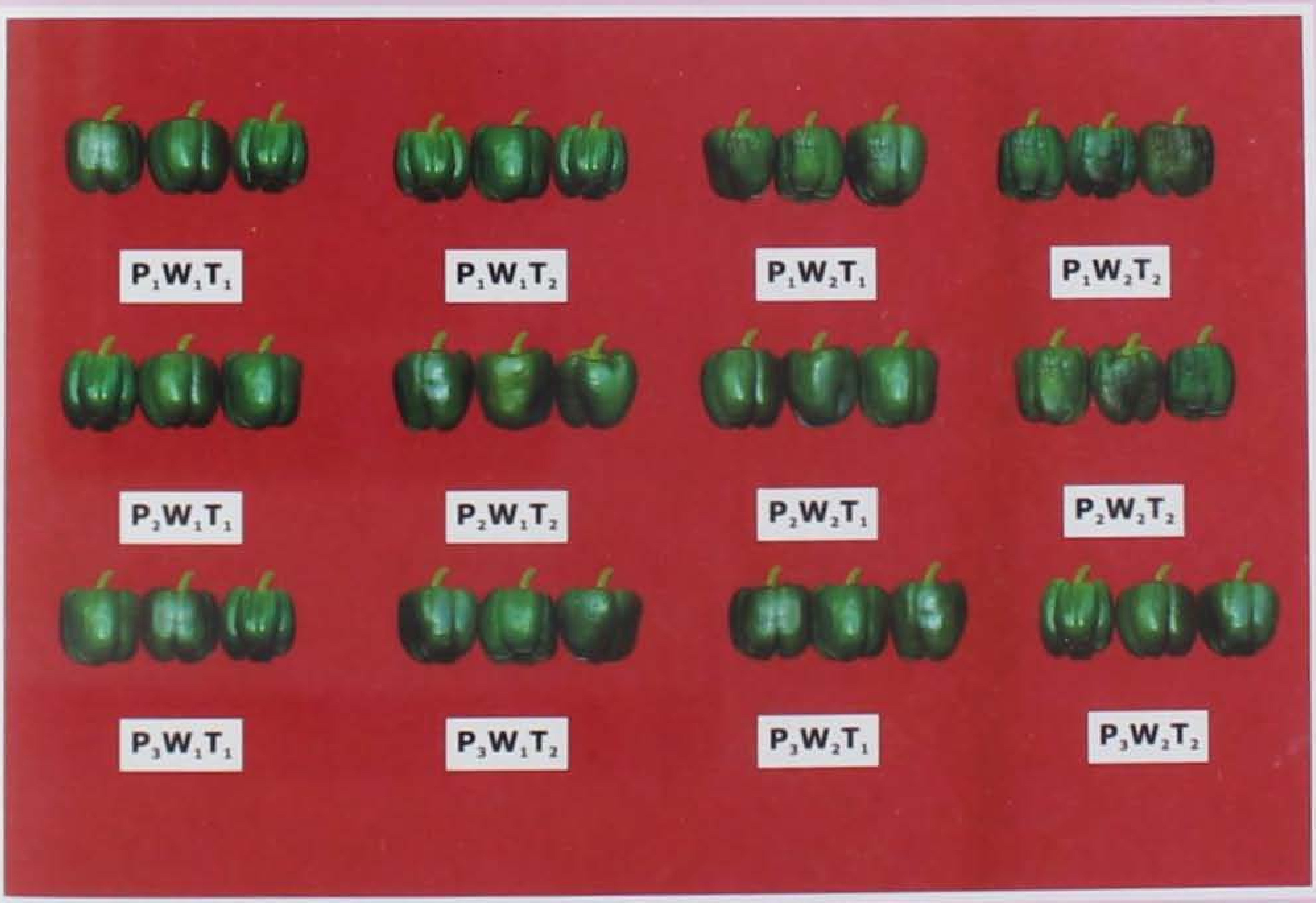


Plate IV. Effect of packaging, perforation and low temperature on bell pepper cv. 'Indra' after 10 days of storage.

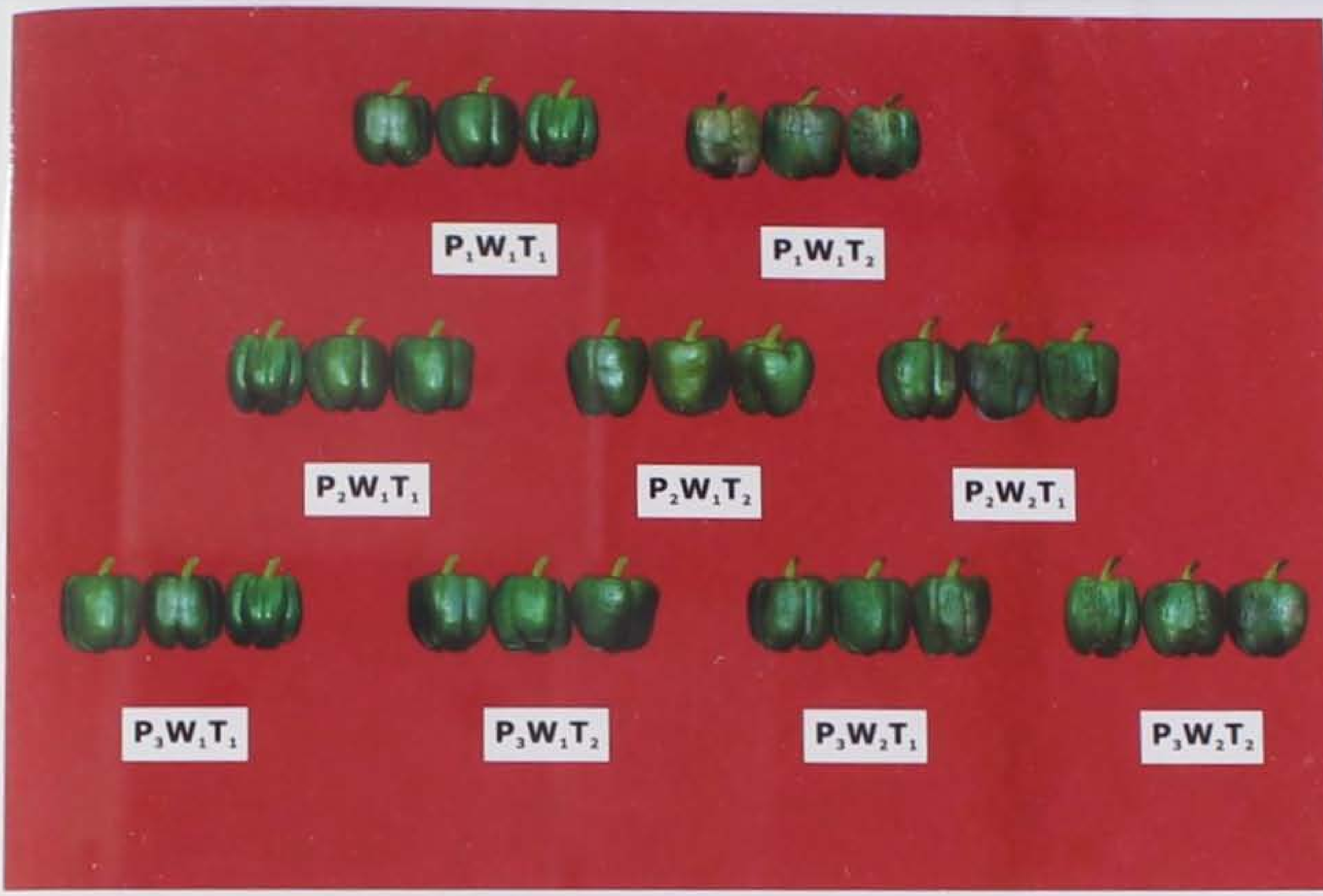


Plate V. Effect of packaging, perforation and low temperature on bell pepper cv. 'Indra' after 15 days of storage.

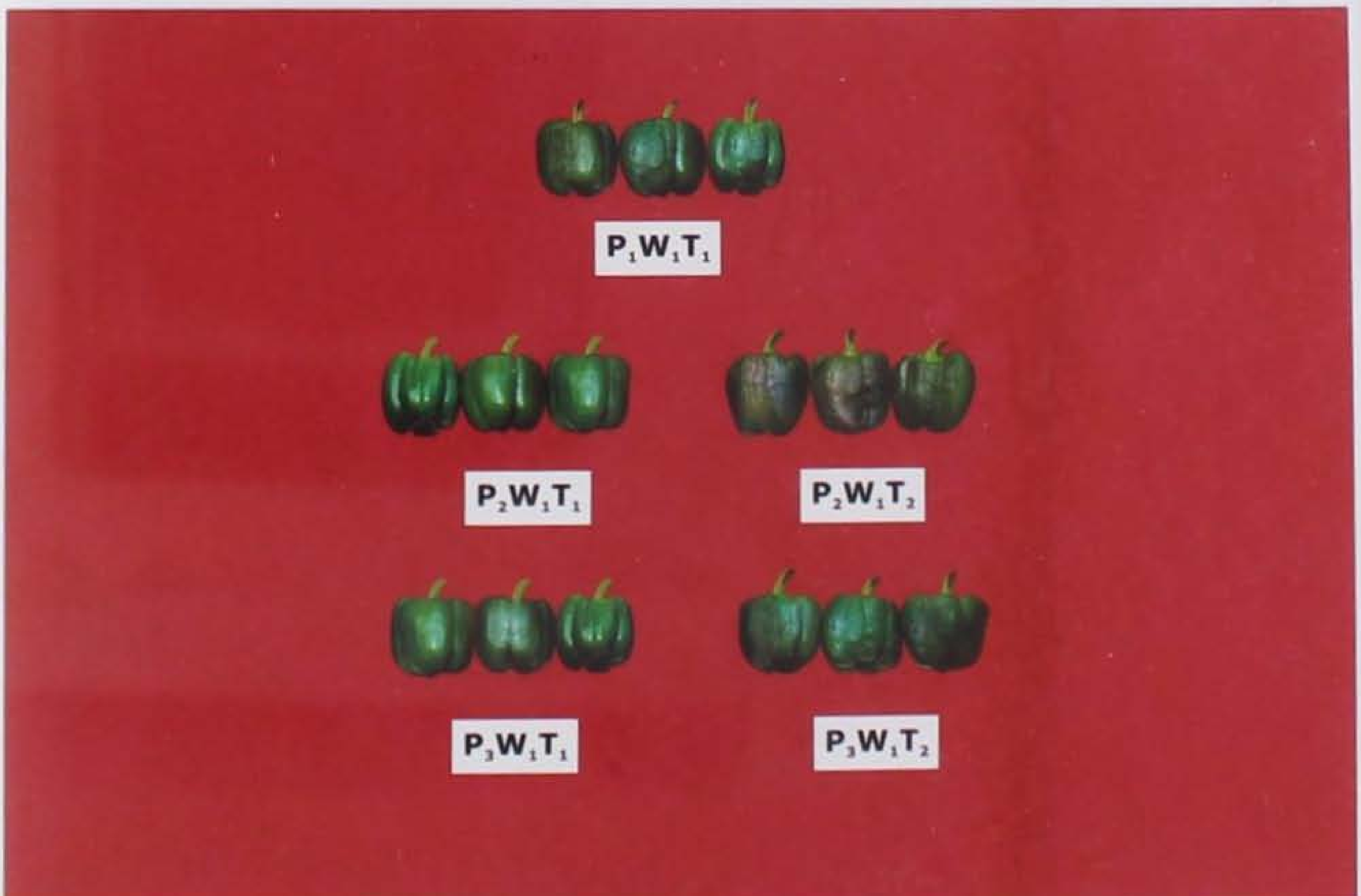


Plate VI. Effect of packaging, perforation and low temperature on bell pepper cv. 'Indra' after 20 days of storage.

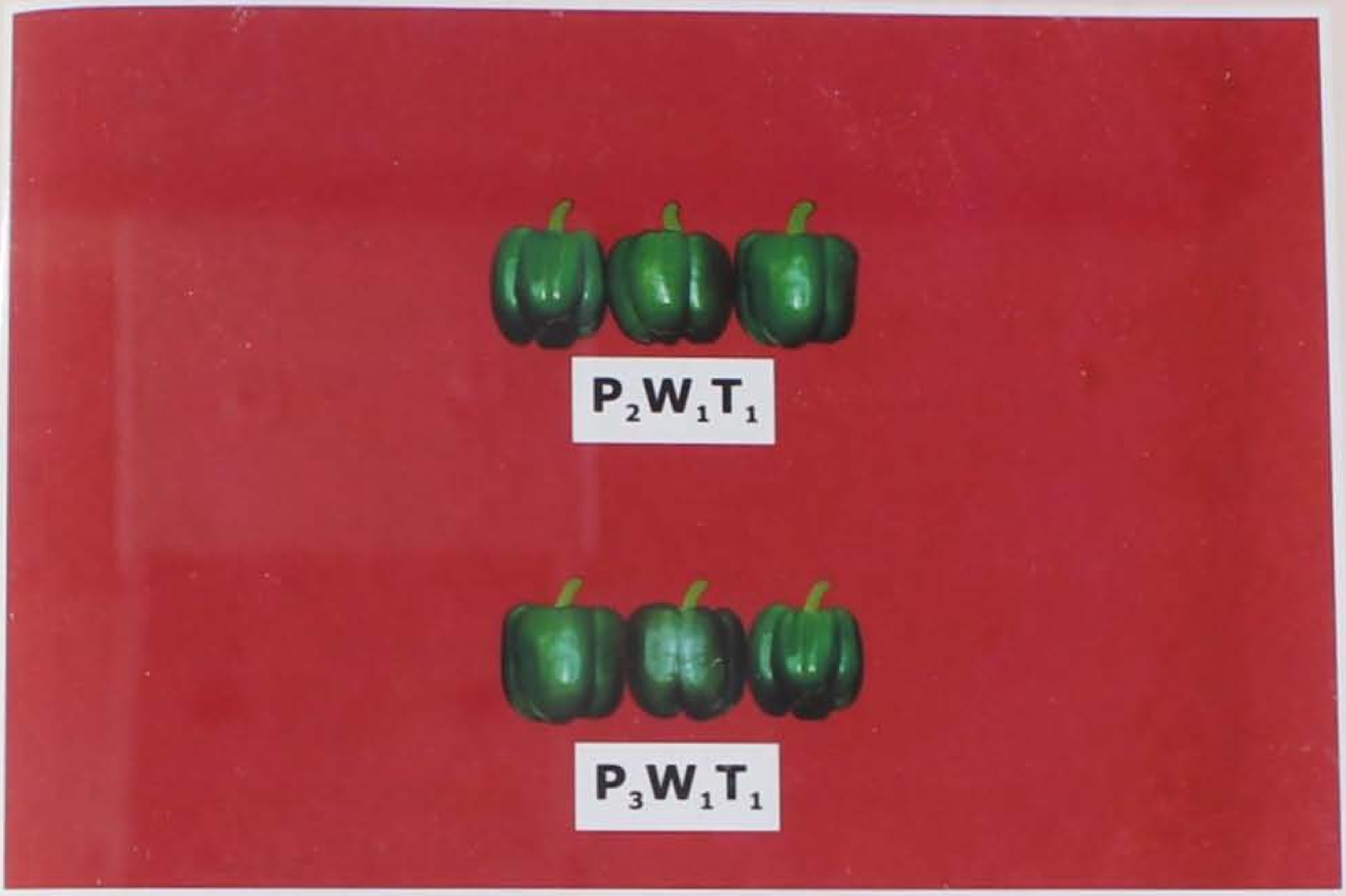


Plate VII. Effect of packaging, perforation and low temperature on bell pepper cv. 'Indra' after 25 days of storage.

Plate VIII. Spoilage in bell pepper fruits

4.12. Disease incidence (%)

The data pertaining to disease incidence as affected by packaging, perforation and temperature on the 5th, 10th, 15th, 20th and 25th day of storage is presented in Table 4.25, Table 4.26 and graphically illustrated in Fig. 4.11. On the 5th day of storage, disease incidence was not observed in treated fruits. However, disease incidence increased with the passage of time, regardless of treatments (Table 4.25).

4.12.1. Effect of Packaging

Packaging did not have a significant influence on disease incidence in bell pepper fruits on the 5th day of experimentation (Table 4.25). On the 10th day, disease incidence was significantly the lowest (9.70 %) in bell pepper fruits packed in polyethylene bags of 400 gauge thickness. Whereas, the highest disease incidence was noticed in fruits kept in bags of 200 gauge thickness (12.59%).

4.12.2. Effect of Perforation

Glimpses of Table 4.25 indicated a significant effect of perforation on disease incidence in bell pepper fruits only on the 10th day of investigation. Disease incidence was lower (8.79%) in bell pepper fruits packed in unperforated bags. Whereas, higher disease incidence (13.17%) was observed in perforated bags.

Table 4.25 : Effect of polyethylene packaging, perforation and temperature on disease incidence (%) in bell pepper fruits cv. 'Indra' on 10th day of storage.

Treatments	10th day
Polyethylene Packaging (P)	
P_1 – 200 gauge thickness	12.59
P_2 – 300 gauge thickness	10.65
P_3 – 400 gauge thickness	9.70
Mean	10.98
S.Em. ±	0.350
CD at 5%	1.02
With and Without Perforation (W)	
W_1 - Without perforation	8.79
W_2 - With perforations	13.17
Mean	10.98
S.Em. ±	0.286
CD at 5%	0.83
Temperature (T)	
T_1 - 8⁰C temperature	9.64
T_2 - 12⁰C temperature	12.32
Mean	10.98
S.Em. ±	0.286
CD at 5%	0.83
CV%	11.03

* Initial value 0.00 %

Note: Disease incidence was not observed in treated fruits on the 5th day of storage

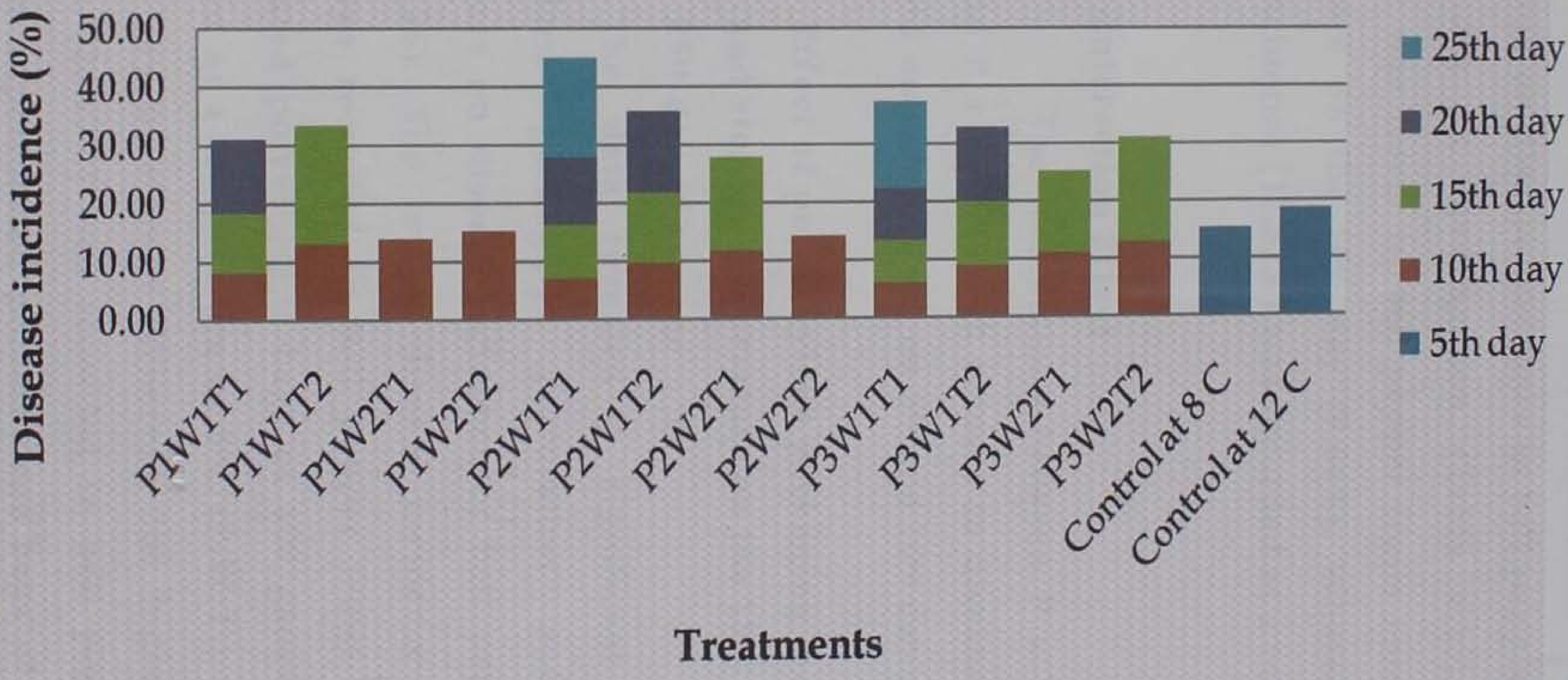
Table 4.26 : Effect of polyethylene packaging, perforation and low temperature storage on disease incidence (%) in bell pepper fruits cv. 'Indra'.

Treatments	5th day	10th day	15th day	20th day	25th day
$P_1W_1T_1$	0.00	8.05	10.37	12.54	-
$P_1W_1T_2$	0.00	13.09	20.27	-	-
$P_1W_2T_1$	0.00	13.98	-	-	-
$P_1W_2T_2$	0.00	15.24	-	-	-
$P_2W_1T_1$	0.00	6.98	9.33	11.48	17.32
$P_2W_1T_2$	0.00	9.64	12.20	13.93	-
$P_2W_2T_1$	0.00	11.69	16.25	-	-
$P_2W_2T_2$	0.00	14.28	-	-	-
$P_3W_1T_1$	0.00	6.08	7.27	9.06	15.12
$P_3W_1T_2$	0.00	8.91	11.04	12.90	-
$P_3W_2T_1$	0.00	11.06	14.26	-	-
$P_3W_2T_2$	0.00	12.75	18.24	-	-
Mean	0.00	10.98	13.25	11.98	16.22
S.Em. ±	-	-	0.434	0.471	-
CD at 5%	-	-	1.29	1.48	-
Control at 8°C	15.33	-	-	-	-
Control at 12°C	18.74	-	-	-	-
Mean	17.04	-	-	-	-
Treated vs. Control					
S.Em. ±	0.165	-	-	-	-
CD at 5%	0.48	-	-	-	-
Within Control					
S.Em. ±	0.306	-	-	-	-
CD at 5%	0.89	-	-	-	-
CV%	4.38	11.03	5.67	6.81	-

*Initial value 0.00%

Note: Disease incidence was not observed in treated fruits on the 5th day of storage

Fig. 4.11 Effect of packaging, perforation and low temperature storage on disease incidence (%) of bell pepper cv. 'Indra'



4.12.3. Effect of Low Temperature Storage

There was a non-significant effect of temperature on disease incidence in bell pepper fruits on the 5th day of investigation (Table 4.25). Disease incidence was lower in bell pepper fruits stored at 8^0C temperature on the 10th day (9.64%). Whereas, higher disease incidence (12.32%) was recorded at a temperature of 12^0C.

4.12.4. Interaction Effect

The interactions between P x W, P x T, W x T and P x W x T with respect to disease incidence were found non-significant on 5th and 10th day of storage.

4.12.5. Effect of polyethylene packaging, perforation and storage temperature on the 15th, 20th and 25th day of storage

The data revealed a significant effect of polyethylene packaging, perforation and storage temperature on disease incidence of bell pepper fruits (Table 4.26). The lowest disease incidence (7.27 and 9.06%) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at a temperature of 8^0C ($P_1W_1T_1$) on the 15th and 20th day of storage. Whereas, the highest disease incidence (20.27%) was recorded in bell pepper fruits packed in unperforated polyethylene bags of 200 gauge thickness stored at 12^{0}C storage temperature ($P_1W_1T_2$) on the 15th day and in unperforated polyethylene bags of 300 gauge stored at 12^{0}C ($P_2W_1T_2$) on the 20th day (13.93%). On the 25th day of storage, $P_3W_1T_1$ combination recorded the lowest disease incidence (15.12 %).

4.12.6. Within Control

The data pertaining to disease incidence presented in Table 4.26 showed significant results for disease incidence on the 5th day of storage.

Lower disease incidence (15.33%) was registered in bell pepper fruits kept in plastic crates at 8^{0}C temperature. Whereas, higher disease incidence (18.74%) was registered at 12^{0}C.

4.12.7. Treated vs. Control

The data pertaining to disease incidence presented in the Table 4.26 showed significant results on the 5th day of storage.

Treated fruits were free from disease, on the 5th day. Whereas, higher disease incidence (17.04%) was recorded in rigid plastic crates. Due to loss in quality, bell pepper fruits were discarded on the 5th day.

DISCUSSION

V. DISCUSSION

In this chapter, an endeavor has been made to discuss the results of the present investigation in the light of information generated. Findings of previous workers have also been cited for supporting the results obtained in the present study.

5.1 Physiological parameters

5.1.1 Physiological loss in weight (%)

The physiological loss in weight of bell pepper fruits was significantly affected by polyethylene bags, perforation and storage temperature (Table 4.1 to 4.6).

Weight loss in fresh bell pepper is primarily due to transpiration and respiration. Transpiration is a mechanism in which water is lost due to differences in vapour pressure of water in the atmosphere and the transpiring surface. Respiration leads to weight reduction because a carbon atom is lost from the fruit each time a carbon dioxide molecule is produced from an absorbed oxygen molecule and evolved into the atmosphere (Bhowmik and Pan, 1992). In the present investigation, physiological loss in weight was the lowest in bell pepper fruits packed in polyethylene bags of 400 gauge thickness, which could be attributed to the maintenance of humidity in the micro atmosphere within the package by the respiring fruits and due to low water vapour transmission rates of packaging material (Onwuzulu *et al.*, 1995; Geeson *et al.*, 1985). These finding are in conformity with those of Manolopoulou *et al.* (2010) in bell pepper.

As the thickness of polyethylene bags increased, PLW decreased significantly. This could be due to reduced moisture loss from the stored fruits. Similar results were recorded by Yadav *et al.* (2009) in tomato.

Bell pepper fruits packed in unperforated bags had lower PLW than those packed in perforated bags. Lower weight loss in unperforated bags may be due to the confinement of moisture around the produce. This increases the relative humidity and reduces transpiration (Thompson, 1996).

Bell pepper fruits stored at 8^0C temperature had lower PLW than those stored at 12^0C temperature. This could be attributed to temperature effects on vapour pressure deficit and increased water retention (Tasdelen and Bayindirli, 1998). In addition, high temperature accelerated the rate of respiration and other metabolic processes which caused depletion of substrates like sugars and proteins resulting into further weight loss (Buescher, 1979). Similar results were reported by Bussel and Kenigsberger (1975) in green bell pepper.

The interaction effect of P x W was found significant for PLW on the 5th and 10th day of storage (Table 4.2). Bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness, registered the lowest physiological loss in weight probably due to a reduction in rate of respiration and loss of moisture under these conditions.

The interaction effect of P x T was found significant for PLW on the 5th and 10th day of storage (Table 4.3). Bell pepper fruits packed in polyethylene bags of 400 gauge thickness and stored at 8^{0}C temperature revealed the lowest physiological loss in weight. Lower weight loss coincided with a decrease in storage temperature which was in agreement with the findings of Tindall (1983) and Sealand (1991). Lower weight loss in packaging is due to the confinement of moisture around the produce by polyethylene bags. This increased relative humidity and reduced transpiration (Thompson, 1996). This could be the reason behind low PLW in the treatment combination comprising of 400 gauge polyethylene bags and storage at 8^{0}C. Batu and Thomson (1998) observed the lowest weight loss in tomato fruits cv. Liberto when packed in polyethylene bags and stored at 13^{0}C temperature.

The interaction effect of W x T was found significant for PLW on the 5th and 10th day of storage (Table 4.4). Bell pepper fruits packed in unperforated polyethylene bags and stored at 8^{0}C temperature revealed the lowest physiological loss in weight. This could be attributed to a slowdown in physiological processes such as respiration and transpiration at low temperatures (Kays, 1991).

The interaction effect of P x W x T was found significant for PLW on the 5th and 10th day of storage (Table 4.5). Bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^{0}C temperature showed the lowest physiological loss in weight.

With regard to treatment combinations, fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^{0}C ($P_3W_1T_1$) recorded the lowest PLW on the 15th, 20th and 25th day of storage. In a similar study on sweet pepper cv. California Wonder, the lowest weight loss was noticed in unperforated polyethylene bags stored at 4 and 6.5^{0}C temperature (Nyanjage *et al.*, 2005).

5.1.2 Chilling injury (%)

Chilling injury was not observed in bell pepper fruits on the 5th, 10th and 15th day of storage regardless of treatments. However, differences were statistically significant on the 20th day of storage (Table 4.7). The lowest chilling injury was recorded in bell pepper fruits packed in unperforated polyethylene bags of 300 gauge thickness stored at 12°C temperature. On the 25th day of storage, minimum chilling injury was noticed in unperforated polyethylene bags of 400 gauge thickness stored at 8°C temperature.

Packaging has been reported to reduce chilling injury in many fruits. Forney and Lipton (1990) reported that packing bell pepper fruits inside a polyethylene bag creates a modified atmosphere within the package, thus reducing its susceptibility to chilling injury. A modified atmosphere induced by packing okra fruits in PVC films reduced the development of chilling injury when stored at a temperature of 5°C (Fernando *et al.*, 2008).

In banana, a modified atmosphere was generated by wrapping fruits in non-perforated polyethylene bags which resulted in lower chilling injuries (Nguyen *et al.*, 2004). Similar results were observed in grapefruit coated with commercial waxes and stored at 4°C for two months (Dou, 2004). Use of unperforated polyethylene bags enabled the storage of brinjal fruits at 8°C temperature for more than three weeks without sustaining any chilling injury (Fallik *et al.*, 1995).

Chilling injury symptoms observed at 8°C and 12°C could be a result of dissociation of enzymes and other proteins into structural sub-units and hence a change in the kinetics of enzyme activity and structural proteins (Graham and Patterson, 1982; Morris, 1982 and Wang, 1990). Low temperature induces change in the physical properties of cell membrane due to a change in the physical state of membrane lipids. These results are in close conformity with the findings of Nyanjage *et al.* (2005) in sweet pepper and Ngure *et al.* (2009) in okra.

5.1.3 Total Chlorophyll and Carotenoid content (mg/100g)

Chlorophyll and carotenoid content in bell pepper fruits was significantly influenced by polyethylene packaging, perforation and storage temperature (Table 4.8 to 4.11).

Higher chlorophyll and carotenoid content was registered in polyethylene bags of 400 gauge thickness. It seems that CO_2 accumulation (evolved during respiration) in polyethylene films was an important factor in preventing chlorophyll and carotenoid degradation in bell pepper fruits (Wang, 1971). Rapid chlorophyll and carotenoid degradation in untreated fruits may be due to higher loss water in these fruits which caused more degradation of pigments (Singh *et al.*, 1980). This could also be attributed to thylakoids losses.

Chloroplast losses thylakoids and contains only vesicles and plastoglobuli (Bartley and Hallam, 1979). Similar results were reported by Singh *et al.* (2004) in zinnia and Ghadge (2008) in spinach.

Chlorophyll and carotenoid content was significantly higher in bell pepper fruits packed in unperforated bags. As mentioned earlier, chlorophyll and carotenoid degradation is related to water loss in bell pepper fruits. Minimal water loss in unperforated polyethylene bags may have contributed to higher chlorophyll and carotenoid content.

Bell pepper fruits stored at 8^0C temperature showed higher retention of chlorophyll and carotenoid pigments. This is primarily due to transpiration and respiration. During these processes, low moisture loss occurred at 8^0C than at 12^0C and this is an important factor in the retention of chlorophyll and carotenoid content in bell pepper fruits. Similar results were obtained by Fernando *et al.* (2008) in okra and Deb and Suresh (2008) in chilli.

The highest chlorophyll and carotenoid content was recorded in fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$) during the entire period of storage.

5.1.4 Rate of Respiration (CO_2 mg/kg/hr)

Respiration rate in bell pepper fruits was significantly altered by polyethylene bags, perforation and storage temperature (Table 4.12 and 4.13).

Results of the present investigation showed that polyethylene packaging delayed the rise in respiration. The lowest respiration rate was recorded in bell pepper fruits packed in polyethylene bags of 400 gauge. This could be due to differential permeability of the packaging material. The rate of diffusion of O_2 from the atmosphere through the outer layer of the fruit was reduced and this in turn reduced the number of glucose molecules oxidized per unit time. Elevated CO_2 concentration inhibits the activity of phosphofructokinase, which is an important regulatory enzyme in glycolytic pathway. Also, accumulation of fructose-6-phosphate and reduction in fructose, 1-6-bisphosphate suggest an inhibitory effect of CO_2 on phosphofructokinase activity (Kerbel *et al.*, 1988). These finding are in conformity with those of Anandaswamy *et al.* (1963) in okra and Babitha (2006) in tomato. Low oxygen atmosphere also reduced the respiration rate in bell pepper (Rahman *et al.*, 1993) and tomato (Artes *et al.*, 1999).

The rate of respiration was significantly lower in fruits packed in unperforated bags, probably because of higher CO_2 levels. Mishra and Khatkar (2009) also observed lower respiration rate in cucumbers packed in unperforated polyethylene bags.

Bell pepper fruits stored at 8^0C temperature had significantly lower respiration rate than those stored at 12^0C temperature. This could be attributed to lower water loss which is governed directly by storage temperature (Policegoungra and Aradhya, 2007). These observations tally with the results of Halloran *et al.* (2000) in bell pepper and Chandra *et al.* (2008) in lettuce.

The lowest rate of respiration was registered in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$) on the 15^{th}, 20^{th} and 25^{th} day of storage.

5.2 Physical parameters

5.2.1 Firmness (kg/cm^2)

Firmness is an important quality attribute in bell pepper. Firmness was significantly affected by polyethylene packaging, perforation and storage temperature (Table 4.14 and 4.15).

Maximum firmness was recorded in 400 gauge polyethylene bags. Lurie *et al.* (1986) reported a strong relationship between firmness and weight loss in bell pepper. Polyethylene bags of 400 gauge thickness also recorded the lowest PLW. As loss in weight was minimum in fruits packed in 400 gauge polyethylene bags, they retained the maximum firmness. Identical reasons were advanced by Sakaldas and Kaynas (2010) in sweet pepper.

Firmness was significantly higher in fruits packed in unperforated because of lower weight loss in these bags. A similar observation was previously made by Mishra and Khatkar (2009) in case of cucumber. They reported higher firmness in cucumbers when packed in unperforated polyethylene bags.

Fruits stored at 8^0C temperature were more firm as compared to those stored at 12^0C temperature. The minimum weight loss in fruits at 8^0C could be the reason behind higher firmness. Sakaldas and Kaynas (2010) also recorded higher firmness in bell pepper fruits when stored at a temperature of 6-7^0C and 90-95% relative humidity.

The highest firmness was observed in fruits packed in unperforated polyethylene bags of 400 gauge thickness and kept at 8^0C temperature ($P_3W_1T_1$) on the 15^{th}, 20^{th} and 25^{th} day of storage.

5.2.2 Shrinkage (%)

There was a significant impact of polyethylene packaging, perforation and storage temperature on shrinkage in bell pepper fruits (Table 4.16 and 4.17).

Shrinkage is associated with excessive water loss. George *et al.* (1982) reported that weight loss is primarily due to water loss in bell pepper. Minimum weight loss was observed in polyethylene bags of 400 gauge thickness which implies that moisture was retained and confined in these bags. Therefore, the lowest shrinkage was observed in polyethylene bags of 400 gauge thickness. Water loss from fresh produce causes deterioration through wilting and shriveling, loss of textural quality and nutritional quality (Thompson, 1996). Shrinkage was significantly lower in fruits packed in unperforated bags because of lower water loss.

Bell pepper fruits stored at 8^0C temperature had significantly lower shrinkage than those stored at 12^0C temperature. Higher temperatures increase the rate of respiration and other metabolic processes that cause depletion of substrates like sugars and proteins resulting into weight loss (Buescher, 1979). As water evaporates from the tissue, turgor pressure decreases and the cell begins to shrink thus leading to higher shrinkage (Wills *et al.*, 1998).

The lowest shrinkage was recorded in fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_1W_1T_1$) for the entire period of storage.

5.2.3 Bulk density (g/cm³)

Polyethylene packaging, perforation and storage temperature had a significant effect on bulk density of bell pepper fruits (Table 4.18 and 4.19).

The highest bulk density was recorded in 400 gauge polyethylene bags. Bulk density is related to PLW and shrinkage. Results indicated the minimum PLW and shrinkage in 400 gauge polyethylene bags. Consequently, the highest bulk density was recorded in polyethylene bags of 400 gauge thickness. In a similar study on bell pepper, Kadam and Singh (2006) recorded maximum increase in bulk density after 12 day of storage using polyethylene bags.

Bulk density was significantly higher in fruits packed in unperforated polyethylene bags. Minimum PLW and shrinkage in unperforated polyethylene bags may have contributed to higher bulk density.

Bell pepper fruits stored at 8^0C temperature had significantly higher bulk density than those stored at 12^0C temperature. As bulk density is the ratio of weight and volume of fruits, it is directly correlated to PLW and shrinkage. As stated earlier, the minimum PLW and shrinkage were observed at 8^0C temperature. Therefore, fruits stored at 8^0C temperature had higher bulk density.

Unperforated polyethylene bags of 400 gauge thickness stored at 8^0C temperature ($P_3W_1T_1$) recorded the highest bulk density in bell pepper fruits on the 15^{th}, 20^{th} and 25^{th} day of storage.

5.3 **Biochemical parameters**

5.3.1 **Ascorbic acid (mg/100g)**

Significant differences were observed in the ascorbic acid content of bell pepper fruits due to polyethylene packaging, perforation and storage temperature (Table 4.20 and 4.21).

Ascorbic acid has a significant role in assimilation of proteins obtained from other sources. It is also essential for the formation of normal bones and teeth. Absence of vitamin C results in scurvy. Preservation of ascorbic acid content is a difficult task as it undergoes oxidation. However, in the present investigation, the highest ascorbic acid content was recorded in bell pepper fruits packed in polyethylene bags of 400 gauge thickness. This can be attributed to the maintenance of CO_2 levels and reduced O_2 concentration under modified atmospheric packaging (Babitha, 2006). Similar results were forwarded by Ghadge (2008) in spinach and Akbudak (2008) in long pepper.

Ascorbic acid was significantly higher in bell pepper fruits packed in unperforated polyethylene bags, probably due to the maintenance of CO_2 levels.

There was a gradual decline in ascorbic acid content of fruits throughout the storage period. This might be due to increased activity of ascorbic acid oxidase in stored fruits. These results confirm the findings of Deb and Suresh (2008) in green chilli.

During the course of this investigation, the highest ascorbic acid was recorded in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$).

5.3.2 TSS (%)

The total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. Sugars constitute 80-85 per cent of soluble solids.

TSS in bell pepper fruits was significantly affected by polyethylene packaging, perforation and storage temperature (Table 4.22 and 4.23). The highest TSS was recorded in 400 gauge polyethylene bags. It was also higher in unperforated polyethylene bags and in fruits stored at 8^0C temperature.

The TSS content was maximum on the 10^{th} day of experimentation but started decreasing gradually afterwards in all treatments. Yadav *et al.* (2009) also reported an increase in TSS up to 10 days followed by a gradual decrease in tomato.

Gonzalez-Aguilar and Tiznado (1993) and Ozden and Bayindirli (2002) examined changes in TSS during the storage of bell pepper and observed an increase in TSS content during storage. However, towards the end of storage, decreases were also noticed. Ramakrishna *et al.* (2001) reported that the initial increase in TSS content might be due to conversion of carbohydrates into sugar, while the later decrease in TSS content was perhaps due to consumption of sugars and organic acids for respiration during storage.

The highest TSS was recorded in fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature ($P_3W_1T_1$) on the 15^{th}, 20^{th} and 25^{th} day of storage.

5.4 Overall Visual Quality (OVQ) measurement

Overall Visual Quality of bell pepper fruits as affected by packaging, perforation and low temperature was illustrated in Table 4.24. It is evident from the table that post harvest treatments had a profound bearing on the visual quality of fresh bell pepper fruits.

The maximum retention of green colour was observed in unperforated polyethylene bags (200,300 and 400 gauge thickness) stored at low temperatures (8 and 12^0C). This may due to the generation of a modified atmosphere in the package which retarded the activity of chlorophyllase, an enzyme believed to be responsible for chlorophyll degradation (Ardao and Vennesland, 1966 and Boger, 1965). Lowering the temperature of non-climacteric fuits like sweet pepper lowers their rate of ripening and deterioration (Kays, 1991) and hence the high retention of green colour observed in the fruits stored at 4°C and 6.5°C.

Bell pepper fruits packed in unperforated polyethylene bags of 200, 300 and 400 gauge thickness and stored at 8°C had the highest OVQ scores for general appearance and succulence. Lower water loss in the above treatments may have helped retain succulence.

Higher scores for odour were observed in unperforated polyethylene bags of different thickness stored at 8 and 12°C temperatures. Even in the remaining treatment combinations, fruit odour was found to be good.

5.5 Pathological disorders

5.5.1 Disease incidence

Disease incidence in bell pepper fruits was significantly affected by polyethylene packaging, perforation and storage temperature (Table 4.25 and 4.26).

The lowest disease incidence was observed in polyethylene bags of 400 gauge thickness. Lowest disease incidence could be due to the optimum permeability of gases and moisture in bags of 400 gauge thickness as compared to other treatments. A similar reduction in disease incidence with polyethylene packaging was earlier reported by Anandaswamy *et al.* (1963) in okra, Ben and Shapiro (1984) in bell pepper and Brar *et al.* (2000b) in chili.

Disease incidence was significantly lower in unperforated bags. Perforations may have exposed fruits to microorganisms which could have led to higher disease incidence.

Bell pepper fruits stored at 8^0C temperature had lower disease incidence than those stored at 12^0C temperature. Low temperature retards the growth of pathogens and this could have reduced disease incidence. These results are akin to those reported by Tano *et al.* (2008) in bell pepper.

The lowest disease incidence was observed in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at a temperature of 8^0C ($P_1W_1T_1$) throughout the storage period.

SUMMARY

AND

CONCLUSSION

VI. SUMMARY AND CONCLUSION

An experiment was conducted at the Department of Vegetable Science and Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during the year 2010 to assess the effect of polyethylene packaging and low temperature on the shelf life of bell pepper (*Capsicum annum* L.) cv. Indra. The objective of this investigation was to identify the right thickness of polyethylene packaging and storage temperature for extending shelf-life in bell pepper without compromising on visual and biochemical aspects of quality. It was also felt necessary to evaluate the effect of perforations in polyethylene bags on the shelf life and quality of bell pepper fruits.

The experiment comprising of twelve treatment combinations and three replications was evaluated in a Completely Randomized Design based on Factorial concept (FCRD). The salient findings of the investigation are summarized hereunder.

1. There was a significant influence of thickness of polyethylene bags, perforation and temperature on all attributes considered for this trial.
2. Polyethylene bags of 400 gauge thickness recorded the lowest PLW, respiration rate, shrinkage and disease incidence. The highest chlorophyll and

carotenoid content, firmness, bulk density, ascorbic acid content and TSS were also observed in the same thickness.

3. Unperforated bags had the highest chlorophyll content, carotenoid content, firmness, bulk density, ascorbic acid content and TSS. Whereas, perforations induced the highest PLW, rate of respiration, shrinkage and disease incidence.
4. Between the two temperatures, storage at 8^0C resulted in the lowest PLW, shrinkage and disease incidence and the highest chlorophyll content, carotenoid content, firmness, bulk density, ascorbic acid content and TSS.
5. Of the various parameters evaluated, interactions were found significant only for physiological loss in weight.
6. The lowest PLW was observed in bell pepper fruits packed in unperforated polyethylene bags of 400 gauge thickness; fruits packed in bags of 400 gauge thickness stored at 8^0C temperature and fruits packed in unperforated bags stored at 8^0C.
7. Fruits packed in unperforated polyethylene bags of 400 gauge thickness and stored at 8^0C temperature showed significantly the lowest PLW, chilling injury, rate of respiration, shrinkage and disease incidence. Significantly the highest chlorophyll and carotenoid content, firmness, bulk density, ascorbic

acid content and TSS were also observed in the same treatment combination.

8. Bell pepper fruits packed in unperforated polyethylene bags (300 and 400 gauge thickness) and stored at 8^0C temperature were of excellent visual quality as reflected by their OVQ scores for fruit colour, succulence, odour and general appearance.
9. Between the two control treatments, storage at 8^0C resulted in significantly higher chlorophyll and carotenoid content, firmness, bulk density, ascorbic acid content and TSS. It also recorded significantly lower PLW, respiration rate, shrinkage and disease incidence.
10. Treated fruits had significantly higher chlorophyll and carotenoid content, firmness, bulk density, ascorbic acid content and TSS. However, significantly higher physiological loss in weight, respiration rate, shrinkage and disease incidence were observed in untreated fruits.

Conclusion

Based on the above trial it can be inferred that bell pepper fruits cv. Indra when packed in unperforated polyethylene bags of 400 gauge thickness and kept at a temperature of 8^0C had a storability of up to 25 days. This treatment combination arrested biochemical deterioration and resulted in the lowest PLW, spoilage and shrinkage. Fruits under these conditions exhibited better retention of firmness, green colour and succulence.

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*Original not seen

APPENDICES

APPENDIX - I

The nutritive values for 100 g of green bell pepper

Nutrient	Nutritive value
Energy	18Kcal
Carbohydrates	2.9g
Crude fibre	2.0g
Protein	1.2g
Fat	0.2g
Calcium	36mg
Iron	1.1mg
Phosphorus	19mg
Carotene	427mcg
Thiamine	0.55mg
Riboflavin	0.05mg
Niacin	0.1mg
Vitamin C	137mg
Magnesium	12mg
Copper	0.12mg
Zinc	0.13mg

Source: ICMR, NIN Hyderabad

(www.timeswellness.com)

APPENDIX - II

Day-wise meteorological data during experimentation.

Date	Ambient temperature			
	Temperature (^0C)		Relative humidity (%)	
	Max.	Min.	Morning	Evening
16/11/ 2010	34.0	23.0	91	67
17/11/ 2010	32.5	22.5	91	61
18/11/ 2010	33.0	22.5	91	58
19/11/ 2010	34.0	23.5	92	52
20/11/ 2010	33.0	22.5	91	48
21/11/ 2010	33.5	24.0	84	83
22/11/ 2010	30.0	22.5	91	66
23/11/ 2010	31.0	22.5	95	75
24/11/ 2010	29.5	22.5	95	77
25/11/ 2010	28.0	21.2	91	68
26/11/ 2010	28.5	21.0	91	58
27/11/ 2010	29.0	21.3	93	53
28/11/ 2010	30.0	19.4	87	59
29/11/ 2010	30.5	22.3	86	42
30/11/2010	33.0	21.0	93.0	45.0
01/12/2010	33.0	21.4	81.0	54.0
02/12/2010	31.5	20.4	73.0	52.0
03/12/2010	31.5	19.0	92	49
04/12/2010	32.0	19.7	91	49
05/12/2010	32.0	21.0	63	56

Source: Agricultural Meteorological Observatory, Agricultural Experimental Station, Navsari Agricultural University, Navsari.

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy of any part of this thesis at a time through reprographic process, if necessary for rendering reference services in a library or documentation centre.

Place : Navsari

Date : 6th September, 2011

Rajan

(R. P. Patel)