CHAPTER I

INTRODUCTION

The onion (Allium cepa L.) is a species of the Alinaceae family and is cultivated as a vegetable throughout the world. Onion bulb is a series of concentric swollen leaves attached to a short stem or base. India ranks second after China in world onion production followed by USA, Turkey, Pakistan, Iran, Indonesia, Vietnam and Myanmar etc. Area covered by onion in India is about 1173.35 thousand hectare with production of 18927.41 thousand metric tonnes and productivity of 16 metric tonnes/hectare in 2014-2015 (Anon 2015). The productivity is quite low as compared to other countries. The productivity of onion in India is at least 5 times lesser as compared to republic of Korea (66.16 t/ha), about 4 times less than USA (56.13 t/ha), Spain (55.21 t/ha), Netherland (51.64 t/ha) and Myanmar (46.21 t/ha) (Chengappa et al 2012). Area covered by onion in Punjab is 8.38 thousand hectare and production is about 188.18 thousand metric tonnes in 2014-2015 (Anon 2015). In India maximum productivity is in Gujarat 24.40 t/ha followed by Bihar (Anon 2011a). Maharashtra’s stands alone contribution is 32.6 per cent in total production and the rest shared by Karnataka, Gujarat and Madhya Pradesh in India (Anon 2012).

Various varieties are available such as Bhima Shweta, Bhima Shubra, Pusa Red, Pusa Madhavi, Early Grano, Pusa White Round, Pusa White Flat, Hisar-2 Agrifound Rose etc (Anon 2015). Punjab Selection, S-148, Agri Found Dark Red (AFDR), PRO-6 (2003), Punjab White (1997) and Punjab Naroya (1995) are the various varieties developed by PAU, Ludhiana (Anon 2013).

Onion is a cool season vegetable and grows well under mild climate without extreme heat or cold or excessive rainfall. It does not thrive when the average rainfall exceeds 75-100 cm during monsoon period. The ideal temperature for vegetative growth is 12.8-23°C. For bulb formation it requires long days and still higher temperature (20-25°C). Onion prefers a well-drained, loose and friable soil rich in humus. It is sensitive to high acidity and alkalinity and the ideal pH is 5.8 to 6.5. Alkaline and low lying soils are not suitable for onion cultivation. Common onion (Allium cepa var. cepa), Multiplier onion or potato onion (Allium cepa var. aggregatum), Shallot (Allium cepa var. ascalonicum), Tree onion or Egyptian onion (Allium cepa var. viviparaum / proliferum), Chive (A. schoenoprasum) are the types of onion grown in India (Anon 2015). Lawande et al (2009) stated some important varieties of onion cultivated in kharif season are Baswant–780, N-53, Agrifound Dark Red, Arka Kalyan and Bhima Super; in late kharif, Baswant–780, Phule Samarth, Bhima Red and Agrifound Light Red and in rabi season, varieties N-2-4-1, Arka Niketan, Agrifound Light Red, Pusa Red, Pusa Madhavi, Bhima Raj, Bhima Red can be cultivated.
According to the USDA National Nutrient Database for Standard Reference, the nutritional composition of raw onions, per 100g of edible portion is 89.11g of water, 1.10g of protein, 0.10 total lipids (fat), 0.35g of ash, 9.34g of carbohydrate, 4.24g of total sugars and 1.7g of total dietary fibre, corresponding to an energy of 40kcal (Anon 2007). The most important minerals are potassium, calcium and selenium. Water-soluble carbohydrates constitute 60–80% of the dry weight of onion bulbs (Rutherford and Whittle 1982) and comprise glucose, fructose and sucrose, and a series of oligosaccharides called fructans (Darbyshire and Henry 1978). The non-digestible carbohydrates are good for the human health and have a prebiotic effect, improving the intestinal flora especially the bifidobacteria intestinal conditions against pathogen agents (Mota et al 2009). Onion contains 11 amino acids. One hundred g of raw onion bulb contains about 501 µg vitamins A, 0.03 mg of thiamine, 0.04 mg of riboflavin, 0.02 mg of niacin and 9 mg of ascorbic acid and rest are the carbohydrates which make up the dry matter of the bulb (Watt and Merrill 1950).

Onion is a strong flavored vegetable used in a wide variety of ways, and the biological and medical functions of onion and garlic (pungency) are mainly due to their high organo-sulphur compounds (Augusti and Mathew 1974). Onion contain phenolic compounds particularly flavonols, are known to be potent free radical scavengers and antioxidants and also they are considered to be protective against cardiovascular diseases and to contribute in the prevention of colorectal cancer in humans (Corzo Martinez et al 2007). Quercetin and quercetin glucosides have been reported the main onion flavonols. Quercetin (3,4,5,7-pentahydroxyflavone; Q) is a major flavonoid in onions and is primarily found in the form of quercetin glucoside (QG) and to a lesser extent in a glycone (free) quercetin. In a survey of 28 vegetables and 9 fruits, onion was ranked highest in Q compounds (Hertog et al 1992).

The onion is preferred mainly because of its green leaves, immature and mature bulbs that used either raw or cooked as a vegetable. The onion bulbs are used in soups, sauces, condiments, spice, in medicine, seasoning of many foods and for the preparation of value added edible products like powder, flakes and salts. Onion has many uses as folk medicine and reports suggests that onion play an important role in preventing heart diseases (Augusti 1990).

Curing is the most important post-harvest operation which is used to reduce the post-harvest losses to a larger extent. Curing is a drying process meant to dry off the neck and outer scale leaves of the onion bulbs to prevent the loss of moisture and attack by microbes during storage and it promotes rapid healing of wounds inflicted during harvesting. Thus curing finally makes the tubers and bulb crops more resistant to wounds, or injuries during subsequent handling operation (Hassan 1988). Curing may be done in sun, shade, and artificially. A properly cured onion bulb can be stored for longer duration.

Onion is a major vegetable in the diet of Indian. Onion is a semi-perishable having a short storage life. Deterioration of considerable quantities of onion takes place during storage
During storage, they start to sprout and root and the onions decrease in weight. The fungal bulb rot imparts to about 15-30% losses during storage of different varieties. There are diverse fungal pathogen species like Aspergillus spp, Penicillium spp, Alternaria spp, Fusarium spp, Rhizopus spp, Colletotrichum spp, Pseudomonas spp, Lactobacillus sp, Erwinia spp and Botrytis spp which attacks onion bulb during the post-harvest storage period. Amongst all Aspergillus spp (Especially A.niger) is the most virulent fungal pathogen in the field and during the postharvest storage (Kumar et al 2015). In most cases, rots appear as well, mainly Black Neck Rot caused by the fungus Aspergillus niger in warm and humid conditions (Abd Alla et al 2006), Botrytis rot caused by Botrytis allii, which first infects the sprout and spreads to the neck, especially in wounded green necks (Li et al 2011), and Fusarium basal rot caused by Fusarium oxysporum f. sp. cepae in long storage (Galvan et al 2008).

Currently, the total capacity available in both conventional and scientific storage structure within the country is estimated to be around 7.76 lakh tonnes. Maharashtra, which is the highest onion producing state in the country also reportedly, has the highest storage capacity, which is estimated to be around 3.5 lakh tonnes. But for the present scale of production in the country, the storage capacity requirement is estimated to be around 11.30 lakh tonnes. Thus, there is a deficit of around three to four lakh tonnes. Hence there is an urgent need to establish the scientific storage facility at the farm level itself to meet the storage requirement with minimum of post-harvest losses (Singhal 2000).

However quantitative assessment of harvest and post-harvest losses at national level has been reported of the order of Rs.44,143 crore per annum at 2009 wholesale prices for 46 agricultural produces in 106 randomly selected districts (Anon 2010). In India three crops of onions are grown: Rabi (March-June), Kharif (October-December) and Late Kharif (January-March). The Rabi crop is harvested in April to June accounts for 60-65%. The rabi season produce need to be stored for further five to six months for to avoid marketing glut and get good economics from the onion crop. Estimated storage of onion during 2012-13 in Punjab is about 0.75 lakh MT. Postharvest losses are assumed to be 10% of fresh arrivals and 2% monthly of stored onions (Anon 2014a). However, 50-90% storage losses are recorded depending upon genotype and storage conditions. The total storage losses are comprised of physiological loss in weight (PLW) i.e. moisture loss and shrinkage 30-40%, rotting 20-30% and sprouting 20-40% (Anon 2011b). The main reason for postharvest losses are poor handling, growth of spoilage microorganism’s action of naturally occurring enzymes, chemical reactions, high moisture content during storage. Different storage methods are used to improve the quality and to enhance shelf life of fruits and vegetables.

The storage losses of onion have been stated to reduce extensively by treatments with maleic hydrazide (Shafi 1981), ultra-violet radiation (Bochkareu and Krasnostanova 1982) and controlled atmosphere storage (Thompson et al 1972). Although cold storage systems are used
in certain countries for onion storage, these are normally not adopted in India due to poor economics and lack of cold chain facilities required to maintain the quality (Barakade 2011).

Onion storage in ventilation condition is quite satisfactory when the temperature is maintained between 25°C to 30°C with a relative humidity range of 65 to 70%. This environment reduces the storage losses, which are in the form of physiological loss in weight, rotting and sprouting (Sidhu 2008).

Although there were several studies have been done on storage of onion at different conditions. Taking the above facts and situations into consideration, the present investigation has been planned and carried out to develop low cost farm level technology to extend the shelf life of fresh vegetable produce, such as onion to increase its marketability and to make fresh onion available to the consumer throughout the year at a reasonable price.

Keeping in view all these points, the present investigation has been planned with the following specific objectives:

i. To fabricate the small capacity ventilated storage structure for onion.
ii. To study the effect of mechanical curing on storability.
iii. To compare the storage life of onion in fabricated structure with commercially adopted practices of low temperature storage in cold stores.
CHAPTER II

REVIEW OF LITERATURE

Onion is one of the most important commercial vegetable crops grown on a large scale in India. There is considerable loss in onion during storage is due to sprouting, rotting, peel loss, physiological loss in weight, loss due to deterioration, loss in flavour and vitamin C content. The research work done by other scientists/professional in this field is presented as per scheme described below:

2.1 Storage and storage conditions

2.2 Effect of Storage structures on storability of onions.

2.3 Effect of curing methods on storability of onions.

2.4 Biochemical changes during storage of onion.

2.1 Storage and storage conditions

Brice et al (1995) reported that sprouting is primarily temperature dependent. Onions should be held at 0-5°C to minimize storage losses. However, such low temperatures are impracticable. In these cases, high temperature storage may be viable but losses may be higher at 25-30°C than at 0-5°C. By providing ventilation during specific periods of the day, the temperature of onions (and the humidity around the onions) can be increased or decreased. Ventilation during cool nights reduces temperature in the store and therefore reduces the temperature of onions.

Gregorio (1998) reported that after 3 months, at 20°C, 90% of onions were sealable, although the percentage fell to <50 after 5 months storage.

According to Benkeblia and Selselet-Attou (1999) that cold treatment at 9°C was more effective on break of dormancy than at 0°C, but in both cases cold temperatures caused a rapid break of dormancy. Changes in oligosaccharides and glucose were likely to occur at different sprouting stages, with higher concentrations at the onset of sprouting for cold treatments of 9°C for 3 weeks and 0°C for 2 weeks; for the other treatments (9°C for 2 weeks and 0°C for 3 weeks) the high concentrations were reached after sprouting. On the one hand, there was an inverse relation between sprouting and phenolics and peroxidase activity on the other hand. These results underlined a positive effect of low temperature on breaking dormancy of onion bulbs and the negative role of phenolics and peroxidase on inner bud development.

Ramin (1999) informed that during first 3-4 months of storage at high temperature (30°C), there was no significant change in the pH, TSS and acidity of bulbs. Result also shows that weight loss varies between different cultivars.

Hong et al (2000) investigated that atmospheres of 0.1–0.2% O₂ or 0.1–0.2% O₂ containing 7.5–9% CO₂ were the CA conditions at 5°C that best maintained the visual
appearance and prolonged shelf life to more than 2 weeks in both intact and cut onions. Extension, growth or ‘telescoping’ of the inner white leaf bases of the minimally processed onions at 5°C were not completely controlled by CA treatment. Heat treatment (55°C water for 2 min) of the white leaf bases effectively controlled ‘telescoping’ of cut onions stored at 5°C. Total soluble sugars generally decreased in intact and minimally processed green onions, but were retained in heat-treated cut onions. Heat treatment did not affect thiosulfinate concentrations during 14 days at 5°C, except for treated cut onions not stored under CA.

Hole et al (2000) were computed the strength, stiffness, strains at fracture and moisture content of onion skins after incubation at a range of humidity. Higher relative humidity (RH) resulted in skins which had greater moisture content, were stronger in multidirectional tests. Skins exposed to 95% RH were about twice as resistant to breaking in multidirectional testing as those exposed to 16% RH. This effect seemed to result from a much greater ability to extend before fracture occurred.

Song et al (2000) reported that onion which was stored at low temperature when exposed to O₃ had half of the mould growth as compared to the untreated onions.

Ko et al (2002) kept onions in large, specialised stores such as the UK, in developed temperate countries. Ventilation is required, and temperature is usually maintained around 5°C, but can be as low as -1°C. In warm climates, such as the tropics, high temperature storage is realistic, but involves a compromise between sprouting losses and rotting losses.

Bose et al (2003) mentioned that post-harvest application of borax is to minimise losses and sustain quality of onions in storage.

Doug (2004) studied that onions needed to be stored at 0°C (32 °F) and at 65 to 70% relative humidity. Temperatures above 0°C (32 °F) may cause the onion to sprout. Sprouting leads onion bulbs to become rotten, decrease in weight and increase moisture loss. Relative humidity above 70% may cause the onion’s roots to sprout. Air movement through the pile is valuable to reduce disease spread that could occur from a wet pile. The length of time an onion may be safely stored will depend on the degree of maturity and the variety, which will determine its dry matter content. Yellows are the best storage onions, followed by reds, whites and then Spanish onions. The more pungent the onion (i.e. yellows and reds), the longer it usually can be stored. The sweeter the onion is, (i.e. Spanish), the poorer storage onion it will be.

Waskar et al (2004) reported that delayed sprouting and extended storage depends on storage environment like relative humidity and temperature, crop management, breeding programmes and use of growth inhibiting chemicals like Maleic Hydrazide (MH). The Maleic Hydrazide chemical acts as an inhibiting substance and has played a role in modifying the rate of gaseous exchange that takes place through the surface of the bulb by changing the balance of carbon dioxide and oxygen in the bulbs and thus minimizes the respiration and
transpiration which in turn reduce the rate of moisture loss and ultimately prevented the loss in weight.

Onions were regarded as non-climacteric with consistently low endogenous ethylene production during storage (<0.1µL kg−1 h−1 at 0–5°C) (Suslow 1998). Adamicki et al (1998) concluded that the continuous application of ethylene at the supposedly saturated concentration of 0.2µL−1 and the pre harvest application of Ethephon have both been shown to increase the storage and shelf life of onions.

An atmosphere consisting of 5Kpa CO₂ and 3Kpa O₂ had been recommended for mild onion cv. Granex bulbs (Smittle 1988). Low oxygen storage inhibits sprouting of onion bulbs, and reduces weight loss (Yoo and Pike 1996, Praeger et al 2003). Chope et al (2006) studied the detrimental effect on the quality of sweet onions as resulted in increase in the pungency of onions. Removal of bulbs from CA storage results increase in respiration rate as a result of this accelerating of sprouting occurs.

Khokhar and Jilani (2006) studied the effect of two onion sets which were stored at 5°C for nine chilling durations and readings were taken between 10 and 90 days. A control treatment (at room temperature of 20°C) was also done for comparison. Onion sets of both cultivars treated for 90 days at 5°C produces nearly seven times more bolters than those treated for 20 days. Cool temperature treatment for 10 days was too short to induce bolting. Storage of onion bulbs at 20°C for 90 days appear to be optimum as it checked bolting and increased average bulb weight in both cultivars.

Boyhan et al (2008) studied the storage of Vidalia onions in CAS (3% O₂, 5%CO₂) at 1-2°C, which helps in prolonging the market availability of Vidalia onions from May to September in Georgia.

Pozzo et al (2008) found that onion is stated to have good storage potential, but successful storage depends upon the variety, maturity, cultural practices and post-harvest handling, water loss, sprouting and pathogenic diseases. The considerable post-harvest deterioration of each of these components to the total weight loss varies between cultivars.

Pandiselvam et al (2013) reported that as the moisture content of onions increased from 9.8% to 29.6% (db), rupture force was found to decrease from 116.73 to 40.14 N, whereas the angle of repose and terminal velocity were found to increase from 28.11 to 37.41° and 1.7 to 2.6 m/s correspondingly.

2.2 Effect of curing methods on storability of onions.

Maw et al (1997a and 1997b) reported that onions harvested at optimum maturity, need around 48 h to obtain a good level of curing. They noticed that a small benefit was observed when curing was prolonged to 72 h. Curing was sufficient for 24h, such as in late harvested onions.
Maw et al (1998) studied that onions were cured by removing moisture in preparation for being either sold as fresh onions or stored for sale at a later time. Removing moisture changes the weight and possibly the grade of onions. Onions were cured in order to enhance dormancy, to seal against water loss during storage and to extend shelf life by limiting the access of disease.

Wright and Grant (1997) reported that forced air curing of onions reduced the incidence of black mould rot regardless of harvest method. Skin staining was also reduced by forced air drying in most harvest method treatments. Spraying the onions with MH @ 375g/100m² and then storage of onions could be increased up to 7 months at 20 and 0-1°C.

Bhattarai and Subedi (1998) studied the effect of curing methods on storage behaviour of onion. They found that seven days curing before storage was sufficient and lower loss in weight (31.9%) than without curing (43.9%) for 120 days of storage were noticed.

Singhal (2000) reported field curing by Windrow method for three to five days, shade curing with tops for 10 to 12 days and 2.5 cm neck length are found effective in reducing storage losses in onion. He also found that curing for 10 to 12 days in shade helps in development of more number of scales and their colour retention for longer period.

Bahasawy (2000) concluded that a reduction of 4% in the onion weight was found during curing process. Field curing is the least expensive of all curing methods. It was recorded that the highest percentage of losses during storage as well as the highest sprouting percentage in field cured onion bulbs.

Satish and Ranganna (2002) conducted tests in which onion bulbs were best cured in the artificial curing of 10 to 14 hours at 45°C with air flow rate of 222 m² per minute compared to 8 to 10 days of sun curing. They also reported the hardness of onion bulb had significant increase (9.75 to 10.5 kg/cm²) with curing. The curing operation resulted in development of dull red colour from dull purple red of cured bulbs.

Gubb and MacTavish (2002) concluded that water loss continues throughout storage because of evaporation and low-level respiration. Water accounts for 80-93% of the fresh weight of freshly harvested onions. The actual amount depends on cultivar and growing conditions. Water loss during curing and drying is rapid and is around 5% of fresh weight.

Maw et al (2004) conducted tests whereby approximately 4 m² of onion sets for each test were passed through a continuous-flow drier. Set-point temperatures of 43°C, 43°C, and 46°C and durations of heat treatment of 17, 24, and 24 h were used, respectively, during the three tests. In comparing the least square means, 24 h of heat treatment resulted in a lower incidence of disease than 17 h. Similarly, a set-point temperature of 46°C resulted in a lower
incidence of disease than 43°C. Based upon the results of the study, a combination of heat treatment and conventional curing was recommended.

Bulbs were artificially cured for durations of 24, 48, 72 or 96h. They were cured at three depths, referred to as being at the bottom, middle or at the top of a stack of onions in curing chambers 1.2m high (Maw and Mullinix 2004). Harvest maturity had the greatest influence on the variation of moisture loss during curing, diminishing from 10.1%-early, to 7.3%-optimal, to 5.9%-late. Duration of curing had influenced moisture content of onion bulbs and moisture loss ranging from 7.2%/24h to 10.3%/96h. Depth had a limited effect on the variation of moisture loss. Local ambient conditions also influenced moisture loss.

Lisa and Kader (2004) declared that curing root and tuber crops such as sweet potatoes, potatoes, cassava and yarns is an important practice and by curing these crops can be stored for any length of time. Several methods of artificial curing have been tried, but the method most commonly used for onions and garlic's bulbs involves moving heated air at 35 to 45 °C (95 to 113 F) vertically through a grill on which the bulbs placed in mesh bags. Such treatment continued for a period of 8 to 12 hr usually provides satisfactory curing for either immediate shipment to market or storage for later sale.

Abd-Alla et al (2006) studied that postharvest onions are stored for upto 3 months without cooling and upto 8 months at 0-2°C. During storage they start to sprout and root and the onions decrease in weight. In most cases, rots appear as well, mainly Black Neck Rot caused by the fungus Aspergillus niger in warm and humid conditions.

Rahman et al (2009) studied that during field curing, the bulbs moisture content decreased gradually from initial moisture of 87-90 % ±0.5% (w.b) to a final level of 81.5 % ±0.5% (w.b) after 16 day (384 h). At maturity stages of 20, 30, 40, and 50 % of tops down, the results shown that, curing of onion bulbs artificially can reduce the required time of curing by about 68.8, 71.9, 75 and 81.3 % for large size of bulbs, and by 71.9, 75, 78 and 81.3 for medium and small size of bulbs, compared with traditional curing method of bulbs (control treatment). The storability of onion bulbs improved with a bout of 12.73 % for bulbs harvested at 40 and 50 % tops down, while it was 12.44 % for bulbs harvested at 30 % tops down comparing with traditional curing.

The storability of onion bulbs is dependent upon the incidence and rate of sprout growth. Onion bulbs were treated before or after curing (28°C for 6 weeks) with a single dose of 10µ/L ethylene or 1µ/L 1-Methylocyclopene for 24 hr at 20 °C, or no treatment (control) (Downes et al 2009a). Onion bulb respiration rate increased significantly after being treated with ethylene but to a lesser extent or not at all treated with 1-MCP. Fructose concentration of onion treated with ethylene or 1-MCP before curing were not significantly different , however after curing concentrations were about 2 fold higher compared with control. It appears that inhibition of sprout growth can be achieved using just a short 24h treatment with
ethylene or 1-MCP. However skin thickness or permeability, which is dependent on curing and cultivar, may affect the methylene or 1-MCP influx and therefore efficacy of sprout suppressant action.

Downes et al (2009b) concluded that anthocyanins and flavonols may play a major role in varying skin color of red onions cured at different temperatures; however, the difference between curing temperatures may not have been sufficient to represent a correlation between darkening of brown onions and flavonol concentration. Curing is done at 20, 24 or 28°C for six weeks and effects of curing temperature on flavonol concentration in the skin of brown onions and on flavonol and anthocyanin concentration in the skin of red onions detected. It was noticed that skin of brown onions was darker and had a lower Hue angle (H°) immediately after being cured at 28°C compared to 20°C. In contrast, skin of red onions had a higher H° but no change in lightness L* when cured at 28°C compared to 20°C. Total flavonols and total anthocyanins were negatively correlated with H° in the skin of red onions but no similar correlation found between total flavonols and H° in case of brown onions.

Fast curing is done at 30°C and 98% RH for up to 9 days of postharvest, the onion neck get narrower by 52% after 6 days i.e. similar to the effect of cold storage for about 5 months. Fast curing also changed the color of treated onion bulbs. Fast curing of onions reduced weight loss and rots by 30% and 80% respectively. In this fast curing process is done i.e. at high temperature and high humidity and Eshel et al (2013) concluded that early harvesting of onions with long necks followed by high temperature curing in high humidity would reduce skin cracks, increase skin stability and reduce storage rots. Fast curing keeps the onion tunic and inner fleshly scales intact and postharvest quality remains, even after 8 months cold storage. The high temperature used for Fast curing can be easily reached in hot-climate storage areas with minimal energy requirement.

Ghulam et al (2013) studied that the onion bulb quality can be retained longer by curing with foliage intact and then stored in cold storages. Significant retention of quality and storage life can also be achieved by using mud rooms for storing onion, when cold storage facility cannot be availed.

Nabi et al (2013) studied the curing of onion bulbs with and without foliages and then stored under different conditions e.g. cold store, cemented room and mud room for four months. They evaluated different quality attributes. Results indicated that the quality of onion bulbs was considerably affected by curing methods, storage conditions and duration. The maximum dry matter (17.5%) and TSS (11.5%) was recorded in bulbs cured with foliage as compared to 15.7% DM and 9.36% TSS with curing without foliage accordingly. The DM (21.2%) and TSS (14.9%) recorded in cold stored bulbs was followed by 15.65 and 13% DM with 9.44 and 6.65% TSS in mud and cemented room storage accordingly. Curing with
foliage resulted in significantly lower weight loss, sprouting and rotting. The rate per month weight loss (1.95%), sprouting (2.4%) and rotting (0.4%) were the lowest in cold stored bulbs, while maximum 59.3, 59.5 and 31.3% accordingly were observed in bulbs stored cemented room. Weight loss, sprouting and rotting percentage increased with increasing storage duration. The lowest weight loss, sprouting and rotting (0% each) obtained in cold store during the 1st month storage duration and highest percentage (13, 2.5 and 1.67 respectively) recorded with cemented room. After four months storage, the minimum percentage of weight loss (6%), sprouting (9.6%) and rotting (1.7%) was recorded in cold stored bulbs while the maximum weight loss (98%), sprouting (100%) and rotting (70%) was observed in bulbs stored cemented room.

Rekha et al. (2014) studied different curing methods such as, curing under forced hot air dryer with foliage, curing under forced hot air dryer without foliage, curing under poly tunnel with foliage, curing under poly tunnel without foliage, curing under 35 per cent shade with foliage, curing under 35 per cent shade without foliage, curing under 100 per cent shade with foliage, curing under 100 per cent shade without foliage. Among them the bulbs cured under experiment 35 per cent shade with foliage followed by 35 per cent shade without foliage showed minimum physiological loss in weight, sprouting, rotting and maximum percent of marketable bulbs.

Nega et al. (2015) conducted tests in which onion bulbs were cured under shade for 0, 5, 10 and 15 days, respectively. The tops removed immediately, or removed 5, 10 or 15 days after curing or not at all. The experiment was laid out as a RCBD factorial (4x5x7 curing, topping, storage time respectively) and each treatment combination replicated three times. Data were collected with 15 days interval up to 90 days after curing. Cured bulbs for 10 days and none topped combination showed that highest marketable bulb (65.56%), less moisture loss (34.43%), no rotted bulbs; minimum sprouted bulbs (23.5%) and less total loss (23.5%). Therefore, cured bulbs for 10 days and none topped bulbs selected as the best practice until 90 days of storage.

2.3 Effect of storage structures on storability of onions.

Abbey (2000) studied that onion bulbs fumigated with sulphur dust before storage under natural ventilation were found to be have better shelf life for 16 weeks.

Bhattarai (2000) stored potato tubers under ZECC recorded significantly lower physiological loss in weight PLW (8.54%) and total weight loss (12.835%) compared to ambient storage conditions (14.00% and 27.38%, respectively) after storage period of four months.

Maini and Chakrabarti (2000) reported that mud or straw cottage was used for storing onions in Sudan. Straw cottage was constructed in such a way that, they were aerated by the prevailing wind passing through them. After five months of storage by Straw cottage method,
50 to 60 per cent of bulbs were marketable. The higher temperature of 30 and 35°C caused less sprouting but higher rotting and loss in weight was observed as compared to lower temperature (20-25°C).

Kumbhar (2000) studied the economics of production and marketing of rabi onion in Pune district and revealed that the per hectare average gross returns and net profit were Rs. 65,239.76 and Rs. 20,736.70, respectively, and the returns per rupee were 1.46, which indicated that it was a profitable crop.

Gorabal (2001) concluded that storing turmeric seed rhizomes in ZECC was found best method with least per cent PLW (12.31%), sprouting (18.61%), rotting (1.91%) and maximum recovery of healthy rhizomes (95.86%) at the end of storage period (90 days) compared to 57.73 per cent in control.

Ranpise et al (2001) used the conventional onion storage structure called chawl. Chawl constructed which has no aeration at bottom and onion can be stored upto 1.5 to 2.0 metre height with resulting into lot of bruising and decay. They also reported that onion stored in modified improved storage structure with bottom and central ventilation with raised floor (60 cm) of structure above ground reduced the storage losses from 99.2 to 70.0 per cent during five months storage. The storage temperature of 15°C along with relative humidity of 50 to 70 per cent could be helpful to reduce the rotting and desiccation to a desired level to increase the storage life of onion bulbs in storage.

Tripathi and Lawande (2003) reported that the total losses in low cost bottom ventilated structure are much lower (35.17%) than recommended bottom ventilated structure (44.96%). The sprouting and black mould infection was also noticed lower in low cost storage structure.

NHRDF developed onion storage structure of capacity 25 MT and 50 MT. They considered various points during construction such as lower base of onion storage structure should be raised from the ground level by 1.5’ to 2.00’ for that the foundation should be laid out according to soil type. Pillar height should be 1.5’ to 2’. Skeleton of structure should be rest on these pillars and it should be made up of iron angles/wooden material. Lower base can be made up of iron angles wooden battens. Its breadth should be a 5’. Side wall should be made up to bamboo battens/iron angle with the support and help of iron angles. Its height should be 5’. Height of roof of onion storage structure should be 2’ above onion stored. For roof iron/cement/manglore tiles should be used. Material of roof should be heat resistant. Also, according structural design roof should have sufficient slope. To avoid droplets rain water and sunlight, sides of roof should be sufficiently projected outside and also same from direction of rain (south-west) (Anon 2012).

There are three types onion storage structure developed by NHRDF and domestic onion storage structure located at Kalwan. The construction cost per sq.ft.of this structure i.e
Traditional onion storage structure, Dindigul onion storage structure, Improved low cost onion storage structure developed by NHRDF, and Low cost onion storage structure (Kalwan) were calculated. The quantity of onions were stored in different onion storage structure during the last week of May is about 1000kg. There are some losses such as weight losses, rotting losses and sprouting losses were found to be in storage and thus calculated (Borole et al 2013). These losses were found high in storage structure developed by NHRDF as compared to domestic onion storage structure (Kalwan). The Cost per sq.ft (Rs) and per kg storage cost against construction cost (Rs) of domestic onion storage structure is less as compare to onion storage structures in NHRDF.

Fennir (2014) studied that Red Amposta and Yellow Spanish i.e. two onion cultivars were stored in shade and underground bunker-like traditional house (UGH). Temperature and relative humidity inside UGH were stable while those measured in the shade exhibited wide variations. Red Amposta onions were kept in both sites for 100 days, weight losses were about 27% and 21% in shade and in UGH, respectively. However, Yellow Spanish onions were better in term of losses and storage duration in both sites. They kept sprout free for 152 days, mass losses were 18% and 16% in shade and in UGH, respectively. Onion storage in larger scales using shed structure and ventilated UGH in the WM region of Libya may deserve further explorations.

Priya et al (2014) studied methods of storage in India which were adopted mostly depends on the traditional knowledge and commonly practised methods which are generally used bag, pucca/room, tat storage, bamboo, chawl structure and the losses associated are quite higher. Sprouting, desiccation and microbial spoilage are often observed in storage and it compels to choose advanced techniques like modified ventilated structures, modified atmospheric (MA) and controlled atmospheric (CA) storage. The controlled atmosphere and modified atmosphere storage reduces the application of chemicals for sprout inhibition by manipulating the gas composition which extend the storage period of the onions.

Abullahi (2014) conducted a study to determine the effect of shade on the performance of crib in curing and storage of onion bulb. Cribs of the same dimensions were constructed and located at two sites of the experiment (under the shade and directly under or in the sun). During this, six parameters were observed Temperature values recorded for the onion in the crib under the shade were lower, higher relative humidity of 77-83% were recorded under the shade compared to 65-77% in the sun, the result obtained indicated significant difference i.e higher percentage weight loss were recorded when onions was stored in the sun compared to those under the shade at (P<0.05). No significant difference in rottening was observed under both shade and sun sets. Change in skin colour was observed with the onion located in the sun faster compared to those onion bulbs located under the shade.
Falayi and Yusuf (2014) reported the onion storage structure which was constructed with 50.8 mm × 50.8 mm and 50.8 mm × 76.2 mm soft wood. The storage structure is made naturally ventilated and was covered with asbestos roofing sheets and chicken mesh. The storage structure is 2000 mm × 1800 mm × 1900 mm for length, breadth and height respectively and is divided into three compartments (A, B and C). The parameters measured included temperature, relative humidity and weight of the onions and the results were subjected to appropriate statistical analysis. Temperatures within and outside the structure ranged from 25.1°C to 31.6°C in the morning period, 29.0°C to 41.7°C in the afternoon period and 24.0°C to 31.4°C in the evening period. Physical examination performed on the stored onions bulbs after nine weeks revealed minimal deterioration, with onions stored at compartment C recording the lowest percentage of weight loss of 5.91% while compartment B had a 6.80% weight loss and compartment A recorded a 6.69% weight loss. Relative humidity measured within and outside the structure ranged from 74% to 96% in the morning, 54% to 95% in the afternoon and 70% to 96% in the evening. The highest relative humidity value (96%) was recorded in the morning period and the lowest (54%) was recorded in the afternoon. The test of correlation analysis performed on the results indicated large significant difference between the internal and external temperature and relative humidity readings. It then can be concluded that the structure has performed well by reducing ambient temperature and relative humidity thereby prolonging the shelf life of the product.

Imoukhuede et al (2014) studied some storage structures of onions which were constructed with different roofing materials. The response of the materials to the weather parameters like temperature and relative humidity were evaluated to know their effects on the performance of the storage structures. The temperature and relative humidity were taken three times daily. The highest temperature was observed in the structure with Asbestos roofing materials and no significant difference in the temperature value in the structure with thatched and Iron materials; highest relatively humidity was found in Asbestos roofing material while the lowest in the structure with Iron materials. Besides temperature and relative humidity, the weight of the onion in each of the structures; the losses as indicated by loss indices like shrinkage, rottenness, sprouting and colour were identified and percentage loss per week determined. The highest mean percentage loss (22%) was observed in the structure with iron roofing materials whilst structure with thatched materials had the lowest (9.4%). It was conclusively found that the storage structure with thatched roof had the best performance in terms of losses.

During storage of onion bulbs various losses occurred. To minimized storage losses and develop efficient onion storage structure, seven storage structures were studied by Tripathi and Lawande (2015) i.e. Traditional double row storage structure, Modified bottom ventilated storage structure, Top and bottom ventilated storage structure with mud-plastered
walls, Modified bottom ventilated storage structure with chain linked side walls, Traditional single row storage structure, Modified bottom ventilated single row storage structure and Bottom ventilated single row low cost thatched roof storage structure. They were designed and constructed at NRC for Onion and Garlic, Rajagurunagar, Pune, India. These storage structures were gauged for storage of onion. The physiological loss of weight (PLW) was lowest (15.92 %) in Top and bottom ventilated structure with mud plaster walls followed by Bottom ventilated single row low cost thatched roof storage structure (17.44%). Physiological loss of weight was significantly lower in bottom ventilated structures (19.06%) as compared to traditional without bottom ventilated structures (22.11%). The rotting was significantly higher (22.72 %) in Traditional without bottom ventilated double row structure as compared Top and bottom ventilated structure with mud plastered sidewalls (7.52 %). The rotting was statistically lower in bottom-ventilated structures (12.69%) than traditional without bottom-ventilated structures (19.92%). The highest sprouting (3.29 %) was recorded in Modified bottom ventilated storage structure with chain-linked sidewalls. The net return per tonne was highest (Rs 1207) in Bottom ventilated single row low cost thatched roof storage structure. The judgments of this experiment indicates that bottom ventilated structures were found efficient in reduction of storage losses in onion stored at ambient atmospheric conditions.

2.4 Biochemical changes during storage of onion.

Kallokumar et al (1999) studied that onion bulbs of poor keeping varieties had low dry matter content, low TSS, high relative rate of loss and high moisture loss especially in the period immediately after harvest. This results in softening, shrivelling and loss of weight during storage of onion bulbs.

Phenylalanine ammonia-lyase (PAL) and Peroxidase (POD) enzyme activities, total phenolics and pyruvic acid were measured during storage at 4°C and 20°C (Benkebelia 1999). An inverse relationship has found out between phenolic content and the amount of sprouting development of onion bulbs. Pyruvic acid production appeared to be influenced by temperature, but in the last period of storage, the effect of temperature on PA production was less. This also demonstrated that PAL activity which is linked to phenolic metabolism and POD are highly involved in the sprouting of onion bulbs and these two activities are much influenced by low temperature.

Sarode (2000) reported that there were reduced loss in weight and TSS was increased during storage period in onion bulbs.

Kumar and Sreenarayan (2000) found that ascorbic acid content was significantly reduced in all storage methods, whereas sugar content slightly increased during storage.

Horbowicz and Grzegewska (2000) found a negative correlation between sugar content and storability of onion.
Satish and Ranganna (2002) found that the sensory evaluation of artificially cured bulbs showed more appearance, relatively bright and glossiness compared to the sun cured bulbs.

Yamazaki et al (2002) reported that in onion bulb abscisic acid (ABA) concentration decreased exponentially after harvest and was concurrent with the decline in storage potential. Onion bulb ABA concentration at harvest (measured on a fresh weight basis) may prove to be a better indicator of storage life.

Uddin et al (2003) studied onion bulbs were stored under regular atmosphere (RA: 21% O₂/0.1% CO₂) and controlled atmospheres (CA2/2: 2% O₂/2% CO₂; and CA2/8: 2% O₂/8% CO₂) with 80% relative humidity (RH) at 0.59 /0.5 8°C for 9 weeks. Total pyruvic acid content (PY), changes in S-alk(en)yl-L-cysteine sulfoxide (ACSO) flavour precursors and alliinase activity were quantified before and after storage. Both PY and total ACSO contents were significantly increased by RA storage (9-11%) and significantly depleted by CA storage. PY and total ACSO contents were depleted by 4.8 and 19%, respectively under CA2/2, and by 13.5 and 22%, respectively under CA2/8.

Benkeblia and Varoquaux (2003) investigated the effect of nitrous oxide on respiration rate, soluble sugars and quality attributes of onion bulbs during storage. Concentrations of 50, 80 and 100 kPa of N₂O were applied for 5, 10 and 15 days at 18°C and compared to control samples and samples kept under 100 kPa N₂. Respiration rates reduced by 50% after 5 days were restored progressively and the difference between control and N₂ and N₂O treated bulbs was approximately 17 and 25% less after 10 and 15 days, respectively. Soluble sugars were slightly higher in treated onions and averaged 6.97% under 100 kPa N₂, and 7.17, 6.18 and 6.58% under 50, 80 and 100 kPa N₂O. However in control bulbs, soluble sugars averaged 5.33%. During treatments of bulbs with N₂ and N₂O, organic acid contents increased and accumulation was observed throughout the time of exposure. Large variability of sprouting of treated bulbs observed, but no significant difference was noted between control and N₂O or N₂ treated samples. N₂O effectively reduced rotting of bulbs whereas those kept under N₂ showed higher rotting than control and N₂O treated bulbs.

Chope et al (2005) studied the effect of controlled atmospheric storage on abscisic acid concentration of onion bulbs. Onion bulbs of cultivators with long-, medium- and short storage lives were stored in controlled atmosphere (CA) conditions (3.03 Kpa CO₂, 5.05 Kpa O₂; 2°C). Bulb abscisic acid concentration (ABA), pyruvate, fructans, total soluble solids and firmness measured during storage. Bulbs ABA concentration declined exponentially during storage. The greatest decrease occurred during first 80 days of storage. Onion bulb ABA concentration at harvest may prove to be a better indicator of storage life. It is hypothesised that the storage potential of bulbs of different onion cultivars is inversely related to the time at
which they reach a minimal ABA content. Thus the storage life of short-storing cultivars might be prolonged by slowing the decline in ABA concentration. This could help us to extend the period for supplying these onions from temperate regions.

Kukanur (2005) conducted tests in which onion bulbs were stored at different storage conditions have differences with respect to ascorbic acid content of bulbs during the entire storage period. Amongst the different storage conditions, bulbs stored in Zero Energy Cool chamber retained significantly higher ascorbic acid content closely followed by bulbs stored in low cost structure and in improved structure. The lowest retention of ascorbic acid may be due to the build-up of respiratory heat in the centre of structure.

Gemma et al (2006) conducted that maximising onion bulb ABA concentration prior to storage and inhibition of the degradation of ABA by cultural, environmental or genetic manipulation may delay sprouting and extend storage life. It follows that prolonging the storage life of short-storing cultivars through elevating ABA concentration or delaying the rate of decline in ABA concentration might help increase the period for supply of onions.

Sidhu (2008) reported that the initial soluble solid content was increase in the short day cultivars may have been the result of high loss in mass. Increase in soluble solid content may have also due to conversion of non-soluble highly polymerized fructans to soluble sugar during that time.

The storability of onion bulbs is dependent upon the incidence and rate of sprout growth. Onion bulbs were treated before or after curing (28°C for 6 weeks) with a single dose of 10µ/L ethylene or 1µ/L 1-Methylcyclopropene for 24 hr at 20 °C, or no treatment (control) (Downes et al 2009a). Onion bulb respiration rate increased significantly after being treated with ethylene but to a lesser extent or not at all treated with 1-MCP. Fructose concentration of onion treated with ethylene or 1-MCP before curing were not significantly different, however after curing concentrations were about 2 fold higher compared with control. It appears that inhibition of sprout growth can be achieved using just a short 24h treatment with ethylene or 1-MCP. However skin thickness or permeability, which is dependent on curing and cultivar, may affect the methylene or 1-MCP influx and therefore efficacy of sprout suppressant action.

Rodrigues et al (2009) studied the effects of postharvest practices on flavonoid content of red and white onion cultivars i.e. two Portuguese landrace varieties of onions. The content of some major flavonols and anthocyanins was measured in red and white onion bulbs (from 2005 and 2006 harvests) during seven months of storage under refrigerated and traditional bulk storage in the field. Total flavonols increased upto 64% after 6 or 7 months of storage. In red onions, bulbs stored in the field reached higher levels of flavonoids (64% maximum) than refrigerated onions (40% maximum). For red onions, the increase after 6 months storage usually has place when the flavonol postharvest levels are low (40-64%
increase), whereas for white onions the increase after 6 months storage is important for onions with higher levels after harvest (44-60% increase). This proposed that storage at fluctuating ambient temperature can positively affect flavonol metabolism, while keeping the flavonol profile. However, there were no significant modifications of the total levels of anthocyanin pigments after 6 months of storage, but after 7 months anthocyanin content was reduces between 40% and 60%.

Katherine et al (2009) concluded that the storability of onion bulbs is dependent on the incidence and rate of sprout growth. Exogenous ethylene applied continuously has been demonstrated to act as a sprout suppressant in onion. However, the ethylene binding inhibitor, 1methylcyclopropene (1-MCP), can also suppress sprouting in onion.

Laura et al (2009) reported that onion varieties having 15 per cent soluble solids contents could be stored for 6 months at 0 °C and 60°65% relative humidity.

Abrameto et al (2010) studied that pyruvate analysis would be less expensive and more objective than taste tests for evaluations of several hundred bulbs.

Anbukkarasi (2010) reported that the preharvest spray at 30 days before harvest a combination of maleic hydrazide @ 2000 ppm + carbendazim @1000 ppm with 2 cm neck length of bulbs stored in low cost bottom ventilated storage structure registered the least physiological loss in weight, sprouting, rotting and total loss, no rooting and improved the quality parameters like TSS, total sugar, reducing sugar and sulphur content of the bulbs. The above treatment also enhanced the shelf life (up to six months), reduced the physiological loss of weight (5.72 and 5.18 %), sprouting loss (0.58 and 0.62 %), rotting, rooting and total loss (6.58 and 6.78 %) and improved the quality parameters like TSS content (17.14 and 17.22 °Brix), total sugar (6.76 and 6.83 %) reducing sugar content (1.44 and 1.49 %) and sulphur content (0.697 and 0.704 %) during the first and second season respectively. In this experiment, ascorbic acid (10.19 and 10.24 mg100 g-1), pyruvic acid (2.48 and 2.53 µmol g-1) and also total phenoilc content (621.11 and 625.56 µg g-1) showed decreasing trend with increasing storage period up to three months.

Gallina et al (2012) studied that there are different methods to assess the pungency like HPLC method and Spectrophotometric method.

Sharma et al (2013) analysed the flavonoids, sugars, phenylalanine, and tryptophan have been carried out in different onion scales during storage at ambient temperature (20–23 °C) and relative humidity (60–80 %). Depending on the length of storage, dry matter content and composition shows variation inside the onion bulbs. Inner sprouts were observed on longitudinally cut bulbs after 2 months and visible sprouts appeared after 5 months of storage. The bulbs lost 20 to 30 % of their weight at the end of the storage. Higher dry matter content was observed in the inner scales. Significantly high content of quercetin in inner scales and high level of quercetin-3,4′-O-diglucoside and quercetin-4′-O-monoglucoside in outer scales.
was observed during a 7 months storage. During storage period, high content of fructose and glucose was observed in the middle scales while sucrose was high in the inner scales. There was no particular trend observed within analyzed amino acids. However, the content of phenylalanine was higher than tryptophan.
CHAPTER III

MATERIALS AND METHODS

The description of procedures, instruments and equipment used for conducting various experiments in this study have been discussed in this chapter.

3.1 Procurement of onions

Onion variety ‘PRO-6’ for storage study was procured from S. Balbir Singh of village Nizampur, District Ludhiana, Punjab and onion variety ‘Punjab Naroya’ used for different methods of curing were procured from fields of Punjab Agricultural University, Ludhiana. Table 3.1 shows the various experiments conducted and Table 3.2 shows the various equipments used during course of the study.

Table 3.1 Details of experiments conducted.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td>Onion PRO-6, Punjab Naroya</td>
</tr>
<tr>
<td>Curing methods</td>
<td>• Field curing</td>
</tr>
<tr>
<td></td>
<td>• Shade curing</td>
</tr>
<tr>
<td></td>
<td>• Mechanical curing</td>
</tr>
<tr>
<td>Storage methods</td>
<td>• Ambient storage</td>
</tr>
<tr>
<td></td>
<td>• Commercial cold storage at temperature of -1 to -2°C</td>
</tr>
<tr>
<td></td>
<td>• Fabricated ventilated storage structure with provision of mechanical air circulation</td>
</tr>
<tr>
<td>Observations</td>
<td>• Man loading and unloading hours</td>
</tr>
<tr>
<td>recorded</td>
<td>• Capacity of structure</td>
</tr>
<tr>
<td></td>
<td>• Angle of repose</td>
</tr>
<tr>
<td></td>
<td>• Bulk density</td>
</tr>
<tr>
<td></td>
<td>• Physiological loss in weight (PLW)</td>
</tr>
<tr>
<td></td>
<td>• Moisture content</td>
</tr>
<tr>
<td></td>
<td>• Rotting</td>
</tr>
<tr>
<td></td>
<td>• Sprouting</td>
</tr>
<tr>
<td></td>
<td>• Hardness</td>
</tr>
<tr>
<td></td>
<td>• Total soluble solids (TSS)</td>
</tr>
<tr>
<td></td>
<td>• Ascorbic acid</td>
</tr>
<tr>
<td></td>
<td>• Reducing sugars</td>
</tr>
<tr>
<td></td>
<td>• Colour</td>
</tr>
<tr>
<td></td>
<td>• Temperature of air</td>
</tr>
<tr>
<td></td>
<td>• Velocity of air</td>
</tr>
</tbody>
</table>

Statistical Analysis

Statistical analysis was done by UNI-ANOVA in general linear model using Statistical Package for Social Sciences (SPSS ,version 16)
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of the equipment</th>
<th>Description</th>
<th>Test performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Precision weighing balance</td>
<td>AND electronic balance FX-320</td>
<td>Weighing of chemicals</td>
</tr>
<tr>
<td>2.</td>
<td>Balance</td>
<td>Excell ZERO NET DC balance with maximum capacity 5kg</td>
<td>Weighing of shade and mechanical cured bulbs</td>
</tr>
<tr>
<td>3.</td>
<td>Weighing balance</td>
<td>Braun Docbel with maximum capacity of 2 kg</td>
<td>Weighing of field cured bulbs</td>
</tr>
<tr>
<td>4.</td>
<td>Weighing balance</td>
<td>LEO weighing balance Model EPS 801 with max capacity of 120 kg</td>
<td>Weighing of storage bulbs</td>
</tr>
<tr>
<td>5.</td>
<td>Hot air dryer</td>
<td>Model- 012B, KILBURN OVEN Macneil and Magor Ltd, India</td>
<td>Curing</td>
</tr>
<tr>
<td>6.</td>
<td>Colour Reader</td>
<td>Konica Minolta Sensing Inc. CR-10</td>
<td>Colour</td>
</tr>
<tr>
<td>7.</td>
<td>Spectrophotometer</td>
<td>RAYLEIGH UV-2601</td>
<td>Reducing sugars</td>
</tr>
<tr>
<td>8.</td>
<td>Hot air oven</td>
<td>NSW-143, range = 0-250°C</td>
<td>Moisture content</td>
</tr>
<tr>
<td>9.</td>
<td>Refractometer</td>
<td>PR-100, range 0-30° brix</td>
<td>TSS</td>
</tr>
<tr>
<td>10.</td>
<td>Vernier Caliper</td>
<td>Forbes</td>
<td>Thickness</td>
</tr>
<tr>
<td>11.</td>
<td>Penetrometer</td>
<td>Effi-gi penetrometer</td>
<td>Hardness</td>
</tr>
<tr>
<td>12.</td>
<td>Vane probe anemometer</td>
<td>Lutron AM-4201</td>
<td>Air velocity (m/sec)</td>
</tr>
<tr>
<td>13.</td>
<td>Infrared</td>
<td>Fluke 574</td>
<td>Air and bulb temperature</td>
</tr>
<tr>
<td>14.</td>
<td>Water Bath</td>
<td>Yorko universal water bath</td>
<td>Extraction of sugars</td>
</tr>
<tr>
<td>15.</td>
<td>Mechanical tray dryer</td>
<td>Electrical heaters with attached blowers</td>
<td>Mechanical curing</td>
</tr>
</tbody>
</table>
3.2 Curing

Curing is the process of drying down the onions to prepare them for storage. As onions cure, the skins dry into papery wrappers, pungent compounds replace sugars, and the necks at the top of the bulb come together to seal out moisture and microorganisms. Removing moisture changes the weight and possibly the grade of onions. Onions were cured in order to enhance dormancy, to seal against water loss during storage and to extend shelf life by limiting the access of disease. Curing was done from days to weeks depending upon the method of curing used. Onion bulbs for curing were procured from fields of Punjab Agricultural University, Ludhiana, Punjab. Curing was done by three methods. The samples were abbreviated as $T_1$, $T_2$ and $T_3$.

Where,

$T_1$ = Field curing of onions.

$T_2$ = Shade curing of onions.

$T_3$ = Mechanical curing of onions.

3.2.1 Field curing

The crop was harvested at maturity i.e. 130 days after transplanting when 50% of the plants showed drying and falling of their tops as shown in Fig 3.1. The plants were pulled along with leaves and kept for in the field until proper curing of onion bulbs was done as shown in Fig 3.2. Temperature of the air and onion bulbs was noticed during the morning and afternoon by using infrared thermometer as shown in Fig.3.5. Neck of the onion bulbs were reduced during curing and measured by using vernier caliper as shown in Fig. 3.4. Change in weight of onion bulbs were noticed by using Dochel weighing balance as shown in Fig. 3.3. Temperature of the air during morning i.e. at 9am and during afternoon i.e. at 2:30 pm were recorded during experiment.
Fig. 3.1 Mature onion crop ready for harvest in the field of PAU farm, Ludhiana

Fig. 3.2 Curing of onion in sun in the vegetable field PAU, Ludhiana

Fig. 3.3 Measuring weight loss during field curing
Fig. 3.4 Measurement of neck thickness of harvested onions

Fig. 3.5 Infrared thermometer for measuring bulb surface and air temperature

Fig. 3.6 Cured onion bulbs in vegetable field PAU, Ludhiana
3.2.2 Shade curing

In case of shade curing, harvested bulbs with their tops removed were kept under shade till the end of curing period in Pilot plant, Department of Processing and Food Engineering, PAU, Ludhiana. The temperature of the room were recorded and varied from 35-36°C. The change in the weight of the sample with respect to time was recorded. Some onions bulbs were tagged to notice the change in the thickness of the neck of onion bulbs. Fig. 3.7 and Fig. 3.8 show the initial onion bulbs and final cured bulbs in shade curing.

![Fig. 3.7 Freshly harvested onion bulbs ready for curing in shade in Pilot Plant lab](image1)

![Fig. 3.8 Shade cured onion bulbs in Pilot Plant lab](image2)
3.2.3 Mechanical curing of onion bulb

Curing of onion bulbs were carried out in a laboratory scale cross-flow tray dryer in Pilot plant as illustrated in Fig. 3.9 and Fig. 3.10 at a temperature of 36-38°C. Dryer consists of centrifugal blower which circulates air inside the dryer with maximum air velocity of 2m/s. The tray drier consists of a cabinet consisting of a series of perforated trays which are placed upon one another. Dry air passes through the bottom of the trays and through the perforations and then to the samples. The moist air escapes the cabinet from the top through an opening. Samples of known quantity were placed on the trays. The weights of empty and loaded onion bulbs tray was measured by using electronic balance of 5 kg capacity at regular time intervals. Curing was done until desired neck thickness is obtained.

At the end of curing period, a composite sample of four kilogram bulbs was taken and was used for storage studies under ambient conditions as shown in Fig. 3.11.
3.3 Location of the study area

The research work was carried out in the Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Punjab Agricultural University, Ludhiana and Shivam cold store, Village Gajipur, Rajpura, India. Design, Fabrication and evaluation of ventilated onion storage structure were carried out in the Workshop of Department of Processing and Food Engineering, PAU, Ludhiana. The structure was kept in the Pilot Plant and experiments were conducted to determine the effect of ventilation on various quality parameters and physical parameters of onions in different laboratories of the departments.

3.4 Estimation of physical properties of onion

3.4.1 Average size of onions

Wire mesh size was selected on the basis of average size of onions i.e. smallest average size of onion being 32.75 mm and load of onion on storage structure. Wire mesh size of 25.4 mm x 25.4 mm was selected. Average size of the onions is measure with digital vernier calliper as shown in Fig 3.12.

3.4.2 Angle of repose

Angle of repose was determined from the height and diameter of the naturally formed heap of onions in the floor. The angle of repose was calculated from the following equation.

\[ \theta = \tan^{-1} \left( \frac{2H}{D} \right) \]
Where, $\theta$ - angle of repose, degree; H - height of the heap, mm; D – diameter of the heap formed, mm. From the calculated angle of repose, we can choose the desired value of slope given to the storage structure which would help in ease of unloading.

3.4.3 Bulk density

Bulk density measured by measuring the weighed sample in a known volume, height was calculated.

$$\text{Bulk density (kg/m}^3) = \frac{\text{Weight}}{\text{Volume}}$$

3.5 Design of Ventilated storage structure

3.5.1 Dimensions of storage structure

Storage structure was designed for 1.25 tonne capacity. Keeping the width of structure constant i.e. according to size of wire mesh available in market, height of structure was calculated by using following formulas.

As we know that, Structure composed of two parts i.e. cuboid and triangular prism.

$$\text{Volume} = \frac{\text{Weight}}{\text{bulk density}}$$

$$\text{Volume of cuboid} + \text{Volume of triangular prism} = \frac{\text{Weight}}{\text{bulk density}}$$

$$L \times B \times H_1 + \frac{1}{2} L \times B_1 \times H_2 = \frac{\text{Weight}}{\text{bulk density}}$$

Where L, B and $H_1$ are the length, breadth and Height of cuboid and $B_1$ and $H_2$ is the base and height of triangular prism respectively.

By knowing the values of length and breadth and angle of repose, required height can be calculated.

3.5.2 CFM (cubic feet per minute) required for storage structure

The volume of air that must be circulated through the room is measured in CFM (cubic feet per minute). Poor ventilation results in an increase in humidity and that can encourage rotting and sprouting to occur. Required CFM can be calculated by taking the volume of storage structure and multiply by air changes per hour and then divide the answer by 60 minutes per hour to find the required room CFM.

$$\text{Required CFM} = \frac{\text{Volume of storage structure} \times \text{Air changes per hour}}{60 \text{ minutes}}$$

Air change per hour is defined as the how many times air enters and exits a storage structure in one hour or how many times a room or storage structure would fill up with the air from the supply registers in sixty minutes.

3.5.3 Frame assembly

The frame was made up of MS angle iron of dimensions 38.1 x 38.1 x 6.25 mm. This angle iron was used because it provided sufficient strength to the structure without adding any unnecessary weight. The supports (legs) were welded to this frame. Construction of this
structure was done on raised platform to prevent moisture and dampness due to direct contact of the bulbs with floor. Increased centre height and more slope for better air circulation and preventing humid micro climate inside structure was done. Bottom and side ventilations were provided for free and faster air circulation and to avoid formation of hot and humid pockets between the onion layers. MS flat of thickness 19.30 x 6.35 mm were used to provide sufficient strength and support to the wire mesh of storage structure as shown in Fig 3.13.

![Fig 3.13 MS angle iron, MS flat and Wire mesh for storage structure](image)

### 3.6 Experimental set-up for storage of onion bulbs

#### 3.6.1 Ventilated storage structure

Onions were stored under ventilated storage structure and composite sample of 10 kg of 5 onion bags were placed at different positions of storage structure and at different air velocities and was used for further storage studies.

#### 3.6.2 Cold storage structure

Cold stored onions were procured from Shivam cold storage, Village Gajipur, Patial Road, Rajpura, Punjab, India. Shivam cold store consists of four cooling chambers with capacity of each cooling chamber is 1250 MT. In case of onions, the capacity of cooling chamber reduced to 950 MT because of the different stacking pattern i.e. 8 x 2 to avoid pressure bruising as shown in Fig. 3.14. Temperature inside the cooling chamber is maintained between 0 to -1°C by cooling coils which were mounted against the wall as shown in Fig. 3.15. Fans were used for circulation of refrigerated air. Onions were stored in jute/nylon net bags and space between stored bags was 1 inch to allow refrigerated air to pass properly. Temperature of onions stored inside the chamber was around 0°C which was measured by digital thermometer as shown in Fig. 3.16. For loading and unloading operations conveyer was employed. Before storage of onions about 5-6 days drying was normally done on the outside by them and then they store onions in cold chamber. After every 20 days shifting of stored bags was done so as to refrigerated air pass thoroughly and to check the rotting of stored onions. They stored onions from 1st May to 31st September and rent of stored onions was around 5 Rs/kg including labour i.e. loading and unloading. Properties of cold stored onions and that of ventilated stored onions were compared.
Fig. 3.14 Stacking pattern of onions inside cold storage room

Fig. 3.15 Cooling coils and conveyor

Fig. 3.16 Digital thermometer
3.7 Quality assessment parameters

The following observations were recorded on bulbs during the period of storage. Initial observations were recorded before imposing treatments. Physiological loss in weight (PLW, %), sprouting percentage, rotting percentage or black mould incidence, percent moisture content, TSS content, ascorbic acid, sugars, hardness of the bulb and colour of the bulbs were recorded at 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77 and 84 days after storage (DAS) in ventilated storage structure and at 15, 30, 45, 60, 75 and 90 DAS in cold storage.

The details of the methodology adopted for recording these observations during experimentation are described below

3.7.1 Physical parameters

3.7.1.1 Physiological loss in weight (%) 

The weight of the bulbs was recorded on 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77 and 84 days after storage using an electronic balance. The loss in weight of bulbs was measured by using LEO weighing balance (Max. capacity 120 kg) and expressed as percent physiological loss in weight using the formula given below.

\[
\text{PLW} (\%) = \frac{P_0 - P_1 \text{ or } P_2 \text{ or } P_3 \text{ or } P_4 \text{ or } P_5 \text{ or } P_6 \text{ or } P_7 \text{ or } P_8 \text{ or } P_9 \text{ or } P_{10} \text{ or } P_{11} \text{ or } P_{12}}{P_0}
\]

\(P_0\) = initial weight  
\(P_1\) = weight after 7 days  
\(P_2\) = weight after 14 days  
\(P_3\) = weight after 21 days  
\(P_4\) = weight after 28 days  
\(P_5\) = weight after 35 days  
\(P_6\) = weight after 42 days  
\(P_7\) = weight after 49 days  
\(P_8\) = weight after 56 days  
\(P_9\) = weight after 63 days  
\(P_{10}\) = weight after 70 days  
\(P_{11}\) = weight after 77 days  
\(P_{12}\) = weight after 84 days

3.7.1.2 Rotting percentage

The weight of the rotted bulbs at the end of 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77 and 84 days after storage was recorded on the basis of total weight stored in nylon net bag under each treatment / storage condition and the rotting percentage was calculated by using the formula.

\[
\text{Rotting Percentage} = \frac{\text{Weight of rotted bulbs}}{\text{Initial weight of the bulbs}} \times 100
\]

3.7.1.3 Sprouting percentage

For determining the sprouting percentage on stipulated days after storage, the bulbs showing a sprout were separated from the lot and weighed on an electronic balance. Sprouting loss was measured on the basis of total weight of onions stored in a nylon net bag. The sprouting percentage, which indicated the weight of the bulbs sprouted on 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77 and 84 days after storage was calculated by using the formula given below.
Weight of the sprouted bulbs

\[
\text{Sprouting Percentage} = \frac{\text{Weight of the sprouted bulbs}}{\text{Initial weight of the bulbs}} \times 100
\]

3.7.1.4 Moisture content

The moisture of fresh onion bulbs as well as stored onion bulbs was determined from time to time for keeping the proper record and identification of the samples. Several different oven procedures are available for moisture determination of different materials. The usual procedure is to remove the moisture from the product in a hot air oven. For onions, whole onion was placed in an oven at 105°C for 24 hours as given by (AOAC 2000). The fresh and stored onion bulbs were weighed with the help of electronic balance (universal weighing machine) with the sensitivity of 0.001 g (1.200kg capacity). The moisture content was calculated using the equation.

\[
\text{Moisture content (\%, weight basis)} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight of bulbs}} \times 100
\]

3.7.1.5 Total soluble solids (TSS, % Brix)

Sugars, acids, water soluble vitamins, amino acids etc. are the major soluble solids in the juices of fruits and vegetables. The amount of TSS present in the juice is considered to be a reliable index in judging the maturity of fruit or vegetable. Scales from randomly selected bulbs were macerated thoroughly in pastle motor and then from the macerated pulp the juice is extracted by passing through muslin cloth. Total soluble solids of the juice were determined by using a Hand Refractometer (PR-100) 0 to 32° Brix percent range as shown in Fig. 3.17.

![Fig. 3.17 Refractometer for measuring TSS](image)

3.7.1.6 Hardness of onion bulbs

The hardness of onion bulbs was measured using a hand penetrometer as shown in Fig. 3.18 (Effegi fruit penetrometer – mounted on drill press stand, Make: Effegi, Model: PT 327) and the pressure required to penetrate the bulb was recorded in pounds-force (lbf) or kilograms-force (kgf).
Method: Remove a disc (about 2cm in diameter) of the skin or peel of onion with a stainless steel vegetable peeler or a sharp knife. Use an appropriate tip i.e. 8mm in case of onions (plunger).

Thus, necessary pressure for the probe’s penetration into the bulb was measured at three specified points on the onion. Given numbers were averaged and the obtained number indicated tissue firmness.

Hold the onion bulbs against a stationary hard surface and force the tip into the onion bulb at a uniform speed (take 2 seconds). Depth of penetration should be consistent to the inscribed line on the tip and then record the reading to the nearest 0.5 pounds-force (lbf) or kilograms-force (kgf).

![Eff-e-gi penetrometer](image)

**Fig. 3.18 Eff-e-gi penetrometer**

3.7.1.5 Estimation of colour

Colour is one of the important parameters, which is an indicative of the commercial value of the product. The basic purpose was to get an idea of the comparative change in colour of fresh and stored onion bulbs as a result of different storage methods. Colour was determined by using Hunter Lab Miniscan XE Plus Colorimeter (Konika Minolta Sensing Inc.) as shown in Fig. 3.19. Before measuring the colour parameters, colorimeter was calibrated using standard white and black plates provided with the instrument. The colour is described by tristimulus value of L, a, b with the positive value of a, b indicating red and yellow colour and negative values indicating green and blue colour respectively. Values of a, b closer to zero indicates grey colour. L indicates the intensity of colour i.e. lightness which varies from L=100 for perfect white to L=0 for black. For determination of colour, colorimeter was put on the sample and the values of L, a, b were measured. The sample was filled in transparent pouch provided with no light is allowed to pass during the measuring process. The colour change was determined using the formula:

\[
\text{Colour change} \quad \Delta E = \sqrt{(\Delta L^2 + \Delta a^2 + \Delta b^2)}
\]
ΔL, Δa and Δb are deviations from 'L', 'a' and 'b' values of fresh sample.

ΔL = L stored sample – L fresh sample;
Δa = a stored sample – a fresh sample;
Δb = b stored sample – b fresh sample,
+ Δa means sample is redder than standard, - Δa means sample is greener than standard
+ Δb means sample is yellower than standard, - Δb means sample is bluer than standard.

3.7.2 Chemical Parameters

3.7.2.1 Estimation of Ascorbic Acid:-

The most satisfactory chemical method of estimation is reduction of 2,6 dichlorophenol indophenols by ascorbic acid. The ascorbic acid content was analysed by using method AOAC (2006b).

Preparation of chemicals

MP-AA solution: 40 ml of acetic acid and 15g of metaphosphoric acid were dissolved in 450 ml of distilled water.

Dye solution: 52 mg of 2,6 dichlorophenol indophenols and 42 mg of sodium bicarbonate in 200ml of dw and solution was filtered.

Standard ascorbic acid: 20 mg of vitamin C was dissolved in 100 ml of MP-AA solution.

Estimation of ascorbic acid: 1g of sample was crushed using MP-AA solution and then filter. 5ml extract was titrating against the dye. Volume of dye used to oxidize vitamin C in sample was noted.

\[
\text{Ascorbic acid content (mg/100g)} = \frac{\text{Titre value} \times \text{D.F.} \times \text{vol. made}}{\text{Wt. of sample} \times \text{aliquat}} \times 100
\]

D.F= Dye factor = (0.5/titre value)
3.7.2.2 Estimation of reducing sugars

The Nelson-Somogyi method was used and is one of the classical and widely used methods for the quantitative determination of reducing sugars.

Materials

Alkaline Copper tartarate

(A) Dissolve 2.54g anhydrous sodium carbonate, 2g sodium bicarbonate, 2.5g potassium sodium tartrate and 20g anhydrous sodium sulphate in 80mL water and make up to 100mL.

(B) Dissolve 15g copper sulphate in a small volume of distilled water. Add one drop of sulphuric acid and make up to 100mL. Mix 4mL of B and 96mL of solution A before use. Arsenomolybdate Reagent: Dissolve 2.5g ammonium molybdate in 45mL water. Add 2.5mL sulphuric acid and mix well. Then add 0.3g disodium hydrogen arsenate dissolved in 25mL water. Mix well and incubate at 37°C for 24 to 48 hours. Standard Glucose Solution: Stock: 100mg in 100mL distilled water. Working Standard: 10mL of stock diluted to 100mL with distilled water [100mg/mL].

Procedure

1. Weigh 500 mg of the sample and extract the sugars with the hot 80% ethanol twice (10mL each time) by using waterbath as shown in Fig. 3.20.
2. Collect the supernatant and evaporate it by keeping it on a water bath at 80°C.
3. Add 10mL water and dissolve the sugars.
4. Pipette out aliquots of 0.1 or 0.2mL to separate test tubes.
5. Pipette out 0.2, 0.4, 0.6, 0.8 and 1mL of the working standard solution into a series of test tubes.
6. Make up the volume in both standard and sample tubes to 2mL with distilled water.
7. Pipette out 2mL distilled water in a separate tube to set a blank.
8. Add 1mL of alkaline copper tartrate reagent to each tube.
9. Place the tubes in boiling water for 10 minutes.
10. Cool the tubes and add 1mL of arsenomolyabolic acid reagent to all the tubes.
11. Make up the volume in each tube to 10 ml with water.
12. Read the absorbance of blue colour at 510 nm after 10min as shown in Fig. 3.21.
13. From the graph drawn, calculate the amount of reducing sugars present in a sample.

Formula Used: 
\[ \frac{O.D \text{ of standard} \times O.D \text{ of sample} \times \text{Volume made (mg/g)}}{\text{Conc. of standard} \times \text{fresh weight} \times \text{Volume taken} \times 1000} \]
3.8 Statistical analysis

The data was analyzed statistically by using analysis of variance (ANOVA). Factorial experiments in CRD was used to see if there were statistical differences of different storage methods on the TSS, moisture content, PLW, rotting, sprouting, hardness, reducing sugars, ascorbic acid by using software CPCS1. Statistically significant differences among the methods were identified at 5% level of significance.
CHAPTER IV

RESULTS AND DISCUSSION

The results achieved from the present investigations entitled “Fabrication of ventilated structure for storage of onion” have been presented and discussed after analysis of the data. Ventilated onion storage structure of about 1.25 metric ton capacity has been developed. Onion bulbs were also cured by different methods and thus they were stored under ambient conditions. Effect of storage period from 8th of May to 6th August i.e. for about three months and different air flow on quality parameters such as Physiological loss in weight (PLW %), rotting, sprouting, moisture content, ascorbic acid, reducing sugars, hardness and colour change were studied using standard techniques of estimation of each parameter. Properties of cold stored onions and ventilated stored onions were compared. Appropriate statistical packages were used to analyse the data.

4.1 Effect of different curing methods on curing times and bulbs moisture content

The onions after harvesting at appropriate stage at PAU vegetable farm as indicated by the condition of stalk were studied for its curing before storage. This was carried out under three different sets of conditions namely Fields curing, Shade curing and Mechanical curing. The outcomes of these experiments conducted are discussed below:

4.1.1 Field curing

Under favourable climatic conditions, bulbs were usually cured in field. The daily average ambient air temperature during morning were 32-34°C, while afternoon were 48-49.5°C noticed. Fig. 4.1 illustrates the changes in average bulb moisture content as related to the curing time for the mechanical curing, shade curing and field curing method. The time taken for curing in different treatments ranged from 3-9 days (Annexure I, Table I.1).

Table 4.1 Variation of temperature during morning and afternoon in the field

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onion Bulbs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning:</td>
<td>_</td>
<td>36.5°C</td>
<td>37.5°C</td>
<td>42°C</td>
<td>43°C</td>
<td>40°C</td>
</tr>
<tr>
<td>Afternoon:</td>
<td>45°C</td>
<td>52°C</td>
<td>51°C</td>
<td>54.5°C</td>
<td>49.5°C</td>
<td>52°C</td>
</tr>
<tr>
<td>Air</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning:</td>
<td>_</td>
<td>30.5°C</td>
<td>32°C</td>
<td>36°C</td>
<td>34.5°C</td>
<td>35°C</td>
</tr>
<tr>
<td>Afternoon:</td>
<td>41.5°C</td>
<td>47.5°C</td>
<td>42°C</td>
<td>52°C</td>
<td>46.5°C</td>
<td>50°C</td>
</tr>
</tbody>
</table>
Fig. 4.1 Effect of different curing methods on change in the average bulbs moisture content and time

It shows that a gradual decrease in moisture content from initial moisture content 86.5% to a final level of 81% after 5 day (120h) in case of field curing as shown in Annexure I and Table I.1. It also reveals that initially moisture content decreases and remained nearly constant during the end of curing period. Similar results were also obtained by Abd-el Rahman and Ebeaid (2009) in which the bulbs moisture content decreased gradually from initial moisture of 87-90% ±0.5% (w.b) to a final level of 81.5% ±0.5% (w.b) after 16 day (384 h) at a temperature of 21.4 to 26.5°C. The temperature among the bulbs occasionally got as high as 52°C and these bulbs decayed as a result of heat injury (boiling effect) as shown in Fig. 4.2 and Fig. 4.3.

Fig. 4.2 Heat injury due to field curing  Fig. 4.3 Change in colour from pink to yellow

4.1.2 Shade curing

In shade curing harvested bulbs were cured under 100% shade and at air temperature of 35-36°C. It can be seen from the Fig. 4.1 that a curing period continued until the bulbs
moisture content decreased from initial moisture content 86.5% and to a final level of 81.25% after 9 days (216h). The maximum time was taken for about 216h when cured by shade curing method in comparison to both other methods. The time taken for curing in different treatments ranged from 4 hours to 288 hours. The lesser time of curing is due to high temperature of 50°C with a rate of air flow 222 m³/min in the forced hot air dryer (Satish and Ranganna 2002). The maximum time taken for curing was observed in bulbs cured under 100% shade about 288h with and without foliage due to less temperature (18 to 25°C).

4.1.3 Mechanical curing

Mechanical curing was carried out in Pilot plant laboratory and it can be observed that curing onion bulbs artificially in a cabinet dryer at air velocity of 2.2-2.3 m/s and at a temperature of air at 37-38°C caused a gradual decrease in the bulbs moisture content from initial to a final moisture in 3 days (72h) as shown in Fig. 4.1. Thus curing of onion bulbs artificially can reduce the required time of curing by about 68.8, 71.9, 75 and 81.3 % for large size of bulbs, and by 71.9, 75, 78 and 81.3 % for medium and small size of bulbs, compared with traditional curing method of bulbs (control treatment) (Abd-el Rahman and Ebeaid 2009).

Similar results were also observed by Wilson and Estes (1994) showed that the air heated by gas or other types of heaters will dry onions satisfactorily in 48 to 72 hours, depending upon the condition of the onions and the atmospheric conditions. They stated that fans should be sized to provide from 3 to 5 cubic feet of air per minute per bushel of onions (2 to 3.35 m³/min. ton) of onions.

Air heated to 37.8 °C is sufficient for rapid drying. They also stated that air temperatures above 43.3 °C will damage the bulbs. A reduction of 5 to 8 % in the bulb weight is usual during artificial curing.

4.2 Storage of cured onion under ambient conditions

4.2.1 Total Loss in weight

The storability of onion bulbs in term of total loss in weight of onions is a good indicator of curing process. Storability was measured during a storage period of 3 months after curing process of the onion bulbs. Significant differences were observed at CD 5% level of significance among the curing methods on the physiological loss in weight of the bulbs throughout the storage period (Annexure I, Table I.2). There was a significant increase in the per cent physiological loss in weight of onion bulbs during storage period of 90 days in all the treatments.
The physiological loss in weight values increased progressively from 4.55 per cent at 10 days after storage to 22.55 per cent at 90 days after storage. Among the treatments, significantly minimum per cent of physiological loss in weight was recorded in mechanical cured onion bulbs (15.8 %). However, maximum physiological loss in weight was found in field cured onion bulbs (22.55 %) as shown in Fig. 4.4.

This may be that too high temperatures accentuate cracking and splitting of skins, and the outer fleshy tissue in the neck region becomes soft and appears partially cooked. After a few weeks storage the affected tissue collapses and was invaded by bacteria. The recorded data revealed that during the mechanical cured process the average weight of total loss during a storage period decreased as compared to field curing. The very slow curing in the shade has allowed an increased proportion of B. allii infections in leaves to enter the bulb shoulder before topping and cause decay in comparison to bulbs cured in artificial cured bulbs. The least physiological loss in weight may be attributed due to the proper drying of the outer scales and formation of tight neck checking further escape of moisture and thus reduced the weight loss during storage.

Similar findings were also reported by Goburdhan (1980) that field curing for 21 days extended the storage life from three months (control) to five months and this was further prolonged by artificial curing at 37°C. Similar findings were reported by Rekha et al (2014), who observed that maximum physiological loss in weight was found in onion bulbs cured under forced hot air dryer at 50°C without foliage (26.84 %) at 60 DAS. Similar results were also observed by Bahnasawy (2000) concluded that a reduction of 4 % in the onion weight was found during curing process. Field curing is the least expensive of all curing methods but it recorded the highest percentage of losses during storage as well as the highest sprouting percentage.
Table 4.2 Physical characteristics of onion

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Physical characteristics</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Average size</td>
<td>32.75-68.67 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Angle of repose</td>
<td>26°</td>
</tr>
<tr>
<td>3.</td>
<td>Bulk density</td>
<td>560 kg/m$^3$</td>
</tr>
</tbody>
</table>

4.3 Design of storage structure

4.3.1 Estimation of dimensions of ventilated storage structure

Bulk density of a sample measured by weighing them in a known volume and thus height was calculated.

$$\text{Bulk density (kg/m}^3\) = \frac{\text{weight (kg)}}{\text{volume (m}^3\)}$$

Bulk density was 560 kg/m$^3$ for that sample. Angle of repose was calculated and came around 26° and thus inclined surface at the base has been provided for ease of unloading of onions.

Therefore, for designing 1.25 ton capacity bin,

Volume = Weight/bulk density

Volume of cuboid + Volume of triangular prism = Weight/bulk density

$$L \times B \times H_1 + \frac{1}{2} B_1 \times B_1 \times H_2 = \frac{1250}{560}$$

Keeping the length and breadth constant i.e. according to the wire mesh available in the market, height was calculated by using above formula.

$$1.21 \times 1.21 \times H_1 + \frac{1}{2} 1.21 \times 1.21 \times H_2 = \frac{1250}{560} \ldots \ldots \ldots \text{equation (I)}$$

As value of $H_2$ was calculated by using angle of inclination at the bottom,

$$\tan 26° = \frac{H_2}{B_1}$$

Thus $H_2 = 0.48 \times 1.21 = 0.58m$

Putting the value of $H_2$ in equation (I), value of $H_1$ was calculated

$H_1 = 1.22$ m and $H_2 = 0.58$m

Thus front height i.e. $H_1+H_2$ were obtained and came around 1.8m and back height i.e. $H_1$ were approx. 1.21m as shown in Fig. 4.5 to 4.7.
Fig. 4.5 Side view of storage structure
Fig. 4.6 Front view (All dimensions in inches)

Fig. 4.7 Isometric view of storage structure
Fig. 4.8 Ventilated storage structure
The onion storage structure build on a raised platform of 0.35m height from front side and 0.90m from back side with bottom and side ventilations. The total height of the structure is 7 feet (84 inches) as shown in Fig. 4.6. Drawing of storage structure was made in Solid works software.

Similarly, angle of repose were also calculated by Bahnasawy et al (2004) which studied the physical and mechanical properties of Egyptian onion cultivars and concluded that rolling angle ranged from 20° to 31° in the stable position and from 14° to 23° in the non-stable position. The highest values of rolling angles were obtained on rubber surface followed by the plywood and the galvanized steel surfaces. The rolling angle increases with onion size. Pandiselvam et al (2013) studied the Frictional, Mechanical and Aerodynamic Properties of Onion Seeds and concluded that as the moisture content increased from 9.8% to 29.6% (db), the angle of repose and terminal velocity were found to increase from 28.11 to 37.41° and 1.7 to 2.6 m/s.

Ranpise et al (2001) also reported onion stored in modified improved storage structure with bottom and central ventilation with raised floor (60 cm) of structure above ground reduced the storage losses from 99.2 to 70.0 per cent during five months storage.

National Horticultural Research and Developmental Foundation also constructed a ventilated onion storage structure of about 25 MT capacity. The storage of onion will be on raised perforated platform of 0.60 m height with bottom and side ventilations. The ground clearance may be 60 cm with side opening of upto 80%. Height of storage under ventilation storage should be in the range of 90 cm to 150 cm. The size of onion storage area will be 4.5m X 6.0m. The overall dimensions of a 25 MT structure may be 6.5 m X 7.0 m. The dimensions can be adjusted depending upon the capacity and site conditions (Anon 2012).

**4.3.2 CFM (cubic feet per minute) required for storage structure:**

Required CFM can be calculated by taking the volume of storage structure and multiply by air changes per hour and then divide the answer by 60 minutes per hour to find the required room CFM. The recommended ventilation rate is 60 air changes per hour at 0°C and is 50 air changes per hour at temperatures up to 35°C.

\[
\text{Required CFM} = \frac{\text{Volume of storage structure} \times \text{Air changes per hour}}{60 \text{ minutes}}
\]

\[
\text{Required CFM} = \frac{77.48 \text{ ft}^3}{\text{min}} \times 60 \text{ min}
\]

\[
\text{Required CFM} = 77.48 \text{ ft}^3/\text{min}
\]

Thus during storage period ventilation air flow rate 1 CFM per cubic foot (1 m³/min/m²) for onion is required. Air circulation should be sufficient to prevent heating and to remove moisture from within bins or sacks; at least 1 cfm/ton of bulbs is required (Vincent 2010). Circulating the air within the storage will be necessary to maintain even temperatures through-out the onion pile. In addition to natural ventilation a provision of mechanical
Aeration has been provided at the base of this storage structure. Three axial flow fans at the base created variable air flow rate with air velocities of 0.27 m/s, 0.32 m/s, 0.69 m/s, 0.9 m/s and 1.38 m/s. Five different air flow rates were selected i.e. 1.38 m/s at the centre position, 0.9 m/s at the half position, 0.69 m/s at the top position, 0.32 m/s at the front position near the pillars and 0.27 m/s at the back position near the pillars of the structure. Onions in bulk were filled in the structure and samples of 10 kg of five onion bags were kept at different location and at different velocities within the structure for this study.

### 4.3.3 Man hours loading and unloading

Loading of onions was done from the upper side which has opening of around 20 inches. For loading 2-3 persons were required as shown in Fig 4.9.

To load 450 kg of onions in storage structure time required = 10 minutes.

Thus, to load 1250 kg onions in storage structure time required = \( \frac{10}{450} \times 1250 \) ≈ 28 minutes approx.

Unloading of onions was done from lower portion and has opening of 13 inches which consists of sliding MS sheet as shown in Fig 4.10.

To unload 450 kg of onions from storage structure time required = 3 minutes

Thus, to unload 1250 kg onions from storage structure time required = \( \frac{3}{450} \times 1250 \) ≈ 8 minutes approx.

---

**Fig. 4.9 Loading of onions**  
**Fig. 4.10 Unloading of onions**
4.3 Effect of storage on different physical and chemical parameters of onions stored in Ventilated storage structure and Shivam cold store.

4.3.1 Physiological loss in weight of onions (PLW)

Physiological loss in weight was found to be the major factor responsible highest loss during storage and ranged from 20 to 87 per cent as observed by (Sidhu 2008). Since water loss is a function of storage temperature and relative humidity, high rate of water loss in the cultivar could be partly due to the high temperature and low relative humidity during storage. Physiological loss in weight of onion in storage structure subjected to different air velocity was significant at CD 5% level of significance. From statistical analysis, with duration, the PLW was much significant than with flow rates. Total PLW at air velocity $T_1$, $T_2$, $T_3$, $T_4$ and $T_5$ were 25.8, 25.15, 24.65, 20.8 and 21.8 per cent, respectively (Annexure I, Table I.3).

But with duration, the physiological loss in weight was much significant than with flow rates. During the initial months of storage PLW was more i.e. 19.15 at 28 days of storage. This may be due to the high temperature which results in more water loss and shrinkage of onion bulbs. Least PLW were noticed in $T_4$ i.e. 20.8 and maximum in $T_1$ i.e. 25.8 as shown in Fig.4.11.

![Fig. 4.11 Effect of storage conditions and storage duration on PLW](image-url)

The maximum PLW was noticed in onions which stored at air velocity $T_1$ i.e. near the pillars of the storage structure compared to the other part of the chamber which might be happened that onion bulbs near the pillar absorbed heat through the pillar and also the onion in that region get less ventilation as compared to other area. It was observed that initially moisture content was very high in onions and water loss occurred. Since water loss is a function of storage temperature and relative humidity, high rate of water loss in the cultivar could be partly due to the high temperature and low humidity during storage.
Statistically also, CD at 5 per cent level of significance between air velocities $T_1$ and $T_3$ was more than 0.659, proving that air velocities affects PLW significantly.

### 4.3.2 Rotting of onion bulbs

Rotting of onion bulb during storage is begun by numerous bacteria and fungi and postharvest disease may place a major limitation on the long term storage of onion (Fig. 4.13 and 4.14). Rotting was observed maximum at 14 days of storage with a value of 3.8% (Annexure I, Table I.4). After this, rotting decreased to 2 per cent only at 42 days of storage. In the last weeks of storage period, rotting was very less and in the 11th week, rotting was nil. It decreased due to gradual availability of required environmental conditions.

**Fig. 4.12 Effect of different air velocities and duration of storage on rotting of onion bulbs**

Maximum rotting was observed in air velocity of 0.27m/s as they were placed at front position of storage structure and in more depth so pressure there was more as a result pressure bruising occurs which results in more rotting of onions as shown in Fig 4.12. For the onions with air velocity of 0.9m/s and 1.38 m/s rotting was minimum and comparable due to the proper ventilation. But from statistical analysis, with duration, the rotting was much significant than with flow rates.

Kukanooor (2005) studied that the minimum rotting and black mould 7.22 per cent was observed in low cost storage structure with bottom and side ventilation and the maximum rotting 10.22 per cent were noticed in thatched roof structure without bottom ventilation. The higher rotting and black mould per cent may be due to the build-up of respiratory heat and humidity within the onion pile creating favourable condition for the proliferation of the spoilage pathogens (Chavan et al 1997).
Statistically also, CD at 5 per cent level of significance between air velocities was more than 0.046, proving that air velocity affects rotting significantly.

**4.3.3 Sprouting of onion bulbs**

Sprouting in stored bulbs is a result of physiological change in which storage can only affect its rate. Sprouting of onion greatly reduces their utilization value and accelerates deterioration. Significant differences were observed at CD 5% level of significance among the air velocities on the sprouting of the bulbs throughout the storage period. Dormancy of onion bulbs disappear at low temperature ranges. It can be seen from the Table I.5 that sprouting losses were minimum during first 56 days of storage as initially the onions were in dormant stage. Then at high relative humidities and high temperatures, dormancy is broken and onions started sprouting as shown in Fig. 4.15. Sprouting was most severe in last weeks of July and starting of August when relative humidity is high due to rains.
It was observed from the Fig. 4.15 that sprouting was least at air velocity of 1.38 m/s and this is due to the low relative humidity and better air circulation rate and movement of air amongst individual bulbs. Kukanoor (2005) reported that sprouting caused shriveling of bulbs, consequently onion bulbs lost marketable quality and observed that storing bulbs in low cost storage structure and improved storage structure with bottom and side ventilation recorded significantly lowest sprouting percentage (3.05%).

![Fig. 4.16 Sprouting of onion bulbs stored in ventilated storage structure](image)

On comparing F-ratios, it was found that air velocity was more significantly affecting the values of sprouting than storage duration.

### 4.3.4 Total Losses

Initially 460 kg of onions were stored in ventilated storage structure. PLW loss was more during initial months of storage as there were more rotting losses observed in ventilated storage structure as shown in Table 4.3. However, PLW losses were very less of onions which stored at Shivam cold store i.e. at 0 to -1°C (Lot No. 35/393). Losses due to rotting were very less and no sprouting was observed. 184 onion bags of Lot No. 35/393 were stored during the 20th May 2015 and 168 bags were ready at the end of storage (10th October 2015). Sorting and grading of onions were done after 20 days and rotted onions were removed. Total losses, sprouting losses and rotting losses were very less as compared to that of ventilated storage structure. Total PLW was 26.04% observed at the end of storage in ventilated onion storage structure. The PLW (10.23%) was very less in cold stored onion at the end of storage period. This may be due to that at temperature of 0 to 1°C onions remain dormant and few losses were observed. Initially no rotting was observed and then rotting is increased as duration of storage increased in case of cold stored onions as shown in Table 4.4.
Table 4.3 Overall PLW (%age), rotting percentage and sprouting percentage (Ventilated storage structure)

<table>
<thead>
<tr>
<th>Duration (days)</th>
<th>PLW (%age)</th>
<th>Rotting (%age)</th>
<th>Sprouting (%age)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>1.45</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>5.85</td>
<td>2.24</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>10.92</td>
<td>3.55</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>13.13</td>
<td>2.63</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>16.50</td>
<td>1.22</td>
<td>0</td>
</tr>
<tr>
<td>42</td>
<td>18.07</td>
<td>1.33</td>
<td>0</td>
</tr>
<tr>
<td>49</td>
<td>21.18</td>
<td>1.28</td>
<td>0.020</td>
</tr>
<tr>
<td>54</td>
<td>23.28</td>
<td>0.93</td>
<td>0</td>
</tr>
<tr>
<td>63</td>
<td>24.70</td>
<td>0.76</td>
<td>0.026</td>
</tr>
<tr>
<td>70</td>
<td>25.00</td>
<td>0.8</td>
<td>0.128</td>
</tr>
<tr>
<td>77</td>
<td>25.40</td>
<td>0.6</td>
<td>0.126</td>
</tr>
<tr>
<td>84</td>
<td>26.04</td>
<td>0.6</td>
<td>0.228</td>
</tr>
</tbody>
</table>

Table 4.4 Overall PLW (%age), rotting percentage and sprouting percentage (Cold storage)

<table>
<thead>
<tr>
<th>Duration (days)</th>
<th>PLW (%age)</th>
<th>Rotting (%age)</th>
<th>Sprouting (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20th May 2015</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>1.63</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>3.71</td>
<td>1.76</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>5.89</td>
<td>2.33</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>7.52</td>
<td>2.24</td>
<td>0</td>
</tr>
<tr>
<td>10th October 2015</td>
<td>10.23</td>
<td>2.96</td>
<td>0</td>
</tr>
</tbody>
</table>

4.3.5 Moisture content

Changes in moisture content have been effected by the storage treatment and time. Initially moisture content of onions stored under ventilated storage structure was 83.3 per cent. Then there is abrupt fall in the moisture content due to the high temperature and low humidity as shown in Fig. 4.17. This may be due to the better air movement among the onion piles which has helped in reducing moisture content of bulbs to a desired level. Moisture loss maximum was observed in bulbs stored under air velocity 0.69 m/s as shown in Fig. 4.17. This could be due to the onion bulbs placed on the top of the storage structure and more is the ventilation. The results showing the significance of storage period and air velocities at CD 5 % level of significance.
The rise or fall of moisture content with time is a storage function of properties of the environment surrounding the onions as relative humidity and temperature of the environment vary during different periods of the year. However, maximum moisture content was observed in bulbs stored under 0.27 m/s and 0.32 m/s air velocity might have accelerated the sprouting and rotting.

On comparing F-ratios, it was found that storage time was more significantly affecting the values of moisture content than air velocities. Results also showed that aeration does not result in extra loss of moisture. The bulbs which stored at Shivam cold store (0 to -1°C) shows less moisture loss as compare to ventilated storage structure as shown in Table 4.5. Malek and Heidarisoltanabadi (2015) also showed the similar results in which the moisture drop in traditional treatment is higher than cold treatment (1 to 4°C)

**Table 4.5 Variations in moisture content of onions stored in cold storage (Values are Mean ± SD)**

<table>
<thead>
<tr>
<th>Duration (days)</th>
<th>Moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>84.2 ± 0.05</td>
</tr>
<tr>
<td>15</td>
<td>84.4 ± 0.11</td>
</tr>
<tr>
<td>30</td>
<td>83.8 ± 0.57</td>
</tr>
<tr>
<td>45</td>
<td>83.72 ± 0.005</td>
</tr>
<tr>
<td>60</td>
<td>82.9 ± 0.23</td>
</tr>
<tr>
<td>75</td>
<td>82.9 ± 0.40</td>
</tr>
<tr>
<td>90</td>
<td>82.72 ± 0.01</td>
</tr>
</tbody>
</table>
4.3.6 Total soluble solids

TSS is defined as the total of all the solids that dissolve in water, including sugars, salts, protein and organic acids. The Total Soluble Solids (TSS) content of bulbs was significantly affected by different air velocities and storage period at CD 5 per cent level of significance. There was also significant difference of TSS with different locations with different air velocities. The difference between means is more between minimum and maximum air velocities.

Initial Total soluble solids of onions were 11.6° Brix. There was a gradual increase of TSS during storage in all the storage methods. The increase in TSS was mainly due to the conversion of polysaccharides into soluble form of sugars. The maximum TSS was recorded in onion bulbs at air velocity T₃ and T₅ 13.6° Brix and 13.4° Brix respectively. The minimum TSS recorded in onion bulbs at air velocity T₁ i.e. 12.8° Brix. As shown in Fig 4.18.

![Fig. 4.18 Effect of different air velocities and storage duration on TSS (°Brix)](image)

The higher per cent TSS may be due to more loss of moisture and increased in dry matter content of the bulb which leads to increase in TSS content. Similar findings were observed by Sainmbhi and Randhawa (1982) and Patil and Kale (1988) in onion. Kukanoor (2005) also observed that among the different storage conditions, bulbs stored in low cost storage structure showed maximum TSS and was closely followed by bulbs stored in improved storage structure, while bulbs stored in zero energy cool chambers (ZECC) recorded minimum TSS (12.30%) and also in improved storage structures concluded by Kukanoor (2005).
The onion bulbs which stored at cold storage showed minimum increase in TSS i.e. 12° Brix as compare to onions stored at ventilated storage structure (Table 4.6). This may be due to lower temperature which might have reduced rate of respiration of bulbs in turn would have regulate the biochemical changes leading to lower total soluble solids. Similar results were also observed by Siddiqui and Gupta (1990) in ber and Nagaraju et al (1992) in sapota.

Table 4.6 Variation of TSS of onion bulbs in Cold store (Values are Mean ± SD)

<table>
<thead>
<tr>
<th>Duration (days)</th>
<th>Total soluble solids (° Brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11.2 ± 0.057</td>
</tr>
<tr>
<td>15</td>
<td>11.2 ± 0.11</td>
</tr>
<tr>
<td>30</td>
<td>11.6 ± 0.57</td>
</tr>
<tr>
<td>45</td>
<td>11.6 ± 0.57</td>
</tr>
<tr>
<td>60</td>
<td>12 ± 0.57</td>
</tr>
<tr>
<td>75</td>
<td>11.8 ± 0.23</td>
</tr>
<tr>
<td>90</td>
<td>12 ± 1.15</td>
</tr>
</tbody>
</table>

4.3.7 Hardness

Hardness of onion bulbs was measured by penetrometer and the pressure required to penetrate the bulb was recorded in kilograms per sq. cm. Initially the hardness of onion bulbs was 12.5 kgf. There is a rise in hardness of onion bulbs before 14 days of storage as shown in Fig. 4.19. This may be due to the more moisture loss initially which results in hardness of onion bulbs. Thereafter is a fall in hardness which may be due to increased rotting which softens the onion bulbs and then it decreased slightly may be due to decreased in rotting. Hardness decreased more at air velocity T₁ (7 kg/cm²) and maximum hardness (9 kg/cm²) observed in onion bulbs which stored at air velocity T₅ as shown in Fig. 4.19.
On comparing F-ratios, it was found that storage time was more significantly affecting the values of moisture content than air velocities. Statistically also, CD at 5 per cent level of significance between air velocity $T_1$ and $T_5$ was more than 0.074, proving that air velocity affects firmness significantly.

Onion tissue firmness was not affected by cold storage and it remained nearly same because of the very less rotting and no sprouting which maintains firmness and does not soften the onion bulbs as shown in Table 4.7.

**Table 4.7 Variation of hardness during cold storage (Values are Mean ± SD)**

<table>
<thead>
<tr>
<th>Duration of storage (days)</th>
<th>Hardness (KgF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12.85 ± 0.02</td>
</tr>
<tr>
<td>15</td>
<td>12.45 ± 0.01</td>
</tr>
<tr>
<td>30</td>
<td>12.67 ± 0.05</td>
</tr>
<tr>
<td>45</td>
<td>12.64 ± 0.01</td>
</tr>
<tr>
<td>60</td>
<td>12.45 ± 0.02</td>
</tr>
<tr>
<td>75</td>
<td>12.64 ± 0.05</td>
</tr>
<tr>
<td>90</td>
<td>12.50 ± 0.023</td>
</tr>
</tbody>
</table>

### 4.3.8 Colour

Colour is an important characteristic of food products because it is usually among the first properties that consumers pay attention. Colour change in food products during processing and storage is due to various factors (Liu *et al.* 2010). The initial value of ‘L’, ‘a’ and ‘b’ of onions were 49.3, 16.8 and 2.1 respectively. It can be seen from the table that significant variations in redness value ‘a’ were observed in different locations of ventilated structure with respect to different air velocities. However, colour difference value ‘$\Delta E$’ increase from 0 to 4.48 and redness value ‘a’ decrease from 16.8 to 14.6 during storage period as shown in Fig 4.20 and Fig 4.21. The results show that there were significant differences in ‘$\Delta E$’ values observed at different air velocities at CD 5 per cent level of significance.

![Fig. 4.20 Effect of storage duration and different air velocities on redness value](image-url)
Fig. 4.21 Effect of storage duration and different air velocities on colour difference

However in case of cold storage maximum retention of redness and minimum colour difference were observed as compare to onions stored in ventilated storage structure. Initially the ‘L’, ‘a’ and ‘b’ values of onions stored in cold storage were 31.5, 20 and 1.9 respectively. The redness value ‘a’ decreased from 20 to 19.4 and colour difference value ‘ΔE’ increase from 0.28 to 1.54 were observed as shown in Table 4.8.

Table 4.8 Effect of cold storage on Redness value ‘a’ and colour difference ‘ΔE’. (Values are Mean ± SD)

<table>
<thead>
<tr>
<th>Duration of storage (days)</th>
<th>Redness value ‘a’</th>
<th>Colour difference ‘ΔE’</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20 ± 1.15</td>
<td>0.28 ± 0.05</td>
</tr>
<tr>
<td>15</td>
<td>20 ± 0.57</td>
<td>0.28 ± 0.05</td>
</tr>
<tr>
<td>30</td>
<td>19.8 ± 0.11</td>
<td>0.80 ± 0.34</td>
</tr>
<tr>
<td>45</td>
<td>19.75 ± 0.02</td>
<td>0.97 ± 0.01</td>
</tr>
<tr>
<td>60</td>
<td>19.64 ± 0.05</td>
<td>1.22 ± 0.05</td>
</tr>
<tr>
<td>75</td>
<td>19.52 ± 0.05</td>
<td>1.37 ± 0.01</td>
</tr>
<tr>
<td>90</td>
<td>19.4 ± 0.17</td>
<td>1.54 ± 0.02</td>
</tr>
</tbody>
</table>

4.3.9 Ascorbic acid (mg/100g)

There was a significant difference of vitamin-C with airflow rates and with duration at CD 5 per cent level of significance. Initially vitamin-C content was 13.2 mg/100g of fresh onions. However, the gradual decrease of ascorbic acid in all the storage methods with advancement of storage period may be due to oxidative destruction of ascorbic acid in the presence of molecular oxygen by ascorbic acid oxidase enzymes (Mapson 1970). It was also found that there was no marked difference in vitamin-C of two different sizes of the bulbs.
Air velocity $T_1$ (1.38 m/sec) gave the best retention of ascorbic acid as compared to other air velocities as shown in Fig. 4.22 and Annexure I, Table I.11.

![Fig. 4.22](image)

**Fig. 4.22 Effect of storage duration and different air velocities on Ascorbic acid (mg/100g)**

Ascorbic acid content of onions which stored at air velocities $T_1$ and $T_2$ were nearly same at the end of storage period and was about 10.6 mg/100g fresh onions. Same in the case of onion bulbs which were stored at air velocity $T_3$ and $T_4$ ascorbic acid content decreased to 11.69 mg/100g of fresh onions. The lowest retention of ascorbic acid may be due to the build-up of respiratory heat in the centre of structure. The ascorbic acid content of onion stored in cold storage was decreased from 10.64 mg/100g to 9.25 mg/100g of fresh onions weight (Table 4.9). It is evident from the results that storing bulbs under cold storage and at air velocity 1.38 m/sec recorded maximum retention of ascorbic acid.

**Table 4.9 Effect of cold storage on ascorbic acid content (Values are Mean ± SD)**

<table>
<thead>
<tr>
<th>Duration of storage (days)</th>
<th>Ascorbic acid (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.64 ± 0.57</td>
</tr>
<tr>
<td>15</td>
<td>10.64 ± 0.57</td>
</tr>
<tr>
<td>30</td>
<td>10.64 ± 1.15</td>
</tr>
<tr>
<td>45</td>
<td>9.50 ± 0.57</td>
</tr>
<tr>
<td>60</td>
<td>9.50 ± 2.3</td>
</tr>
<tr>
<td>75</td>
<td>9.25 ± 0.57</td>
</tr>
<tr>
<td>90</td>
<td>9.25 ± 0.57</td>
</tr>
</tbody>
</table>

**4.4.0 Reducing sugars**

Water soluble carbohydrates in onion bulbs include fructose, glucose and sucrose and a series of oligosaccharides called fructans as suggested by Darbyshire and Henry (1978). It
was observed that gradual decrease of reducing sugar at different velocities in ventilated storage structure occurred as shown in Fig. 4.23 and Annexure I, Table I.12. This may be due to that the reducing sugars like glucose and fructose may get utilised for respiratory process and sprouting during storage. The initial reducing sugar content was found in onions 15.8 g/100g. On comparing F-ratios, it was found that storage time was more significantly affecting the reducing sugars than air velocities.

Fig. 4.23 Effect of storage duration and different air velocities on reducing sugars

Among the different air velocities, maximum retention of reducing sugars observed in onion bulbs which stored at air velocity $T_3$, i.e. 14 g/100g at the end of storage period. Whereas minimum retention of reducing sugars was noticed in onion bulbs which stored at air velocity $T_1$. However there was comparable decrease in reducing sugars were observed in onion bulbs stored at air velocity $T_3$ and $T_4$.

Very less difference in reducing sugars were noticed in cold storage of onions. The initial value of reducing sugars was 15.5 g/100g and at the end of storage 15 g/100g was observed i.e. very less change is observed as shown in Table 4.10. This may be due to no sprouting was found and sugars like fructose and glucose may not get utilise.

Table 4.10 Effect on reducing sugars of onions stored in cold store (Values are Mean ± SD)

<table>
<thead>
<tr>
<th>Duration of storage (days)</th>
<th>Reducing sugars (g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15.5 ± 0.28</td>
</tr>
<tr>
<td>15</td>
<td>15.5 ± 0.23</td>
</tr>
<tr>
<td>30</td>
<td>15.25 ± 0.57</td>
</tr>
<tr>
<td>45</td>
<td>15.5 ± 0.57</td>
</tr>
<tr>
<td>60</td>
<td>15.25 ± 1.15</td>
</tr>
<tr>
<td>75</td>
<td>15 ± 0.57</td>
</tr>
<tr>
<td>90</td>
<td>15 ± 1.15</td>
</tr>
</tbody>
</table>
Similar results were observed by Kukanoor (2005) where maximum per cent reducing sugar was found in bulbs stored in ZECC followed by bulbs stored in thatched roof structure at 30, 45, 60, 75 and 90 DAS. Whereas minimum per cent of reducing sugars content observed in bulbs which stored in low cost storage structure and bulbs stored in improved storage structure at 30, 45, 60, 75 and 90 DAS.

4.5 Economics

**Given:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of storage structure</td>
<td>Rs. 2000/-</td>
</tr>
<tr>
<td>Expected useful life</td>
<td>10 years</td>
</tr>
<tr>
<td>Re-sale value (5% of I.C.)</td>
<td>Rs. 2000 x 5/100 = Rs. 100/-</td>
</tr>
<tr>
<td>Storage Capacity</td>
<td>1250 kg</td>
</tr>
<tr>
<td>Market value at time of storage</td>
<td>Rs. 10/kg</td>
</tr>
<tr>
<td>Market value after storage</td>
<td>Rs. 20/kg</td>
</tr>
<tr>
<td>Storage period</td>
<td>3 months</td>
</tr>
<tr>
<td>Loss of weight of onions</td>
<td>26 percent</td>
</tr>
</tbody>
</table>

**Calculations**

(A) 1. Depreciation = \( \frac{I.C.-R.V}{Life} \) = \( \frac{2000-100}{10} \) = Rs. 190 per year

2. Interest on capital = 9 per cent of I.C.
   i. On Structures = 2000 x 9/100 = Rs. 180 per year
   ii. On product = 1250 x 10 x 9/100 = Rs. 1125 per year

3. Housing (1.5% of I.C.) = 2000 x 1.5/100 = Rs. 30 per year

4. Handling (2% of I.C.) = 1250 x 10 x 2/100 = Rs. 250 per year

5. Electricity consumption for fans = 400 units for 3 months
   Cost of one unit = Rs. 7/-
   Electricity charges = 400 x 7 = Rs. 2800/-

Value of depreciation, interest on capital, housing and handling for 3 months
= (190 + 180 + 1125 + 30 + 250) / 3
= Rs. 591.6/-

Total cost for 3 months = 2800 + 591.6 = Rs. 3391.6/-

(B) Loss of onions during 3 months storage = 26% = 1250 x 26/100 = 325 kg

(C) Quantity of onions after storage = 1250-325 = 925 kg

(D) Market value after storage = 925 x 20 = Rs. 18,500/-

(E) Net profit = 18,500 – (10,000 + 3391.6) = Rs. 5,108/-
CHAPTER V

SUMMARY

A study of design, fabrication and evaluation of forced ventilation storage structure for onions was carried out to assess the effects of different air velocities at different location of structure and storage time on storage period. About 4 quintal of onion bulbs was stored in 1.25 ton capacity of ventilated storage structure. Composite samples of 10 kg of 5 onion bags were placed at different locations of structure under air velocities of 0.27, 0.32, 0.69, 0.9 and 1.38 m/s respectively. Appropriate statistical packages were used to analyse the data.

Different types of curing methods were also performed on onion bulbs such as shade curing, field curing and mechanical curing and cured bulbs were stored under ambient conditions. During shade curing, the bulbs were cured under 100% shade and at air temperature of 35-36°C and moisture content decreased from initial moisture content 86.5% and to a final level of 81.25% after 9 days (216h). The bulbs were also cured in field and temperature of the air were varied from 32-33°C during morning and while afternoon were 48-49.5°C and it took 5 days (120h). Mechanical curing of onions was artificially done in cabinet dryer at air velocity of 2 m/s and at air temperature of 37-38°C which caused a gradual decrease in the bulbs moisture content from initial to a final moisture in 3 days (72h). The time taken for curing in different treatments ranged from 72 hours to 216 hours.

The maximum time taken for curing was observed in bulbs cured under 100% shade about 216h due to less temperature (35 to 36°C). At the end of curing period, a composite sample of four kilogram bulbs was taken and was used for storage studies under ambient conditions. Maximum loss in weight i.e. 22.55% during storage was recorded in field cured onion bulbs which might be due to that the temperature among the bulbs occasionally got as high as 52°C during curing and too high temperatures accentuate cracking and splitting of skins, and the outer fleshy tissue in the neck region becomes soft and appears partially cooked. After a few weeks storage the affected tissue collapses and is invaded by bacteria.

The very slow curing in the shade has allowed an increased proportion of B. allii infections in leaves to enter the bulb and cause decay in comparison to bulbs cured in artificial cured bulbs. The least physiological loss in weight was recorded in artificial cured onion bulbs i.e. 15.8% may be attributed due to the proper drying of the outer scales and formation of tight neck checking further escape of moisture and thus reduced the weight loss during storage.

Properties of cold stored onions i.e. onions obtained from Shivam cold store and ventilated stored onions were compared. The storage period was from 8th May to 8th August of onions stored in ventilated storage structure. Different parameters studied were Physiological Loss in Weight (PLW %), Rotting, Sprouting, Moisture content, Total soluble
solids, Hardness, Colour, Ascorbic acid and Reducing sugars. Based on overall discussion made over the results obtained, following conclusions were drawn.

- Physiological loss in weight of stored onion bags in different locations of ventilated structure and under different velocities i.e. 0.27, 0.32, 0.69, 0.9 and 1.38m/s were 25.8, 25.15, 24.65, 20.8 and 21.8 respectively.
- Initially rotting was increased due to high moisture content of the onions and then rotting decreased after 35 days of storage period. Cumulative rotting at different air velocities were 21.15, 20.6, 17.6, 11.45 and 9.96 per cent respectively.
- Almost negligible sprouting occurred till 56 days of storage. Cumulative sprouting was 2.85, 2.15, 0.94, 0.4 and 0.2 per cent respectively in case of ventilated storage structure.
- Total losses in ventilated storage structure and Shivam cold store were comprised of rotting, sprouting and physiological loss in weight and recorded as 17.39%, 0.52% and 26.04% in case of ventilated storage structure and 9.29, 0 and 10.23% in cold stored onions respectively at the end of the storage.
- Moisture loss maximum was observed in bulbs stored under air velocity 0.69 m/s. This could be due to the onion bulbs placed on the top of the storage structure and more is the ventilation. Results also showed that aeration does not result in extra loss of moisture. The bulbs which stored at Shivam cold store (0 to -1⁰C) shows less moisture loss as compare to ventilated storage structure.
- The maximum TSS was recorded in onion bulbs at air velocity T₃ and T₅ 13.6⁰ Brix and 13.4⁰ Brix respectively. The higher per cent TSS may be due to more loss of moisture and increased in dry matter content of the bulb which leads to increase in TSS content. The onion bulbs which stored at cold storage showed minimum increase in TSS i.e. from 11.2 to 12⁰ Brix as compare to onions stored at ventilated storage structure.
- There is a rise in hardness of onion bulbs before 14 days of storage. This may be due to the more moisture loss initially which results in hardness of onion bulbs. Then there is a fall in hardness which may be due to increased rotting which softens the onion bulbs and then it decreased slightly may be due to decreased in rotting. Onion tissue firmness was not affected by cold storage and it remained nearly same because of the very less rotting and no sprouting which maintained firmness of onion bulbs.
- Colour difference value ‘ΔE’ increase from 0 to 4.48 and redness value ‘a’ decrease from 16.8 to 14.6 during storage period. However in case of cold storage maximum retention of redness which varied from 20 to 19.4 and minimum colour difference
which increased from 0.28 to 1.54 were observed as compare to onions stored in ventilated storage structure.

- There was a definite loss of vitamin-C content with storage time. Initially vitamin-C content was 13.2 mg/100g of fresh onions and it decreased to 10.6 mg/100g after 84 days of storage. It is evident from the results that storing bulbs under cold storage and at maximum air velocity recorded maximum retention of ascorbic acid.

- The initial reducing sugar content was found in onions 15.8 g/100g and decreased to 11.5 g/100 g. Maximum retention of reducing sugars observed in onion bulbs which stored at air velocity T₅ i.e. 14 g/100g at the end of storage period.

- Very less difference in reducing sugars were noticed in cold storage of onions. The initial value of reducing sugars was 15.5 g/100g and at the end of storage 15 g/100g was observed. This may be due to no sprouting was found and sugars like fructose and glucose may not get utilise.

- Rent of cold stored onions was around 5-7 Rs/kg. Although cold storage results in minimum losses of onions. But these are normally not adopted in India due to poor economics and lack of cold chain facilities required to maintain the quality.

- Overall study of storage conducted on onions revealed that air ventilation through the bed of stored onions in ventilated storage structure is one of the most important parameters. Parameters like rotting, sprouting, weight loss, moisture content, colour, ascorbic acid and reducing sugars were significantly affected by aeration and storage time.
REFERENCES


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