

Studies on curing and storage of Onion
(Allium cepa L.)

Rekha Eda

**DEPARTMENT OF POST HARVEST TECHNOLOGY
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
ARABHAVI - 591 310
UNIVERSITY OF HORTICULTURAL SCIENCES,
BAGALKOT - 587 102
JUNE, 2011**

Studies on curing and storage of Onion (*Allium cepa* L.)

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In

Post Harvest Technology

By

Rekha Eda

**DEPARTMENT OF POST HARVEST TECHNOLOGY
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
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DEPARTMENT OF POST HARVEST TECHNOLOGY
Kittur Rani Channamma College of Horticulture,
Arabhavi - 591 310
University of Horticultural Sciences, Bagalkot - 587 102

CERTIFICATE

This is to certify that the thesis entitled “**Studies on curing and storage of Onion**” submitted by **Rekha Eda** for the degree of **Master of Science (Horticulture)** in **Post Harvest Technology** of the University of Horticultural Sciences, Bagalkot is a record of research work done by her during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Arabhavi

Date: June, 2011

(LAXMAN KUKANOOR)

Associate Professor

Dept of Post Harvest Technology

K.R.C.C.H, Arabhavi.

Approved by
Chairman:

(LAXMAN KUKANOOR)

Members: 1.

(K.N. KATTIMANI)

2.

(BALAJI S. KULKARNI)

3.

(V. D. GASTI)

4.

(G. PRABHULING)

5.

(PRAVEEN JHOLGIKER)

Affectionately Dedicated To

My DAD, MOM,

SWEET SIS

and

LOVELY BROTHER

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INTRODUCTION



1. INTRODUCTION

Onion (*Allium cepa* L.) is an important commercial crop grown almost all over the country. It belongs to family Alliaceae and was originated in Central Asia. Onion is valued and consumed throughout the World due to its characteristic flavour, taste and pungency. The pungency in onion is due to a volatile compound known as allyl-propyl disulphide. Onion has many uses as folk medicine and reports suggest that, onion play an important role in preventing heart diseases and other ailments (Augusti, 1990). According to Watt and Merrill (1950), onion contains 11 amino acids. One hundred gram of raw onion bulb contains about 501 µg vitamin '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. It is used as salad or cooked in various ways in all curries, fried or baked and also in processed forms like flakes, powder, paste, pickles etc. It is highly nutritive and has very good medicinal value.

India ranks second in area (8.34 lakh ha) and production (135.65 lakhT) after China and third in export (16.71 lakh MT) after Netherlands and Spain .The major onion growing states are Maharastra, Karnataka, Gujarat, Tamil Nadu, Bihar, Rajasthan, Madhya Pradesh, and Andhra Pradesh. (Anon., 2010a)

Karnataka is one of the leading State in the cultivation of onion next to Maharashtra and Gujarat with an area of 134534 hectare and production of 2158283 metric tons. In Karnataka, the leading six districts in area are Dharwad (26978 ha), Gadag (25159 ha), Chitradurga (16784 ha), Bagalkot (10643 ha), Bijapur(9983 ha), Haveri (8295 ha) and production wise are Dharwad (435276 M T), Chitradurga (333888 MT), Gadag (26028 MT), Bijapur(231658 MT), Haveri (174248 MT), Bagalkot (173193 MT) respectively (Anon., 2010b).

Onion is a seasonal crop and has low storability. The bulbs have to be stored for longer periods due to seasonal glut in market. A significant loss in quality and quantity of onion occurs during storage, especially in tropical countries like India. Storage is an important aspect of post harvest management. The post harvest loss occurs due to physiological loss in weight, sprouting, rotting *etc.* Therefore proper storage is necessary to extend its period of availability through arresting metabolic breakdown and microbial spoilage.

The onion produce is available in market during October-November (20%) as *kharif* crop, January-February (20%) as late *kharif* crop and April-May (60%) as *rabi* crop. The *rabi* crop has more storability and used for domestic, export and seed bulb purposes from June to

November. This is the critical period in whole country, where there is no supply of fresh onions to the market resulting in price fluctuation. As such storage becomes a paramount importance for steady supply.

Curing is an important operation in post harvest technology of onion. It is done to form a complete, dry, outer skin which reduces the water loss and suppresses the incidence of diseases.

Storage methods have their own impact on post-harvest life and keeping quality of onion. There is a problem of sprouting and rotting of bulbs when stored in high humidity and temperature. High humidity coupled with high temperature favours sprouting and rotting of bulbs, which ultimately leads to loss of keeping quality, thereby reducing their storage life. In storage, the bulbs tend to lose weight and chemical constituents. Normally, in Karnataka, the bulbs are stored in thin gunny bags and kept in a room, which results in quick spoilage. Storage temperature and relative humidity have been found to be correlated with physiological loss in weight, sprouting, rotting and these are further correlated with storage periods.

The present storage practices have lead to reduced storage life of the onions. Thus, during the seasonal glut, the farmers are forced to sell the produce immediately after harvest at very low prices. Many a times, there will be distress in selling of the produce as the storage of the crop would further enhance the loss due to physiological loss in weight, rotting, sprouting *etc.*

Thus, the curing and storage condition that tend to improvement in the quality and storage life of onion would go a long way in improving the marketability and there by the socio-economic condition of the onion growers. Hence, there is a need to take research work to standardize the curing and storage conditions for better storability of onion. Keeping in view all these points, the present study was undertaken with the following objectives.

1. To standardize the curing techniques to improve the keeping quality of onion.
2. To study the shelf life of onion by different storage methods.
3. To study the economics of different storage methods of onion.

REVIEW
OF
LITERATURE



2. REVIEW OF LITERATURE

Onion is one of the important commercial vegetable crops grown on a large scale in India. The onion bulbs are to be stored for long period for their use during off-season as 60 per cent of produce is from *rabi* crop, a considerable losses occurs by way of physiological loss in weight, rotting, sprouting, moisture evaporation during storage. Several workers have reported that curing is an important post-harvest operation which reduces post-harvest losses of onion bulbs. The low cost farm level storage structures needs to be developed to extend the storage life of onion to increase its marketability and to make fresh onion available to the consumer throughout the year at a reasonable price.

The literature pertaining to these aspects relevant to the present study has been reviewed under the following headings.

1. Effect of curing methods on storability of onion
2. Effect of storage conditions on storability of onion
3. Economics of curing and storage

2.1 Effect of curing methods on storability of onion

Curing is the most important post harvest operation to reduce the post harvest losses to a larger extent. It is a drying process intended 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. The essentials of curing are heat, good ventilation preferably with low humidity. It removes the field heat and detachment of soil adheres to the roots. It also helps in shedding of dried roots and removal of foliage leaving 2.5-3 cm was found beneficial after curing which helps in reducing the post harvest losses. Curing may be done in sun, shade, and artificially. A properly cured onion bulbs can be stored for longer duration.

Rao *et al.* (1967) carried out trials on curing of bulbs in the field for minimizing storage losses and reported that, curing of onion bulbs in the shade for four days considerably reduced the decay and spoilage losses. Bottner (1970) observed the effect of different temperature during curing and noted that cool air ventilation particularly reduced the rotting of stored onion.

Thompson *et al.* (1972) studied the effect of curing methods on storage behavior of onions and found that both field and artificial curing methods were superior in reducing physiological loss in weight and rotting percentage than the non-cured bulbs during storage.

Maw *et al.* (1997) reported that storability was prolonged by 48 hours of curing and was enhanced by low humidity. For the early-harvested onions, storability was enhanced by curing for as long as 72 hours.

Goburdhan (1980) reported 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.

Buffington *et al.* (1981) reported that forced heated air curing the onions were heated to 29°C and 46°C at 60, 30 hours respectively. Onions cured at 29°C were sold even after 12 weeks, but curing at 46°C was detrimental. Curing by electric infrared radiation also gave good results, over 90% of the onions being sold after 12 weeks in cv. Texas Grano 502.

Field curing by pre-drying bulbs in shade for about 3-15 days was found to improve the storability of onion (Sidhu and Chadha, 1986) and further observed that the tops were removed after 15 days of storage gave better result (the neck of the bulb was completely dried and turned deep red in colour) even then chemicals, whereas the tops were removed immediately after harvest the per cent sprouted bulbs was two times more than that of maleic hydrazide treated bulbs.

Four days field cured onions with 4 cm neck length recorded minimum losses due to sprouting, rotting and shrinkage (Anon, 1986). Curing of onion bulbs for 21 days significantly reduced the reducing sugar content, while non-reducing sugar showed increased trend (Rasal, 1987).

Curing of onion bulbs for four days in the field by windrow method followed by curing in shed for 21 days before storage decreased the reducing sugar content which improved the storage life of bulbs. Bulbs stored after full curing recorded lower storage losses (38.70%) compared to non-cured bulbs (47.80%) (Kale *et al.*, 1992).

The average per cent of sprouted bulbs at the end of 75 days of storage was highest in bulbs with the tops intact (35.78%) and lowest (7.42%) in those with tops removed 15 days after harvest in N-53 cultivar (Chadha and Sidhu, 1989).

Sanguansri and Gould (1990) observed that artificial cured onions had lower weight loss and more enhanced colour and firmness when compared to field cured onion bulbs.

Curing did not influence the dry matter and TSS content but bulbs stored after curing recorded lowest storage losses (Kale *et al.* 1992).

Pandey *et al.* (1992) found that lowest per cent loss due to sprouting and physiological loss in weight was obtained with curing under sun with foliage. Lowest storage loss of 13 per cent was recorded when bulbs of Bangalore Rose onion were cured in shade, whereas non-cured bulbs recorded highest loss (16.11%) after two months of storage (Bhonde and Bhadauria, 1995).

The lowest total storage losses (19.43%) were obtained with windrow method + 10 days shade curing with tops + cutting the neck to 2.5 cm when compared to other treatments (Chauhan *et al.*, 1995).

The lowest sprouting, decay and total loss (0.27%, 6.47% and 25.82%, respectively) in storage were recorded when the bulbs cured for three days and this treatment also recorded in lower physiological loss in weight during storage than other treatments (Bhonde *et al.*, 1996). Srivastava *et al.* (1996) observed that five days field and five days shade curing along with chemical spray of topsin-M @ 0.1 per cent combined with streptocyclin @ 0.02 per cent reduced the storage losses effectively with highest net returns.

Curing of onion in the field for four days by windrow method followed by shade curing for 21 days resulted in decreased levels of reducing sugars and improved storage life of the bulb (Warade *et al.*, 1997b).

Wright and Grant (1997) found that heated air curing of bulbs reduced the incidence of rots regardless of harvest methods. Bhattarai and Subedi (1998) studied the effect of curing methods on storage behaviour of onion and found that seven days curing before storage was lower loss in weight (31.9%) than without curing (43.9%) for 120 days of storage.

Singhal (2000) reported field curing by windrow method for 3-5 days, shade curing with tops for 10 to 12 days and 2.5 cm neck length were found effective in reducing storage losses in onion and also found curing for 10 to 12 days in shade helps in development of more number of scales and colour retention for longer period.

Onion bulbs were best cured in the artificial curing of 10 to 14 hours at 45°C with air flow rate of 222 m³ per minute compared to 8 to 10 days of sun curing and also reported the hardness of onion bulb had significant increase (9.75 to 10.5 kg/cm²) with curing (Satish and

Ranganna, 2002a). Curing with heap height of 60 to 75 cm and shade curing for seven and 14 days considerably reduced the storage losses (Anon., 2003). The moisture loss of onions during curing is important in case of early harvested onions and they require 96 hours of curing than optimal or late harvested onions (Maw and Mullinix 2005).

Kukanoor *et al.* (2006a) studied the effect of different methods of curing on storability of onion. Among different treatments the minimum physiological loss in weight, rotting, sprouting and maximum hardness, highest marketable bulbs was observed in curing under 50% shade (15 days) +tops removed 15days after harvest. There is an effect of curing and cooking on flavonols and anthocyanin in traditional varieties of onion bulbs and showed that field curing results in increase in quercetin content. (Rodrigues *et al.*, 2009)

Katherine *et al.* (2009) studied the effect of curing on the onion bulbs and reported that curing had a role on anthocyanin in skin color and water loss during curing. Chope and Terry (2010) reported that storage life was not significantly affected by curing temperature. Sucrose concentration increased, and glucose concentration decreased during curing at all temperatures, however, immediately after curing the concentrations of glucose and fructose were less in those onions cured at 28⁰C, whereas the sucrose concentration was higher in onions cured at lower temperatures.

2.2 Effect of storage conditions on storability of onion

Despite the achievements in production technology, the post-harvest losses during storage still pose a great problem. Various methods and storage structures have been reported by several workers attempting to reduce these losses.

Karmarkar and Joshi (1941) found that reducing sugar increased during storage of the onion bulbs at low temperature. Sprouting was more in bulbs stored in plastic crates at room temperature as compared to other methods of storage of onion. (Singh and Singh, 1973).

Kirti and Dalijit (1973) found that storage with brick base was comparatively better stored than other local methods of onion storage. Storage in crates at room temperature and storage with ground base were not economical.

Iordachescu and Nihailescu (1979) observed the lowest losses in the onion stored in ventilated structure (11.80%) and highest in those kept in bags (17.2%) for 180 days after storage.

Iordachescu *et al.* (1983) studied six methods of onion storage with the cv. Staltgart Giant. In the variants under natural ventilation, the storage period lasted five months with storage losses of 4.18 to 4.71 per cent, whereas in forced ventilation, the storage period was extended to eight months with 2.21 to 2.25 per cent losses. The cured bulbs were the best for storing of onion under ambient condition followed by the hanging method. The maximum loss was obtained under farmer's method followed by nylon net bag method of storage (Moazam, 1983).

Khurana and Singh (1984) reported that onion bulbs stored in a shed lost 25.75 per cent after 90 days of storage compared to 48.42 per cent in onion stored in room without ventilation and also found that with increase in ventilation by partitioned the 'tat', the per cent of loss in weight was decreased as compared to the completely filled tat without gap.

Mahadevswamy (1984) observed that maleic hydrazide @ 800 ppm sprayed bulbs stored in polyethylene bags recorded lower rotting (15.8%) as compared with the untreated bulbs (17.6%). The same treatment recorded less sprouting and sprout length as compared with control.

Thomas *et al.* (1986) studied the storage trials at pimpalgaon in Maharashtra in a traditional storage shed known as chawl and model stores in rabi onion and revealed that, after five months storage period, the storage losses were 70 per cent in poorly ventilated chawl compared with 50 per cent in better ventilated model store. In India, different storage methods were practiced by the farmers. Among those, split bamboo storage structure with control hallow was found better and the extent losses by way of spoilage, sprouting were minimum during storage (Krishnamurthy *et al.*, 1987).

Patil and Kumkar (1988) reported that maximum total loss in weight (34.19%), rotting (16.76%) and physiological loss in weight (15.25%) was observed in bamboo basket storage than floor storage (14.49, 1.92 and 2.57 per cent, respectively). The total storage loss at the end of five months in Nasik type storage structure was 21 per cent in cv. Bellary Red which was considered acceptable. The total cost of the structure was Rs. 5000 (Murthy *et al.*, 1988).

Bhatnagar *et al.* (1989) suggested that the designing of low cost farm level storage structure capable of reducing losses in stored onion could be helpful in encouraging onion storage by the farmers.

Datar and Mulekar (1989) observed the increase in rotting of onions stored under tarpaulin cover (150-180 cm) and in open field (30-60 cm) layer compared to proper ventilated bamboo storage structure and two tier onion storage structure. Kepka *et al.* (1989) concluded that bulk storage of onion with forced air ventilation was better than bulb storage in boxes with natural ventilation.

Subbaramu *et al.* (1990) reported that in ventilated bamboo storage structure for onion, the total losses reduced to 39.23 per cent compared to conventional storage structure 53 per cent after five months storage.

Bhandal and Naik (1991) reported in potato that maximum loss in weight of about 60 per cent due to shrinkage and rotting in thatched hut than cold storage, where only three to eight per cent loss in weight was recorded.

Mukeshkumar *et al.* (1991) reported that, all the storage parameters gradually increased with an increase in storage duration irrespective of storage method but were significantly lower for onion kept in 30 per cent perforated brown paper packets followed by hanging in bunches. Hanging method of storage was effective for short period of storage (45 days), whereas cage method was effective for longer periods (90 days) in minimizing bulb rots caused by *Aspergillus niger* (Chavan *et al.*, 1992).

Mondal and Pramanik (1992) suggested that to prolong storage life and minimize storage losses, onion bulbs could be stored at low temperature (<15°C) and low relative humidity (50-70%).

Arora *et al.* (1993) reported that the minimum sprouting (60.5%), rotting (15.0%) and total loss (35.0%) in wire mesh shed storage compared to ordinary room storage of onion bulbs (77.5, 20.5 and 72.7%, respectively).

Shukla *et al.* (1994) evaluated two perforated concentric type storage structure made of 25 x 25 x 25 mm welded wire mesh, each having capacity of one tone. One of the structures was used for natural ventilation, whereas other was attached to a blower to circulate air. Onion bulbs quality evaluated after three months storage in both structures are considered and suitable for adaption at the farm level.

Out of different storage methods, dry sand on pucca floor was the best method with respect to lowest physiological loss in weight, rotting, sprouting and total loss in weight during 150 days of storage (Deka *et al.*, 1995).

Medlicott *et al.* (1995) observed that forced air storage bins resulted in significantly higher in quality of all four cultivars studied after 13 weeks of storage. The percentage of marketable bulbs in forced air storage bins were 82 per cent as compared with control stored under ambient condition 37 per cent for Granex 33.

Warade *et al.* (1995) found that the provision of bottom ventilation to storage structure reduced the storage losses from 54 to 39 per cent after 150 days of storage. Maini *et al.* (1997) reported that two tier system was better than single or bamboo storage structure for physiological loss in weight and storage point of view.

The physiological loss in weight was least in two tier storage system (26%) followed by single tier (38%) and conventional bamboo storage structure (47%) during storage period of 100 days. Maximum retention quality was observed in two tier system (Maini *et al.*, 1997).

Mulabagalaiah (1997) recorded minimum sprouting, sprout length, weight loss when tubers were stored in cold storage followed by storing tubers in zero energy cool chamber compared to that in gunny bag storage. Warade *et al.* (1997a) investigated the effect of different recommendations on storability of onion bulbs cv. N-2-4-1 for six months under modified storage structure with bottom and central ventilation and observed that the modified storage structure had reduced losses 32 per cent as compared to the conventional method (52%).

Warade *et al.* (1997b) found that storage loss were least in gunny bags which were stored in two horizontal layers (34.7%) and highest in control (52.6%). Storage losses from most of the high yielding cultivars were very high, reaching 80 to 90 per cent within the 16 weeks period when stored in a simple structure with natural ventilation under ambient condition (Rajkumar *et al.*, 1998).

Ramin (1999) observed in cv. Grano and Dorcheh, sprouting was inhibited at high storage temperature (25-30°C) as a result of significant reduction in the relative growth rate of sprout within the bulbs and onions become nearly dormant and maintained marketability for a period of three months. Bulbs fumigated with sulphur dust before storage under natural ventilation were found to have better shelf life for 16 weeks (Abbey, 2000).

Maini and Chakrabarti (2000) reported that in Sudan mud or straw cottage was used for storing onions. Straw cottage was constructed in such a way that, they were ventilated by the prevailing wind passing through them. After five months of storage by this 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).

Mukeshkumar *et al.* (2000) reported that storage parameters gradually increased with an increase in storage duration irrespective of storage methods, but they were significantly lower for onion cv. N-53 kept in 30 per cent perforated brown paper packets followed by hanging in bunches.

Ranpise *et al.* (2001) used the conventional onion storage structure called chawl which has no aeration at bottom and onion can be stored upto 1.5 to 2.0 meter height with resulting into lot of bruising and decay, and 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. 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 lengthen 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 lower in low cost storage structure.

Ahmad *et al.* (2006) reported that the dry matter, total soluble solids and sucrose reached the maximum during the first 30 days of storage in cv Swat-1 and in cv. NARC-91, the reducing sugars and dry matter reached the maximum during the first 15 days of storage. Kukanoor *et al.* (2006b) studied different methods of storage of onion where the total losses were observed minimum in bulbs stored under low cost storage structure followed by improved storage structure.

Surviliene (2006) reported that the most frequent onion diseases during storage were neck rot, *fusarium* bulb rot, blue mould rot, black mould rot and bacterial soft rots. Mixed rots of onion bulbs were predominant and yield losses ranged from 3.98 per cent to 13.15 per cent in storage.

Tripathi and Lawande (2007) reported that there was no rotting, sprouting and black mould infection in cold storage, while considerable amount of rotting and black mould was noticed in ambient stored onions in storage structure.

Sidhu (2008) reported that total storage loss in onion ranged from 13.70 to 43.00 per cent. Physiological weight loss was the major factor responsible for the highest percentage of loss during storage (20-87%), rotting percentage varied from 5 to 66 per cent and sprouting losses ranged from 2 to 12 per cent.

Ilic *et al.* (2009) reported that quantity (mass loss, sprouting, rooting) and quality changes (dry matter, total sugar, glucose and fructose, content of sucrose and vitamin-C) of onion bulbs stored under ambient conditions resulted in significant decrease in marketable bulbs, up to 40-60 per cent and an increase of the amount of sprouted bulbs up to 30-50 per cent. Depending on cultivars, the sugars content (4.5-10.5%) and vitamin C contents (12.4 to 14.9 mg/100 mg) slightly decreased after long term storage (depends of storage temperatures), while a little change between the initial levels and the levels after 6 months in dry matter content was observed.

Rodrigues *et al.* (2009) studied the change of flavonoids during storage. The onion bulbs stored under traditional treatment showed higher increase than stored under refrigerated storage. Tripathi *et al.* (2009) reported that the lowest total losses are less in modified bottom ventilated double row storage structure which was on par with the top and bottom ventilated double row storage structure in garlic.

Yadav and Sharma (2011) reported that, among different model structures tried for storing of onion two- tier onion storage structure made of bamboo showed less physiological loss in weight, sprouting and decay compared to other model structures.

2.3 Economic studies

Storage plays an important role in marketing of onions. It helps in adjustment of a particular commodity in relation to its demand in the market. Storage thus helps to secure relatively better price to a product by adjusting supply with reference to existing demand and there by avoids glut in the market. Onion being a semi-perishable crop its storage for getting higher returns is important which in turn depends on different storage methods and their capacity.

Kumbhar (2000) studied economics of production and marketing of rabi onion in Pune district. He 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 spent was 1.46, which indicated that it was a profitable crop.

Bhor (2003) reported that per quintal net returns were maximum (Rs. 52.37) for stored onion than that of non-stored (Rs. 10.96) onion. The net returns per rupee spent were also higher (1.14) for stored onion than that of non-stored onion (1.04).

Pramod *et al.* (2005) reported that farmers stored onions on kutchha floors, pucca floors, and bamboo mats the cost of storage was highest on marginal farms and on bamboo mats the highest percentage losses were highest and the producer's margin and the marketing efficiency were highest in the direct marketing channel.

Kukanoor *et al.* (2006b) reported that among different methods of storage of onion bulbs low cost storage structure followed by improved storage structure got maximum returns per rupee spent. Kassali and Idowu (2007) reported that onion storage operational efficiency is a measure of economic performance of marketing functions. The major determinants of operational efficiency were the type of storage system with the granary having a significant coefficient, the amount of storage space, the duration between two consecutive sales, the quantity sold per sale, and the duration of the storage. It is recommended that onion producers keep onion bulbs over longer period of time using the granary system and more on-farm storage space be made available.

Hile *et al.* (2008) studied the cost, economics and problems of rabi onion storage in Pune and reported that onion producers get more remunerative profit for stored onions than for non-stored ones. Producers with storage get five times more profit (Rs. 52.37) as compared to those with no storage (Rs. 10.96). The producers' share in the consumer rupee was higher for stored onions (65.11%) than for non-stored onions (63.14%).

Tripathi *et al.* (2009) reported that among different methods of storage modified bottom ventilated double row storage structure and top and bottom ventilated double row storage structure were economically good for storage of garlic and got high net profit.

Yadav and Sharma (2011) reported that among different methods of storage structures two tier bamboo storage structure has highest BC ratio followed by single tier onion storage structure and structure made of bricks walls with cylindrical shaped structures of bamboo strips supported with mild steel bar ring for air circulation.

*MATERIAL
AND
METHODS*



3. MATERIAL AND METHODS

The present investigation was carried out in Department of Post-harvest Technology, Kittur Rani Channamma College of Horticulture, Arabhavi during *kharif* and *rabi* seasons of 2010-11. The details of the material used and methods adopted during the course of investigations are presented here under.

3.1 Location and climatic conditions

Geographically, Arabhavi is situated in Northern dry tract of Karnataka State at 16°15' North latitude and 94°45' East latitude and at an altitude of 612 m above the mean sea level. Arabhavi, which comes under zone-3 of region-2 of agro-climatic zone of Karnataka, has the benefit of both Southwest and Northeast monsoons. The mean rainfall of this area is about 550 mm, which is distributed over a period of six to seven months from May to November. The mean maximum temperature goes upto 38.5°C (May) and mean minimum temperature drops down to 18.5°C (February). The mean relative humidity varies between 42.65 (April) and 81.00 per cent (December).

3.2 Varietal description

The variety of the onion used to study the effect of different curing methods on storability was Bellary Red. It is red coloured, flatish-globe shaped and medium sized. The bulbs has good keeping quality and less pungent. It is high yielder (165 q/ha) and popular variety of the state.

The onion variety used to study the effect of different storage methods was Agri Found Light Red. It was developed at National Horticultural Research and Development Foundation, Nashik. The bulbs are of globular shape with tight skin, light color, 4-6 cm in size with 13 per cent TSS. It has good keeping quality with an average yield of 300-325 quintal per hectare

3.3 Experimental details

3.3.1 Experiment-I Effect of different curing methods on storability of onion.

This experiment was carried out in Completely Randomised Design with eight treatments and three replications.

Treatment details:

T₁- Curing under forced hot air dryer with foliage

T₂- Curing under forced hot air dryer without foliage

T₃- Curing under polytunnel with foliage

T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage

T₆- Curing under 35 per cent shade without foliage

T₇- Curing under 100 per cent shade with foliage

T₈- Curing under 100 per cent shade without foliage

Harvesting

The crop was harvested by observing the maturity indices. The crop maturity was indicated by the change in colour of the leaves from green to yellowish and neck fall. The plants were uprooted from the net plot area of each plot separately. The harvested bulbs were subjected to different curing treatments.

T₁: The harvested bulbs along with foliage were kept under forced hot air dryer at a temperature of 50⁰C for a period of five hours.

T₂: The tops were removed leaving 2.5 cm neck length and were kept under forced hot air dryer at a temperature of 50⁰C for a period of five hours.

T₃: The harvested bulbs along with foliage were kept under polytunnal structure.

T₄: The tops were removed leaving 2.5 cm neck length and are kept under polytunnal structure.

T₅: The harvested bulbs along with foliage were kept under 35 per cent shade.

T₆: The tops were removed leaving 2.5 cm neck length and are kept under 35 per cent shade.

T₇: The harvested bulbs along with foliage were kept under 100 per cent shade.

T₈: The tops were removed leaving 2.5 cm neck length and were kept under 100 per cent shade.

All the bulbs were kept in respective condition till the bulbs cured and time taken for curing of bulbs was recorded and expressed in hours.

Then a composite sample of five kilogram bulbs from each plot was drawn and packed in thin gunny bag for storage studies under ambient conditions.



Forced hot air drier (outer and inner view)



Curing under poly tunnel (outer view)



Curing under poly tunnel (inner view)

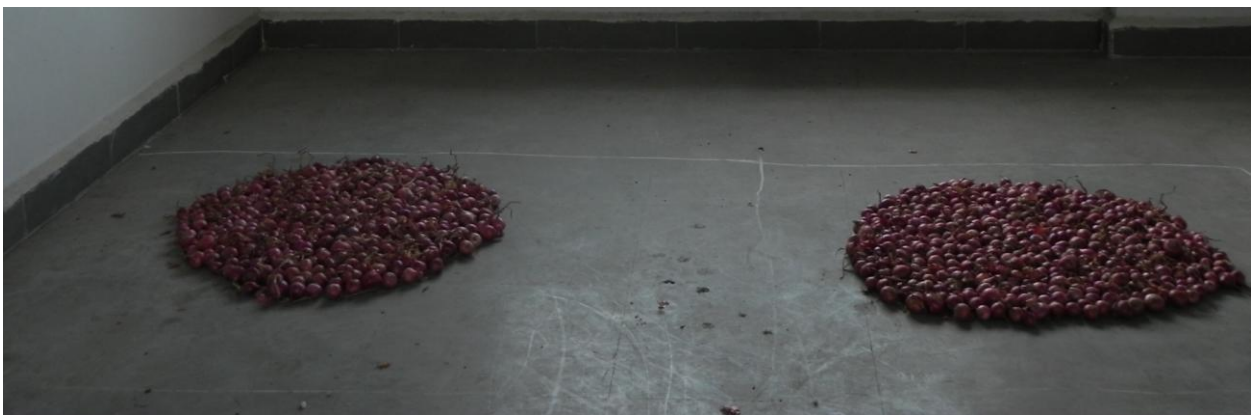
.....
Plate 1.(a) Different curing methods of onion
.....



Curing under 35 per cent shade (outer view)



Curing under 35 per cent shade (inner view)



Curing under 100 per cent shade



General view of storage of cured onion

.....
Plate 1.(b) Different curing methods of onion
.....

3.3.2 Experiment No.2 Effect of different storage conditions on storability of onion.

This experiment was carried out in Completely Randomised Design with ten treatments and three replications.

Treatment details:

T₁: Bamboo battens thatched roof storage structure (sugarcane trash) without bottom ventilation

T₂: Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation

T₃: Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation

T₄: Wooden battens storage structure with AC Sheet roofing with bottom and side ventilation

T₅: Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation

T₆: Wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation

T₇: Welded mesh cage with bottom and side ventilation

T₈: Plastic crate storage

T₉: Nylon net bags storage

T₁₀: Control (Farmers method in gunny bags)

3.3.2.1 Storage structures / methods

3.3.2.1.1 Thatched roof structure

It is an ordinary farm level storage structure prepared out of wooden pole frame, split bamboo wall without ventilation. The roof was covered with dried sugarcane trash.

3.3.2.1.2 Low cost storage structure

Low cost storage structure was made of wooden pole frame, split bamboo walls, split bamboo floor (45 cm above the ground) and the roof was covered with dried typhy grass. In this structure, both side and bottom ventilation were provided.



(T₁) Bamboo battens thatched roof structure without bottom ventilation (outside and inside view)



(T₂) Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation (outside and inside view)



(T₃) Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation (outside and inside view)



(T₄) Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation (outside and inside view)

Plate 2(a). Different storage methods of onion



(T₁) Bamboo battens thatched roof structure without bottom ventilation (outside and inside view)



(T₂) Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation (outside and inside view)



(T₃) Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation (outside and inside view)



(T₄) Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation (outside and inside view)

Plate 2(a). Different storage methods of onion

3.3.2.1.3 Bamboo battens storage structure

Improved storage structure was made of iron angle frame with split bamboo walls, split bamboo floor (45 cm above the ground) and the roof was covered with AC sheet. In this structure, both side and bottom ventilation was provided.

3.3.2.1.4 Wooden battens storage structure

Improved storage structure was made of iron angle frame with wooden battens, wooden battens floor (45 cm above the ground) and the roof was covered with AC sheet. In this structure, both side and bottom ventilation was provided.

3.3.2.1.5 Galmenium sheet roofing structure

The improved storage structure with galmenium sheet roofing, wooden battens floor and walls of 2.5 cm thickness was made.

3.3.2.1.6 Mangalore tiles roofing structure

Improved storage structure was made of iron angle frame with wooden battens, wooden battens floor (45 cm above the ground) and the roof was covered with mangalore tiles. In this structure, both side and bottom ventilation was provided

3.3.2.1.7 Welded mesh cage

This was locally fabricated with iron angle (6 mm gauge) and welded mesh.

3.3.2.1.8 Plastic crates

Plastic crates of size 48 x 30 x 20 cm with ventilated sides and bottom were used for storage of onion bulbs.

3.3.2.1.9 Nylon net bags and gunny bags

Nylon net bags and gunny bags of size 45 x 60 cm were used for storage of onion bulbs.

In case of T₁, T₂, T₃, T₄, T₅ and T₆ 90 kg cured onion bulbs (30 kg/replication) were stored directly on the floor of the storage structures. In case of T₇, 90 kg cured bulbs (30kg/replication) were stored directly in the cage. Then in case of T₈, T₉ and T₁₀, cured onion bulbs (10 kg/replication) were placed in plastic crates, nylon net bags and gunny bags, respectively, which were kept under ambient condition.

3.4 Observations recorded

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, per cent moisture content, per cent dry matter, TSS content, ascorbic acid, sugars (reducing sugars and non reducing sugars), incidence of post-harvest diseases (black mould), per cent loss of scales, hardness of the bulb and marketable bulbs were recorded at 10 days interval upto 60 days in case of first experiment and at interval of 15 days upto 90 days in case of second experiment.

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

Initially, five kilogram bulbs were selected in each treatment. These bulbs were used each time for recording physiological loss in weight (PLW), rotting and sprouting percentage and post-harvest disease incidence.

3.4.1 Physical parameters

3.4.1.1 Physiological loss in weight (%)

The weight of the bulbs was recorded at 10 days intervals upto 60 days of storage for curing studies and 15 days interval upto 90 days for storage studies using an electronic balance. The cumulative loss in weight of bulbs was calculated and expressed as per cent physiological loss in weight using the formula given below.

$$\text{PLW (\%)} = \frac{P_0 - P_1 \text{ or } P_2 \text{ or } P_3 \text{ or } P_4 \text{ or } P_5 \text{ or } P_6}{P_0} \times 100$$

Where, P_0 = initial weight P_1 = weight after 10/15 days

P_2 = weight after 20/30 days P_3 = weight after 30/45 days

P_4 = weight after 40/60 days P_5 = weight after 50/75 days

P_6 = weight after 60/90 days

3.4.1.2 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. The sprouting percentage, which indicated the weight of the bulb sprouted on 10, 20, 30, 40, 50

and 60 DAS for curing studies and 15, 30, 45, 60, 75, 90 DAS for storage studies was calculated by using the formula given below.

$$\text{Sprouting percentage} = \frac{\text{Weight of the sprouted bulbs}}{\text{Initial weight of bulbs}} \times 100$$

3.4.1.3 Rotting percentage

The weight of the rotted bulbs at the end of 20, 30, 40, 50 and 60 DAS for curing studies and 30, 45, 60, 75, 90 DAS for storage studies was recorded under each treatment / storage condition and the rotting percentage was calculated by using the formula

$$\text{Rotting percentage} = \frac{\text{Weight of the rotted bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

3.4.1.4 Per cent dry matter

Bulbs were randomly selected from each treatment and cut into small pieces with the help of stainless steel knife. A known weight of the sample was kept in hot air oven at 60°C temperature till a constant weight was obtained. From this, the per cent dry matter was calculated by the following formula.

$$\text{Per cent dry matter} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.4.1.5 Moisture content (%)

Moisture content was determined by moisture analyser. It is expressed as percentage.

3.4.1.6 Total soluble solids (TSS)

Scales from randomly selected bulbs were macerated for juice extraction and total soluble solids of the juice was determined by using a digital hand Refractometer. The values were expressed as per cent total soluble solids of the bulbs.

3.4.1.7 Hardness of the bulb (kg/cm²)

The hardness of onion bulbs was measured using a hand penetrometer (Fruit Pressure Tester, Make: Effegi, Model: PT 327) and the pressure required to penetrate the bulb was recorded in kg per cm².

3.4.1.8 Per cent loss of scales

Dried scales were counted on the marked bulbs by considering the number of scales separated from the bulbs. Same bulbs were used for observation at different days of storage. At the end of storage period, the bulbs were cut transversely and the remaining scales were counted. Per cent scales were computed by the formula given below.

$$\text{Per cent loss of scales} = \frac{\text{Number of scales separated}}{\text{Total number of scales}} \times 100$$

3.4.1.9 Incidence of black mould (%)

The incidence of black mould, a major storage disease caused by *Aspergillus niger* was recorded at ten days interval upto 60 days. The incidence of black mould was expressed as percentage of bulbs affected out of 100 bulbs.

3.4.1.10 Marketable bulbs (%)

At the end of storage period (60 DAS for curing studies and 90DAS for storage studies), the rotted and sprouted bulbs were separated and the weight of healthy bulbs was recorded. The recovery of marketable bulbs was calculated by using the following formula.

$$\text{Marketable bulbs (\%)} = \frac{\text{Weight of the healthy bulbs obtained}}{\text{Initial weight of bulbs stored}} \times 100$$

3.4.2 Chemical parameters

3.4.2.1 Ascorbic acid (mg/100 g bulb)

Ascorbic acid content was estimated titrimetrically using 2, 6-dichlorophenol indophenols dye as per the modified procedure of (Anon., 1984). Five grams of fresh pulp was macerated and diluted the juice with 4 per cent oxalic acid and filtered through muslin cloth and the volume was made up to 25 ml with oxalic acid. Five ml of aliquot was titrated against 2, 6-dichlorophenol indophenols dye solution till the pink colour appeared. The result was expressed as mg of ascorbic acid per 100 g of onion.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Ascorbic acid content in standard (mg)}}{\text{ml of aliquot}} \times \frac{\text{Total sample volume}}{\text{Weight of sample}} \times \frac{\text{TV}_2}{\text{TV}_1} \times 100$$

3.4.2.2 Sugars

Five grams of fresh bulb obtained from random bulb sample under each treatment was preserved in 80 per cent alcohol and kept in a refrigerator. The bulb samples were taken on 0, 10, 20, 30, 40, 50 and 60 days after storage for curing studies and 15, 30, 45, 60, 75, 90 days after storage for storage studies.

Reducing sugar (%)

The percentage of reducing sugar in the juice was determined by Dinitro-salicylic acid (DNSA) method (Miller, 1972). A known volume of alcohol extract was taken and allowed to evaporate the alcohol completely. Clear solution was taken for estimation of reducing sugar by using DNSA by following above methods and values are expressed in percentage.

Total sugar (%)

The total sugar in the sample was estimated by same method as that of reducing sugars after inversion of the non-reducing sugars using dilute hydrochloric acid (Anon., 1984). One ml of evaporated extract was taken and kept in boiling water till the alcohol completely evaporated and allowed it to cool. Then phenolphthalein indicator was added followed by 1 N sodium hydroxide till the solution turned to pink. Again 0.1 N hydrochloric acid was added to discolour the solution. Then Dinitro-salicylic acid (DNSA) method for reducing sugar was followed. The results obtained were expressed in terms of percentage.

Non-reducing sugar (%)

The percentage of non-reducing sugar was obtained by subtracting the values of reducing sugar from that of total sugar and multiplying the same with 0.95 as given below (Somogyi, 1952).

$$\text{Non-reducing sugar (\%)} = (\text{Total sugar} - \text{reducing sugar}) \times 0.95$$

3.5 Statistical analysis

The data on the physico-chemical parameters were subjected to completely randomised design analysis and interpretation of the data was carried out in accordance with Panse and Sukhatme (1985). The level of significance used in “F” and “t” test was $p=0.05$ and $p=0.01$.

3.6 Meteorological data

During the period of experimentation, the daily maximum and minimum temperature and relative humidity in the laboratory and storage structure, where the onion bulbs were stored, were recorded daily with the help of digital thermo-hygrometer and are given in Appendix-I and Appendix-II.

EXPERIMENTAL

RESULTS



4. EXPERIMENTAL RESULTS

An investigation was planned and conducted at Kittur Rani Channamma College of Horticulture, Arabhavi (University of Horticultural Sciences, Bagalkot) during 2010-11 to find out the effect of different curing methods (cv. Bellary Red) and different storage conditions for onion (cv. Agri Found Light Red) for reducing the storage losses of onion.

4.1 Experiment 1: Effect of different curing methods on storability of onion

4.1.1 Time taken for curing (hours)

The time taken for curing of onion bulbs is represented in Table-1. There was no difference in time taken for curing between the treatments with foliage and without foliage.

The minimum time taken for curing was about 4 hours in onion bulbs cured under forced hot air dryer with foliage and without foliage. The maximum time taken for curing was about 288 hours in bulbs cured under 100 per cent shade with foliage and without foliage.

4.1.2 Physiological loss in weight (%)

The data on physiological loss in weight of onion bulbs is presented in Table-1. Significant differences were observed among the curing methods on the physiological loss in weight of the bulbs throughout the storage period.

There was a significant increase in per cent physiological loss in weight of onion bulbs during storage period of 60 days in all the treatments. The physiological loss in weight values increased progressively from 2.16 per cent at 10 DAS to 26.84 per cent at 60 DAS.

Among the treatments, significantly minimum per cent of physiological loss in weight was recorded in T₅ onion bulbs cured under 35 per cent shade with foliage (2.16, 6.83, 8.71, 10.88, 12.64 and 15.21%) which was on par with the T₆ onion bulbs cured under 35 per cent shade without foliage (2.35, 6.52, 8.92, 11.21, 14.31 and 16.86%) at 10, 20, 30, 40, 50 and 60 DAS, respectively. However, maximum physiological loss in weight was found in T₂ onion bulbs cured under forced hot air dryer without foliage (8.06, 10.24, 14.86, 18.16, 22.58 and 26.84 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.3 Sprouting (%)

It could be noted from the results given in Table-1 revealed that there was no sprouting observed upto 10 days of storage in all the treatments. Significantly maximum percentage of sprouting (2.26, 9.25, 13.22, 15.96 and 17.27%) was recorded in T₄ onion bulbs

Table 1. Influence of different curing methods on time taken for curing (hours), Physiological loss in weight (%) and sprouting (%) in onion bulbs during storage.

Treatment	Time taken for curing (hours)	Days after storage										
		Physiological loss in weight (%)						Sprouting* (%)				
		10	20	30	40	50	60	20	30	40	50	60
T ₁	4	6.18	9.40	13.49	16.24	20.14	24.61	3.42	9.11	12.14	14.27	16.15
T ₂	4	8.06	10.24	14.86	18.16	22.58	26.84	3.94	8.93	12.35	14.59	16.47
T ₃	240	2.23	7.74	8.32	12.61	14.31	17.07	2.26	9.25	13.22	15.96	17.27
T ₄	240	2.48	8.12	10.84	13.73	17.80	19.24	2.80	9.57	13.44	16.22	17.66
T ₅	264	2.16	6.83	8.71	10.88	12.64	15.21	1.46	8.24	11.92	13.06	14.09
T ₆	264	2.35	6.52	8.92	11.21	14.31	16.86	2.76	8.55	12.00	13.33	14.24
T ₇	288	3.24	8.24	11.48	14.01	18.34	20.16	6.22	11.07	14.27	16.76	18.15
T ₈	288	3.19	8.89	12.36	15.31	19.55	21.64	6.81	11.24	14.86	17.95	19.24
S.E m±	-	0.029	0.068	0.032	0.410	0.423	0.427	0.035	0.026	0.028	0.416	0.474
C.D. @ 5%	-	0.088	0.204	0.096	1.230	1.270	1.282	0.107	0.078	0.085	1.247	1.421
C.D. @ 1%	-	0.117	0.270	0.128	1.629	1.682	1.698	0.141	0.103	0.112	1.652	1.883

*upto 10 days there was no sprouting of bulbs

- T₁- Curing under forced hot air dryer with foliage
- T₂- Curing under forced hot air dryer without foliage
- T₃- Curing under polytunnel with foliage
- T₄- Curing under polytunnel without foliage
- T₅- Curing under 35 per cent shade with foliage
- T₆- Curing under 35 per cent shade without foliage
- T₇- Curing under 100 per cent shade with foliage
- T₈- Curing under 100 per cent shade without foliage

cured under polytunnel without foliage followed by T₃ curing under polytunnel with foliage (2.80, 9.57, 13.44, 16.22 and 17.66%) at 20, 30, 40, 50 and 60 DAS, respectively. However, minimum sprouting (1.46, 8.24, 11.92, 13.06, 14.09 %) was seen in T₅ onion bulbs cured under 35 per cent shade net with foliage which was on par with the bulbs cured under 35 per cent shade net without foliage (2.76, 8.55, 12.00, 13.33 and 14.24%) at 20, 30, 40, 50 and 60 DAS, respectively.

4.1.4 Rotting (%)

The data showed the influence of different curing methods on per cent rotting are presented in Table-2.

In general, no loss of bulbs due to rotting was observed in any of the treatments upto 10 DAS. The different curing methods showed significant difference with respect to per cent rotting during the entire storage period. Among all the curing methods experimented, maximum loss of onion bulbs due to rotting (4.00, 8.32, 9.25, 11.63 and 13.44%) was observed in (T₁) onion bulbs cured under forced hot air dryer with foliage which was on par with the onion bulbs cured under T₂ forced hot air dryer without foliage (3.80, 8.04, 9.37, 11.06 and 13.07%) at 20, 30, 40, 50 and 60 DAS, respectively. However, minimum rotting (2.41, 4.81, 6.34, 8.82 and 9.22%) was observed in onion bulbs cured under (T₅) 35 per cent shade with foliage followed by onion bulbs cured under (T₆) 35 per cent shade without foliage (3.22, 5.95, 7.32, 8.92 and 9.62%) at 20, 30, 40, 50 and 60 DAS, respectively.

4.1.5 Black mould (%)

The data pertaining to influence of different curing methods on black mould incidence of onion bulbs during the course of storage are presented in Table-2. The per cent loss of bulbs due to black mould incidence increased progressively with advancement in storage period. There was no black mould incidence upto 10 DAS in all the treatments, whereas minimum percentage of black mould was recorded in bulbs cured under 35 per cent shade with foliage T₅ (1.00, 2.00, 3.00, 3.50 and 4.16 %) followed by bulbs cured under 35 per cent shade without foliage T₆ (2.00, 2.50, 3.50, 4.13 and 5.83 %), while maximum black mould percentage was seen in T₄ bulbs cured under polytunnel without foliage (3.50, 4.50, 5.40, 6.20 and 7.86 %) at 20, 30, 40, 50 and 60 DAS, respectively.

4.1.6 Moisture content (%)

The data on per cent moisture content as influenced by different curing methods are presented in Table-3. The moisture content irrespective of curing methods decreased gradually

Table 2. Influence of different curing methods on rotting (%) and black mould incidence (%) in onion during storage

Treatment	Days after storage									
	Rotting* (%)					Black mould incidence ** (%)				
	20	30	40	50	60	20	30	40	50	60
T ₁	4.00	8.32	9.25	11.63	13.44	2.00	2.66	3.50	4.50	6.00
T ₂	3.80	8.04	9.37	11.06	13.07	2.50	3.00	4.00	5.20	6.50
T ₃	3.41	6.91	8.18	9.83	11.67	3.20	3.86	4.50	5.73	7.06
T ₄	3.61	7.02	9.10	10.62	12.07	3.50	4.50	5.40	6.20	7.86
T ₅	2.41	4.81	6.34	8.82	9.22	1.00	2.00	3.00	3.50	4.16
T ₆	3.22	5.95	7.32	8.92	9.62	2.00	2.50	3.50	4.13	5.83
T ₇	2.81	6.046	8.62	10.41	11.32	3.20	4.00	5.00	5.50	6.50
T ₈	3.00	5.32	7.37	9.87	10.12	3.83	4.50	5.60	6.00	7.00
S.E m±	0.144	0.126	0.336	0.311	0.212	0.058	0.063	0.035	0.033	0.098
C. D. @ 5%	0.432	0.380	1.008	0.932	0.636	0.176	0.190	0.105	0.099	0.295
C.D. @ 1%	0.573	0.503	1.335	1.235	0.842	0.233	0.251	0.140	0.132	0.391

* upto 10 days there was no rotting

** upto 10 days there was no black mould incidence

T₁- Curing under forced hot air dryer with foliage

T₂- Curing under forced hot air dryer without foliage

T₃- Curing under 35 per cent shade with foliage

T₄- Curing under 100 per cent shade with foliage

T₅- Curing under 35 per cent shade without foliage

T₆- Curing under 100 per cent shade without foliage

T₇- Curing under polytunnel with foliage

T₈- Curing under polytunnel without foliage

gradually from 89.62 per cent at 10 days after storage to 85.00 per cent at 60 DAS where initial moisture content was 89.84 %.

The different curing methods varied significantly with respect to moisture content of the bulb throughout the storage period. Minimum per cent moisture was found in bulbs (T_1) cured under forced hot air dryer (88.15, 87.35, 86.92, 86.32, 85.41 and 85.00%) followed by (T_2) the bulbs cured under forced hot air dryer without foliage (88.28, 87.42, 86.87, 85.92, 85.54 and 85.41%) at 10, 20, 30, 40, 50 and 60 DAS, respectively, whereas bulbs cured under 35 per cent shade with foliage T_5 recorded maximum per cent moisture content (89.42, 88.60, 88.24, 88.11, 87.22 and 87.15%) followed by bulbs cured under 35 per cent shade without foliage at (89.62, 88.21, 87.23, 87.00, 86.69 and 86.44 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.7 Dry matter (%)

It could be observed from the results given in Table-3 that, there was a gradual increase in dry matter content of onion bulbs from initial to 9.46 per cent to 15.00 per cent at 60 days after storage.

The variation between the curing methods regarding dry matter content of onion bulbs during storage were found significant. Maximum per cent dry matter was found in (T_1) bulbs cured under forced hot air dryer with foliage (11.85, 12.65, 13.06, 13.68, 14.59 and 15.00 %) followed by bulbs cured under forced hot air dryer without foliage T_2 (11.72, 12.58, 13.13, 14.08, 14.46 and 14.59%) at 10, 20, 30, 40, 50 and 60 DAS, respectively, whereas bulbs cured in 35 per cent shade with foliage recorded minimum per cent dry matter (10.58, 11.40, 11.76, 11.89, 12.78 and 12.85%) followed by bulbs cured under polytunnel without foliage T_4 (11.57, 11.99, 12.37, 12.82, 13.00 and 13.17 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.8 Hardness of bulb (kg/cm²)

A perusal of data given in Table-4 revealed that the mean values of hardness of the bulbs increased with the advancement of storage period. It increased progressively from 5.00 kg per cm² from the initial to 9.84 kg per cm² at 60 DAS.

The hardness of the bulbs was significantly higher in bulbs curing under 35 per cent shade with foliage (6.15, 6.73, 7.86, 8.42, 9.83 and 9.84 kg/cm²) which was on par with curing under polytunnel without foliage T_4 (5.73, 6.21, 7.31, 8.12, 9.81 and 9.82 kg/cm²) at

Table 3. Influence of different curing methods on moisture content (%) and dry matter content (%) of onion during storage.

Treatment	Moisture content* (%)						Dry matter** (%)					
	Days after storage											
	10	20	30	40	50	60	10	20	30	40	50	60
T ₁	88.15	87.35	86.92	86.32	85.41	85.00	11.85	12.65	13.06	13.68	14.59	15.00
T ₂	88.28	87.42	86.87	85.92	85.54	85.41	11.72	12.58	13.13	14.08	14.46	14.59
T ₃	88.24	87.94	87.50	87.08	86.42	86.14	11.76	12.06	12.50	12.92	13.58	13.86
T ₄	88.43	88.01	87.63	87.18	87.00	86.83	11.57	11.99	12.37	12.82	13.00	13.17
T ₅	89.42	88.60	88.24	88.11	87.22	87.15	10.58	11.40	11.76	11.89	12.78	12.85
T ₆	89.62	88.21	87.23	87.00	86.69	86.44	10.38	11.79	12.77	13.00	13.33	13.56
T ₇	88.61	88.02	87.66	87.18	86.56	86.22	10.40	11.98	12.34	12.82	13.44	13.78
T ₈	88.82	87.92	87.34	86.83	86.47	86.11	11.18	12.06	12.66	13.37	13.54	13.89
S.E m±	0.191	0.187	0.204	0.206	0.292	0.300	0.120	0.177	0.114	0.208	0.204	0.207
C.D. @ 5%	0.574	0.562	0.612	0.618	0.876	0.900	0.361	0.530	0.341	0.625	0.612	0.623
C.D. @ 1%	0.760	0.745	0.811	0.818	1.160	1.192	0.479	0.703	0.452	0.827	0.810	0.825

* Initial moisture content was 89.84(%)

** Initial dry matter content was 10.16(%)

- T₁- Curing under forced hot air dryer with foliage
- T₂- Curing under forced hot air dryer without foliage
- T₃- Curing under polytunnel with foliage
- T₄- Curing under polytunnel without foliage
- T₅- Curing under 35 per cent shade with foliage
- T₆- Curing under 35 per cent shade without foliage
- T₇- Curing under 100 per cent shade with foliage
- T₈- Curing under 100 per cent shade without foliage

Table 4. Influence of different curing methods on hardness (kg/cm²) and per cent loss of scales (%) of onion during storage.

Treatment	Hardness* (kg/cm ²)						Per cent loss of scales (%)					
	Days after storage											
	10	20	30	40	50	60	10	20	30	40	50	60
T ₁	5.24	6.11	7.21	8.61	9.20	9.24	5.26	8.94	12.36	14.28	18.62	20.22
T ₂	5.36	6.24	7.44	8.13	9.12	9.21	5.53	9.07	13.26	14.80	16.82	18.40
T ₃	5.68	6.45	7.61	8.54	9.35	9.48	4.46	8.26	11.82	13.81	17.82	18.89
T ₄	5.73	6.21	7.31	8.12	9.81	9.82	4.83	8.60	12.10	14.13	18.26	21.46
T ₅	6.15	6.73	7.86	8.42	9.83	9.84	3.26	5.28	6.32	8.63	10.82	14.24
T ₆	6.01	6.58	7.52	8.58	9.20	9.27	3.53	4.81	6.14	11.34	13.28	16.28
T ₇	5.89	6.34	7.06	8.72	9.10	9.14	3.83	5.22	8.40	12.81	15.28	18.46
T ₈	5.47	6.14	7.23	8.83	9.3	9.45	4.26	5.80	8.84	13.03	14.80	19.59
SE m±	0.012	0.041	0.035	0.032	0.052	0.033	0.060	0.052	0.099	0.086	0.141	0.163
C.D. 5%	0.037	0.125	0.106	0.098	0.158	0.100	0.180	0.156	0.297	0.258	0.424	0.490
C.D. 1%	0.049	0.165	0.140	0.130	0.210	0.133	0.238	0.207	0.394	0.342	0.562	0.649

* Initial hardness 5.00 (kg/cm²)

T₁- Curing under forced hot air dryer with foliage

T₂- Curing under forced hot air dryer without foliage

T₃- Curing under polytunnel with foliage

T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage

T₆- Curing under 35 per cent shade without foliage

T₇- Curing under 100 per cent shade with foliage

T₈- Curing under 100 per cent shade without foliage

10, 20, 30, 40, 50 and 60 DAS, respectively. However, minimum hardness was observed in bulbs cured under 100 per cent shade with foliage (5.89, 6.34, 7.06, 8.72, 9.10 and 9.14 kg/cm²) followed by bulbs cured under forced hot air dryer without foliage T₂ (5.36, 6.24, 7.44, 8.13, 9.12 and 9.21 kg/cm²) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.9 Per cent loss of scales (%)

The data pertaining to influence of different curing methods on per cent loss of scales of onion bulbs during the course of storage are presented in Table-4.

Significant differences with respect to per cent loss of scales were observed among the different curing methods at 10, 20, 30, 40, 50 and 60 DAS. The maximum per cent loss of scales was found in bulbs cured under forced hot air dryer without foliage (5.53, 9.07, 13.26, 14.80, 16.82 and 22.40%) followed by bulbs cured under forced hot air dryer with foliage (5.26, 8.94, 12.36, 14.28, 18.62 and 20.22 %) at 10, 20, 30, 40, 50 and 60 DAS respectively. The minimum per cent loss of scales was observed in bulbs cured under 35 per cent shade with foliage (3.26, 5.28, 6.32, 8.63, 10.82 and 14.24 %) followed by bulbs cured under 35 per cent shade without foliage (3.53, 4.81, 6.14, 11.34, 13.28 and 16.28 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.10 Total soluble solids (%)

The data pertaining to the influence of different curing methods on total soluble solids content of onion bulbs are presented in Table-5.

Irrespective of curing methods, the per cent TSS content of the bulbs had increased gradually from 10.23 per cent at 10 DAS to 14.22 per cent at 60 DAS.

There was a significant difference with respect to per cent TSS throughout the storage period due to different curing methods. Among the different curing methods studied, (T₅) bulbs cured under 35 per cent shade with foliage recorded the highest TSS (10.86, 11.20, 12.20, 12.80, 13.51 and 14.22 %) followed by curing under 35 percent shade without foliage T₆ (10.50, 10.91, 12.24, 12.61, 13.40 and 14.00%), while (T₂) bulbs curing under forced hot air dryer without foliage recorded the lowest TSS (10.82, 11.13, 11.60, 11.90, 12.30 and 12.80 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.11 Ascorbic acid (mg/100 g)

Irrespective of different curing methods, the mean ascorbic acid content of onion bulbs decreased progressively from 9.37 mg per 100 g bulb at 10 DAS to 6.13 mg per 100 g bulb at

Table 5. Influence of different curing methods on Total Soluble Solids (%) and ascorbic acid (mg/100g) of onion during storage.

Treatment	Days after storage											
	Total Soluble Solids* (%)						Ascorbic acid ** (mg/100g)					
	10	20	30	40	50	60	10	20	30	40	50	60
T ₁	10.47	10.80	11.21	11.80	12.50	13.00	9.42	8.12	8.71	7.16	7.81	6.21
T ₂	10.82	11.13	11.60	11.90	12.30	12.80	9.37	8.00	8.60	7.21	7.61	6.13
T ₃	10.23	10.67	11.20	12.10	12.80	13.42	9.46	8.70	8.08	7.81	7.21	6.80
T ₄	10.40	10.90	11.80	12.60	13.11	13.80	9.44	8.68	8.14	7.72	7.37	6.62
T ₅	10.86	11.20	12.20	12.80	13.51	14.22	10.51	10.12	9.25	8.61	8.20	7.45
T ₆	10.50	10.91	12.24	12.61	13.40	14.00	10.41	10.06	9.51	8.91	7.66	7.21
T ₇	10.62	11.03	11.91	12.58	13.18	13.62	10.24	9.85	8.90	8.15	7.49	7.12
T ₈	10.78	10.95	11.81	12.68	13.16	13.56	10.12	9.74	8.45	7.91	7.11	6.91
S.E m±	0.040	0.045	0.091	0.019	0.035	0.023	0.032	0.047	0.015	0.006	0.007	0.008
C.D. @ 5%	0.122	0.137	0.275	0.057	0.106	0.071	0.097	0.142	0.046	0.019	0.023	0.024
C.D. @ 1%	0.162	0.181	0.364	0.075	0.140	0.095	0.129	0.189	0.061	0.025	0.031	0.033

* Initial TSS was 10.00 (%)

**Initial Ascorbic acid content was 11.24 (mg/100g)

T₁- Curing under forced hot air dryer with foliage

T₂- Curing under forced hot air dryer without foliage

T₃- Curing under polytunnel with foliage

T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage

T₆- Curing under 35 per cent shade without foliage

T₇- Curing under 100 per cent shade with foliage

T₈- Curing under 100 per cent shade without foliage

60DAS. The initial ascorbic content is 11.24 mg/100g (Table-5).

The curing methods showed significant difference with respect to ascorbic acid content of bulbs during entire storage period. Among the curing methods, T₅ curing under 35 per cent shade with foliage (10.51, 10.12, 9.25, 8.61, 8.20 and 7.45 mg/100 g bulb) followed by curing under 35 per cent shade without foliage (10.41, 10.06, 9.51, 8.91, 7.66 and 7.21 mg/100 g) showed maximum retention of ascorbic acid, whereas bulbs cured under forced hot air dryer without foliage retained lower ascorbic acid (9.37, 8.00, 8.60, 7.21, 7.61 and 6.13 mg/100 g) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.12 Reducing sugars (%)

The data on reducing sugars content as influenced by different curing methods are presented in table 6 and revealed that reducing sugar content decreased progressively from 3.58 per cent at 10 DAS to 2.53 per cent at 60 DAS irrespective of curing methods.

There was a significant difference with respect to reducing sugars throughout the storage period due to different curing methods. Among the different curing methods studied, maximum per cent reducing sugar was found in (T₅) bulbs cured under 35 per cent shade with foliage (3.56, 3.25, 3.16, 3.08, 2.88 and 2.74 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively, whereas (T₈) bulbs cured under 100 per cent shade without foliage recorded minimum per cent reducing sugars (3.44, 3.04, 2.84, 2.70, 2.58 and 2.48 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.13 Non-reducing sugars (%)

The non-reducing sugars content irrespective of curing methods increased progressively from 2.80 per cent at 10 DAS to 5.18 per cent at 60 DAS.

The treatment differed significantly with respect to non-reducing sugar content of bulbs throughout the storage period. Among the curing methods studied, maximum per cent of non-reducing sugar was recorded in bulbs cured under 35 per cent shade with foliage (3.12, 3.87, 4.08, 4.44, 4.98 and 5.18%) at 10, 20, 30, 40, 50 and 60 DAS respectively whereas bulbs curing under forced hot air dryer with foliage recorded minimum per cent non-reducing sugar (2.80, 3.19, 3.38, 4.04, 4.33 and 4.45 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively (Table-6).

Table 6. Influence of different curing methods on reducing sugars (%) and non-reducing sugars (%) of onion during storage.

Treatment	Days after storage											
	Reducing sugars * (%)						Non-reducing sugars ** (%)					
	10	20	30	40	50	60	10	20	30	40	50	60
T ₁	3.34	3.09	3.04	2.82	2.67	2.53	2.80	3.19	3.38	4.04	4.33	4.45
T ₂	3.42	3.04	2.98	2.86	2.72	2.56	2.81	3.28	3.46	4.03	4.40	4.62
T ₃	3.48	3.19	3.12	2.92	2.75	2.62	2.96	3.67	3.95	4.36	4.59	4.86
T ₄	3.44	3.16	3.14	2.96	2.80	2.67	2.98	3.64	3.69	4.18	4.46	4.65
T ₅	3.56	3.25	3.16	3.08	2.88	2.74	3.12	3.87	4.08	4.44	4.98	5.18
T ₆	3.58	3.22	3.12	2.96	2.82	2.72	2.81	3.83	4.04	4.47	4.86	5.02
T ₇	3.38	3.01	2.98	2.78	2.60	2.54	2.98	3.63	3.75	4.23	4.54	4.56
T ₈	3.44	3.04	2.84	2.70	2.58	2.48	2.94	3.64	3.87	4.38	4.65	4.88
S.E m±	0.011	0.008	0.019	0.016	0.006	0.006	0.015	0.005	0.011	0.005	0.004	0.020
CD @ 5%	0.033	0.026	0.058	0.049	0.020	0.019	0.047	0.016	0.035	0.016	0.014	0.062
CD @ 1%	0.044	0.034	0.077	0.066	0.026	0.026	0.063	0.022	0.046	0.021	0.019	0.083

* Initial Reducing sugar content was 3.64(%)

** Initial Non reducing sugar content was 2.36 (%)

T₁- Curing under forced hot air dryer with foliage

T₂- Curing under forced hot air dryer without foliage

T₃- Curing under polytunnel with foliage

T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage

T₆- Curing under 35 per cent shade without foliage

T₇- Curing under 100 per cent shade with foliage

T₈- Curing under 100 per cent shade without foliage

4.1.14 Total sugar (%)

The data on total sugar content of different curing methods of onion during storage is given in table 7.

The total sugar content irrespective of curing methods increased progressively from 6.14 per cent at 10 DAS to 7.92 per cent at 60 DAS.

Significant and maximum level of total sugar (6.68, 6.92, 7.24, 7.52, 7.86 and 7.92%) was recorded in (T₅) bulbs cured under 35 per cent shade with foliage T₅ followed by bulbs (T₆) cured under 35 per cent shade without foliage (6.52, 7.06, 7.16, 7.43, 7.68 and 7.74%), whereas minimum total sugar (6.14, 6.28, 6.42, 6.86, 7.00 and 7.12%) was found in bulbs cured under forced hot air dryer with foliage followed by bulbs cured under forced hot air dryer without foliage (6.23, 6.32, 6.54, 6.89, 7.06 and 7.18 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.1.15 Marketable bulbs

The data on marketable bulbs as influenced by different curing methods are presented in Table 7. The percentage of marketable bulbs irrespective of curing methods decreased throughout the storage period.

The significant differences were observed among different methods of curing at all the stages of storage. The maximum percentage of marketable bulbs were observed in bulbs cured under 35 per cent shade with foliage (97.84, 89.30, 78.24, 70.86, 65.48 and 61.48 %) followed by bulbs cured under 35 per cent shade without foliage (97.52, 85.47, 72.57, 63.73, 55.36 and 51.03 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively where as bulbs cured under forced hot air dryer without foliage showed minimum percentage of marketable bulbs (91.94, 82.04, 68.16, 60.12, 51.77 and 43.62 %) at 10, 20, 30, 40, 50 and 60 DAS, respectively.

4.2 Experiment-II Effect of different storage conditions on storability of onion

4.2.1 Physiological loss in weight (%)

The results on physiological loss in weight of onion bulbs were given in Table-8. The physiological loss in weight of the bulbs irrespective of storage condition increased from 3.00 per cent at 15 DAS to 17.00 per cent at 90 DAS.

Significant differences were observed in the physiological loss in weight of the bulbs among the storage methods throughout the storage period. Minimum physiological loss in

Table 7. Influence of different curing methods on total sugar (%) and marketable bulbs (%) of onion during storage.

Treatment	Days after storage											
	Total sugar* (%)						Marketable bulbs (%)					
	10	20	30	40	50	60	10	20	30	40	50	60
T ₁	6.14	6.28	6.42	6.86	7.00	7.12	93.82	83.18	69.08	62.37	53.96	45.80
T ₂	6.23	6.32	6.44	6.89	7.06	7.18	91.94	82.04	68.16	60.12	51.77	43.62
T ₃	6.44	6.86	7.07	7.28	7.34	7.48	97.77	86.59	75.52	65.99	51.98	52.59
T ₄	6.42	6.80	6.98	7.14	7.26	7.32	97.52	85.47	72.57	63.73	55.36	51.03
T ₅	6.68	7.12	7.24	7.52	7.86	7.92	97.84	89.30	78.24	70.86	65.48	61.48
T ₆	6.52	7.06	7.16	7.43	7.68	7.74	97.65	87.50	76.58	69.47	63.44	59.28
T ₇	6.36	6.64	6.73	7.01	7.14	7.28	96.76	82.73	71.49	61.80	54.49	50.37
T ₈	6.38	6.68	6.71	7.08	7.23	7.36	96.81	81.30	71.07	62.46	52.63	49.00
S.E m±	0.101	0.093	0.103	0.115	0.080	0.088	0.388	0.532	0.499	0.563	0.596	0.511
C.D. @ 5%	0.304	0.279	0.310	0.345	0.241	0.264	1.164	1.596	1.496	1.688	1.789	1.533
C.D. @ 1%	0.402	0.369	0.410	0.457	0.320	0.350	1.542	2.113	1.981	2.236	2.369	2.030

* Initial Total Sugar was 6.00 (%)

T₁- Curing under forced hot air dryer with foliage

T₂- Curing under forced hot air dryer without foliage

T₃- Curing under polytunnel with foliage

T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage

T₆- Curing under 35 per cent shade without foliage

T₇- Curing under 100 per cent shade with foliage

T₈- Curing under 100 per cent shade without foliage

weight (2.46, 4.82, 6.48, 7.42, 8.60 and 9.86%) was recorded in the bulbs stored in bamboo battens storage structure with AC sheet roofing with bottom and side ventilation followed by bulbs stored under wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation (3.34, 6.24, 8.64, 9.48, 10.20 and 11.58%) at 15, 30, 45, 60, 75 and 90 DAS, respectively. However, the maximum physiological loss in weight (3.92, 6.45, 10.26, 12.36, 15.80 and 17.00%) was recorded in the bulbs stored in bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.2 Rotting (%)

There was no loss of bulbs due to rotting in all storage methods upto 15 days. The per cent rotting of bulbs irrespective of storage methods increased from 2.00 at 30 DAS to 11.00 at 90 DAS.

The different storage conditions showed significant differences with respect to per cent rotting during all the stages of storage period. Among the storage conditions evaluated, maximum loss due to rotting was recorded in bulbs stored in plastic crates (2.62%) at 30 DAS. However, at later stage of storage, the maximum loss due to rotting was recorded in bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation (5.68, 7.82, 9.42 and 11.00 %) at 45, 60, 75 and 90 DAS respectively, whereas minimum rotting was observed in bamboo battens storage structure with AC sheet roofing with bottom and side ventilation (2.00, 2.46, 3.00, 3.48 and 4.20 %) at 15, 30, 45, 60, 75 and 90 DAS, respectively (Table-8).

4.2.3 Black mould incidence (%)

The data given in Table-8 revealed that the per cent loss of bulbs due to black mould (*Aspergillus niger*) increased with the advancement of storage period.

There was no black mould rot upto 45 days in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation and nylon net bag storage where as upto 30 days in all other storage conditions. After 45 DAS, minimum per cent black mould was noticed in bulbs stored in bamboo storage structure with AC sheet roofing and with bottom and side ventilation (1.00, 2.16 and 3.50 %) at 60, 75, 90 DAS, respectively, whereas maximum black mould per cent was found in bulbs stored in wooden battens storage structure with AC sheet roofing and with bottom and side ventilation (2.00, 4.00, 8.33 and 10.00 %) at 45, 60, 75 and 90 DAS, respectively.

Table 8: Influence of different storage conditions on physiological loss in weight (%), rotting (%) and black mould incidence (%) during storage of onion.

Treatment	Days after storage														
	Physiological loss in weight (%)						Rotting (%)					Black mould incidence (%)			
	15	30	45	60	75	90	30	45	60	75	90	45	60	75	90
T₁	3.92	6.45	10.26	12.36	15.80	17.00	2.52	5.68	7.82	9.42	11.00	2.00	4.00	6.00	8.00
T₂	3.86	5.92	9.06	12.28	14.80	16.26	2.40	4.64	6.72	8.94	10.08	1.00	2.00	4.00	6.20
T₃	2.46	4.82	6.48	7.42	8.60	9.86	2.00	2.46	3.00	3.48	4.20	0.00	1.00	2.16	3.50
T₄	3.12	6.00	7.28	9.64	11.82	12.28	2.26	4.48	6.48	7.15	7.60	2.00	4.00	8.33	10.00
T₅	3.00	5.04	6.86	9.24	11.00	11.80	2.32	4.62	6.72	7.40	8.00	1.00	2.00	5.20	7.40
T₆	3.34	6.24	8.64	9.48	10.20	11.58	2.45	4.80	6.84	7.62	8.26	1.00	2.66	3.40	5.20
T₇	3.08	5.86	7.00	9.58	11.48	12.58	2.28	5.02	6.41	8.24	9.84	1.00	2.40	3.00	5.40
T₈	3.62	6.04	9.28	12.36	14.92	16.58	2.62	5.15	7.39	9.48	10.50	1.50	3.66	4.26	5.73
T₉	2.92	5.12	6.73	9.00	10.64	12.14	2.58	4.27	6.40	8.00	9.14	0.00	1.00	2.66	4.66
T₁₀	3.06	5.24	6.88	11.24	13.82	15.00	2.60	4.28	6.34	9.10	10.26	1.00	2.00	4.16	5.00
S.E m±	0.09 2 0.27	0.091	0.096	0.091	0.091	0.090	0.020	0.010	0.006	0.005	0.015	0.241	0.255	0.242	0.178
C.D. @ 5%	2 0.36	0.269	0.283	0.269	0.270	0.276	0.060	0.031	0.018	0.017	0.046	0.712	0.753	0.715	0.527
C.D. @ 1%	0	0.356	0.375	0.356	0.356	0.365	0.080	0.041	0.024	0.023	0.061	0.958	0.995	0.945	0.697

T₁-Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation

T₂-Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation

T₃-Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation

T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation

T₅-Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation

T₆-Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation

T₇-Welded mesh cage with bottom and side ventilation

T₈- Plastic crate storage **T₉**- Nylon net bags storage **T₁₀**- Control (Farmers method in gunny bags)

4.2.4 Moisture (%)

The data on per cent moisture content as influenced by different storage conditions during storage is given in Table-9. Irrespective of storage conditions, the per cent moisture content was decreased gradually from initial 88.00 per cent to 82.46 per cent at 90 DAS.

The different storage conditions differed significantly with respect to moisture content of the bulbs throughout the storage period. The minimum per cent moisture was found in bulbs stored in bamboo battens low cost storage structure with typha roofing with bottom and side ventilation (86.52, 85.40, 84.00, 83.20, 82.70 and 82.46%) at 15, 30, 45, 60, 75 and 90 DAS, respectively, which was on par with bulbs stored in nylon net bags (86.45, 86.00, 85.00, 84.18, 83.20 and 82.80%) at 15, 30, 45, 60, 75 and 90 DAS, respectively, whereas bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation recorded maximum per cent moisture content (88.50, 87.80, 87.24, 86.42, 85.00 and 84.56%) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.5 Dry matter (%)

A glance of the results presented in Table-9 revealed that, the dry matter content of onion during storage was gradually increased from the initial 12.00 per cent to 17.54 per cent at 90 DAS.

The variation between the different storage conditions regarding dry matter content of onion bulbs during storage were found to be significant. Maximum per cent dry matter was recorded in bulbs stored in bamboo battens low cost storage structure with typha roofing with bottom and side ventilation (13.48, 14.60, 16.00, 16.80, 17.30 and 17.54%) 15, 30, 45, 60, 75 and 90 DAS, respectively, which was on par with bulbs stored in plastic crates (13.55, 14.00, 15.00, 15.82, 16.80, 17.20%) at 15, 30, 45, 60, 75 and 90 DAS, respectively, whereas bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation recorded minimum per cent dry matter (11.50, 12.720, 12.76, 13.58, 15.00 and 15.44%) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.6 Hardness of bulb (kg/cm²)

A perusal of data given in Table-10 revealed that the hardness of the bulbs increased with the advancement of storage period. It increased progressively from 8.60 kg per cm² from the initial to 12.80 kg per cm² at 90 DAS.

The hardness of the bulbs was significantly higher in bulbs stored under wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation (9.80, 10.40, 11.06, 11.66, 12.66 and 13.28 kg/cm²) at 15, 30, 45, 60, 75 and 90 DAS, respectively,

Table 9. Influence of different storage conditions on moisture content (%) and dry matter content (%) of onion during storage.

Treatment	Days after storage											
	Moisture content*(%)						Dry matter** (%)					
	15	30	45	60	75	90	15	30	45	60	75	90
T₁	87.5	86.00	85.20	84.80	84.20	84.24	12.50	14.00	14.80	15.20	15.80	16.76
T₂	86.52	85.40	84.00	83.20	82.70	82.46	13.48	14.60	16.00	16.80	17.30	17.54
T₃	88.50	87.80	87.24	86.42	85.00	84.56	11.50	12.20	12.76	13.58	15.00	15.44
T₄	86.45	84.50	84.13	83.80	83.24	83.00	13.55	15.50	15.87	16.20	16.76	17.00
T₅	87.50	86.42	85.80	85.00	84.24	83.96	12.50	13.58	14.20	15.00	15.76	16.04
T₆	87.42	86.50	85.20	84.36	83.40	83.12	12.58	13.50	14.80	15.64	16.60	16.88
T₇	87.00	86.24	85.42	84.20	83.76	83.28	13.00	13.76	14.58	15.80	16.24	16.72
T₈	87.64	86.37	85.62	84.82	83.80	83.42	12.36	13.63	14.38	15.18	16.20	16.58
T₉	86.45	86.00	85.00	84.18	83.20	82.80	13.55	14.00	15.00	15.82	16.80	17.20
T₁₀	87.82	87.00	86.48	85.60	84.40	83.92	12.18	13.00	13.52	14.40	15.60	16.08
S.E m±	0.182	0.204	0.184	0.182	0.547	0.380	0.182	0.258	0.036	0.184	0.182	0.129
C.D. @ 5%	0.538	0.602	0.543	0.538	1.615	1.121	0.539	0.761	0.108	0.543	0.538	0.281
C.D. @ 1%	0.711	0.795	0.717	0.712	2.135	1.481	0.713	1.006	0.143	0.718	0.712	0.303

*Initial moisture content was 88.00 per cent

**Initial dry matter content was 12 per cent

T₁-Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation

T₂-Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation

T₃-Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation

T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation

T₅-Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation

T₆-Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation

T₇-Welded mesh cage with bottom and side ventilation

T₈- Plastic crate storage

T₉- Nylon net bags storage **T₁₀**- Control (Farmers method in gunny bags)

The hardness of the bulbs was significantly higher in bulbs stored under wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation (9.80, 10.40, 11.06, 11.66, 12.66 and 13.28 kg/cm²) at 15, 30, 45, 60, 75 and 90 DAS, respectively, followed by bulbs stored under wooden battens storage structure with AC sheet roofing and with bottom and side ventilation (10.60, 11.00, 11.80, 12.06, 12.40 and 12.86%) which was on par with the bulbs stored under nylon net bags (9.46, 10.40, 11.21, 12.26, 12.46 and 12.80%) at 15, 30, 45, 60, 75 and 90 DAS, respectively. However, minimum hardness was observed in bulbs stored under bamboo battens low cost storage structure with typha roofing with bottom and side ventilation (9.00, 9.46, 9.60, 9.86, 10.00 and 10.46 kg/cm²) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.7 Per cent loss of scales (%)

The data pertaining to influence of different storage methods on per cent loss of scales of onion bulbs during the course of storage are presented in Table-10.

Significant differences with respect to per cent loss of scales were observed among the different storage methods at 15, 30, 45, 60, 75 and 90 DAS. The maximum per cent loss of scales (4.61, 8.00, 10.20, 12.26, 14.16 and 16.82%) was found in bulbs stored under bamboo battens thatched roof structure without bottom ventilation followed by bulbs stored under wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation (4.26, 7.46, 9.38, 11.38, 13.24 and 15.50 %) at 15, 30, 45, 60, 75 and 90 DAS respectively. The minimum per cent loss of scales was observed in bulbs stored under bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (2.66, 4.98, 7.00, 9.19, 11.00 and 13.08 %) which was on par with bulbs stored in gunny bags (2.80, 5.07, 7.28, 9.46, 11.61 and 13.15%) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.8 Total soluble solids (%)

The total soluble solids (TSS) content of the onion bulbs irrespective of storage conditions increased progressively from an initial 11.50 per cent to 16.20 per cent at 90 DAS (Table-11).

Significant differences with respect to per cent TSS was observed throughout the storage period due to different storage conditions. Among the different storage conditions studied, bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation showed maximum TSS (14.30, 14.72, 14.81, 15.14, 15.22 and 16.20%) at 15, 30, 45, 60, 75 and 90 DAS, respectively. The minimum TSS was found in

Table 10. Influence of different storage conditions on hardness (kg/cm²) and per cent loss of scales (%) during storage of onion.

Treatment	Days after storage											
	* Hardness (kg/cm ²)						Per cent loss of scales (%)					
	15	30	45	60	75	90	15	30	45	60	75	90
T₁	9.50	9.80	10.00	10.26	10.46	11.00	4.61	8.00	10.20	12.26	14.16	16.82
T₂	9.00	9.46	9.60	9.86	10.00	10.46	3.42	6.00	8.24	10.53	12.80	14.28
T₃	9.60	10.26	10.60	10.86	11.20	11.44	2.66	4.98	7.00	9.19	11.00	13.08
T₄	10.60	11.00	11.80	12.06	12.40	12.86	4.11	7.22	9.16	11.22	12.28	14.62
T₅	9.80	10.40	11.06	11.66	12.66	13.28	3.81	6.27	8.68	11.07	12.41	14.50
T₆	11.00	11.26	11.82	12.06	12.26	12.60	4.26	7.46	9.38	11.38	13.24	15.50
T₇	9.20	10.60	10.84	11.26	11.47	11.66	3.10	5.42	7.14	9.00	11.52	13.50
T₈	10.00	10.20	10.62	11.06	11.26	11.40	3.24	5.86	7.87	9.66	11.81	13.83
T₉	9.46	10.40	11.21	12.26	12.46	12.80	2.46	4.86	6.84	8.47	10.38	12.86
T₁₀	9.26	9.60	9.86	10.13	10.86	11.13	2.80	5.07	7.28	9.46	11.61	13.15
S.E m±	0.036	0.042	0.185	0.066	0.078	0.064	0.062	0.129	0.090	0.098	0.091	0.141
C.D. @ 5%	0.108	0.124	0.546	0.196	0.231	0.189	0.185	0.383	0.265	0.289	0.270	0.416
C.D. @ 1%	0.142	0.164	0.721	0.259	0.306	0.249	0.244	0.506	0.350	0.382	0.357	0.550

*Initial hardness was 8.60 (kg/cm²)

- T₁**- Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation
T₂-Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation
T₃- Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation
T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation
T₅-Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation
T₆- Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation
T₇- Welded mesh cage with bottom and side ventilation
T₈- Plastic crate storage
T₉- Nylon net bags storage
T₁₀- Control (Farmers method in gunny bags)

bulbs stored in nylon net bags (12.13, 12.62, 13.11, 13.38, 13.52 and 14.00 %) which was on par with the bulbs stored in gunny bags (12.40, 12.80, 13.20, 13.62, 13.66 and 14.36 %) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.9 Ascorbic acid content (mg/100g)

It could be observed from the results given in Table-11 that gradual decrease in ascorbic acid (mg/100 g bulb) content of onion bulbs with advancement of storage period. The decrease in ascorbic acid content from initial 12.00 mg per 100 g to 6.18 mg per 100 g at 90 DAS.

The different storage condition showed significant differences with respect to ascorbic acid content of bulbs during the entire storage period. Among the different storage conditions, bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation retained significantly higher ascorbic acid content (13.26, 12.14, 10.83, 10.00, 9.46 and 8.48 mg/100 g) which was on par with bulbs stored in nylon net bags (13.58, 12.40, 11.08, 10.45, 9.42 and 8.14 mg/100 g) whereas bulbs stored in bamboo battens thatched roof structure retained lowest ascorbic acid (12.42, 11.56, 10.40, 8.26, 7.45 and 6.18 mg/100 g bulb) which was on par with the bulbs stored in plastic crates (12.56, 11.62, 10.54, 9.26, 8.10 and 6.24 mg/100 g bulb) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.10 Reducing sugars (%)

The reducing sugars content irrespective of storage conditions decreased progressively from 6.62 per cent from initial to 3.94 per cent at 90 DAS (Table-12).

The effect of different storage conditions on reducing sugar content was significant at all the stages of storage. Among the different storage conditions, maximum per cent reducing sugar was found in bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (6.10, 6.00, 5.80, 5.46, 5.24 and 5.20%) which was on par with bulbs stored in nylon net bags (6.28, 6.14, 6.00, 5.60, 5.24 and 5.00 %) at 15, 30, 45, 60, 75 and 90 DAS, respectively, whereas minimum per cent reducing sugar was noticed in bulbs stored in bamboo battens thatched roof storage structure without bottom ventilation (6.75, 6.42, 5.96, 5.26, 4.84 and 3.94 %) which was on par with the bamboo battens low cost storage structure with typha roofing with bottom and side ventilation storage (6.50, 6.26, 5.62, 5.00, 4.50 and 4.00%) at 30, 45, 60, 75 and 90 DAS, respectively.

Table 11. Influence of different storage conditions on total soluble solids (%) and ascorbic acid content (mg/ 100g) of onion during storage.

Treatment	Days after storage											
	Total soluble solids* (%)						Ascorbic acid content** (mg/ 100g)					
	15	30	45	60	75	90	15	30	45	60	75	90
T₁	12.22	12.48	12.62	12.84	13.43	14.60	12.42	11.56	10.40	8.26	7.45	6.18
T₂	12.42	12.62	12.85	13.14	13.82	14.86	13.14	12.28	10.24	9.56	8.62	7.40
T₃	14.30	14.72	14.81	15.14	15.22	16.20	13.26	12.14	10.83	10.00	9.46	8.48
T₄	12.46	13.28	13.86	14.20	14.42	14.56	13.00	11.80	11.00	9.14	8.46	7.89
T₅	13.40	13.56	13.82	14.20	15.66	15.70	12.90	11.62	10.88	9.28	8.32	7.00
T₆	14.62	14.81	14.92	15.20	15.80	15.96	13.10	12.00	11.08	10.28	8.18	6.58
T₇	13.26	13.61	13.81	14.28	14.46	15.00	12.24	11.82	10.45	9.46	8.58	7.14
T₈	11.73	12.06	12.42	12.76	14.26	15.26	12.56	11.62	10.54	9.26	8.10	6.24
T₉	12.13	12.62	13.11	13.38	13.52	14.00	13.58	12.40	11.08	10.45	9.42	8.14
T₁₀	12.40	12.80	13.20	13.62	13.66	14.36	12.82	11.42	10.68	9.63	8.82	7.24
S.E m±	0.064	0.182	0.183	0.060	0.066	0.122	0.091	0.091	0.091	0.096	0.037	0.091
C.D. @ 5%	0.190	0.539	0.542	0.179	0.196	0.360	0.270	0.269	0.269	0.283	0.109	0.269
C.D. @ 1%	0.252	0.712	0.717	0.236	0.259	0.476	0.356	0.356	0.356	0.375	0.145	0.356

*Initial TSS was 11.50 per cent

** Initial ascorbic acid content was 12.00 (mg/100g)

- T₁**- Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation
T₂-Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation
T₃- Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation
T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation
T₅-Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation
T₆- Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation
T₇- Welded mesh cage with bottom and side ventilation
T₈- Plastic crate storage
T₉- Nylon net bags storage **T₁₀**- Control (Farmers method in gunny bags)

Table 12. Influence of different storage conditions on reducing sugar (%) and non-reducing sugar (%) of onion during storage.

Treatment	Days after storage											
	Reducing sugar * (%)						Non-reducing sugar ** (%)					
	15	30	45	60	75	90	15	30	45	60	75	90
T₁	6.54	6.42	5.96	5.26	4.84	3.94	3.14	3.56	4.10	4.84	5.32	6.32
T₂	6.38	6.26	5.62	5.00	4.50	4.00	3.28	3.76	4.48	5.14	5.68	6.28
T₃	6.42	6.00	5.80	5.46	5.24	5.20	3.68	3.98	4.58	5.24	6.20	6.80
T₄	6.32	6.14	5.85	5.32	5.00	4.80	3.42	3.78	4.36	5.12	5.74	6.14
T₅	6.48	6.21	6.00	5.50	5.14	4.38	3.54	3.88	4.14	4.80	5.36	6.16
T₆	6.42	6.14	5.82	5.42	4.80	4.34	3.48	3.78	4.34	4.76	5.40	5.94
T₇	6.52	6.20	5.74	5.14	4.82	4.20	3.36	3.76	4.28	4.90	5.38	6.18
T₈	6.58	6.32	5.82	5.38	5.02	4.46	3.24	3.60	4.42	4.88	5.52	6.12
T₉	6.28	6.14	6.00	5.60	5.24	5.00	3.58	3.90	4.32	4.92	6.10	6.72
T₁₀	6.48	6.27	5.786	5.24	4.92	4.56	3.40	3.68	4.38	5.10	5.86	6.24
S.E m±	0.091	0.006	0.019	0.007	0.019	0.073	0.008	0.007	0.008	0.007	0.009	0.007
C.D. @ 5%	0.270	0.019	0.056	0.021	0.056	0.215	0.024	0.023	0.026	0.021	0.027	0.023
C.D. @ 1%	0.356	0.026	0.074	0.027	0.074	0.285	0.032	0.030	0.034	0.028	0.036	0.030

*Initial reducing sugar is 6.62 per cent

** Initial non reducing sugar is 2.90 per cent

T₁-Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation

T₂-Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation

T₃-Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation

T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation

T₅-Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation

T₆- Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation

T₇- Welded mesh cage with bottom and side ventilation

T₈- Plastic crate storage

T₉- Nylon net bags storage,

T₁₀- Control (Farmers method in gunny bag

4.2.11 Non-reducing sugars (%)

The data on per cent non-reducing sugar as influenced by different storage conditions during storage is given in Table-12. Irrespective of storage conditions, the non-reducing sugar content was increased progressively from an initial 2.90 per cent to 6.80 per cent at 90 DAS.

The different storage conditions differed significantly with respect to non-reducing sugar content of bulbs throughout the storage period. Among the storage conditions studied, maximum per cent non-reducing sugars content was found in onion stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (3.68, 3.98, 4.58, 5.24, 6.20 and 6.80 %) at 15, 30, 45, 60, 75 and 90 DAS, respectively. The minimum per cent of non reducing sugar was found in the bulbs stored in wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation (3.48, 3.78, 4.34, 4.76, 5.40 and 5.94%) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.12 Total sugar (%)

The data presented in Table-13 revealed that, the total sugar content irrespective of different storage methods increased progressively from an initial 9.52 per cent to 12.00 per cent at 90 DAS.

The different storage conditions had higher and significant influence on the total sugar content of the bulbs throughout the storage period. Maximum level of total sugar (9.98, 9.94, 10.38, 10.70, 11.44 and 12.00%) was recorded in bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation at 15, 30, 45, 60, 75 and 90 DAS, respectively. The minimum per cent total sugar (9.89, 9.98, 10.06, 10.10, 10.16 and 10.26%) was seen in bulbs stored under bamboo battens thatched roof storage structure without bottom ventilation which was on par with the bamboo battens low cost storage structure with typha roofing with bottom and side ventilation (9.78, 10.02, 10.10, 10.14, 10.18 and 10.28 %) and the wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation (9.90, 9.92, 10.16, 10.18, 10.20 and 10.28%) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.2.13 Marketable bulbs (%)

The data given in Table-13 revealed that irrespective of storage conditions, the mean marketable bulbs (%) has decreased throughout the storage period.

Table 13. Influence of different storage conditions on total sugar (%) and marketable bulbs (%) of onion during storage.

Treatment	Days after storage											
	Total sugar * (%)						Marketable bulbs (%)					
	15	30	45	60	75	90	15	30	45	60	75	90
T₁	9.89	9.98	10.06	10.10	10.16	10.26	96.08	91.03	84.12	79.82	74.78	72.00
T₂	9.78	10.02	10.10	10.14	10.18	10.28	96.14	91.68	86.53	81.00	76.26	73.70
T₃	9.98	9.94	10.38	10.70	11.44	12.00	97.54	93.18	91.06	89.58	87.92	85.94
T₄	9.74	9.92	10.21	10.44	10.74	10.94	96.88	91.80	88.24	83.88	81.03	80.12
T₅	10.2	10.9	10.14	10.30	10.50	10.54	97.00	92.64	88.58	84.54	81.60	80.20
T₆	9.90	9.92	10.16	10.18	10.20	10.28	96.66	91.31	86.56	83.68	82.18	80.16
T₇	9.88	9.96	10.02	10.04	10.22	10.38	96.92	92.26	88.00	84.01	79.28	77.14
T₈	9.82	9.92	10.24	10.26	10.54	10.58	96.38	91.34	85.63	80.26	75.60	73.16
T₉	9.86	10.04	10.32	10.52	11.36	11.72	97.12	92.30	89.09	84.60	81.36	78.72
T₁₀	9.88	9.96	10.16	10.36	10.78	10.80	96.94	92.16	88.84	82.42	77.08	74.74
S.E m±	0.179	0.164	0.175	0.167	0.177	0.672	0.564	0.912	0.917	0.914	0.914	0.917
C.D. @ 5%	0.528	0.486	0.517	0.493	0.524	1.982	1.665	2.693	2.706	2.697	2.697	2.707
C.D. @ 1%	0.698	0.642	0.684	0.652	0.692	2.620	2.200	3.558	3.576	3.564	3.564	3.577

* Initial total sugar was 9.52 per cent

- T₁**- Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation
T₂- Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation
T₃- Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation
T₄- Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation
T₅- Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation
T₆- Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation
T₇- Welded mesh cage with bottom and side ventilation
T₈- Plastic crate storage
T₉- Nylon net bags storage,
T₁₀- Control (Farmers method in gunny bags)

There was highly significant differences among the different storage conditions regarding per cent marketable bulbs at 15, 30, 45, 60, 75 and 90 DAS. Maximum per cent of marketable bulbs (97.54, 93.18, 91.06, 89.58, 87.92 and 85.94 %) was recorded in bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation followed by bulbs stored in wooden battens storage structure with galmenium sheet roofing and with bottom and side ventilation (97.00, 92.64, 88.58, 84.54, 81.60 and 80.20%) which was on par with the wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation (96.66, 91.31, 86.56, 83.68, 82.48 and 80.16 %) and bulbs stored in wooden battens storage structure with AC sheet roofing and with bottom and side ventilation (96.88, 91.80, 88.24, 83.88, 81.03 and 80.12 %) at 15, 30, 45, 60, 75 and 90 DAS, respectively. The minimum per cent of marketable bulbs was found in bamboo battens thatched roof structure without bottom ventilation (96.08, 91.03, 84.12, 79.82, 74.78, 72.00%) at 15, 30, 45, 60, 75 and 90 DAS, respectively.

4.3 Economics

Among the different storage conditions the highest net returns (Rs.395.78) and highest return per rupee spent (1.62) in the bulbs stored under bamboo battens with AC sheet roofing and with bottom and side ventilation and followed by bulbs stored under wooden battens with galmenium sheet roofing and with bottom and side ventilation with net return of (Rs.331.90) and return per rupee spent (1.53) and onion bulbs stored under wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation with a net return (Rs.331.92) return per rupee spent (1.52). The lowest net returns (Rs.224.00) and lower return per rupee spent (1.35) was observed in onion bulbs stored under bamboo battens thatched roof structure. The data related to the economics of the onion bulbs in different storage structures is given in Table 14.

Table 14. Economics of storage of onion as influenced by different storage conditions.

Sl.No	Particular	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀
1.	Value of onion at the time of storage (Rs. 600/ q)	600	600	600	600	600	600	600	600	600	600
2.	Cost of storage of onion (Rs./ q for 3 months)	15.00	12.50	10.50	6.50	5.50	5.00	4.00	57.50	16	22
3.	Cost of handling (Rs. / q)	10	10	10	10	10	10	10	10	10	10
4.	Cost of transport and marketing(Rs. / q)	15	15	15	15	15	15	15	15	15	15
	Total expenditure (Rs.) (1+2+3+4)	640	637.50	635.50	631.50	630.5	630	629	682.50	641	647
5.	Total salable goods (kg)	72.00	73.70	85.94	80.12	80.20	80.16	77.14	73.16	78.72	74.74
6.	Gross returns @ RS. 1200/q	864	884.40	1031.28	961.44	962.40	961.92	925.68	877.92	944.64	896.88
	Net returns (Rs.)	224	246.5	395.78	329.94	331.90	331.92	296.68	195.42	303.64	249.88
	Return per rupee spent (Rs.)	1.35	1.38	1.62	1.52	1.53	1.52	1.47	1.28	1.47	1.38

T₁- Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation

T₂- Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation

T₃- Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation

T₄- Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation

T₅- Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation

T₆- Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation

T₇- Welded mesh cage with bottom and side ventilation

T₈- Plastic crate storage

T₉- Nylon net bags storage

T₁₀- Control (Farmers method in gunny bags)

DISCUSSION



5. DISCUSSION

Onion is one of the major bulbous commercial vegetable crop grown in India. It is a semi-perishable crop and therefore post harvest losses occur during transportation and storage. Onion is harvested from October to November (20%), January to February (20%) and April to May (60%). From October to May harvesting of onions goes on countrywide. As there is no harvest from June to November, storage of onion is of great importance for continuous supply to market. Country needs to store 40-45 lakh tons of onion annually. The estimated post harvest losses of onion are about 40 to 50 per cent. Curing is important operation to be carried out to reduce the post harvest losses in stored onions.

Onions can be stored for a longer period to balance its demand and supply in the market, provided the bulbs are thoroughly cured before storage. Further the farmers had very poor knowledge about curing techniques and post-harvest management practices. Storage methods have their own impact on post-harvest life and keeping quality. There is a problem of sprouting, rotting, weight loss of bulbs and tend to loose chemical constituents when stored in an environment of high temperature and humidity. High humidity coupled with high temperature favours sprouting and rotting of bulbs and ultimately leads to the loss of keeping quality, thereby reducing their post harvest storage life.

Keeping this in view, attempts have been made in the present investigation to study the influence of different curing methods and different storage conditions with respect to physiological loss in weight, rotting, sprouting and biochemical changes during storage. The results obtained on these aspects are discussed in this chapter.

5.1 Effect of different curing methods on storability of onion

The moisture content of onion bulbs was about 90 per cent at the time of harvesting and reduces about 82 to 84 per cent upon proper curing (drying). Curing is the most important operation in the post-harvest management of onions, wherein the excess moisture from the outer skin and neck of the freshly harvested onion is removed to a level where shrinkage from the interior is minimum and infection by diseases causing organisms is reduced at later stages during storage.

Curing of onion bulbs specifically involves drying of superficial scales to protect the bulbs against subsequent microbial infection and bulbs were cured for 14 to 21 days and stored at the room temperature, the storage life of the bulbs could be extended upto two months over the control (Gobardham, 1980).



Fresh onions with foliage and without foliage before curing



Onions with foliage and without foliage after curing in 35 per cent shade



Best treatments with foliage (T₅) and without foliage (T₆) after two months in 35 per cent shade curing.

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Plate3. Influence of different curing methods on storage of onion
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Purpose of curing is the removal of excess moisture from the outer skin and neck portion of onion which helps in reducing the infection of diseases. This also helps in minimising shrinkage due to moisture loss from the interior portion. Bulbs are cured either in field or in open sheds before or in storage. Onion bulbs can be cured by artificial methods by forced hot air dryers where temperature is not suitable for field curing especially during *khariif* season (Satish and Ranganna,2002a). Onions are considered to be cured when neck is tight and outer scales are dried until they rustle. The time length required for curing operation largely depends on the weather condition.

5.1.1 Effect of different curing methods on marketable bulbs

Among the different curing methods, the highest per cent marketable bulbs was recorded in bulbs cured under 35 per cent shade with foliage (Fig.6) followed by bulbs cured under 35 per cent shade without foliage (T₆) at 60 DAS. The highest marketable bulbs (Table.7 and Fig.6) may be attributed to minimum physiological loss in weight, per cent rotting and per cent sprouting in 35 per cent shade with foliage (T₅) and 35 per cent shade without foliage. However, the lowest per cent marketable bulbs obtained was observed in bulbs cured under forced hot air dryer without foliage. This could be due to highest weight loss, rotting and sprouting in bulbs cured under forced hot air dryer. This may be due to high temperature of 50⁰C for a longer period of five hours which made the bulbs loose more in weight, highest per cent of rotting and sprouting. These results were in similar with findings of Kukanoor *et al.* (2006a).

5.1.2 Effect of different curing methods on physical parameters

The time taken for curing in different treatments ranged from 4 hours to 288 hours. Among the different methods of curing the minimum time taken for curing of onion bulbs (4 hours) was observed in forced hot air dryer with and without foliage. The lesser time of curing is due to high temperature of 50⁰C with a rate of air flow 222m³/min in the forced hot air dryer (Satish and Ranganna, 2002a). The maximum time taken for curing was observed in bulbs cured under 100 per cent shade with and without foliage due to less temperature (18 to 25⁰C).

The weight loss during different days of storage was significantly influenced by different curing methods. Among the curing methods, the lowest physiological loss in weight was recorded in bulbs cured under 35 per cent shade with foliage followed by bulbs cured under 35 per cent shade without foliage (Table.1 and Fig.1) and maximum weight loss was

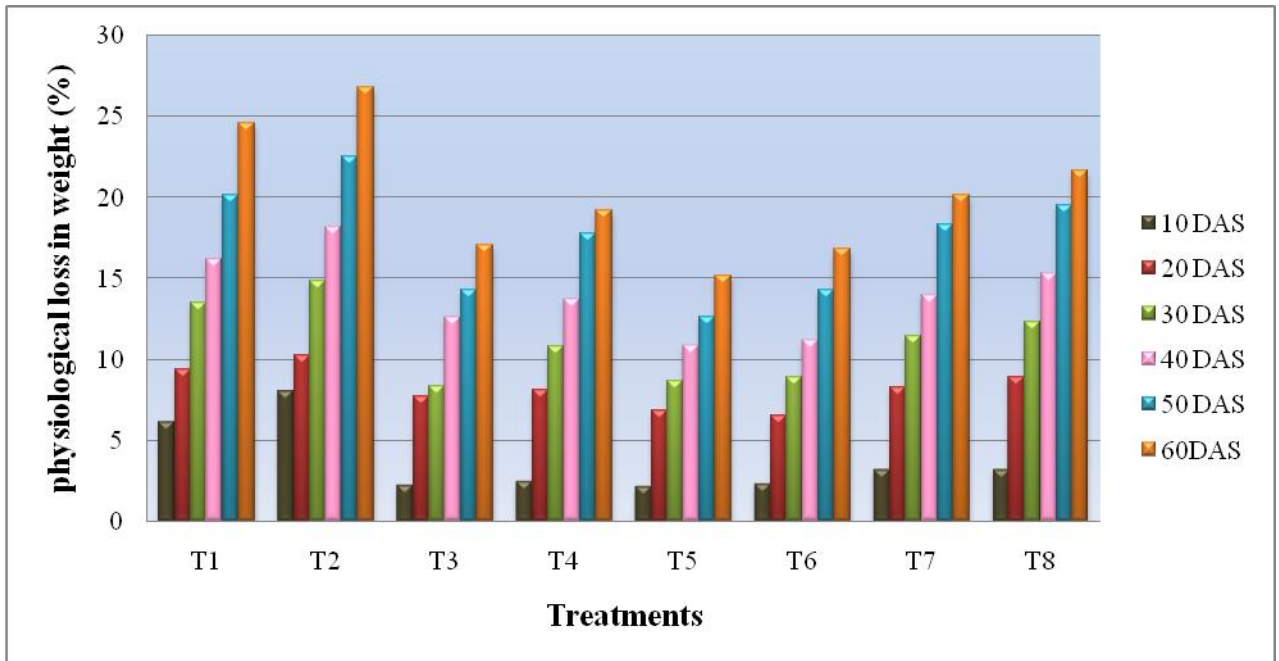


Fig. 1. Influence of different curing methods on physiological loss in weight (%) during storage of onion

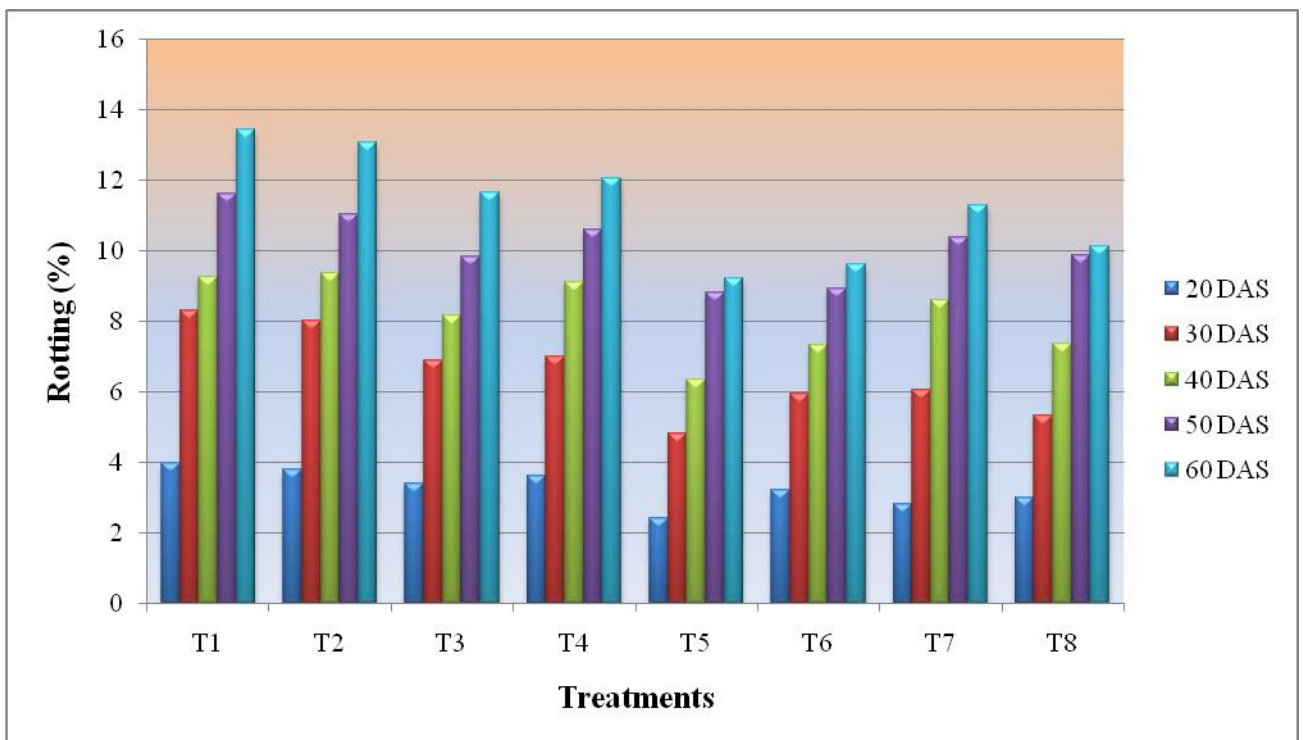


Fig. 2. Influence of different curing methods on rotting (%) during storage of onion

Legend :

- | | |
|--|--|
| T ₁ - Curing under forced hot air dryer with foliage | T ₅ - Curing under 35 per cent shade with foliage |
| T ₂ - Curing under forced hot air dryer without foliage | T ₆ - Curing under 35 per cent shade without foliage |
| T ₃ - Curing under polytunnel with foliage | T ₇ - Curing under 100 per cent shade with foliage |
| T ₄ - Curing under polytunnel without foliage | T ₈ - Curing under 100 per cent shade without foliage |

recorded in bulbs cured under forced hot air dryer without foliage at 60 DAS. 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 reported by Kukanoor *et al.* (2006) who observed that maximum physiological loss in weight may be due to absence of foliage resulting in full exposure of the bulbs to the temperature leading to increased surface temperature of the bulbs helping to hasten the process of moisture reduction. Similar findings were reported by Thompson *et al.* (1972) and Sidhu and Chadha (1986) who observed that physiological loss in weight was lesser in cured bulbs during storage.

Sprouting is one of the major causes for qualitative as well as quantitative deterioration of stored onion bulbs. Sprouting leads to transfer of both dry matter and water from the edible fleshy scales into the sprouts resulting in increased shrivelling and loss of market quality of such bulbs. The sprouting per cent was significantly influenced by different curing methods at all the stages of observations. Among the different curing methods, bulbs cured under 35 per cent shade with foliage (T₅) was recorded significantly minimum sprouting due to moderate temperature of 32 to 36 °C. This may be due to thin neck and suppression of sprout growth. Similar kind of results was also observed by Associated Agricultural Development Foundation, Nasik. These findings were in accordance with the Kukanoor *et al.* (2006) and Katherine *et al.* (2009).

Among the curing methods, significantly lowest rotting and black mould incidence was recorded in bulbs cured under 35 per cent shade with foliage (Table.1 and Fig.1) compared to all other curing methods. The least rotting and black mould percentage may be due to the fact that the neck of the bulb was completely dried and closed which helps in reducing the chances of microorganisms entry into the bulbs and lower order of pathological decay of microorganisms due to reduction in the moisture content of the onion bulbs. Similar findings were observed by Sidhu and Chadha (1986) and Kukanoor *et al.* (2006a) in onion. The maximum rotting was observed in bulbs cured under forced hot air dryer with foliage followed by bulbs cured under forced hot air dryer without foliage may be due to the high temperature (50°C) in forced hot air dryer.

Among the curing methods, significant and maximum moisture loss was noticed in bulbs cured under forced hot air dryer with foliage followed by forced hot air dryer without foliage. This may be attributed to proper drying of bulbs owing to more evaporation of moisture from the bulbs due to exposure of bulbs to higher temperatures where as minimum

moisture loss was observed in bulbs cured under 35 per cent shade with foliage (T₅). Similar findings were also observed by Maw and Mullinix (2005).

Among the various methods, curing under forced hot air dryer with foliage followed by bulbs cured under forced hot air dryer without foliage (T₅) recorded significantly maximum dry matter content. This could be attributed to the lesser moisture content of the bulbs leading to proper drying which helps to increase in chemical constituents and accumulating dry matter, while minimum dry matter was found in bulbs cured under 35 per cent shade with foliage (T₅) due to maximum moisture retention in the bulbs.

The hardness of the bulbs was significantly influenced by different curing methods during different days of storage. Among the curing methods, the maximum hardness of the bulbs was recorded in bulbs cured under 35 per cent shade with foliage (T₅) which was on par with the bulbs cured under polytunnel without foliage (T₄) compared to other methods of curing, this increase in hardness of bulbs was due to surface drying of onions leading to a rigid and firm bulbs. The fleshy soft skin becomes dry and hard after curing resulting in shrinkage caused by particle slip into more compact arrangement upon drying (Hasatani and Itaya, 1996). These findings are in accordance with Satish and Ranganna (2002b) and Kukanoor *et al.* (2006b).

Among different curing methods, (T₅) bulbs cured under 35 per cent shade with foliage showed minimum per cent loss of scales followed by bulbs cured under 35 per cent shade without foliage at 60 DAS. This may be due to proper drying and fleshy soft skin becomes dry and hard after curing resulting shrinkage caused by particle slip into more compact arrangement upon drying (Hastani and Itaya, 1996), while bulbs cured under forced hot air dryer without foliage (T₂) was found significantly maximum per cent loss of scales.

There was a gradual increase of TSS during storage in all curing methods. Among the curing methods, the maximum total soluble solids was found in bulbs cured under 35 per cent shade with foliage (T₅) followed by bulbs cured under 35 per cent shade without foliage (Table 5. and Fig.3). This might be due to proper drying of the bulbs and the conversion of polysaccharides into soluble form of sugars. However, minimum TSS (12.80%) was found in (T₂) bulbs cured under forced hot air dryer without foliage. The results obtained by Shaha *et al.* (1992) supports the present findings.

5.1.3 Effect of different curing methods on chemical composition

There was gradual decrease of ascorbic acid content throughout the storage period, which may be attributed to oxidative destruction of ascorbic acid in the presence of molecular oxygen by ascorbic acid oxidase enzymes (Mapson, 1970). Among the curing methods, the maximum retention of ascorbic acid was recorded in bulbs cured under 35 per cent shade with foliage (Table 5. and Fig.4) followed by bulbs cured under 35 per cent shade without foliage. This might be due to minimum shrinkage losses caused due to loss of moisture from the interior of the bulbs. These results were in agreement with the results obtained by Franklin *et al.* (1996). However, minimum ascorbic acid content was recorded in bulbs cured under forced hot air dryer without foliage.

Among the curing methods, significantly maximum total sugar, non-reducing sugar and minimum reducing sugar content was found in (T₅) bulbs cured under 35 per cent shade with foliage followed by bulbs cured under 35 per cent shade without foliage compared to other curing methods. This might be due to proper drying and comparatively low moisture content of the bulbs during storage. The maximum non-reducing sugar content might be due to less consumption of sugars in the process of respiration and breakdown of non-reducing sugars is minimised resulting increase in the non-reducing sugar content of the bulbs. The moisture content of the bulbs also helped in retaining the non-reducing sugar content. As the moisture content was more in the bulbs, more loss of sugars due to degradation and respiration. Minimum reducing sugar content in the above treatments may be due to glucose and fructose might get utilised during respiratory process. Hence the level of reducing sugar decreased during storage period. Similar findings were also reported by Misra and Pandey (1979), Gorin and Borosok (1981) and Patil and Kale (1988) in onion.

5.2 Effect of different storage conditions on storability of onion

Storage plays a very important role in marketing of onion. It helps in adjustment of supply of a particular commodity in relation to its demand in the market. Storage thus helps to secure relatively better price to a product by adjusting supply with reference to existing demand and thereby avoid gluts of produce in the market. Onion is a delicate and perishable commodity and difficult to store for a long duration at room temperature, especially in tropical and subtropical countries, due to its high water content and many other factors associated with it. Onion is stored in ambient storage condition in India, where the storage losses are very high. These losses are comprised of

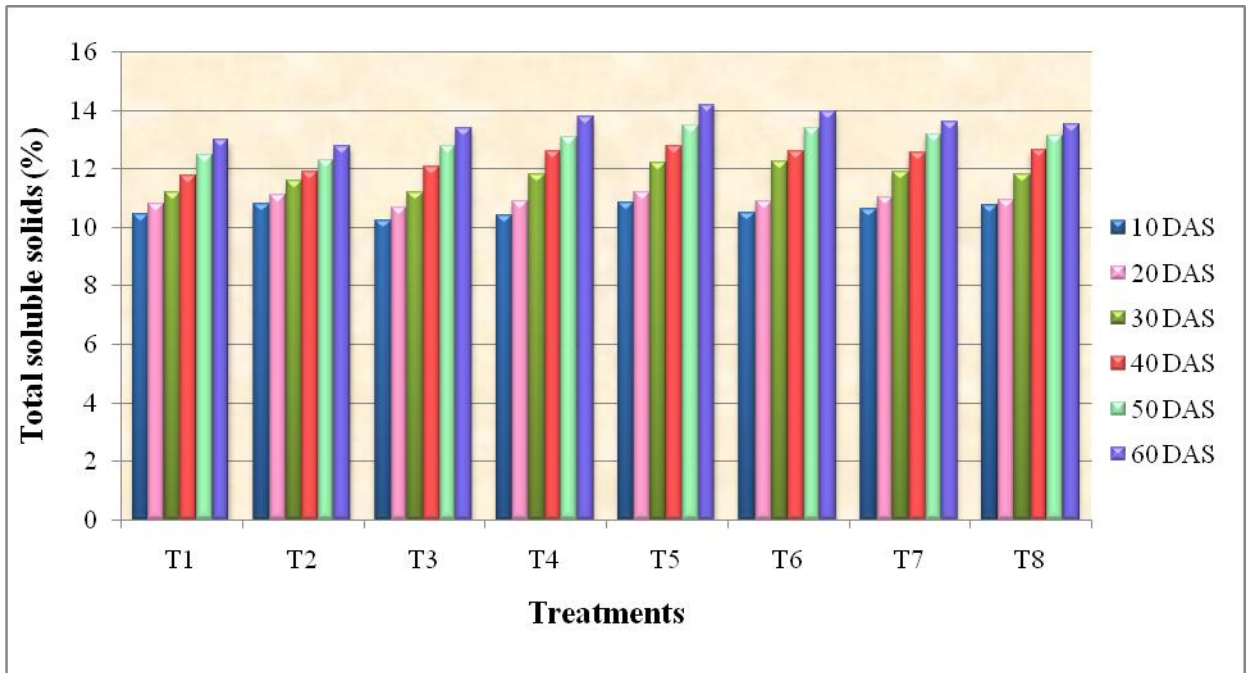


Fig.3. Influence of different curing methods on total soluble solids (%) of onion during storage

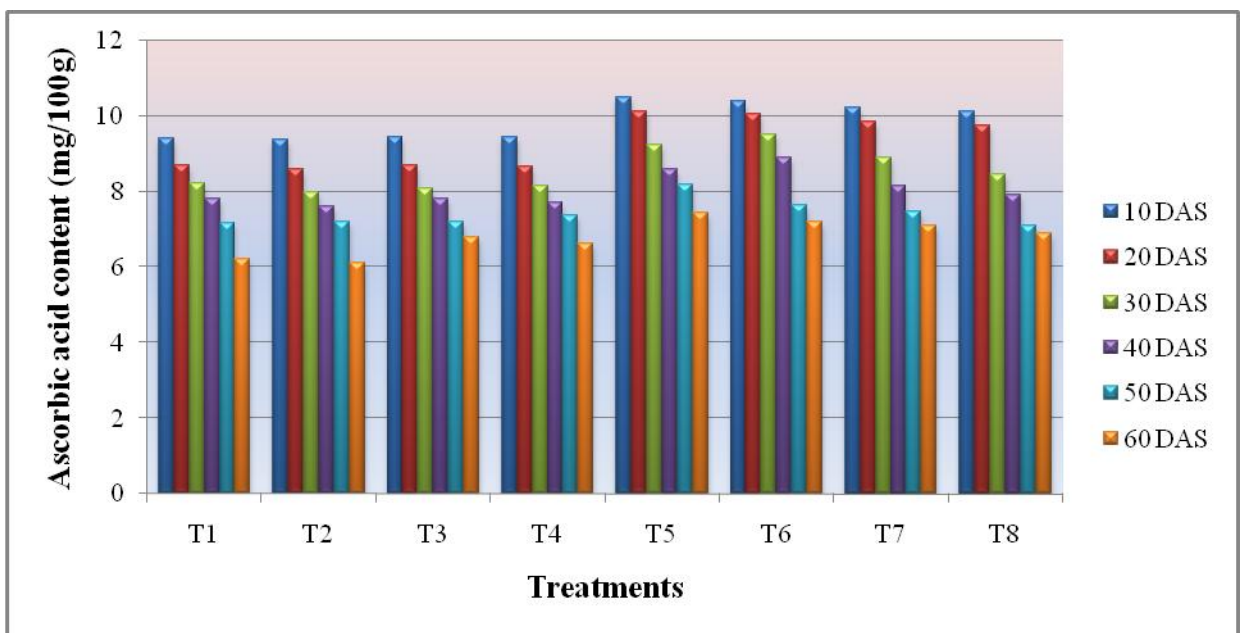


Fig.4. Influence of different curing methods on ascorbic acid content (mg/100g) of onion during storage

Legend :

T₁- Curing under forced hot air dryer with foliage
 T₂- Curing under forced hot air dryer without foliage
 T₃- Curing under polytunnel with foliage
 T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage
 T₆- Curing under 35 per cent shade without foliage
 T₇- Curing under 100 per cent shade with foliage
 T₈- Curing under 100 per cent shade without foliage

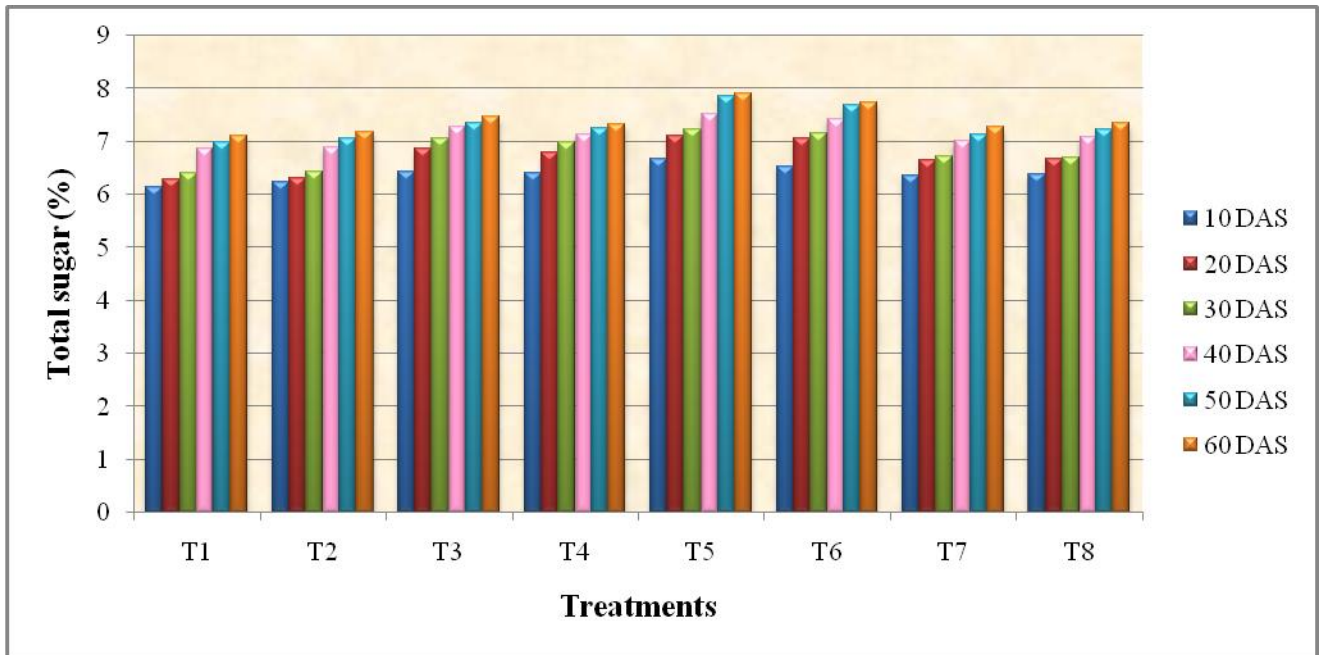


Fig.5. Influence of different curing methods on total sugars (%) of onion during storage

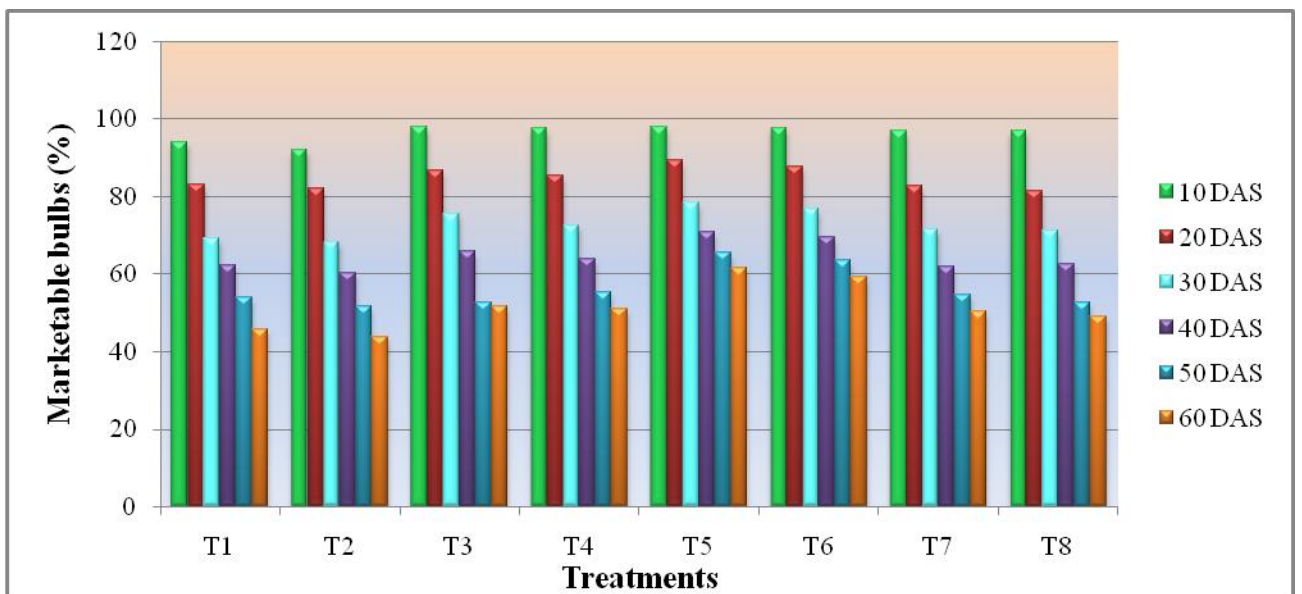


Fig.6. Influence of different curing methods on marketable bulbs (%) of onion during storage

Legend:

T₁- Curing under forced hot air dryer with foliage
 T₂- Curing under forced hot air dryer without foliage
 T₃- Curing under polytunnel with foliage
 T₄- Curing under polytunnel without foliage

T₅- Curing under 35 per cent shade with foliage
 T₆- Curing under 35 per cent shade without foliage
 T₇- Curing under 100 per cent shade with foliage
 T₈- Curing under 100 per cent shade without foliage

physiological loss in weight, moisture losses and shrinkage (30-40%), rotting (10-12%) and sprouting (8-10%). The storage environment during the period of storage plays an important role in the storage life and losses during the storage. In India, the major crop is harvested in summer and stored for four to six months in ambient condition of high temperature and high humidity due to monsoon rains. During this period, the bulbs sprout very easily besides rotting due to the infection caused by fungus and bacterial pathogens. In India, proper storage of bulbs is necessary for both consumption and also for seed production. Various simple methods of storage of onions have been designed through ages and modified according to the local material available for their construction.

5.2.1 Effect of different storage methods on marketable bulbs

Maximum marketable bulbs at the end of storage period (90 DAS) was found in onion bulbs stored in (T₃) bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (85.94%) followed by bulbs stored in wooden battens storage structure with galmenium sheet roofing and with bottom and side ventilation (80.20%) which was on par with the storage structure with mangalore tiles roofing and with bottom and side ventilation (80.16%) and (80.16%) bulbs stored in wooden battens storage structure with AC sheet roofing and with bottom and side ventilation (Table.13 and Fig.12). This may be due to lowest physiological loss in weight and rotting per cent in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation. The present findings were also in confirmation with the result of Srivastava *et al.* (1997) and Sharma and Kamalesh (2000) in onion. This clearly indicates the role of ventilation for maintaining higher marketable bulbs, while the least per cent marketable bulbs obtained in (T₁) bamboo battens thatched roof structure without bottom ventilation (72.00%) may be due to higher weight loss and rotting. Due to lack of proper ventilation in thatched roof structure without bottom ventilation the per cent rotting was more and hence per cent of marketable bulbs were less. (Kukanoor *et al.* 2006b)

5.2.2 Effect of different storage methods on physical parameters of onion

Among the different storage conditions, minimum physiological loss in weight was recorded in the bulbs stored in bamboo battens storage structure with AC sheet roofing with bottom and side ventilation (T₃). It may be due to proper ventilation in the structure, resulting in optimum temperature in the centre of the structure which results in less respiration and transpiration (Maini *et al.*, 1997). These findings were in accordance with Khurana and Singh (1984), Warade *et al.* (1995) and Tripathi and Lawande (2003). While maximum



Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation (T₃)



Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation (T₄)



Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation (S₃)



Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation (T₆)

The best treatments with higher per cent of marketable bulbs



Bamboo battens thatched roof structure without bottom ventilation with lowest per cent of marketable bulbs (T₁)

Plate 4. Influence of different storage methods on storability of onion

physiological loss in weight was observed in onion bulbs stored in bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation. This may be due to the improper ventilation resulting in higher temperature in the centre of the structure due to higher rate of respiration in bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation (Subbaramu *et al.*, 1990).

Microbial spoilage is a major constraint in storability of onion bulbs. They multiply and infect the bulb surface when congenial conditions prevail. Onion bulbs affected by various post-harvest diseases like black mould, neck rot, white rot and soft rot. Among these, the only major post-harvest disease that was responsible for rotting of bulbs in storage was identified as black mould rot caused by *Aspergillus niger*.

It is interesting to note that black mould was not observed upto 45 days in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (T₃) and nylon net bag storage (T₉) where as upto 30 days in all other methods of storage and no rotting was observed upto 15 days of storage. The rotting and black mould per cent of bulbs was significantly influenced by different storage conditions during all the stages of observations. Among the different storage conditions, the minimum rotting and black mould per cent was observed in bulbs stored in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation. This may be due to proper ventilation as well as minimum fluctuation in storage temperature 26⁰C to 36⁰C (Maini *et al.* 1997), while the maximum rotting (11.00%) and black mould incidence (10.00%) were noticed in bamboo battens thatched roof structure without bottom ventilation due to major fluctuation in temperatures ranged from 24⁰C to 40⁰C. 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. These findings were in accordance with Bongiwar and Shirsat (2000) and Surviliene (2006).

Significant difference of moisture content was observed between different storage conditions at all the stages of observations. Minimum per cent moisture content was observed when the bulbs stored in bamboo battens low cost storage structure with typha roofing with bottom and side ventilation which was on par with the bulbs stored in nylon net bags. This may be due to better air movement between the onion which has helped in reducing the moisture content of the bulbs. However, maximum moisture content was observed in bulbs stored under bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (Kukanoor *et al.* 2006b).

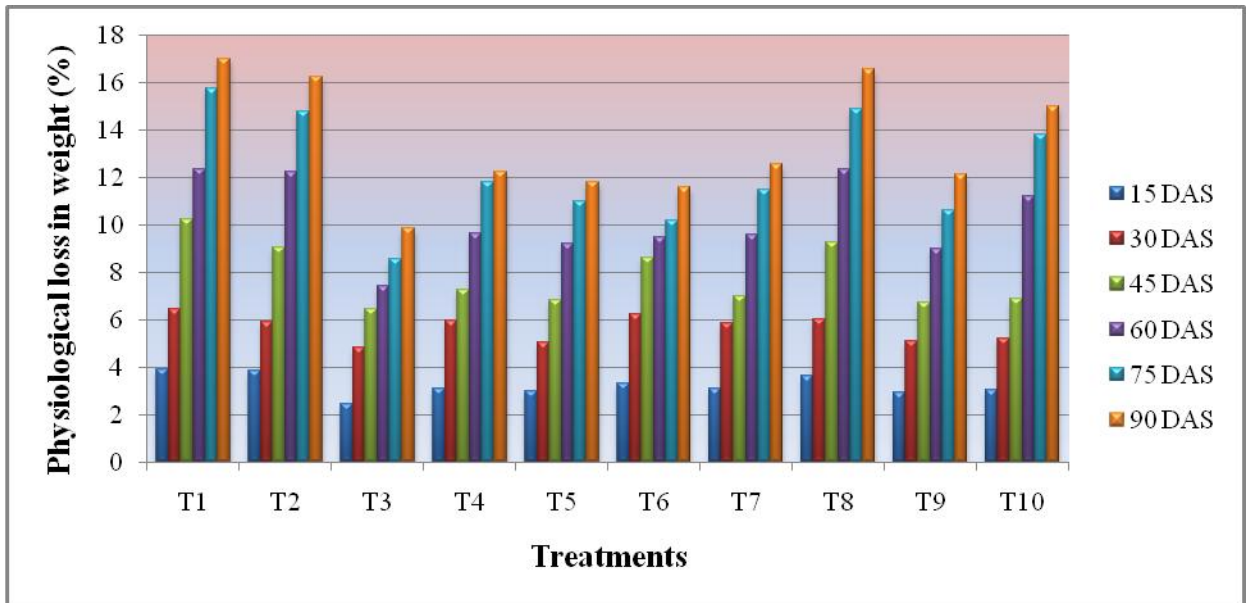


Fig.7. Influence of different storage conditions on physiological loss in weight (%) of onion during storage

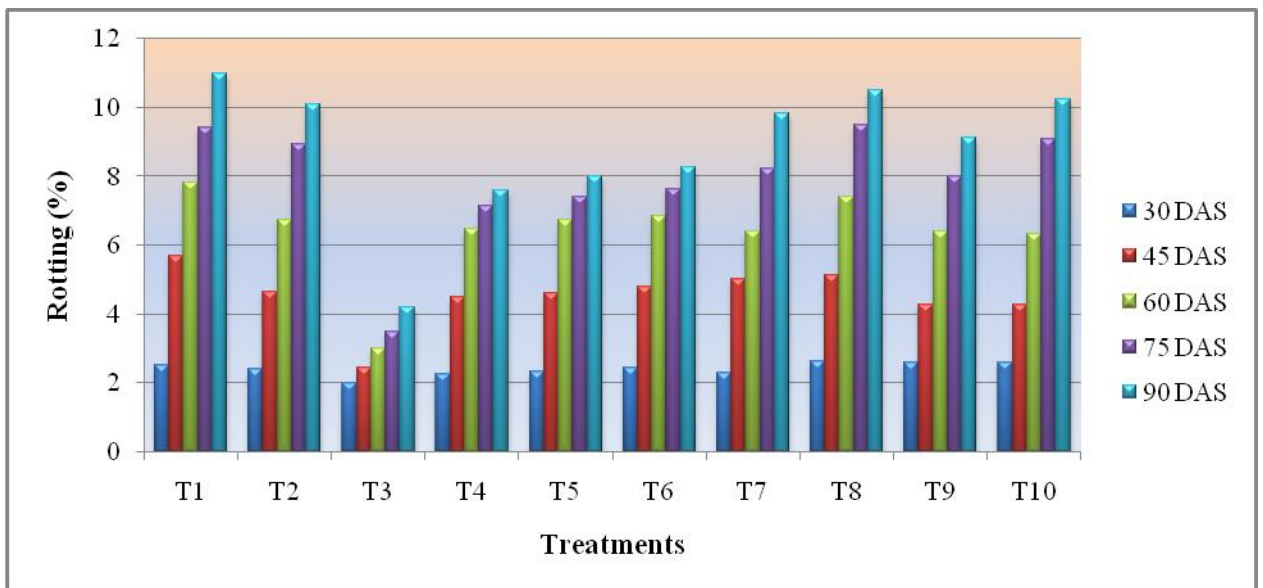


Fig.8. Influence of different storage conditions on rotting (%) of onion during storage

Legend:

- T₁ Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation
- T₂ Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation
- T₃-Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation
- T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation.
- T₅ -Wooden battens storage structure with galmenium sheet roofing with bottom and side Ventilation.
- T₆-Wooden battens storage structure with mangalore tiles roofing and with bottom and side Ventilation.
- T₇-Welded mesh cage with bottom and side ventilation
- T₈- Plastic crates T₉- Nylon net bags T₁₀- Control (Farmers method in gunny bags).

The different storage conditions had significant influence on dry matter content of the onion bulbs at all the stages of observations. Among the different storage conditions, maximum per cent dry matter was recorded in bulbs stored in bamboo battens low cost storage structure with typha roofing with bottom and side ventilation which was on par with bulbs stored in plastic crates. The maximum dry matter content during storage could be reasoned due to the decreased moisture content of the bulbs and increased in chemical constituents in turn resulting in more dry matter. The minimum dry matter content was recorded in bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation. This may be due to more moisture retention by the onion bulbs. Similar findings were also reported by Ahmad *et al.* (2006) and Ilic *et al.* (2009).

The different storage conditions had significant effect on hardness of the bulbs. The hardness of the bulbs was significantly higher in bulbs stored under wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation. The increase in hardness was due to drying of the bulbs (Kukanoor *et al.* 2006b). The minimum hardness was found in bulbs stored under bamboo battens low cost storage structure with typha roofing with bottom and side ventilation due to maximum loss of moisture during storage.

Significant differences with respect to per cent loss of scales were observed among the different storage methods. The maximum per cent loss of scales was found in bulbs stored under bamboo battens thatched roof structure without bottom ventilation (T₁). The minimum per cent loss of scales was observed in bulbs stored under bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (T₃) which was on par with bulbs stored in gunny bags. (Hastani and Itaya, 1996)

There was a gradual increase in 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 TSS was significantly influenced by different storage conditions throughout the storage period. Among the various storage conditions tested, the maximum TSS (Table.11 and Fig.9), was recorded in bulbs stored under bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation (T₃). These results were in close conformity with findings of Saimbhi and Randhawa (1982), Patil and Kale (1988) and Ahmad *et al.* (2006). However, minimum total soluble solids was found in bulbs stored in nylon net bags which was on par with the gunny bags. This may be due to lower temperature and high relative humidity which might have reduced rate of respiration of bulbs in turn would have regulate the biochemical changes leading to lower total soluble solids.

5.2.3 Effect of different storage methods on chemical composition of onion

The ascorbic acid content of the bulbs was significantly influenced by different storage. However, the gradual decrease of ascorbic acid in all the storage methods was observed with the advancement of storage period may be due to oxidative destruction of ascorbic acid in the presence of molecular oxygen by ascorbic acid oxidase enzyme (Mapson, 1970).

It is evident from the results that storing of onion bulbs in (T₃) bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation recorded maximum retention of ascorbic acid as compared to all other storage conditions (Table.11 and Fig.10), while least retention of ascorbic acid content was observed in bulbs stored in (T₁) bamboo battens thatched roof structure without bottom ventilation. The lowest retention of ascorbic acid may be due to the build up of respiratory heat in the centre of structure due to more fluctuations in temperature.

There was gradual increase of total sugar and non-reducing sugars during the storage period. Among the storage conditions, the maximum total sugar, non-reducing sugar and reducing sugar was recorded in onion bulbs stored in (T₃) bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation. The higher per cent total sugar content may be primarily due to desiccation of bulbs. Gradual decrease of reducing sugar in all the storage methods may be due to the reducing sugars like glucose and fructose may get utilised for respiratory process during storage. Hence the level of reducing sugar decreased during storage period. These results were in close agreement with the earlier findings of Darbyshire (1978), Patil and Kale (1988), Kukanoor *et al.* (2006b) and Ilic *et al.* (2009) in onion who observed higher sucrose level at high storage temperature and concluded that changing sugar levels in the bulbs during storage may be implicated together with sucrose and fructose hydrolysis at lower temperature.

5.3 Economics of different storage conditions of onion

Among the different storage conditions the highest net returns (Rs.395.78) and highest return per rupee spent (1.62) in the bulbs stored under (T₃) bamboo battens storage structure with AC sheet roofing and with bottom and side ventilation. This was due to more marketable bulbs (85.94%) and lower physiological loss in weight (9.86%) and rotting (4.20%). This was followed by bulbs cured under wooden battens with galmenium sheet roofing and with bottom and side ventilation with net returns (Rs.331.90), return per rupee spent (1.53) and wooden

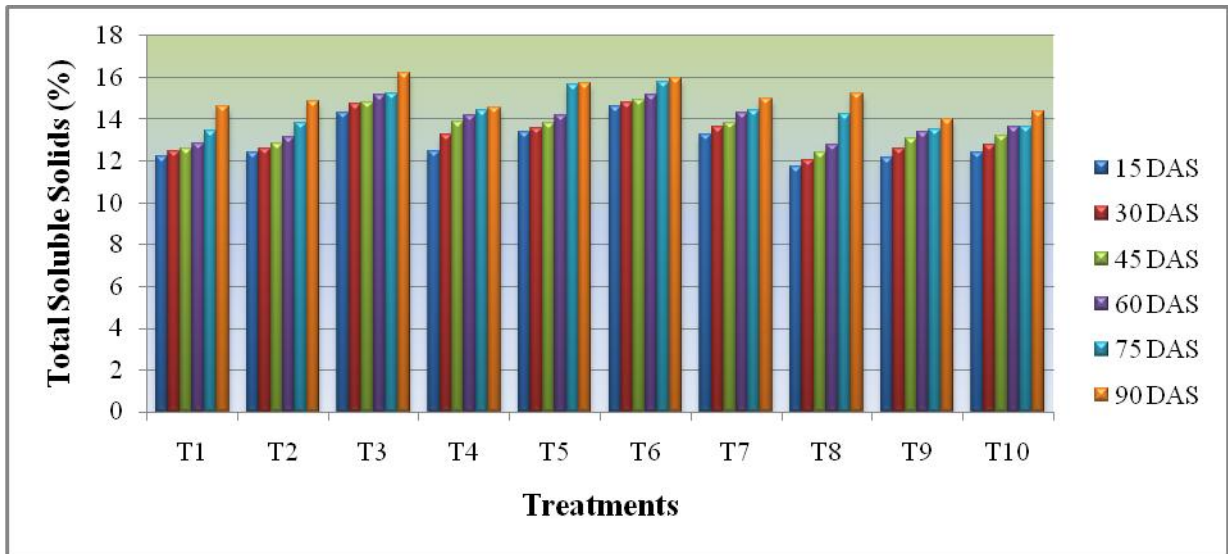


Fig.9. Influence of different storage conditions on total soluble solids (%) of onion during storage.

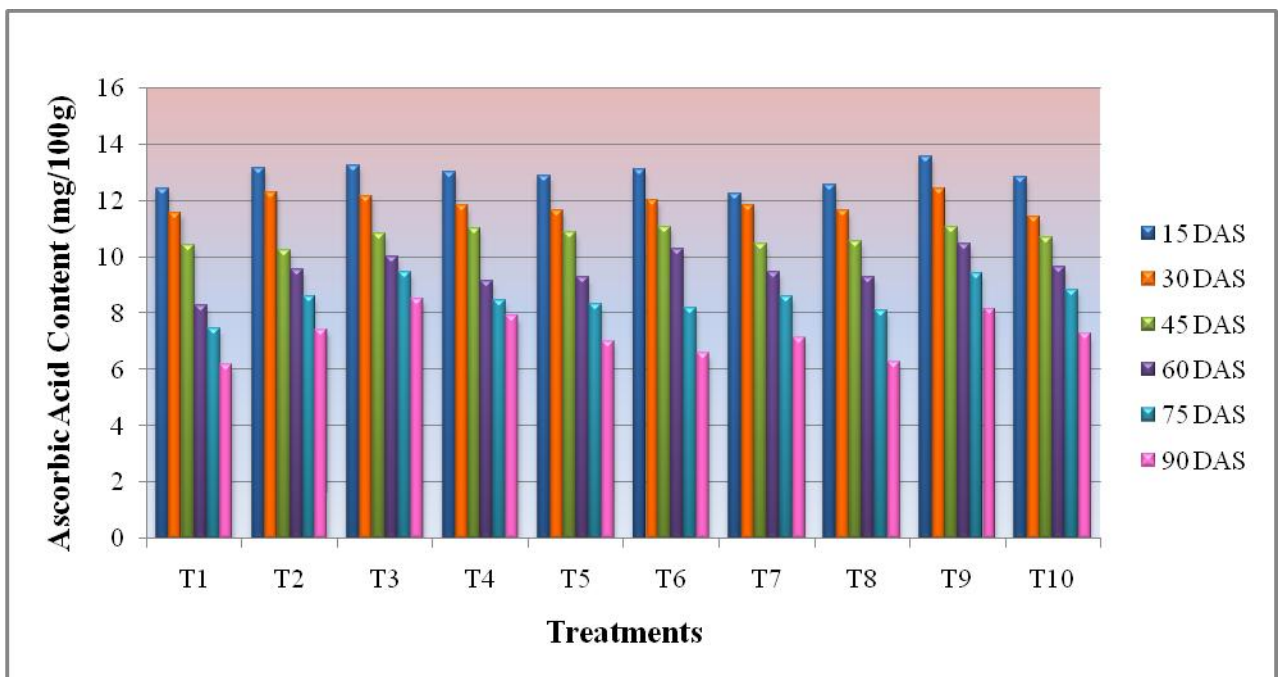


Fig.10. Influence of different storage conditions on ascorbic acid content (mg/100g) of onion during storage.

Legend:

- T₁-Bamboo battens thatched roof structure (sugarcane thrash) without bottom ventilation
- T₂-Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation
- T₃-Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation
- T₄-Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation.
- T₅-Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation.
- T₆-Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation.
- T₇-Welded mesh cage with bottom and side ventilation
- T₈- Plastic crates T₉- Nylon net bags T₁₀- Control (Farmers method in gunny bags).

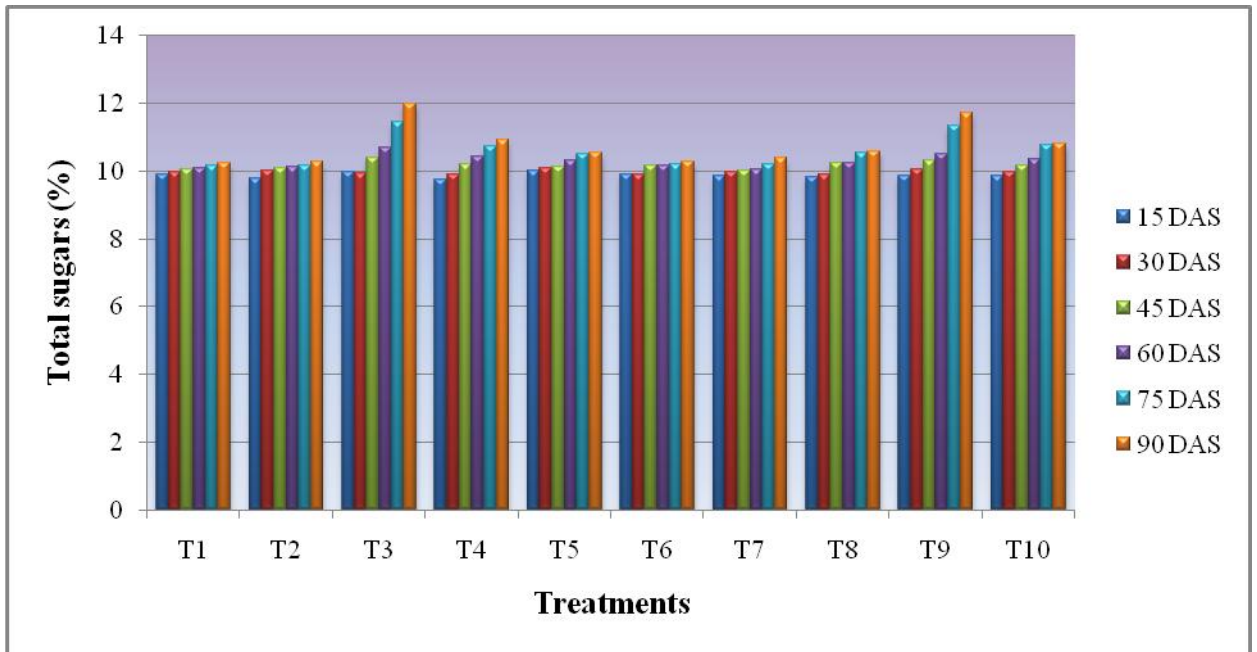


Fig.11. Influence of different storage conditions on total sugar (%) of onion during storage

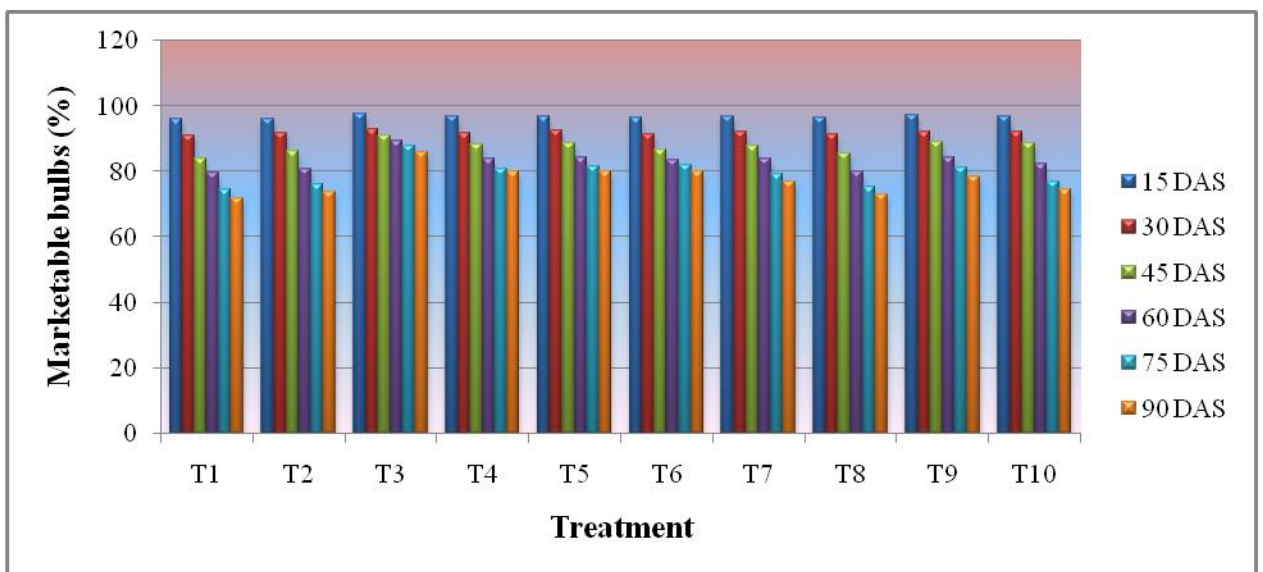


Fig.12. Influence of different storage conditions on marketable bulbs (%) of onion during storage.

Legend:

- T₁- Bamboo battens thatched roof structure (sugarcane trash) without bottom ventilation
- T₂- Bamboo battens low cost storage structure with typha roofing with bottom and side ventilation
- T₃- Bamboo battens storage structure with AC sheet roofing with bottom and side ventilation
- T₄- Wooden battens storage structure with AC Sheet roofing and with bottom and side ventilation.
- T₅- Wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation.
- T₆- Wooden battens storage structure with Mangalore tiles roofing and with bottom and side ventilation.
- T₇- Welded mesh cage with bottom and side ventilation
- T₈- Plastic crates T₉- Nylon net bags T₁₀- Control (Farmers method in gunny bags).

battens storage structure with mangalore tiles roofing and with bottom and side ventilation with net returns (Rs.331.92), return per rupee spent (1.52) .These results were in close agreement with the earlier findings of Kukanoor *et al.* (2006b), Kassali and Idowu (2007) and Tripathi *et al.* (2009).

*SUMMARY
AND
CONCLUSIONS*



6. SUMMARY AND CONCLUSIONS

An investigation on post-harvest studies in onion was carried out in Department of post harvest technology at Kittur Rani Channamma College of Horticulture, Arabhavi (University of Horticultural Sciences, Bagalkot.) during 2010-2011. Two experiments were conducted to study the effect of different curing methods (cv. Bellary Red) and storage conditions (cv. Agri Found Light Red) on post-harvest quality. The salient findings are summarised hereunder.

6.1 Effect of different curing methods on storability of onion

The effect of different curing methods *viz.*, curing under forced hot air dryer with foliage, curing under forced hot air dryer without foliage, curing under polytunnel with foliage, curing under polytunnel 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 on storage quality and marketable bulbs were studied.

The minimum time taken (4 hours) for curing of onion bulbs was under forced hot air dryer and the maximum time taken for the bulbs cured under 100 per cent shade (288 hours). Among the different curing methods bulbs cured under 35 per cent shade with foliage showed minimum physiological loss in weight (2.16, 6.83, 8.71, 10.88, 12.64 and 15.21%), sprouting (1.46, 8.24, 11.92, 13.06 and 14.09% at 20, 30, 40, 50 and 60 DAS respectively), rotting (2.41, 4.81, 6.34, 8.82 and 9.22 % at 20, 30, 40, 50 and 60 DAS respectively), black mould incidence (1.00, 2.00, 3.00, 3.50 and 4.16% at 20, 30, 40, 50 and 60 DAS respectively), per cent loss of scales (3.26, 5.28, 6.32, 8.63, 10.82 and 14.24%) and maximum moisture content (89.42, 88.60, 88.24, 88.11, 87.22 and 87.15%), hardness (6.15, 6.73, 7.86, 8.42, 9.83 and 9.84 kg/cm²), total soluble solids (10.86, 11.20, 12.20, 12.80, 13.51 and 14.22%), ascorbic acid retention (10.51, 10.12, 9.25, 8.61, 8.20 and 7.45 mg/100g) and total sugars (6.68, 7.12, 7.24, 7.52, 7.86 and 7.92%) at 10, 20, 30, 40, 50 and 60 days after storage respectively. The highest marketable bulbs (61.48%) were also observed in this treatment which was closely followed by the bulbs cured under 35 per cent shade without foliage.

6.2 Effect of different storage methods on storability of onion

The effect of different storage conditions *viz.*, bamboo battens thatched roof structure (sugarcane trash) without bottom ventilation, bamboo battens low cost storage

structure with bottom and side ventilation, bamboo battens storage structure with AC sheet roofing with bottom and side ventilation, wooden battens storage structure with AC sheet roofing with bottom and side ventilation, wooden battens storage structure with galmenium sheet roofing with bottom and side ventilation, wooden battens storage structure with mangalore tiles roofing with bottom and side ventilation, welded mesh cage with bottom and side ventilation, plastic crates storage, nylon net bags storage and gunny bags on storage quality and per cent marketable bulbs were studied.

The bulbs stored under (T₃) bamboo battens storage structure with AC sheet roofing with bottom and side ventilation recorded minimum physiological loss in weight (2.46, 4.82, 6.48, 7.42, 8.60 and 9.86%), rotting (2.00, 2.46, 3.00, 3.48 and 4.20% at 30, 45, 60, 75 and 90 days after storage respectively), black mould incidence (1.00, 2.16, 3.50% at 60, 75 and 90 days after storage respectively), dry matter (11.50, 12.20, 12.76, 13.58, 15.00 and 15.44%), per cent loss of scales (2.66, 4.98, 7.00, 9.19, 11.00 and 13.08 %) and maximum moisture content (88.50, 87.80, 87.24, 86.42, 85.00 and 84.56%), hardness (9.60, 10.26, 10.60, 10.86, 11.20 and 11.44 kg/cm²), total soluble solids (14.30, 14.72, 14.81, 15.14, 15.22 and 16.20 %), ascorbic acid retention (13.26, 12.14, 10.83, 10.00, 9.46 and 8.48 mg/100g) and total sugars (9.98, 9.94, 10.38, 10.70, 11.44 and 12.00%) at 15, 30, 45, 60, 75 and 90 days after storage respectively. The highest percentage of marketable bulbs (97.54, 93.18, 91.06, 89.58, 87.92, 85.94% at 15, 30, 45, 60, 75 and 90 days after storage respectively) were also obtained in bamboo battens storage structure with AC sheet roofing with bottom and side ventilation followed by bulbs stored in wooden battens storage structure with galmenium sheet roofing and with bottom and side ventilation (97.00, 92.64, 88.58, 84.54, 81.60 and 80.20% at 15, 30, 45, 60, 75 and 90 days after storage respectively) which was on par with wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation (96.66, 91.31, 86.56, 83.68, 82.18 and 80.16% at 15, 30, 45, 60, 75 and 90 days after storage respectively) and bulbs stored in wooden battens storage structure with AC sheet roofing and with bottom and side ventilation (96.88, 91.80, 88.24, 83.88, 81.03 and 80.12% at 15, 30, 45, 60, 75 and 90 days after storage respectively).

6.3 Economics of different storage methods of onion

Among the different storage conditions the highest net returns (Rs.395.78) and highest return per rupee spent (1.62) was found in the bulbs stored under (T₃) bamboo battens with AC sheet roofing and with bottom and side ventilation. This was due to more marketable

bulbs (85.94 %) and lower physiological loss in weight (9.86%) and rotting (4.20%). This was followed by bulbs cured under wooden battens with galmenium sheet roofing and with bottom and side ventilation with net returns (Rs.331.90), return per rupee spent (1.53) and wooden battens storage structure with mangalore tiles roofing and with bottom and side ventilation with net returns (Rs.331.92), return per rupee spent (1.52).

CONCLUSION

- The curing of onion bulbs under 35 per cent shade with foliage has good storage capacity with highest percentage of marketable bulbs and lower percentage of storage losses compared to other curing methods.
- The bulbs stored under bamboo battens with AC sheet roofing with bottom and side ventilation has good storage capacity with highest percentage of marketable bulbs and lower percentage of storage losses compared to other storage conditions.
- The bulbs stored under bamboo battens with AC sheet roofing with bottom and side ventilation has maximum net returns and return per rupee spent compared to other storage conditions.

Future line of work

- Artificial curing of bulbs through solar dryer and vaccum curing has to be tried for curing of *kharif* onion where climate is not suitable for field curing.
- Artificial curing with lower temperature for longer duration are to be tried (25-35 °C).
- Storage studies are conducted to evaluate the losses with different types of storage structures with locally available low cost materials for bulk storage.

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7. REFERENCES

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APPENDICES



Appendix-I

Minimum and maximum temperature and relative humidity recorded in different curing methods

Date	Curing under polytunnel				Curing under 35 per cent shade				Curing under 100 per cent shade			
	Temperature (°C)		Relative humidity (%)		Temperature (°C)		Relative humidity (%)		Temperature (°C)		Relative humidity (%)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
4-12-2010	44.6	38.50	58.20	30.24	33.24	20.45	60.24	56.42	24.82	18.24	60.82	52.4
5-12-2010	45.24	39.24	60.24	32.44	35.26	26.42	58.24	33.24	25.43	20.84	62.48	34.28
6-12-2010	46.24	38.34	61.26	34.64	36.48	28.44	56.24	34.20	24.36	18.64	63.44	38.62
7-12-2010	42.84	34.24	62.42	32.44	32.45	23.45	58.62	34.24	22.64	16.24	62.24	38.24
8-12-2010	46.82	32.26	63.26	33.48	36.24	35.24	56.45	35.28	25.34	20.24	64.68	36.46
9-12-2010	42.64	33.84	68.20	38.70	33.24	24.24	60.32	30.24	23.54	18.24	62.84	38.54
10-12-2010	40.24	32.84	64.68	30.05	31.54	21.45	59.24	32.14	22.62	16.14	64.28	34.24
11-12-2010	38.26	36.44	65.24	31.28	32.45	22.24	58.66	33.82	21.32	18.26	66.54	35.64
12-12-2010	44.34	32.82	66.24	32.06	32.42	21.45	59.20	32.54	21.64	17.64	62.38	34.62
13-12-2010	46.28	34.28	60.14	30.24	34.64	23.45	58.42	36.26	22.46	19.24	66.14	38.44
14-12-2010	-	-	-	-	32.88	24.62	60.28	32.64	24.34	18.24	64.54	34.28
15-12-2010	-	-	-	-	-	-	-	-	22.64	20.16	66.28	36.24

Appendix-II

Monthly minimum and maximum temperature and relative humidity recorded under different storage conditions

Particular	Temperature (°C)						Relative humidity (%)					
	March		April		May		March		April		May	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Thatched storage structure without bottom ventilation	32.28	26.42	34.26	28.24	40.24	24.65	70.62	35.24	68.24	34.28	66.28	36.24
Improved storage structure with bottom and side ventilation	32.84	28.24	36.24	30.64	42.24	34.28	68.24	32.48	66.24	32.47	62.64	32.28
Bamboo battens AC sheet roofing structure with bottom and side ventilation	33.26	26.54	35.24	28.62	38.24	30.24	67.24	33.24	64.28	32.24	60.24	30.24
Wooden battens AC sheet roofing structure with bottom and side ventilation	34.24	28.46	36.44	28.84	38.64	30.58	68.28	34.24	66.24	32.28	62.28	32.42
Mangalore tiles roofing storage structure with bottom and side ventilation	34.58	28.42	36.54	29.16	38.44	30.04	68.00	34.00	66.38	33.00	62.68	32.84
Galmenium sheet roofing storage structure with bottom and side ventilation	34.88	29.14	37.66	30.42	39.14	30.24	68.64	34.82	66.92	32.64	61.54	31.24
Ambient storage	32.24	24.62	33.24	26.42	38.24	26.42	71.24	36.28	69.42	35.64	67.28	34.62

Appendix-III.

Information on different storage structures

Particulars	Thatched storage structure	Improved storage structure	Bamboo battens AC sheet roofing structure	Wooden battens AC sheet roofing structure	Mangalore tiles roofing storage structure	Galmenium sheet roofing storage structure	Welded mesh cage
Cost per unit dimension (Rs.)	9000	15,000	25,000	80,500	65,000	60,000	6000
Length (m)	3.6	3.6	3.6	3.0	3.0	3.0	1.8
Width (m)	1.5	1.5	1.5	1.2	1.2	1.2	0.75
Side height (m)	1.5	1.5	1.5	2.1	2.1	2.1	1.2
Central height(m)	2.1	2.1	2.1	3.0	3.0	3.0	-
Storage capacity (t)	3	3	3	12	6	6	1
Expected life (years)	5	10	20	50	50	50	30

Studies on curing and storage of Onion (*Allium cepa* L.)

REKHA EDA

2011

DR. LAXMAN KUKANOOR

MAJOR ADVISOR

Abstract

An investigation on studies on curing and storage of onion was carried out at the Department of Post harvest Technology, Kittur Rani Channamma College of Horticulture, Arabhavi during 2010-2011.

Among the different curing methods, the onion bulbs cured under 35 per cent shade with foliage gave good results with respect to both physical and chemical parameters. The time taken for curing of onion bulbs in 35 per cent shade was about 264 hours. The bulbs cured under 35 per cent shade showed minimum physiological loss in weight (15.21%), sprouting (14.09%), rotting (9.22%), black mould incidence (4.16%), per cent loss of scales (14.24%), dry matter (12.85%) and maximum moisture (87.15%), hardness (9.84 kg/cm²), ascorbic acid retention (7.45 mg/100g), total soluble solids (14.22%) and total sugars (7.92%) after 60 days of storage. The highest per cent of marketable bulbs (61.48%) was also observed in the same treatment in cv. Bellary Red after 60 days of storage which was followed by the bulbs cured under 35 per cent shade without foliage.

Among the different storage methods, the onion bulbs stored under bamboo battens storage structure with AC sheet roofing with bottom and side ventilation gave good results with respect to both physical and chemical parameters. They showed minimum physiological loss in weight (9.86%), rotting (4.20%), black mould incidence (3.50%), dry matter (15.44%), per cent loss of scales (13.08%) and maximum moisture content (84.56%), hardness (13.28 kg/cm²), total soluble solids (16.20%), ascorbic acid retention (8.48mg/100g) and total sugars (12.00%) after 90 days of storage. The highest per cent marketable bulbs (85.94%) was also observed in bulbs stored under bamboo battens storage structure with AC sheet roofing with bottom and side ventilation in cv. Agri Found Light Red after 90 days of storage.

Among the different storage conditions the highest net returns (Rs. 395.78) and highest return per rupee spent (1.62) was found in the bulbs stored under bamboo battens with AC sheet roofing and with bottom and side ventilation followed by bulbs stored under galmenium sheet roofing and mangalore tile roofing.