**Effect of Packaging Materials, Storage Conditions and Duration on Shelf Life of Garlic Bulbs**

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**Abstract**

The effect of different packaging materials, storage conditions and duration on physiological weight loss and quality attributes was investigated at regular interval for a period of 9 months during storage study of garlic bulbs. The physiological weight loss of bulbs was found to increase with enhancement of storage period whereas moisture content, flavour strength and water activity of the garlic bulbs decreased gradually during storage period. The maximum physiological weight losses of the garlic bulbs ranged from 25 to 30% during 3rd to 5th months (August to October). These losses were due to the higher RH (upto 79%) of the storage environment. As compared to the garlic bulbs stored at 20 °C storage, the storage losses were higher in garlic bulbs stored at ambient conditions in perforated MS small tray, plastic tray and card box. Unlike the storage losses of garlic bulbs packed with perforated MS big tray, nylon netted bag and bamboo basket were higher at 20 °C storage than bulbs at ambient storage. The losses were minimum in case of card box storage in both conditions of storage.

**Key words:** Garlic bulbs, Packaging, Storage, Physiological weight loss, Flavour strength

**Practical Application**

The major problems related to the garlic bulb storage are moisture loss due to respiration, transpiration and microbiological spoilage. The post-harvest losses cause the increase of the price and decreases the availability. In order to find the solutions to overcome these losses, the present investigation has been focused on the changes in quality parameters such as physiological weight loss, moisture content, water activity and flavour strength, as affected by the various packaging materials and storage temperatures, which are important for the effective shelf life of the garlic bulbs.

1. **Introduction**

Garlic (*Allium sativum* L.) is an important and second most extensively grown *Allium species*. It has been known all over the globe as a precious spice since ancient times for foods and curing numerous diseases and physiological ailments. In the world, India is the second garlic producer with 5.27% share (FAO, 2017). India produced over 1.69 million tons in the year 2017-18. In India 78% share of the garlic was produced by Rajasthan, Madhya Pradesh, and Uttar Pradesh (Madhu et al., 2019). The chemical composition of garlic bulb includes enzymes, protein, vitamins (B1, B2, B6, C), flavonoids, minerals (Ca, Cu, Fe, Mn, P, K, Se), antioxidants and thiosulfinates. Garlic is mostly used in preparation of pickles, food processing, pharmaceutical and medicinal usage, ayurvedic formulations etc.

The consumption of garlic reduces the risk of cardiovascular disease and cancer (Arnault *et al.*, 2005). Garlic is considered the main source of allicin which appears to be effective against *E. coli, Staphylococcus aureus, Clostridium perfringens* and *Salmonella* spp. (Yu and Wu, 1989).

Most of garlic is consumed as such in developing nations and a few efforts have been made to produce garlic paste and powder. Moisture loss due to respiration, transpiration and microbiological spoilage are the major causes, which limit shelf life during storage of garlic bulb. High losses during storage have generated an interest in the development of garlic products such as granulates, powder, flakes, paste and oil and oleoresins. Availability of raw garlic at cheaper prices in many developing nations offers a very attractive opportunity for an entrepreneur to produce garlic products at competitive prices, particularly in view of cheaper labour available in these nations.

Almost 80% of garlic produce is stored by farmers and businessmen for domestic supply throughout the year (Tripathi et al., 2009). Traditional methods of garlic storage lead to physiological loss and deterioration due to pests and insects. The total losses during storage are of 25 to 40% under ambient conditions (Tripathi & Lawande, 2006). Naresh et al. (2013) and Sekara et al. (2017) reviewed the influence of storage duration and conditions on bulb losses in onion and garlic. Many of the garlic and onion growers in Khurda and Ganjam districts of Odisha store by binding and hanging them in bunches in the house (Naresh et al. 2013). Very few researchers have studied the post-harvest losses of garlic bulbs influenced by storage conditions like temperature, relative humidity and various storage structures (Lawande, 2018; Dhall & Ahuja, 2013;Tripathi et al.,2009; Tripathi & Lawande, 2006; Cantwell and Suslow, 2002; Cantwell, 2004; Miedema, 1994; Takagi, 1990).

The post-harvest handling, curing, storage conditions are important factors that affect the storage of garlic. These storage problems can be overcome to a great extent by adopting improved post-harvest technologies and storage structures. Prolonging the storage life of garlic will result in better remunerative prices to both producers and traders. Hence, scientific information on the storage of garlic bulbs is required to reduce post-harvest losses. Therefore, there is a need to standardize the storage parameters for the garlic bulbs in order to decrease the post-harvest losses and retention of flavour strength of bulbs.

1. **Material and methods**

Garlic bulbs of *yamuna safed* variety which are fully matured, cured and in good condition were procured from the experimental research farm of College of Technology and Engineering, Udaipur, Rajasthan for this investigation. Cleaned and graded undamaged garlic bulbs of ≥30 mm were used for conducting experimental trials.

* 1. **Storage of garlic bulbs**

The storage study of garlic bulbs was carried out at two storage temperatures (i.e. at room temperature storage and storage at 20 °C) in interaction with six types of packaging materials (i.e. perforated tray made with mild steel, plastic crate, card box, bamboo basket and nylon netted bag). The temperature and relative humidity were recorded daily at 10.00 AM, 01:00 PM and 04:00 PM during the entire storage period. Temperature and relative humidity were recorded using a Thermo-hygrometer (Make: Zeal, Model: PH1000; Accuracy: Temperature - ±1 °C, Relative Humidity - ±5%). The sample under storage was inspected and weighed every 30 days to determine the physiological weight losses. The diseased and died garlic cloves were removed manually every month. Garlic samples were taken randomly from different systems every month for the determination of moisture content and other quality characteristics viz., moisture content, flavour strength and water activity.

* + 1. **Physiological weight loss**

Weight loss during storage may be due to physiological reasons like dehydration and respiration and also due to diseases. The physiological loss in weight of the bulbs was recorded in 30 days intervals for 10 months using an electronic balance. The cumulative loss in weight of bulbs was calculated and expressed in percentage (%). Physiological loss in weight was calculated by using the formula given below.

 Physiological Weight loss (%) $\frac{P\_{o}-P\_{f}}{P\_{o}}$ ... (1)

Where,

Po - Initial weight of the storage garlic bulb (first day of storage)

Pf - Final weight of the stored garlic bulb (every 30 days)

* + 1. **Moisture content loss**

Moisture losses of garlic samples were recorded at 30-day intervals. Weighed garlic samples were dried using an oven at 105o C for 24 hours until a constant weight was obtained. Weight of dried samples was also recorded. The moisture content was calculated as follows:

 Moisture content (% wb.) $=\frac{M\_{w}-M\_{d}}{M\_{w}}×100$ … (2)

Where,

Mw= Sample weight before drying (kg)

 Md= Sample weight after drying (kg)

* + 1. **Flavour Strength**

Flavour strength was determined by modified method, based on oxidation of volatile content of onion by chloramine-T as reported by [Shankaranarayana](https://www.sciencedirect.com/science/article/pii/S0260877405002864%22%20%5Cl%20%22bib12) et al., 1981. Garlic sample of 15 g was suspended with 250 ml of distilled water in round bottom flask connected with steam distillator (JSGW India). Antifoaming agent and glass beads were added to ensure the uniform boiling. About 100 ml of distillate was collected by dipping the tip of the solution containing 35 ml 10 N sulphuric acid, 15 ml water and 20 ml chloramine-T. The chloramine-T left after reaction was calculated by adding 10 ml potassium iodide solution and titrating the liberated iodine with sodium thiosulfate using starch as indicator. A reagent blank was carried out under the same conditions. The difference in the titric values between the blank and the experimental corresponds to the chloramines-T consumed by steam distillate of garlic sample volatile content.

Flavour strength (%) = (V x N x 100)/ (W x F) ... (3)

Where,

V = Difference in volume (ml) of thiosulfate between blank and the experiment.

N = Normality of thiosulfate

W = Weight of garlic bulb used for oxidation

F = the experimental value of (ml) Chloramine – T per g of garlic oil (90 for garlic).

* + 1. **Water activity**

Water activity is a key parameter in the quality control of moisture sensitive food products. Excessive water in food products can lead to clumping, changes in consistency and reduced shelf life due to microbial growth and water migration. A digital water activity meter (Make: Novaina, Model: Labwift-aw) was used for measuring aw of garlic samples.

* 1. **Statistical analysis**

The influence of packaging materials, storage conditions and duration on the shelf life of the garlic bulb was studied using Analysis of Variance (ANOVA) completely randomized design (CRD) as suggested by Gomez and Gomez (1984 , with reference to 0.05 probability level.

1. **Results and discussion**
	1. **Metrological data of the storage systems**

The monthly maximum and minimum temperature and relative humidity during the storage was presented in Table 1. The maximum and minimum temperature was 23.9 and 17.4 oC corresponding to storage at 20 oC, and 16.2 and 32.9 oC to room temperature storage systems, respectively. The maximum and minimum relative humidity was 83.7 and 30.8% corresponding to storage at 20 oC and 81-30.8% to the room temperature storage systems during the storage period.

**<Table 1. Mean monthly temperature and relative humidity during the storage period>**

**Effect of storage system and packaging type on the physiological weight loss>**

Table 2 shows the total weight loss of the garlic during storage as affected by the storage system and package type. The results indicate that the total weight loss increases with the storage period. It can be seen after 270 days, in the 20 °C storage, the total weight losses ranged from 51.32 – 66.04% for the garlic bulbs which were packaged in different packaging materials. The lowest loses i.e. 40.15% observed in garlic bulbs stored in card (carton) box and highest loses i.e. 66.04% observed in nylon-netted bag followed by perforated MS big tray (63.33%), perforated MS small tray (59.72%), bamboo basket (59.15%) and plastic tray (52.00%).

In the ambient storage system, the total weight losses ranged from 52.30 to 57.27% for the garlic bulbs which were packaged in different packaging materials. The lowest loses i.e. 52.30% were observed in garlic bulbs stored in card (carton) box and highest loses i.e. 65.48% observed in nylon-netted bag followed by perforated MS small tray (62.51%), plastic tray (57.60%), perforated MS big tray (56.79%) and bamboo basket (54.54%). As compared to the garlic bulbs stored at 20 °C storage, at ambient storage the storage losses were more in garlic bulbs packed with perforated MS small tray, plastic tray, and card box. Similar results were reported by Lawande, 2018; Dhall & Ahuja, 2013;Tripathi et al.,2009; Tripathi & Lawande, 2006.

The storage losses of garlic bulbs packed with perforated MS big tray, nylon netted bag and bamboo basket were higher at 20 °C storage than bulbs at ambient storage. The interactions between temperature × duration, temperature × packaging material, packaging material × duration and temperature × packaging material × duration for physiological loss in weightwas significant at P≤0.01.

**< Table 2. Effect of storage environment and conditions on the accumulative physiological loss during the storage>**

* 1. **Effect of storage system and packaging type on the moisture content**

The moisture content is considered as one of the most important factors in maintaining product quality. The rate of water loss from the commodities depends upon the water pressure deficit between the commodity and the surrounding ambient air, which is influenced by the temperature and relative humidity.

Table 3 shows the accumulative moisture loss in the garlic bulbs during storage as influenced by the storage system and packaging type. The results indicate that the moisture content loss increased with the storage period. It can be seen after 270 days, in the 20 °C storage, the moisture content loses ranged from 8.48 to 11.71% for the garlic bulbs which were packaged in different packaging materials. The lowest loses i.e. 8.88% observed in garlic bulbs stored in card (carton) box and highest loses i.e. 11.71% observed in bamboo basket followed by perforated MS big tray (11.12%) perforated nylon-netted bag (11.07%), plastic tray (10.82%) and perforated MS small tray (10.04%).

In the ambient storage system, the moisture content losses ranged from 8.17 to 11.49% for the garlic bulbs which were packaged in different packaging materials. The lowest loses i.e. 8.7% observed in garlic bulbs stored in card (carton) box and highest loses i.e. 11.49% observed in bamboo basket followed by perforated nylon-netted bag (10.83%), perforated MS big tray (10.58%), perforated MS small tray (9.66%) and plastic tray (9.4%). These results were in similar to the results reported by Lawande, 2018; Dhall & Ahuja, 2013;Tripathi et al.,2009; Tripathi & Lawande, 2006. As compared to the garlic bulbs stored at 20 °C storage, at ambient storage the moisture content losses were lower in garlic bulbs packed with perforated MS small tray, perforated MS big tray, plastic tray, card box, bamboo basket and nylon netted bag. The interaction between temperature × duration, temperature × packaging material, packaging material × duration and temperature × packaging material × duration for moisture content lossis significant at P≤0.01.

**<Table 3. Effect of storage environment and conditions on the accumulative losses of garlic moisture during the storage>**

* 1. **Effect of storage system and packaging type on the flavour strength**

Table 4 shows the flavour strength in the garlic bulbs during storage as influenced by the storage system and packaging type. The results indicate that the flavour strength decreased with the storage period. The initial flavour strength of garlic sample was 0.526%. It can be seen after 270 days, at the 20 °C storage, the flavour strength ranged from 0.178 to 0.230% for the garlic bulbs which were packaged in different packaging materials. The lowest flavour strength i.e. 0.178% observed in garlic bulbs stored in nylon netted bag and highest flavour strength i.e. 0.23% observed in perforated MS big tray followed by bamboo basket (0.222%), plastic tray (0.207%) and perforated MS small tray as well as card (carton) box (0.193%).

 In the ambient storage system, the flavour strength ranged from 0.111 to 0.230% for the garlic bulbs which were packaged in different packaging materials. The lowest flavour strength i.e. 0.111% observed in garlic bulbs stored in perforated MS big tray and highest flavour strength i.e. 0.230% observed in bamboo basket followed by (0.222%), perforated MS small tray (0.222%), plastic tray (0.207%) and nylon netted bag (0.178%) and card (carton) (0.133%). As compared to the garlic bulbs stored at 20 °C storage, at ambient storage the flavour strength was more in garlic bulbs packed with perforated MS small tray and bamboo basket. The flavour strength of garlic bulbs packed with perforated MS big tray, nylon netted bag, bamboo basket plastic tray and card box was higher at 20 °C storage than bulbs at ambient storage. The interaction between temperature × duration, temperature × packaging material, packaging material × duration and temperature × packaging material × duration for flavor strengthis significant at P≤0.01.

**<Table 4. Effect of storage environment and conditions on the flavour strength of garlic bulb during the storage>**

* 1. **Effect of storage system and packaging type on the water activity**

The changes in the water activity of garlic bulbs stored in ambient storage and storage at 20 °C for different packaging materials are shown in the Table 5. The results revealed that there was a significant change in the water activity of the garlic bulbs stored in both the storage conditions. The initial water activity of garlic sample was 0.789. It can be seen after 270 days, in the 20 °C storage, the water activity ranged from 0.609-0.636 for the garlic bulbs which were packaged in different packaging materials. The lowest water activity i.e. 0.609 was observed in garlic bulbs stored in bamboo basket and highest water activity i.e. 0.635 was observed in plastic tray followed by perforated MS small tray (0.630), perforated MS big tray (0.627), nylon netted bag (0.616) and card (carton) box (0.614).

 In the ambient storage system, the water activity ranged from 0.586 to 0.617 for the garlic bulbs which were packaged in different packaging materials. The lowest water activity i.e. 0.586 was observed in garlic bulbs stored in nylon netted bag and highest water activity i.e. 0.609 was observed in card (carton) box followed by plastic tray (0.601), bamboo basket (0.595), perforated MS small tray (0.593), and perforated MS big tray (0.589). As compared to the garlic bulbs stored at 20 °C storage, at ambient storage the water activity was less in garlic bulbs packed with perforated MS small tray, perforated MS big tray, plastic tray, card box, bamboo basket and nylon netted bag. The interaction between temperature × duration, temperature × packaging material, packaging material × duration and temperature × packaging material × duration for flavor strengthwas significant at P≤0.01. The interaction between temperature × duration for water activity was found to be significant at P≤0.01 and the interaction between temperature × packaging material was found to be significant at P≤0.05 whereas the interaction between packaging material × duration and temperature × packaging material × duration for water activity was found to be non-significant.

**<Table 5. Effect of storage environment and conditions on the water activity of garlic bulb during the storage>**

1. **Conclusion**

The study revealed that the physiological weight loss of bulbs increased after 270 days (9 months) of garlic bulbs storage during storage period. Moisture content, flavour strength and water activity of the garlic bulbs decreased gradually during storage. The maximum physiological weight losses of the garlic bulbs stored at the both the at environment conditions (i.e. 20ºC temp. storage and ambient storage) ranged from 25 to 30% during 3rd to 5th months (August to October). These losses were due to the higher RH (65 to 79%) of the storage environment. As compared to the garlic bulbs stored at 20 °C storage, at ambient storage the storage losses were higher in garlic bulbs stored in perforated MS small tray, plastic tray and card box. Whereas the storage losses of garlic bulbs packed with perforated MS big tray, nylon netted bag and bamboo basket were higher at 20 °C storage than bulbs at ambient storage. The losses were observed minimum in case of card box storage for both conditions (ambient & 20 °C storage).

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