Int.J.Curr.Microbiol.App.Sci (2020) *9*(11): 611-622

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 11 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.911.075

Effect of Packing and Storage Methods on Quality and Shelf Life of Onion (*Allium cepa* L. var. *Aggregatum* Don.)

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Keywords

CO (ON) 5, Onion, Packing and storage methods, Quality and storage life

Article Info

Accepted:
07 October 2020
Available Online:
10 November 2020

ABSTRACT

In India, presently about 35 to 40 per cent of the onion is estimated to be lost as post-harvest losses during various operations including handling and storage. Serious losses occur during storage due to sprouting and rotting. Keeping this in view, an investigation was carried out to study the effect of different packing and storage methods on storage life of *aggregatum* onion cv. CO on 5. This experiment was conducted at Department of Vegetable Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2008-2010 and laid out in factorial completely randomized design (FCRD) with eight treatments and three replications. Pre-harvest spray with growth inhibitors and fungicides were given. The pre-harvest sprayed onion bulbs were harvested, cured and subjected to different packing and storage methods. Among the different packing and storage treatments, the lowest physiological loss in weight (5.18 %), sprouting (0.62 %), rotting (0.64 %), rooting (0.00 %), total loss (6.78 per cent) and quality parameters *viz*., TSS (17.22 °Brix), ascorbic acid (10.24 mg 100 g^{-1}), pyruvic acid (2.53 µmol g^{-1}), sulphur content (0.704 %), total phenolics content (625.56 µg g^{-1}), phenylalanine ammonia lyase activity (6.86 µg $ml^{-1}min^{-1}$), peroxidase activity (1.825 absorbance $g^{-1}min^{-1}$) and polyphenol oxidase activity (1.321 absorbance $g^{-1}min^{-1}$) were observed and bulbs in ventilated room temperature storage method. The harvested bulbs stored under low cost bottom ventilated storage structure realized maximum shelf life (up to 6 months) compared to spreading of bulbs in room temperature.

Introduction

Onion is one of the potential foreign exchange earners and is one among the vegetables, where India figures prominently in the world's export market. India stands first in production sharing eight per cent of the world production. During 2018-19, onion is cultivated in an area of 21.85 lakh ha with the production of 232.62 lakh tons (National Horticultural Board, 2019). The major Onion producing states are Maharashtra, Madhya Pradesh, Karnataka, Bihar, Rajasthan, Andhra Pradesh, Haryana, West Bengal, Gujarat and Uttar Pradesh in the country. These States account for almost 90 per cent of the total onion production of the country. Multiplier onion or aggregatum onion (*Allium cepa* var.

aggregatum L.) is one of the most important commercial vegetable crops grown in South India especially in Tamil Nadu and Karnataka. The aggregatum onion accounts for nearly 75 percent of the total onion produced in Tamil Nadu with an average productivity of 12 tonnes per hectare (Pugalendhi *et al.,* 2020).

The aggregatum onion produces many number of smaller sized bulbs in cluster form and mostly preferred for their tolerance to pest and diseases and longest storage life than common onion (Brewster, 2008, Anbukkarasi *et al.,* 2012, Anbukkarasi *et al.,* 2013, Pugalendhi *et al.,* 2011a, Pugalendhi *et al.,* 2011b,). Onion possess Quercetin and volatile sulfur compounds which helps in anemia, skin disorders, stomach cancer, eye infection, prevent asthma attack (Ahmed and Bassuorry, 2009 and Lanzotti *et al.,* 2012). The bulb provides 2.0 g protein, 72 mg calcium and 54 mg phosphorus. It also contains vitamins *viz.,* thiamine, riboflavin and niacin and is used for its medicinal value especially in the case of heart problems (Mettananda and Fordham, 2001 and Shabina *et al.,* 2020). Onions contain phenolics and flavonoids that have potential antiinflammatory, anticholesterol, anticancer and antioxidant properties. Onion is highly nutritional and it is used for lowering the toxigenicity of oils. It also shows chemo-preventive effects and lowers down the risk of effect on gastric cancer

The *aggregatum* onion cv. CO On 5 has got better market preference because of its size and appealing attractive pink colour. In India, presently about 35 to 40 per cent of the onion is estimated to be lost as post-harvest losses during various operations including handling and storage. In general, the losses due to reduction in weight, sprouting and rotting (decay) were found to be 20 to 25, 4 to 5 and 10 to 12 per cent respectively (Pandey, 1989; Anon., 1994). The bulb respires and transpires continuously resulting in high weight loss and becomes susceptible to various diseases and spoilage due to inappropriate packaging. Adequate and proper packaging protects the bulb from physical (firmness), physiological (weight) and pathological (decay) deterioration.

One of the major problems confronted by small onion growers is the post-harvest losses due to lack of proper storage structures or lack of suitable field techniques to prevent or minimize these losses during storage. Post-harvest losses mainly manifest through weight loss, sprouting, rooting and rotting of the bulbs etc. Pre-harvest sprays using growth regulator coupled with fungicide were tried in small onion bulbs in order to study their effects in the post-harvest physiology of the bulbs. Use of a proper structure is also one of the methods by which the post-harvest losses can be minimized. In Tamil Nadu, the onion growers are using a local structure called '*pattarai*' in which the onions may be stored for a maximum period of four months. The cost of the '*pattarai*' is comparatively very cheap but the post-harvest losses are considerable, the shelf life is very short and the structure cannot be reused. With this background, the present investigation was carried out to standardize the appropriate packing and storage techniques for enhancing quality and shelf life of onion cv. CO On 5.

Materials and Methods

The present investigations were carried out at the College Orchard, Tamil Nadu Agricultural University, Coimbatore. In addition to regular cultivation practices, Cycocel @ 200 ppm + Carbendazim @ 1000 ppm at 30 days before harvest was sprayed and the bulbs were harvested with 2.0 cm neck length were used in storage studies for three months. At the end of curing period, a composite sample of five kg bulbs were packed in different packing materials *viz.*, 40kg open mesh jute bags weighing 250g, 40kg open mesh nylon net bags weighing 60g, baskets made up with split bamboo sticks (20 x 15 x 25cm) of 5kg capacity, perforated plastic crates (50 x 30 x 28cm) of 15kg capacity and the bulbs were stored in two methods *i.e.*, low cost ventilation storage (constructed as per the specifications given by Tripathi and Lawande, 2005) and two different cold storage environments *viz.*, 15^0C with 60 % RH and 20^0C with 80% RH. The details of the treatments are given below.

Design: Factor completely randomized design

Factor A - Type of packing and storage (T)
Factor B - Period of storage (P)

Factor A. Treatments

T_1 -	Packing in jute bags and kept in room temperature
T_2 -	Packing in nylon net bags and kept in room temperature
T_3 -	Packing in perforated plastic crates and kept in room temperature
T_4 -	Packing in bamboo baskets and kept in room temperature
T_5 -	Spreading of bulbs in ventilated storage
T_6 -	Spreading of bulbs in cold storage at 15^oC
T_7 -	Spreading of bulbs in cold storage at 20^oC
T8 -	Spreading of bulbs in room temperature (Control)

Factor B - Period of storage (P)

P_1- 30 days after storage; P_2- 60 days after storage; P_3- 90 days after storage

Replications: Three Initial observations were recorded before imposing treatments and the storage observations were recorded at 30, 60 and 90 days after storage (monthly intervals). The bio-chemical parameters *viz.,* total soluble solids (hand refractometer technique), ascorbic acid (AOAC, 1975), soluble protein (Lowery *et al.*, 1971), sulphur (Chopra and Kanwar, 1991), pyruvic acid and total phenols (Bray and Thorpe, 1954) were studied. The enzyme activities *viz.*, peroxidase (Srivastava, 1987), polyphenol oxidase (Mayer *et al.*, 1965) and phenylalanine ammonia lyase activity (Dickerson *et al.*, 1984) were analyzed.

The physiological parameters *viz.*, physiological loss in weight (PLW), sprouting loss, rotting loss, total loss (PLW + sprouting loss+ rotting loss) also calculated as per the standard procedures. The per cent marketable bulbs were calculated by adopting the following formula.

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

The rooted bulbs from the storage room were taken out, the weight was recorded and rooting loss was worked out accordingly.

$$\text{Rooting loss (\%)} = \frac{\text{Weight of the rooted bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

The data obtained from the present investigation were subjected to statistical scrutiny by adopting the standard procedure of Panse and Sukhatme (1985).

Results and Discussion

Onion bulbs in storage generally undergo loss in weight owing to physiological changes like sprouting, rooting, rotting and desiccation, nutritional and other bio-chemical changes.

Physiological changes

The lowest physiological loss in weight (5.18 per cent), sprouting (0.62 per cent), rotting (0.64 per cent), rooting (0.00 per cent), total loss (8.19 per cent) and the highest marketable bulb (81.33 %) was observed in T_5 (Spreading of bulbs in ventilated storage). Physiological loss in weight, rotting rooting and total loss was increased during the storage period. The least physiological loss in weight (6.76 per cent), rotting (0.04 per cent), rooting (3.63 per cent), total loss (13.52 per cent) and also the highest marketable bulbs (73.85 %) was recorded in P_1 (30 days after storage). As the storage period increased from 30 to 90 days, sprouting also increased, except in cold storage treatments. In cold storage 90 per cent sprouting was obtained 30 days after storage. The least sprouting was registered in P_3 (90 days after storage) recording values of 1.50 per cent (Table 1, 2 & 3). Interaction between treatments and period of storage showed that, the minimum value of physiological loss in weight (2.72 per cent), sprouting (0.15 per cent), rotting (0.00 per cent), rooting (0.00 per cent), total loss (4.17 per cent) and also maximum marketable bulbs (88.12 and 90.95 %) were recorded in interaction of T_5P_1 (Spreading of bulbs in ventilated storage for 30 days). In the present study, weight loss in bulbs was found to increase with increase in the storage period. Palaniswamy (1980) and Vincent (1980) in small onion also observed a similar phenomenon in storage.

In the present investigation, the bulbs stored in low cost bottom ventilated structure recorded the lowest physiological loss in weight, which is in accordance with the findings of Kopec (1963). This might be due to proper aeration, causing decreased temperature and humidity level inside the structure.

The dormant buds enclosed in the fleshy scales start sprouting in storage and earlier the sprouting in storage, the more is the loss to the growers as the sprouted bulbs have lesser weight than the non-sprouted ones. In the present study, the effect of various treatments on the sprouting of onion bulbs in storage showed that the bulbs started sprouting only after one month of storage. In the present finding, the bulbs kept under low cost bottom ventilated storage structure recorded less sprouting. The results of the present investigation are in conformity with the findings of Singh and Dhankhar (1995) and Kukanoor *et al.,* (2005).

Rotting of onion bulbs is normally met during storage due to the pathogens, *viz*., *Botrytis allii* and *Pseudomonas alliicola* causing neck rot and soft rot developed due to excess humidity in the storage environment and mechanical damage during handling cause considerable loss to the growers. In the present investigation, pre-harvest sprayed bulbs stored in low cost bottom ventilated structure recorded reduced the rotting incidence. This might be due to good aeration and less humidity and optimum temperature inside the structure when compared to outside environment. Similar views were expressed by Shanthi and Balakrishnan (1989) and Waskar *et al.,* (2004). The storage losses in onion bulbs are due to the triggering of metabolic process. Initiation of rooting is the triggering agent which results in depletion of stored food materials which are used as substrates for growth and development of the shoot initials. So, for proper storage of onion bulbs, the metabolic processes have to be blocked. In the present investigation, pre-harvest sprayed bulbs stored in low cost bottom ventilated structure showed lowest rooting. This might be due to less humidity inside the storage structure when compared to outer region. Higher levels of humidity enhanced the rooting (Jones and Mann, 1963).

Table.1 Effect of packing and storage methods on physiological loss in weight (%) and sprouting (%) content in onion

Treatments	Physiological loss in weight (%)				Sprouting (%)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	5.33 (13.35)	7.53 (15.93)	13.75 (21.77)	**8.87 (17.02)**	0.27 (2.56)	0.83 (5.24)	1.30 (6.55)	**0.80 (4.78)**
T_2	4.00 (11.54)	5.72 (13.83)	11.83 (20.12)	**7.18 (15.16)**	0.25 (2.87)	0.75 (4.97)	1.23 (6.38)	**0.74 (4.74)**
T_3	3.55 (10.86)	4.67 (12.48)	10.52(18.91)	**6.25 (14.08)**	0.20 (2.56)	0.70 (4.80)	1.15 (6.16)	**0.68 (4.51)**
T_4	6.95 (15.29)	8.92 (17.37)	15.70 (23.34)	**10.52 (18.67)**	0.35 (3.39)	1.00 (5.74)	1.32(6.59)	**0.89 (5.24)**
T_5	2.72 (9.49)	3.00 (11.54)	9.83 (18.28)	**5.18 (13.10)**	0.15 (2.22)	0.55 (4.25)	1.15 (6.16)	**0.62 (4.21)**
T_6	11.98 (20.25)	13.87 (21.86)	21.10 (27.35)	**15.65(23.15)**	16.00 (23.58)	12.00 (20.27)	2.27 (8.59)	**10.09 (17.48)**
T_7	10.77 (19.16)	12.62 (20.98)	19.80 (26.42)	**14.40 (22.19)**	15.00 (22.79)	10.00 (18.44)	2.17 (8.46)	**9.06 (16.56)**
T_8	8.78 (17.24)	10.78 (19.17)	17.47 (24.70)	**12.34 (20.37)**	0.50 (4.05)	1.10 (6.02)	1.40 (6.80)	**1.00 (5.62)**
Mean	**6.76 (14.65)**	**8.39 (16.65)**	**15.00 (22.61)**	**10.05 (17.97)**	**4.09 (8.00)**	**3.74 (8.72)**	**1.50 (6.96)**	**3.11 (7.89)**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.019	0.012	0.033		0.032	0.019	**0.055**	
CD (0.05)	**0.038**	**0.023**	**0.065**		**0.063**	**0.038**	**0.109**	

Table.2 Effect of packing and storage methods on rotting (%) and rooting (%) in onion

Treatments	Rotting (%)				Rooting (%)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	0.00 (0.91)	0.99 (5.72)	1.48 (6.99)	**0.82 (4.54)**	0.00 (0.91)	0.00 (0.91)	0.00 (0.91)	**0.00 (0.91)**
T_2	0.00 (0.91)	0.96 (5.63)	1.35 (6.67)	**0.77 (4.40)**	0.00 (0.91)	0.00 (0.91)	0.00 (0.91)	**0.00 (0.91)**
T_3	0.00 (0.91)	0.90 (5.44)	1.33 (6.63)	**0.74 (4.33)**	0.00 (0.91)	0.00 (0.91)	0.00 (0.91)	**0.00 (0.91)**
T_4	0.00 (0.91)	1.03 (5.83)	1.72 (7.53)	**0.92 (4.76)**	0.00 (0.91)	0.00 (0.91)	0.00 (0.91)	**0.00 (0.91)**
T_5	0.00 (0.91)	0.85 (5.29)	1.08 (5.97)	**0.64 (4.06)**	0.00 (0.91)	0.00 (0.91)	0.00 (0.91)	**0.00 (0.91)**
T_6	0.12 (1.95)	1.12 (6.07)	2.05 (8.23)	**1.10 (5.42)**	13.00 (21.13)	16.67 (24.10)	31.33 (34.04)	**20.33 (26.42)**
T_7	0.05 (1.28)	1.05 (5.88)	1.95 (8.03)	**1.02 (5.06)**	16.00 (23.58)	20.83 (27.16)	32.67 (34.86)	**23.17 (28.53)**
T_8	0.12 (1.95)	1.22 (6.33)	2.07 (8.27)	**1.14 (5.52)**	0.00 (0.91)	0.00 (0.91)	0.00 (0.91)	**0.00 (0.91)**
Mean	**0.04 (1.22)**	**1.02 (5.77)**	**1.57 (7.29)**	**0.87 (4.76)**	**3.63 (6.27)**	**4.69 (7.09)**	**8.00 (9.30)**	**5.44 (7.55)**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.021	0.013	0.036		0.047	0.029	**0.082**	
CD (0.05)	**0.041**	**0.025**	**0.071**		**0.094**	**0.058**	**0.163**	

Table.3 Effect of packing and storage methods on total loss (%) and marketable bulbs (%) in onion

Treatments	Total loss (%)				Marketable bulbs (%)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	5.60 (13.69)	9.36 (17.81)	16.53 (23.99)	**10.50 (18.50)**	85.12 (67.31)	73.52 (59.03)	63.70 (52.96)	**74.11 (59.77)**
T_2	4.25 (11.90)	7.43 (15.82)	14.42 (22.32)	**8.70 (16.68)**	85.78 (67.85)	73.85 (59.25)	70.77 (57.27)	**76.80 (61.46)**
T_3	3.75 (11.17)	6.27 (14.50)	12.98 (21.12)	**7.67 (15.60)**	86.05 (68.07)	77.57 (61.73)	72.23 (58.20)	**78.62 (62.67)**
T_4	7.30 (15.68)	10.95 (19.32)	18.73 (25.65)	**12.33 (20.22)**	84.00 (66.42)	72.67 (58.48)	67.85 (55.46)	**74.84 (60.12)**
T_5	2.87 (9.75)	5.40 (13.44)	12.07 (20.33)	**6.78 (14.51)**	90.95 (72.49)	79.07 (62.77)	73.98 (59.33)	**81.33 (64.86)**
T_6	28.10 (32.01)	26.98 (31.30)	25.38 (30.25)	**26.82 (31.19)**	35.78 (36.74)	30.52 (33.53)	22.77 (28.50)	**29.69 (32.92)**
T_7	25.82 (30.54)	23.87 (29.25)	23.92 (29.28)	**24.54 (29.69)**	38.97 (38.63)	34.03 (35.69)	28.62 (32.34)	**33.87 (35.55)**
T_8	9.40 (17.85)	13.10 (21.22)	20.93 (27.23)	**14.48 (22.10)**	84.13 (66.53)	68.97 (56.15)	61.78 (51.82)	**71.63 (58.17)**
Mean	**10.89 (17.82)**	**12.92 (20.33)**	**18.12 (25.02)**	**13.98 (21.06)**	**73.85 (60.51)**	**63.78 (53.33)**	**57.71 (49.49)**	**65.11 (54.44)**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.029	0.018	0.050		0.036	0.022	**0.063**	
CD (0.05)	**0.057**	**0.035**	**0.099**		**0.072**	**0.044**	**0.125**	

Table.4 Effect of packing and storage methods on TSS (°Brix) and ascorbic acid (mg 100 g^{-1}) content in onion

Treatments	TSS content (°Brix)				Ascorbic acid content (mg 100 g^{-1})			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	14.77	16.52	18.55	**16.61**	9.75	9.67	9.48	**9.63**
T_2	14.82	16.58	18.62	**16.67**	9.96	9.83	9.75	**9.85**
T_3	15.02	16.78	18.80	**16.87**	10.12	9.95	9.82	**9.96**
T_4	14.52	16.38	18.38	**16.43**	9.68	9.50	9.07	**9.42**
T_5	15.17	17.15	19.33	**17.22**	10.60	10.12	9.99	**10.24**
T_6	14.13	16.15	18.27	**16.18**	9.17	9.08	8.93	**9.06**
T_7	14.18	16.20	18.32	**16.23**	9.47	9.25	9.00	**9.24**
T_8	14.03	16.08	18.03	**16.05**	8.90	8.68	8.47	**8.68**
Mean	**14.58**	**16.48**	**18.54**	**16.53**	**9.71**	**9.51**	**9.31**	**9.51**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.007	0.005	0.013		0.051	0.031	**0.087**	
CD (0.05)	**0.015**	**0.009**	**0.026**		**0.100**	**0.061**	**0.174**	

Table.5 Effect of packing and storage methods on pyruvic acid content (µmol g^{-1}) and sulphur content (%) in onion

Treatments	Pyruvic acid content (µmol g^{-1})				Sulphur content (%)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	2.48	2.44	2.35	**2.42**	0.622	0.692	0.745	**0.686**
T_2	2.50	2.46	2.37	**2.44**	0.630	0.695	0.755	**0.693**
T_3	2.59	2.50	2.40	**2.50**	0.635	0.698	0.765	**0.699**
T_4	2.44	2.40	2.34	**2.39**	0.617	0.685	0.740	**0.681**
T_5	2.60	2.54	2.44	**2.53**	0.643	0.700	0.768	**0.704**
T_6	2.39	2.36	2.28	**2.34**	0.596	0.673	0.688	**0.652**
T_7	2.40	2.39	2.30	**2.36**	0.603	0.675	0.693	**0.657**
T_8	2.35	2.34	2.25	**2.31**	0.610	0.680	0.713	**0.668**
Mean	**2.47**	**2.43**	**2.34**	**2.41**	**0.620**	**0.687**	**0.733**	**0.680**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.004	0.002	0.006		0.005	0.000	**0.001**	
CD (0.05)	**0.007**	**0.004**	**0.012**		**0.001**	**0.001**	**0.002**	

Table.6 Effect of packing and storage methods on phenylalanine ammonia lyase activity (µg $ml^{-1}min^{-1}$) and peroxidase activity (absorbance $g^{-1}min^{-1}$) in onion

Treatments	Phenylalanine ammonia lyase activity (µg $ml^{-1}min^{-1}$)				Peroxidase activity (absorbance $g^{-1}min^{-1}$)			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	5.97	5.00	4.20	**5.06**	1.831	1.662	1.642	**1.712**
T_2	6.30	5.81	5.18	**5.76**	1.833	1.689	1.670	**1.731**
T_3	7.20	6.30	5.64	**6.38**	1.848	1.708	1.683	**1.746**
T_4	5.30	4.80	4.10	**4.73**	1.819	1.472	1.255	**1.515**
T_5	7.75	6.80	6.04	**6.86**	1.895	1.818	1.763	**1.825**
T_6	3.46	2.80	2.00	**2.75**	1.312	0.821	0.647	**0.927**
T_7	4.84	3.70	2.89	**3.81**	1.442	1.063	0.777	**1.094**
T_8	5.15	4.15	3.40	**4.23**	1.810	1.453	1.240	**1.501**
Mean	**5.75**	**4.92**	**4.18**	**4.95**	**1.724**	**1.461**	**1.335**	**1.506**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.003	0.002	0.005		0.002	0.001	**0.003**	
CD (0.05)	**0.006**	**0.004**	**0.010**		**0.003**	**0.002**	**0.005**	

Table.7 Effect of packing and storage methods on polyphenol oxidase activity (absorbance $g^{-1}min^{-1}$) and total phenolics (µg g^{-1}) in onion

Treatments	Polyphenol oxidase activity (absorbance $g^{-1}min^{-1}$)				Total phenolics (µg g^{-1})			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
T_1	1.345	1.194	1.151	**1.230**	622.33	608.67	610.00	**613.67**
T_2	1.362	1.247	1.204	**1.271**	631.67	611.67	613.67	**619.00**
T_3	1.369	1.280	1.216	**1.288**	635.33	619.00	615.67	**623.33**
T_4	1.317	1.058	0.909	**1.095**	619.00	605.67	606.00	**610.22**
T_5	1.382	1.323	1.258	**1.321**	638.33	622.67	615.67	**625.56**
T_6	0.868	0.707	0.571	**0.715**	531.00	531.67	516.00	**526.22**
T_7	0.985	0.807	0.611	**0.801**	558.33	540.67	528.00	**542.33**
T_8	1.310	1.031	0.789	**1.043**	620.00	598.33	582.67	**600.33**
Mean	**1.242**	**1.081**	**0.964**	**1.096**	**607.00**	**592.29**	**585.96**	**595.08**
	T	**P**	**T x P**		**T**	**P**	**T x P**	
SEd	0.002	0.001	0.004		0.455	0.278	**0.788**	
CD (0.05)	**0.004**	**0.002**	**0.007**		**0.902**	**0.553**	**1.563**	

In the present investigation, pre harvest sprayed onion bulbs harvested with 2cm neck bulbs stored in low cost bottom ventilated structure recorded the highest per cent of marketable bulbs compared to other treatments. This may be attributed to minimum physiological loss in weight, rotting and sprouting in these treatments (Blanco and Oliveira, 1971).

Biochemical changes

The highest TSS (16.83 ^{o}brix), ascorbic acid (9.59 mg 100g^{-1}), pyruvic acid (2.48µmol g^{-1}), sulphur (0.694 per cent), total phenolics content (621.08 µg g^{-1}), phenylalanine ammonia lyase activity (6.44 µg ml^{-1}min^{-1}) , peroxidase activity (1.789 absorbance g^{-1} min^{-1}) and polyphenol oxidase activity (1.237 absorbance g^{-1}min^{-1}) was recorded in T_5 (Spreading of bulbs in ventilation storage). The storage period increased from 30 to 90 days, the ascorbic acid, pyruvic acid, total phenolic content, phenylalanine ammonia lyase activity, peroxidase and polyphenol oxidase activity decreased. The maximum ascorbic acid (8.85mg 100 g^{-1}), pyruvic acid (2.42 µmol g^{-1}), total phenolics content (600.01 µg g^{-1}) , phenylalanine ammonia lyase activity (5.41 µg ml^{-1}min^{-1}), peroxidase activity (1.661 absorbance g^{-1}min^{-1}) and polyphenol oxidase activity (1.115 absorbance g^{-1}min^{-1}) was registered in P_1 (30 days after storage). As the storage period increased from 30 to 90 days, the TSS and sulphur content was increased. The highest TSS (17.90 ^{o}brix) and sulphur content (0.726 per cent) was noticed in P_3 (90 days after storage). Interaction between treatments and period of storage showed that the maximum ascorbic acid (9.95 mg 100 g^{-1}), pyruvic acid (2.53 µmol g^{-1}), sulphur content (0.755 per cent), total phenolics content (631.89 µg g^{-1}), phenylalanine ammonia lyase activity (7.23 µg ml^{-1}min^{-1}), peroxidase activity (1.830 absorbance g^{-1}min^{-1}) and polyphenol oxidase activity (1.267 and 1.273 absorbance g^{-1}min^{-1}) was observed in T_5P_1 (Spreading of bulbs in ventilated storage + 30 days after storage) and also the highest TSS content of 18.49^{o}brix was noticed in T_5P_3 (Spreading of bulbs in ventilated storage + 90 days after storage) (Table 4, 5, 6 & 7).

In the present study, the quality parameters of bulbs improved gradually in all the treatments during storage. It might be due to gradual decrease in moisture content of the bulbs during storage and consequent increase in concentration of nutrients present in the tissue. The respiratory rate would be low due to loss of moisture causing increased content of total sugars. These findings are in agreement with the findings of Misra and Pande (1979).

The TSS contributes major part in turgidity maintenance of bulbs and which is governed by the osmo-regulatory mechanism. Increased TSS content evidently shows that the stored food materials undergo either partial or complete hydrolysis and provide substrates for respiration. In the present study, the TSS content of the bulbs, in general, showed an increasing trend with increase in the storage period. This may be due to break down of complex polymers in to simple substances by hydrolytic enzymes (Deol, 1985). Similar observations were also recorded by Palaniswamy (1980).

In the present investigation, the ascorbic acid and pyruvic acid content of the bulbs, decreased gradually with the increase in storage period. This may be due to oxidation of L-ascorbic acid in to dehydro ascorbic acid by enzyme ascorbinase (Joshi and Roy, 1985). In the present study, pyruvic acid content decreased as the storage period increased. The results are also supported by the findings of Shock *et al.,* (2004). The sulphur content of the bulbs gradually increased in all the treatments as the storage period advanced. In the present investigation, pre-harvest sprayed bulbs stored in low cost bottom ventilated structure registered higher sulphur content.

Further, pre-harvest sprayed bulbs stored in low cost bottom ventilated structure showed increased phenylalanine ammonia lyase, peroxidase and polyphenol oxidase activity. The enzymes indirectly reduced the sprouting percentage. Alternatively when the storage period was increased the enzyme activity decreased and increased the sprouting percentage.

The present study indicated that the bulbs stored under low cost bottom ventilated storage structure recorded lowest total phenol content with the increasing storage period. When the total phenol content was high, the enzyme activities were high. This would have induced resistance to pathogen by production of PR (Plant Resistance) proteins (Raskin, 1992).

In conclusion the pre harvest sprayed bulbs stored with 2.0 cm neck length in low cost bottom ventilated storage structure increased the shelf life of *aggregatum* onion cv. CO On 5 up to six months.

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How to cite this article:

Anbukkarasi, V., P. Paramaguru, L. Pugalendhi and Jayakumar, P. 2020. Effect of Packing and Storage Methods on Quality and Shelf Life of Onion (*Allium cepa* L. var. A*ggregatum* Don.). *Int.J.Curr.Microbiol.App.Sci.* 9(11): 611-622. doi: https://doi.org/10.20546/ijcmas.2020.911.075