Berhan International Research Journal of Science and Humanities
(BIRJSH), 2022, 6(1), 85 - 95
Journal homepage: www.journals.dbu.et *ISSN: 2414-2794*

Effect of Storage Temperature on Selected Bioactive Component of Fresh Bombay Red Onion Bulb *(Allium Cepa L.)*

Ayalew Demissew

Amhara Regional Agricultural Research Institute, Bahir Dar Food Science and Post-harvest Handling Research Center

Abstract

In this study the effect of different storage temperature on bioactive components Bombay red onion. Onion (*Allium cepa L.*) is a major commercial vegetable crop grown in almost all parts of the world. In Ethiopian the postharvest loss of onion bulb crop was estimated to be 50% during the production season. So to reduce postharvest loss of onion bulb, determining and employing appropriate storage conditions play an important role. Appropriate storage condition reduces the physiological quality which intern reduces the physicochemical and physicochemical properties of onion. In this study physicochemical and physicochemical properties of onion bulb were investigated under different storage temperature. Onion bulbs were stored at five different storage temperatures the following quality attributes of onion bulb like glucosidase content, pyruvic acid, flavonoid, dry matter and sugar content were determined for storage period of six months. Quality deterioration of onion bulb was higher at storage temperature of 25^{o}C while storage temperature 5^{o}C was found an ideal condition with keeping the quality of onion bulb acceptable. In all the three storage temperatures pyruvic acid, glucosidase and sugar content show irregular pattern. Bombay red onion bulb was stored for six months without significant change of quality attributes of onion bulb at storage temperature of 5^{o}C.

*Corresponding author email: *ayalewdemissew@yahoo.com*
Article information: Received 05 May 2022; Revised 10 August 2022; Accepted 20 November 2022

Introduction

Onion (*Allium cepa L.*) is one of the major commercial vegetable cropsgrown in most parts of the world including Ethiopia their flavor attributes.Now a day'sonion bulb is becoming parts of daily diet all-round the year (Endalew *et al.*, 2014). In Ethiopian mostly the fresh onion bulb was used for preparation of traditional foods and in some part the shredded onion bulb was mixed with other spices so that it will be used for several purposes (Ayalew *et al.*, 2017). Onion bulb is also becoming an important commercial crop for small holder farmers in Ethiopia (Fekaduand Dandena, 2006). Onion bulb is naturally perishable in nature due to having high moisture content.Different onion bulb varieties need different conducive storage temperatures like some needs 0-5^{o}C while others need 25-30^{o}C at an average relative humidity of 65% (Milenkovic *et al.*,2009).Major storage postharvest loss of onion bulb was physicochemical and phyto-chemical attributes and bulb sprouting and rooting. Among all, bulb sprouting and rooting postharvest loss of onion bulbs accounts 46 to 56% under different storage condition of different storage structure (Kukanoor, 2005). Major external factors for onion bulb postharvest loss are temperature, relative humidity, harvesting condition, light, pretreatments and maturity the bulb while the internal factors physiological and metabolic activity of onion bulbs (Biswas *et al.*, 2010).In Ethiopia onion bulbs are stored using different naturally ventilated storage structure or simply heaping the onion bulbs directly on the floor at room temperature (Endalew *et al.*, 2014). During storage period sprouting is a critical physiological factor which restricts the storability of onion bulb. The storage environment of storage structures employed in storing onion bulb plays pertinent role in keeping the all physicochemical attributes of onion bulb. Storage temperature plays critical role from the rest of storage conditions in influencing the quality attributes of onion which actually the exact conducive temperature depend on onion variety (Miedema, 1994). The effect of different storage temperature on physicochemical property of Bombay red onion cultivar along the storage period was not evaluated and reported. Therefore five different temperature storage temperatures were selected based on literature and local trends. Then different physicochemical quality attributes of onion bulb were determined during storage period of six months.

Materials and Methods

Sample collection and preparation

Bombay red onion bulb was collected from Koga experimental site of Adet agricultural research center in Amhara regional state, Ethiopia. The onion harvested when matured and cured there for 8 days. Then it was trimmed of the leaves and roots. The storage experiment was conducted at controlled condition with storage temperatures (5^{o}C, 10^{o}C, 15^{o}C, 20^{o}C, 25^{o}C and relative humidity of 75%). Onion bulb of 250Kg was weighed and stored at five different storage temperatures by weighing 50Kg for each storage condition. The bulbs were placed on stainless steel trays. During the experiment eight onion bulbs were randomly selected for analysis up to the six month where sprouting appears starting from the first day and then within an interval of a month. During sampling each bulb was cleaned and chopped into small parts and then mixed well to get the representative parts of the whole onion bulb.

Characterization of onion bulb

Dry matter content: The dry matter content in onion bulbs was determined by drying chopped samples of 30g according (AOAC, 1995).

Peroxidase activity: The peroxidase activity was determined according to the method by (Gůnes and Bayindirh, 1993).

Analysis of sugar content: Sugar contents of onion bulbs were determined according to a method followed by (Kahane, 2001).

Analysis pyruvic acid: Pyruvic acid content was analyzed a method followed by (Abayomi and Terry, 2009).

Statistical analysis

All the results in the table below are means ± standard deviations of triplicates of samples during the experiment. The data's were analyzed statistically by ANOVA at ($p < 0.05$).

Results and Discussion

In conducting effect of storage temperature on physicochemical quality attributes of onion bulb along a storage period Bombay red onion bulb was chosen because of its high productivity in Amhara region, Ethiopia. During the experimental period inner sprouting was detected by longitudinally cut of onion bulbs along a storage period within time interval of one month in the three storage temperatures. In the present study visible sprouting was found at different time intervals. Sprouting appeared visibly at five month in storage temperature of 5^{o}C and 25^{o}C. For a storage temperature of 10^{o}C and the rest two storage temperatures sprouting seen starting from the fourth month. Although sprouting were less in storage temperature of 25°C other basic quality parameters of onion bulb were not found acceptable. The result found during storage experiment concerning about sprouting does not agree with the result fond and reported by (Ward, 1976) where he reported late sprouting of onion bulb for storage temperature of 25^{o}C. High quality attribute loss onion bulbs at storage temperature of 25^{o}C were found during the experiment where the result obtained coincides with the result determined and reported by (Uddin and MacTavish, 2003 and Sharma *et al.*, 2015).

Weight loss and dry matter content

The dry matter of Bombay red onion Bulb indicates that onion contains 86.60 %of volatile compounds, which largely includes water. The dry matter content foundin this experiment was similar with the results found and reported by (Endalew *et al.*, 2014 and Ayalew *et al.*, 2017) for identical onion cultivar. Storage temperature is critical factor which influence the weight loss and dry matter content of onion bulb during storage. When onion is stored weight loss occurred due to the action of desiccation, respiration and sprouting. These entire phenomenon are directly related with storage temperature to mean that the higher the storage temperature thegreater the weight loss. In the experiment greater weight loss was found at a storage temperature of 25°C which was 21.8%. In contrast to my result obtained (Kamerbee, 1962) determined and reported minimal weight loss of 6% to 14% of the fresh weight at storage temperature of 25^{o}C. Higher storage temperature increases water activity and reaction rate which finally negatively affect quality of onion bulbs. The dry matter content of onion bulb stored at 5^{o}C was found nearly constant up to the 5th months but the dry matter content of onion bulb reduce significantly for the rest storage temperatures. The results obtained were completely different than the result found and reported in (Miedema, 1994). Storage temperature affects degradation of onion bulb organic matter and the processes of conversion of organic substances in to volatile compounds through dormancy break and sprouting (Yasin and Bufler, 2007).

Table 1. Changes in DM of onion bulb at different storage temperature

Storage time (Months)	DM (%) at 5^{o}C	DM (%) at 10^{o}C	DM (%) at 15^{o}C	DM (%) at 20^{o}C	DM (%) at 25^{o}C
0	14.28±1.09^{a}	14.25±1.09^{b}	14.28±1.20^{ac}	14.28±1.20^{ad}	14.28±2.10^{ec}
1	15.34±0.92^{a}	15.02±0.92^{b}	15.00±0.89^{ace}	14.98±0.92^{aa}	14.87±1.32^{ea}
2	16.07± 0.03^{a}	16.01±1.00^{b}	15.8±0.16a^{edc}	15.05±1.50^{dac}	15.32±0.98^{ec}
3	15.65±1.20^{a}	13.46±2.30^{b}	15.7±1.20^{cde}	15.23±2.50^{dba}	15.21±1.32^{eda}
4	14.59±1.50^{a}	12.99 ±1.30^{b}	14.3± 1.80c^{ed}	14.12± 0.98^{dba}	12.78±1.32^{edc}
5	14.48 ±1.20^{a}	14.33±1.20^{b}	13.5±2.50^{cda}	13.89±1.20^{dca}	12.56±3.21^{eda}
6	14.18±0.93^{a}	13.09±0.89 ^{b}	12.6±2.50^{eda}	13.57±1.20^{dea}	13.42±1.56^{ec}

**Values are mean ± standard deviations of triplicate and Values followed by the same letters in the same row are not significantly different p > 0.05*

Peroxidase activity

The enzyme peroxidase involves in oxidation of flavonoids. For the first four months of storage period at all storage temperatures peroxidase activity increases but with different ways. Maximum increment of peroxidase activity was found at 25°C which was 140 units/100g. The result obtained in this experiment contradicts with the report by (Benkeblia and Selselet-Attou, 1999) which was140units/100g at a temperature of 0-5°C. The reason for such complete contradiction may araise the difference in onion cultivar. As it was seen from table-2 below at 5°c peroxidase activity increase up to 140 units/100g in the first three months and then reduced and finally become constant at 120units/100g for the last two months. Peroxidase activity in at low storage temperature was found less significant while sprouting aggravates increment of peroxidase activity of onion bulb. Similar result was found and reported by (Benkeblia *et al.*, 2004). An increase in peroxidase activity facilitates quercetun oxidation and forms new compounds which are basically indices of sprouting of onion bulbs.

Table 2. Peroxidase activity (units/100g FW) of onion bulb at storage temperature

	0	1	2	3	4	5	6
POD 5°C 120±8.7	100.0± 5.1	115±7.1	132±7.1		140±6.5	135±6.8	120± 8.7
POD 10°C 125±5.6	100.0± 5.2	120±6.3	125±6.0		135 ± 4.8	125± 6.22	125±8.7
POD 15°C 112±5.0	100± 4.2	125± 3.2	128±4.2		132±2.8	122±5.1	115±3.1
POD 20°C 110±3.0	100±2.8	131±3.0	135±4.7		136±1.9	124±2.5	112±6.1
POD 25°C 110±6.5	100.0±5.3	140 ±5.8	150±6.9		140±5.7	120±6.7	110±2.44

**Values are mean ± standard deviations of triplicate and POD=peroxidase activity*

Sugar content

In six month storage period with five different storage temperatures sugar content changes differently. At 5°C and 10°C storage temperature sugar content of onion bulb changes with similar pattern while the rest three storage temperature the pattern of sugar content of onion bulb were different. Initially during the 1st month, sugar content increased and then consistent reduction was observed in the following months. Sucrose content was found greater in the stored onion bulb than the fresh at all storage temperatures of the experiment. Similar result was found and reported by (Salamal *et al.*, 1990). Fructose and glucose content of stored onion bulb was found nearly reduced by half from the first to sixth months of storage as it is seen the table-3 below for a storage temperature of 5°C,10°C and 15°C. In the case of 20°C and 25°C storage temperature the glucose of onion bulb increased during 3rd to 5th months and finally decreased but the fructose content decreases starting from the 2nd months. Contradicting result was found reported by (Rutherford and Whittle, 1982.) which states as the total sugar content remained astonishingly constant throughout the storage period. Similar fluctuation of sugar contents were found and reported by (Hurst *et al.*, 1985). Sprouting was the cause of continuous decrement in fructose and glucose contents at 5°C, 10°C and 15°C. At storage temperature of 20°C and 25°C the pattern for the sugar content was different and very less sprouted bulbs were found till the end of the storage. An increase in the concentration of glucose and fructose directly related with the commencement of sprouting as it was stated by (Benkeblia and Selselet-Attou, 1999). In our study, the concentration of fructose and glucose decreased during the internal sprouting at 5°C, 10°C and 15°C.

The reason of such decrement may be due to sprouting after 4 months of storage. Possibilities for decrement of concentration of sugar are related with sprout length where sugars were aggressively metabolized to give energy for the growth of the sprout as it was elaborated by (Chope *et al.*, 2007). The variation for sugar concentration change does not only depend on sprouting but also influenced by the following factors such as variety, initial sugar content and the dormancy release time.

Table 3. Sugar content (μmol/g) of onion bulb at different storage temperature

	0	1	2	3	4	5	6
Sugars 5ºC							
Fructose	0.21±0.01	0.25±0.02	0.18±0.03	0.29±0.02	0.25±0.01	0. 20±0.02	0.16±0.05
Glucose	0.31±0.01	0.39±0.06	0.36±0.09	0.36±0.09	0.32±0.01	0.21±0.02	0.19±0.01
Sucrose	0.16±0.01	0.16±0.02	0.16±0.02	0.12±0.03	0.10±0.09	0.09±0.02	0.09±0.03
Sugars 10ºC							
Fructose	0.21±0.01	0.26±0.02	0.19±0.02	0.16±0.03	0.13±0.05	0.11±0.01	0.10±0.07
Glucose	0.31±0.01	0.33±0.13	0.29±0.13	0.20±0.00	0.12±0.01	0.10±0.06	0.08±0.01
Sucrose	0.16±0.00	0.19±0.15	0.17±0.13	0.130±0.03	0.11±0.01	0.10±0.09	0.09±0.07
Sugars 15ºC							
Fructose	0.21±0.01	0.24±0.01	0.18±0.12	0.14±0.03	0.12±0.01	0.10±0.05	0.08±0.02
Glucose	0.31±0.01	0.31±0.03	0.27±0.03	0.21±0.13	0.15±0.01	0.11±0.12	0.07±0.01
Sucrose	0.16±0.00	0.18±0.02	0.17±0.01	0.15±0.02	0.12±0.12	0.11±0.08	0.09±0.01
Sugars 20ºC							
Fructose	0.21±0.01	0.17±0.02	0.16±0.01	0.13±0.01	0.10±0.01	0.08±0.05	0.06±0.02
Glucose	0.31±0.01	0.25±0.01	0.26±0.00	0.24±0.03	0.23±0.06	0.20±0.01	0.17±0.07
Sucrose	0.16±0.00	0.17±0.09	0.19±0.07	0.17±0.00	0.15±0.02	0.13±0.06	0.10±0.03
Sugars 25ºC							
Fructose	0.21±0.01	0.19±0.03	0.15±0.13	0.10±0.00	0.08±0.01	0.06±0.06	0.05±0.01
Glucose	0.31±0.01	0.28±0.03	0.29±0.13	0.27±0.01	0.27±0.02	0.23±0.07	0.21±0.05
Sucrose	0.16±0.00	0.17±0.12	0.18±0.14	0.19±0.01	0.14±0.01	0.14±0.06	0.13±0.01

**Values are mean ± standard deviations of triplicate*

Pyruvic acid

During onion bulb storage its pungency is correlated with breakage of dormancy. The experimental data for pyruvic acid content as shown in the table-3 below changed significantly in all storage temperatures. The greatest increase of pyruvic acid was seen at 10°C and 15ºC followed by 20°C and 25°C. Minimal increment of pyruvic acid content was found at storage temperature 5ºC. Pyruvic acid content change of onion bulb showed a similar pattern at 10°C and 15°C for the first2months and increased to 42 and 52.5μmol/g of fresh weight (FW), followed by a decrease of 32.6 and

38.5µmol/g FW, correspondingly. Pyruvic acid concentration increased with respect to the fresh sample during the storage in all storage temperatures. Similar result was also reported by (Uddin and MacTavish, 2003).Pyruvic acid content in onion bulb influenced by the following factors such as dry matter, sugar content, cultivars, maturity and sulphur nutrition but during storage, the pyruvic acid content differs with changes of dry matter which is prejudiced by weight loss and dehydration of tissues. This may be the main reason for increment of pyruvic acid content during onion bulb long term storage. Dormancy breakage the flavor precursor decreased and the pyruvic acid stable product of the flavor precursor and is bulb pungency pointer. In this study, the increase pyruvic acid was observed before sprouting at 5°C and 10°C storage temperature. Contradicting result was reported in (Randle and Bussard, 1993).

Table 4. Pyruvic acid content (µmol/g) of onion bulb at different storage temperature

	0	1	2	3	4	5	6
Pyruvic 5°C	22.40±2.4	42.2±8.5	32.2±1.2	32.6±1.8	38.5±2.1	28.8±2.6	28.3±1.9
Pyruvic 10°C	22.40±2.4	52.5±6.3	38.5±2.3	33.6±2.1	36.7±1.9	30.9±2.1	31.0±1.9
Pyruvic 15°C	22.40±2.3	46.3±3.2	47.1±2.8	38.9±5.3	34.7±1.8	33.8±2.3	32.0±2.1
Pyruvic 20°C	22.40±2.4	47.6±4.5	49.5±1.8	40.2±1.2	38.3±3.7	35.3±1.6	32.2±1.9
Pyruvic 25°C 32.8±2.3	22.40±2.4	30.3±1.3	40.2±1.7	33.4±1.7	35.6 ±2.3	34.2±1.2	

**Values are mean ± standard deviations of triplicate*

Conclusion

It is possible to conclude that sprouting and re-growth stage fluctuate at different storage temperatures of onion bulbs. According to storage temperature of onion bulbs, sprouting phase lead to sluggish decrease in chemical composition of onion bulbs which finally reduce dry matter content, sugar and pyruvic acid content. During storage quercetin and glucosides augmented but with some variation. This increment does not directly related to enzymatic activity. Browning of onion bulb outer covers during storage is caused by the autoxidation of quercetin glycosides, after their deglucosylation. During storage of onion bulb at a given storage temperature peroxidase activity enhances quercetin and storage temperature is crucial factor which influence sprouting phase and other onion bulb quality attributes. From this experimental result we found storage temperature and time directly influence the biochemical quality attributes of the onion bulbs. Storage of onion bulb at lower temperature enhances shelf-life onion and accordingly, minimal pyruvic acid content. The consumption of pyruvic acids as a metabolic substrate of respiration is related to reduction in pungency of onion bulbs over the storage period.

References

Abayomi, L.A, Terry L.A. (2009). Implicatins of spatial and temporal changes in concentration of pyruvate and glucose in onion (*Allium cepa L.*) bulbs during controlled atmosphere storage. *Journal of the Science of Food Agriculture*, 89, 683–687.

AOAC. (1995). *Official Method of Analysis Association of Official Analytical Chemists*, Virginia. 15th Edition. Vol.2.

Ayalew, D., Ayenew, M., Mehiret, M. (2017). Testing and Demonstration of Onion Flake Processing Technology in Fogera Area at Rib and Megech River Project. *Journal of Food Process and Technology*, 8, 677.

Benkeblia, N., Onodera, S., Yoshihira, T., Kosaka S, Shiomi N. (2004). Effect of temperature on soluble invertase activity, and glucose, fructose and sucrose status of onion bulbs (Allium cepa) in store. *International Journal of Food Science and Nutrition*, 55, 325–331.

Benkeblia, N., Selselet-Attou, G. (1999). Effects of low temperatures on the changes in oligosaccharides, phenolics and peroxidase in inner bud of onion (Allium cepa L.) during break of dormancy. *Acta Agriculture Scandinaca Section B Soil and Plant Science*, 49, 98–10.

Biswas, S.K., A. Khair, P.K. Sarker and M.S. Alom. (2010). Yield and storability of onion (Allium cepa L.) as affected by varying level of irrigation. Bangladesh. *Journal of Agricultural Research*, 35(2): 247-255.

Bonaccorsi, P., Caristi, C., Gargiulli, C., Leuzzi, U. (2005). Flavonol glucoside profile of southern Italian red onion (Allium cepa L.). *Journal of Agriculture and Food Chemistry*, 53, 2733–2740.

Chope, G.A., Terry, L.T., White, P.J. (2007).The effect of 1-methylcyclopropene (1-MCP) on the physical and biochemical characteristics of onion cv. SS1 bulbs during storage. *Postharvest Biology and Technology*, 44, 131–140.

Darbyshire, B., Henry, RJ. (1979). The associations of fructans with high percentage dry weight in onion cultivars suitable for dehydrating. *Journal of Science Food and Agriculture*, 30, 1035–1038.

Dhumal, K., Datir, S., Pandey, R. (2007). Assessment of bulb pungency level in different Indian cultivars of onion (*Allium cepa L.*). *Food Chemistry*, 100, 1328–1330.

Endalew, W., A. Getahun, A. Demissew, and T. Ambaye. (2014). Storage performance of naturally ventilated structure for bulb onion. *Agricultural Engineering International: CIGR Journal*, 16(3), 97－101.

Fekadu, M., Dandena, G. (2006) Review of the status of vegetable crops production and marketing in Ethiopia. *Uganda Journal of Agricultural Science*, 12, 26-30.

Gůnes, B., Bayindirh, A. (1993). Peroxidase and lipoxigenase inactivation during blanching of green beans, green peas and carrots. *LebensmWis U Technology*, 26, 406–410.

Hansen, SL. (1999). Content and composition of dry matter in onion (Allium cepa L.) as influenced by developmental stage at time of harvest and long-term storage. *Acta Agriculture Scandinaca Section B Soil and Plant Science*, 49(2), 103–109.

Hurst, W.C., Shewfelt, R.L., Schuler, G.A. (1985). Shelf-life and quality changes in summer storage onions (Allium cepa). *Journal of Food Science*, 50, 761–763.

Kaack, K., Christensen, L.P., Hansen, S.L., Grevsen K. (2004). Non-structural carbohydrates in processed soft fried onion (*Allium cepa L.*). *European Food Research and Technology*, 218, 372–379.

Kahane, R., Vialle-Guerin, E., Boukema, I., Tzanoudakis, D., Bellamy, C., Chamaux, C. Kik C. (2001). Changes in non-structural carbohydrate composition during bulbing in sweet and high-solid onions in field experiments. *Environmental and Experimental Botany*, 45, 73–83.

Kamerbee, GA. (1962). Respiration of the iris bulb in relation to the temperature and growth of the primordia. *Acta Botonica Neerlandica* 11, 331–410.

Kukanoor, L. (2005). *Post-harvest studies in onion*. PhD Thesis submitted to the University of Agricultural Sciences, Dharwad. http://etd.uasd.edu/ft/th8441.pdf (accessed April 18.

Miedema, P. (1994). Bulb dormancy in onion. I the Effects of Temperature and Cultivar on Sprouting and Rooting. *Journal of Horticultural Science*, 69, 29–39.

Milenkovic, I.Z., Djurovka, L. M., Trajkovic, R. (2009). The effect of long term storage on quality attributes and storage potentials of different onion cultivars. *Acta Horticulture (ISHS)*, 830, 635-642.

Mogren, L.M., Olsson, M.E., Gertsson, U.E. (2007). Quercetin content in stored onions (*Allium cepa L.*): effects of storage conditions, cultivar, lifting time and nitrogen fertiliser level. *Journal of the Science of Food Agriculture*, 87, 1595–1602.

Randle, W.M., Bussard, M.L., (1993). Pungency and sugars of short-day onions as affected by sulfur nutrition. *Journal of American Society of Horticultural Science*, 118(6), 766–770.

Rutherford, P.P., Whittle, R., (1982). The carbohydrate composition of onions during long term cold storage. *Journal of Horticultural Science*, 57, 349–356.

Salamal, A.M., Hicks, J.R., Nock, J.F. (1990). Sugar and organic acid changes in stored onion bulbs treated with maleic hydrazide. *Hortscience*, 25, 1625–1628.

Sharma, K., Assefa, A.D., Kima, S., Koa, E., Parka, S.W. (2014). Change in chemical composition of onion (*Allium cepa L. cv. Sunpower*) during post-storage under ambiente conditions. *New Zeal Journal of Crop Hortscience* 42, 87–98.

Sharma, K., Assefa, A.D., Ko, E.Y., Lee, E.T., Park, S.W. (2015). Quantitative analysis of flavonoids, sugars, phenylalanine and tryptophan in onion scales during storage under ambient conditions. *Journal of Food Science and Technology*, 52, 2157–2165.

Takahama, U., Hirota, S. (2000). Deglucosidation of quercetin glucosides to the aglycone and formation of antifungal agents by peroxidase dependent oxidation of quercetin on browning of onion scales. *Plant Cell Physiology*, 41, 1021–1029.

Uddin, M., MacTavish, H.S. (2003). Controlled atmosphere and regular storage-induced changes in S-alk(en)yl cysteine sulphoxides and allinase activity in onion bulbs (*AlliumcepaL. cv.Hysam*). *Postharvest Biology and Technology*, 28, 239–245.

Ward, CM. (1976). The influence of temperature on weight loss from stored onion bulbs due to desiccation, respiration and sprouting. Annual Applied Biology, 83, 149–155.

Yasin, H.J., Bufler, G. (2007). Dormancy and sprouting in onion (*Allium cepa L*.) bulbs. I. Changes in carbohydrate metabolism. Journal of Horticultural Science and Biotechnology, 82, 89–96.