MUTUAL EFFECT OF MODIFIED ATMOSPHERIC PACKAGING AND STORAGE TEMPERATURE TO EXTEND THE SHELF LIFE OF CUSTARD APPLE CV. BALANAGAR

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ABSTRACT

"Mutual effect of modified atmospheric packaging and storage temperature to extend the shelf life of custard apple cv. Balanagar" was carried out to improve the quality and shelf life. Custard apple fruits are perishable, so under ordinary conditions, these fruits can be kept well only for 3-4 days after harvest. The uniform sized fully matured but unripe fruits of custard apple cv. Balangar at color turning stage were packed in medium density polyethylene bags (50µ density) with mixture of different gaseous composition and stored in ambient and 12˚C temperatures up to 8 and 10 days respectively. The rate of respiration and ethylene production initially increase up to climacteric rise and then decreased during storage, and that their values were lowered significantly by decreasing the storage temperature. Better retention of color coordinates (L*, a* and b*) and head space (O_2per cent and CO_2per cent) were found in modified atmosphere packaging with low temperatures. Treatment combinations G_2T_2 (5per cent O_2 & 10per cent CO_2 + 12˚C) was found best for maintaining physical and physiological attributes and increased the shelf life up to 10 days.

KEYWORDS: Modified Atmosphere Packaging, Storage Temperature, Shelf Life.

1. INTRODUCTION

Custard apple (*Annona squamosa*) popularly known as "Sitaphal, sugar apple, sweetsop, sharifa, and noi-na", is one of the most important underutilized fruits of India. *Annona squamosa* is one of the finest fruits gifted to India by Tropical America. Custard apple belongs to the family Annonaceae. It is a very hardy tree and grown naturally on marginal and waste land, which do not require extra care. Custard apple has wide adaptability to soil and climatic conditions, tolerant to drought and salinity and resistance against pests and diseases due to its hardy nature and escape from animal damage. In India area under custard apple is reported to be 53,000 ha. Custard apple is mainly grown in the states of

Andhra Pradesh, Maharashtra, Madhya Pradesh, Uttar Pradesh and Rajasthan. The fruit of custard apple has delicious taste and is eaten as fresh. It has many nutritional and medicinal properties. A calorific value of 100 gram edible matter is 105 I.U. The ripe fruits are rich in sugars. The edible portion of the fruit varies from 28 to 55 per cent. The 100g pulp contains 70.5 g moisture, 23.5 g carbohydrate, 1.6 g protein, 0.9 g minerals, 1.5 mg iron, 17 mg calcium, 47 mg phosphorus and 37 mg vit. C (Dashora et al., 2004). Custard apple contains anti-oxidants like Vitamin C, which helps to fight free radicals in our body. *Annonas* are climacteric fruits (Biale and Barcus, 1970). Ripening of *Annona* fruits are characterized by high respiration and high ethylene production rates which makes it highly perishable (Pareek et al., 2011). As it is perishable fruit, under ordinary conditions, fruits can be kept well only for 3-4 days after harvest. If proper packaging and storage is not done, they will decay rapidly making them non-edible. Rapid softening of fruits during transportation and at retail stores is the biggest ongoing problem. The shelf life of fruits can be extended by lowering their respiratory metabolism using low-temperature storage or storing them in a high carbon dioxide atmosphere. The use of several techniques including the use of modified atmosphere packaging (MAP) and cold storage has proved to be useful in maintaining the quality of custard apple and increasing its shelf life. Modified atmosphere packaging is the replacement of air in a pack with a single gas or mixture of gases and proportion of each component is fixed when the mixture is introduced. The basic principle of modified atmospheric packaging is to match the respiration of the product with the O_2 and CO_2 concentration and permeability of packages in order to modify the O_2 and CO_2 concentrations of the atmosphere to desired levels within the package (Beaudry and Lakakul, 1995). Therefore, keeping the above factors in view the present study "mutual effect of modified atmospheric packaging and storage temperature to extend the shelf life of custard apple cv. Balanagar" was conducted in Post Harvest Technology Laboratory, Department of Horticulture, Rajasthan College of Agriculture, Udaipur during 2013-14.

2. MATERIAL METHODS

The uniform sized fully matured but unripe fruits of custard apple cv. Balanagar were obtained from Instructional Farm of KVK, Chittorgarh under Maharana Pratap University of Agriculture and Technology, Udaipur and brought to the Post Harvest Technology Laboratory of the Department of horticulture on the same day. Custard apple fruits were inspected thoroughly for any damage and spoilage. The seven gaseous concentrations were used for packaging the fruits in polyethylene bags of 50 μ thickness. The active modified atmospheres were created by using a gas mixture. The experiment was consisting of 14 treatment combination comprising: G_1 (control) = (21% O_2 and 0.03 % CO_2); G_2 = 5 % O_2 and 10 % CO_2; G_3 = 5 % O_2 and 15 % CO2; G4 = 5 % O_2 and 20% CO_2; G_5 = 10 % O_2 and 10 % CO_2; G_6 = 10 % O_2 and 15 % CO_2; G_7 = 10 % O_2 and 20 %. The packages were stored at ambient temperature (T_1) in the laboratory, 12˚C (T_2) temperature in refrigerator and sampled periodically analyze to various physiological, biochemical and sensory parameters after every 48 hours. The whole experiment was conducted using a factorial completely randomized design with three replications.

Observation were recorded on physiological attributes regarding physiological loss in weight (%), moisture (%), firmness (N), head space gas analysis (% O_2 and % CO_2), respiration rate (ml CO_2 $kg^{-1}h^{-1}$), ethylene evolution rate (µl C_2H_4 $kg^{-1}h^{-1}$), color coordinates (L*, a*, b* value) and specific gravity. The firmness of fruits was determined by Texture Analyzer using cylinder probe with 50 kg load cell and heavy duty platform. Ethylene produced by the fruit was determined by pump module Gas Alert Micro 5 PLD PV (Voilen Canada). Head space O_2 and CO_2 analyses were carried out using an O_2/CO_2 gas analyzer. Electronic Moisture Analyzer was used to determine moisture content of the fruit. Changes in L*, a*, b* color co-ordinates were measured with Hunter Color Flex according to Nielsen (2010).

3. RESULTS AND DISCUSSION

3.1 Cumulative physiological loss in weight (per cent)

Physiological loss of weight during storage is characterized by reduction in fruit weight by the way of loss of moisture through evaporation and / or transpiration. Physiological loss in weight is defined as the transpiration and respiration, which deteriorate the fruit by reducing tissue turgor according to Sothornvit and Rodsamran (2008). The CPLW of custard apple fruits increased with advancement of storage duration but rate of increase in per cent weight loss was significantly affected by different gaseous composition during storage as shown in table 1. On 8th day of storage the minimum CPLW was recorded in G_2T_2 (09.50per cent) and maximum in G_1T_1 (14.00per cent) treatment combination. Further, on 10th day of storage the minimum CPLW was observed in G_2T_2 (13.50per cent) and maximum in G_1T_1 (17.50per cent). The result showed that the use of lower storage temperature contributed to the significant reduction of weight loss during storage.

3.2 Moisture (%)

Moisture per cent of the custard apple fruit decreased with the increase in storage days. On 8th and 10th day of storage, the maximum moisture was recorded in G_2T_2 (63.00per cent and 61.00per cent) while minimum in G_1T_1 (55.00per cent and 53.00per cent) and similar value was observed in G_5T_1 (55.00per cent and 53.00per cent) respectively. Fruit stored at 5˚C lost only 48 per cent of their weight during the entire 12 week of storage duration while the fruit stored at 22˚C and 15˚C lost 70 and 75 per cent of weight, respectively. At three week of storage more than 40 per cent of fruit had shriveled under the 22˚C and 15˚C storage temperatures compared to only 3 per cent under the 5˚C storage temperature (Tembo et al., 2008). Plastic films differentially affected weight loss of litchi during 9 days storage at 13˚C (Somboonkaew and Terry, 2010).

3.3 Firmness (N)

A reference to data presented in Table-1, that the firmness of custard apple fruits decreased with the advancement of storage time during the entire period of experimentation but the rate of decrease in firmness was significantly affected by different gaseous composition during storage. On 8th day of storage the maximum firmness was recorded in G_2T_2 (5.12 N) and minimum in G_4T_1 (3.33 N). Further, at the end of the experiment, the maximum and minimum value was recorded as G_2T_2 (4.75per cent) and G_5T_1 (3.00 N) respectively. Present finding was also supported by Hossain et al. (2013), they reported that at the 8th day of storage, the bananas stored at 14°C temperature remained firmness score of 1 and which kept at 18°C temperature very low changes of firmness but those kept at ambient had firmness score of 3. At 16 day of storage, the bananas stored without plastic bag had firmness score of 4 (eating ripe) but those stored in imperforated plastic bags had firmness score of 2 (sprung).The firmness of banana changes due to conversion of starch into sugars. Modified atmosphere packaging with 5-20 per cent CO_2 and 5-10 per cent O_2 are effective on retarding firmness losses during storage in a wide range of fruits, such as strawberries (Garcia et al., 1998), loquat (Amoros et al., 2008), peaches and nectarines (Akbudak and Eris, 2004).

3.4 Head space O_2 (per cent) and CO_2 (per cent)

The head space O_2 concentration decreased with the advancement of storage period in all the treatments. Data from Fig. 1 revealed that on 8th days of storage, the minimum and maximum value of head space O_2 was recorded in G_3T_1 and G_1T_2 respectively and G_4T_2 was found parallel with G_3T_1. Whereas, on 10th days of storage, the minimum and maximum value was recorded in G_3T_2 and G_1T_2 respectively. It is evident from the Fig. 2 that, the head space CO_2 concentration increased with the advancement of storage period in all the treatment combinations. It was noted that fruit stored at higher temperature accumulated higher concentrations of CO_2 inside the packages. A sharp increase in CO_2 accumulation was observed 2 days in all the storage temperatures. The rate of increase was lower after 2 days. The CO_2 accumulation was nearly at equilibrium between 8 and 10 days of storage in all the temperature. Since O_2 is consumed in respiration process, its concentration decreased rapidly in the first 2 days of storage and then rate of decrease was lower. The O_2 concentration was lowest in polyethylene bag stored at ambient temperature. The pattern of changes in ethylene concentration inside the package was similar to that of CO_2. In loquat fruit head space gas concentrations were also affected by modified atmospheres and storage temperatures (Ding et al., 2002; 2006). Variation in head space gases were also reported by Oms-Oliu et al. (2008) in fresh-cut pears and Rojas Grau et al. (2008) in fresh cut Fuji apple treated with different coatings. Evaluated CO_2 level could influence a decreased in ethylene concentration (Burg and Burg, 1967). High CO_2 has been found to be a putative inhibitor of ethylene production by repressing 1-aminocyclopropane-1-carboxylic acid (ACC) synthesis and activities of ACC synthase (ACS) and/or ACC oxidase (ACO), while moderate CO_2 concentrations can enhance accumulation (Pretel et al., 1999).

3.5 Respiration rate (ml CO_2 kg^{-1} h^{-1}) and Ethylene evolution rate (µl C_2H_4 kg^{-1} h^{-1})

The high CO_2, low O_2 and high relative humidity conditions created by modified atmosphere packaging have been reported to lead to reduction of fruit weight loss, respiration rate, ethylene production and sensitivity, as well as retard changes related to the ripening process, thus maintaining postharvest fruit quality (Diaz-Mula et al., 2011). The respiration rate and ethylene evolution rate of the custard apple fruit sharply increase initially up to climacteric peak (the maximum point of respiration rate) on 4-5 days from harvest and then decrease with the advancement of storage period. Respiration rate and ethylene production increased up to 2 days of storages in ambient temperature and 4 days in 12˚C and thereafter decreased during storage, their value was significantly lowered by lower storage temperature (Figure 3 and 4). Broughton and Tan (1979) found that at 20 °C, the onset of increased rates of CO_2 and C_2H_4 production of sugar apple both occurred about 3 days after harvest, but the peak of the respiratory climacteric (at 7 days) occurred about 1 day before the ethylene climacteric. The CO_2 emission rates for mature sugar apple fruit was 1.42per cent (Silva et al., 2001). 'Balanagar' sugar apple fruits stored at 25˚C and 20˚C had a clear climacteric peak whereas those stored at 15˚C and 10˚C did not show any distinct rise in respiration rate (Prasanna et al., 2000). A high respiration velocity was found with a climacteric maximum of 243.1 ml CO_2 kg^{-1} h^{-1}, 3 day after harvest (Bolivar-Fernandez et al., 2009). The ethylene released by 'Balanagar' sugar apple fruits stored at ambient temperature showed an increase on day 2 of harvest and reached a maximum (2.38 µl kg^{-1} h^{-1}) on day 3, coinciding with the respiration peak (Prasanna et al., 2000). Ethylene production at respiratory maximum after 3 days of harvest in sugar apple fruits was lower than 1.0 µl kg^{-1} h^{-1} (Bolivar- Fernandez et al., 2009). Climacteric in the rate of respiration and ethylene production was observed in harvested custard apple fruit during storage, which suggests that custard apple is a climacteric fruit.

3.6 CIE L* color coordinate (luminosity or lightness)

The color coordinate L*, a* and b * value of custard apple fruits increased with the advancement of storage time during the entire period of experiment but change was significantly affected by different gaseous composition during storage as presented in table 2. Kovacs et al., (2010) found that he most striking feature was found in the morphology of over ripe fruit (brown color). The middle lamellae of cell walls broke down. Cytoplasm was almost completely destroyed. This fruits was too soft, not suitable for eating as fresh fruit. No report has been found on effect of storage temperatures and modified atmospheres on color parameters in custard apple fruits.

Color evaluation associated with the postharvest ripening process is generally delayed in fruits stored under modified atmosphere packaging condition, as compared to those stored in open air, as has been shown in mango (Pesis et al., 2002), table grapes (Martinez et al., 2003b) and loquat (Amoros et al., 2008). Accordingly, all individual color parameters (L*, a* and b*) significantly increased in unwrapped control broccoli during storage, which was related to both the yellow process of broccoli inflorescences and the decrease in chlorophyll (a+b) concentration. However, broccoli under modified atmosphere packaging condition retained the green color characteristics of freshly harvested broccoli after 21 days of storages and chlorophyll degradation and browning mediated by the inhibition of pheophorbide oxigenase and PPO, responsible for chlorophyll loss and browning, respectively (Beaudry, 2000). In addition, color preservation by modified atmosphere packaging storage has been related to the delay in anthocyanin and carotenoid biosynthesis, thus preserving alteration of color (Artes et al., 2006a).

CONCLUSION

Based on the above findings, it can be concluded that the treatment combinations G_2 (5per cent O_2 & 10per cent CO_2) with 12˚C was found to be the best for maintaining qualitative and physiological attributes and increased the shelf life up to 10 days of storage. The study indicates that custard apple can be stored at 12˚C for 10 days of storage with modified atmosphere packaging (5per cent O2 & 10per cent CO2) allowing conservation of custard apple fruits with highest quality parameters and minimum risk of disorder development. This standardized storage technology has promising future for technology utilization by small, medium and large scale processor and entrepreneurs. The stored fruit can be used in lean period for making various products.

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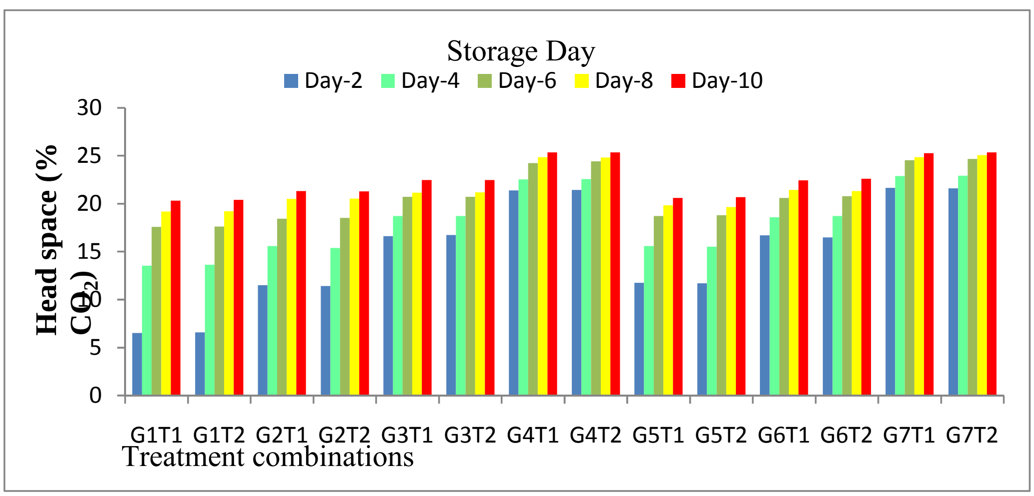

Fig- 1. Interaction effect of gas composition in package and storage temperature on Head space gas analysis (per cent CO_2) during storage

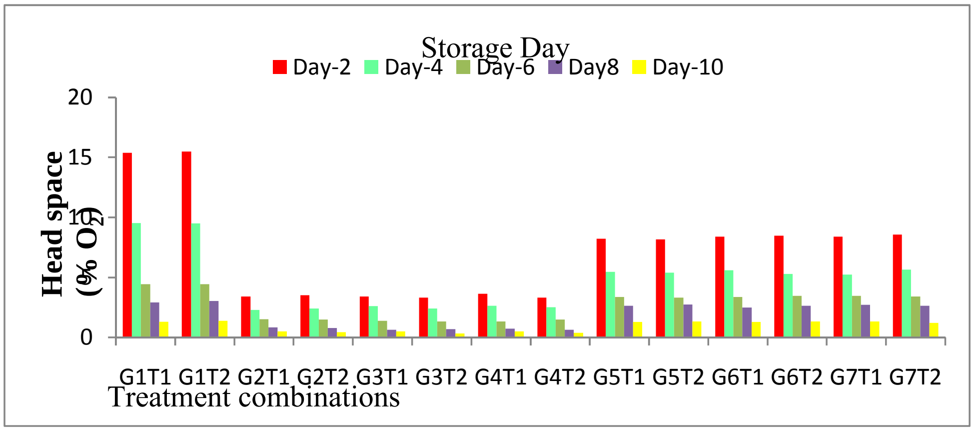

Fig- 2. Interaction effect of gas composition in package and storage temperature on Head space gas analysis (per cent O_2) during storage

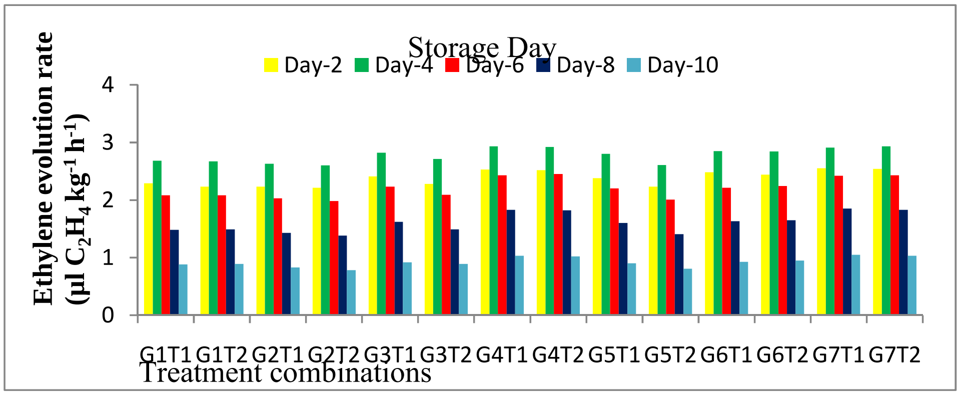

Fig- 3. Interaction effect of gas composition in package and storage temperature on ethylene evolution rate (µl C_2H_4 kg^{-1} h^{-1}) during storage

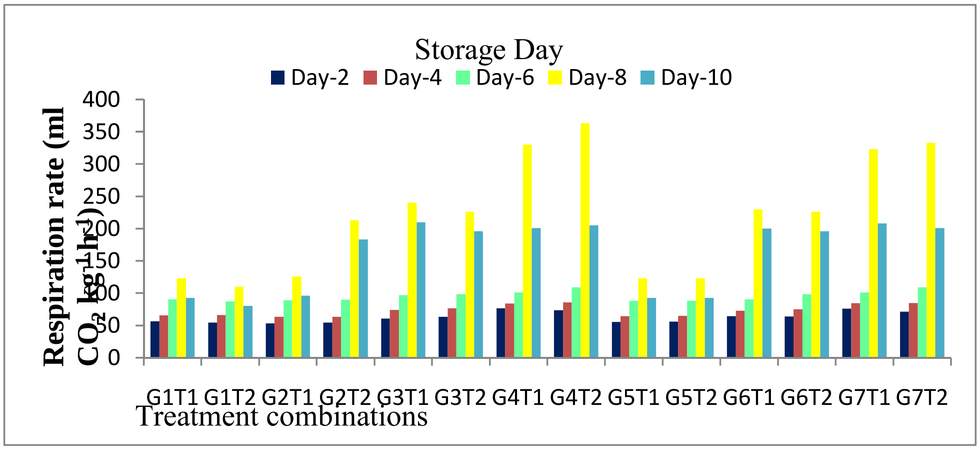

Fig- 4. Interaction effect of gas composition in package and storage temperature on Respiration rate (ml CO_2 kg^{-1} h^{-1}) during storage

Table- 1 Interaction effect of gas composition in package and storage temperature on CPLW (per cent), moisture (per cent) and firmness (N) during storage

Treatment combinations	CPLW (per cent)					Moisture (per cent)					Firmness (N)				
Storage days	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
G_1T_1	6.50	8.50	11.50	14.00	17.50	61.00	59.00	57.00	55.00	53.00	10.40	6.38	4.71	3.58	3.28
G_1T_2	5.50	7.50	09.50	12.00	16.00	66.00	64.00	62.00	60.00	58.00	11.52	7.47	5.31	4.75	4.00
G_2T_1	6.00	8.00	10.00	12.00	14.00	62.00	60.00	58.00	56.00	54.00	11.85	7.92	5.66	4.18	3.81
G_2T_2	3.50	5.50	07.50	09.50	13.50	69.00	67.00	65.00	63.00	61.00	12.89	8.81	6.54	5.12	4.75
G_3T_1	5.00	7.00	09.00	11.00	14.00	67.00	65.00	63.00	61.00	59.00	10.65	6.24	4.66	3.63	3.31
G_3T_2	4.50	6.50	08.50	10.50	14.00	69.00	66.00	64.00	62.00	60.00	12.27	7.26	5.81	4.44	4.00
G_4T_1	5.00	7.00	09.51	11.50	14.50	67.00	64.00	62.00	60.00	58.00	10.87	6.77	4.63	3.33	3.01
G_4T_2	4.50	6.50	08.50	10.50	15.50	69.00	65.00	63.00	61.00	59.00	11.59	7.66	5.56	4.94	4.21
G_5T_1	6.00	8.00	11.00	13.00	16.00	62.00	59.00	57.00	55.00	53.00	10.60	6.33	4.40	3.49	3.00
G_5T_2	5.50	7.50	09.50	11.50	14.50	66.00	64.00	62.00	59.00	54.00	10.64	6.64	4.47	3.77	3.01
G_6T_1	6.00	8.00	10.00	13.00	16.00	63.00	61.00	59.00	57.00	55.00	11.52	7.36	5.80	4.59	4.14
G_6T_2	5.00	7.00	09.00	11.00	15.00	68.00	66.00	64.00	62.00	60.00	11.28	7.94	5.46	4.39	4.01
G_7T_1	6.00	8.00	10.00	13.00	16.50	63.00	60.00	58.00	56.00	54.00	11.83	7.24	5.85	4.58	4.13
G_7T_2	5.50	7.50	09.50	12.50	15.50	66.00	63.00	61.00	58.00	56.00	12.47	8.29	5.90	4.97	4.00

Table- 2 Interaction effect of gas composition in package and storage temperature on color coordinates L*, a* and b * value during storage

Treatment combinations	Color coordinates L* value					Color coordinates a* value					Color coordinates b* value				
Storage days	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
G_1T_1	29.33	38.64	43.79	48.71	54.28	2.83	4.21	8.33	9.84	13.11	13.41	15.72	17.47	18.23	20.31
G_1T_2	27.44	35.53	43.22	47.68	54.23	0.59	1.84	5.98	6.24	9.44	10.33	12.54	14.22	15.27	16.01
G_2T_1	27.78	32.71	41.53	46.24	52.82	2.89	4.01	7.38	9.50	12.39	13.58	15.31	17.57	18.21	19.13
G_2T_2	25.54	31.60	36.94	41.23	50.91	0.41	1.37	4.24	5.47	8.39	12.34	13.82	14.23	15.45	16.22
G_3T_1	27.20	33.75	44.35	47.01	52.78	1.89	3.05	7.45	5.74	10.86	14.89	16.32	18.23	19.42	20.16
G_3T_2	24.34	31.52	40.65	46.11	51.15	1.00	2.51	4.91	6.02	10.22	11.08	13.42	15.13	16.82	17.02
G_4T_1	27.22	34.13	42.02	47.32	53.62	1.51	2.30	6.72	7.91	10.12	13.12	15.36	17.78	18.19	19.10
G_4T_2	23.20	30.13	40.28	45.81	50.22	0.42	1.98	4.62	6.37	7.73	10.68	12.45	14.20	15.13	16.01
G_5T_1	29.72	39.02	44.24	48.91	55.47	1.42	2.88	5.21	7.37	10.29	14.55	16.72	18.51	19.38	20.05
G_5T_2	28.46	33.66	41.40	48.09	54.22	1.15	2.70	6.17	8.25	11.13	13.46	15.47	17.30	18.71	19.25
G_6T_1	29.31	38.81	43.69	48.67	54.20	1.75	3.83	7.38	8.43	12.13	14.49	16.82	18.67	19.48	20.13
G_6T_2	27.16	32.81	41.85	46.41	53.63	0.84	2.00	4.84	6.12	10.01	13.23	15.37	17.38	18.63	19.08
G_7T_1	29.77	39.42	45.23	48.98	55.68	2.04	4.75	7.98	8.31	13.07	12.81	14.28	16.88	17.20	17.33
G_7T_2	29.50	38.84	44.23	48.76	55.13	1.98	2.59	4.73	6.29	9.23	10.33	12.71	14.39	15.72	16.39

*Significance at 5 per cent level of significance.

G_1T_1=control (21per cent O_2&0.03per cent CO_2)+ambient storage temperature; G_1T_2=control (21per cent O_2&0.03per cent CO_2)+12˚C storage temperature; G_2T_1=5per cent O_2&10per cent CO_2+ambient storage temperature; G_2T_2=5per cent O_2&10per cent CO_2+12˚C storage temperature; G_3T_1= 5per cent O_2&15per cent CO_2+ambient storage temperature; G_3T_2= 5per cent O_2&15per cent CO_2+12˚C storage temperature; G_4T_1=5per cent O_2&20per cent CO_2+ambient storage temperature; G_4T_2=5per cent O_2&20per cent CO_2+12˚C storage temperature; G_5T_1=10per cent O_2&10per cent CO_2+ambient storage temperature; G_5T_2= 10per cent O_2 & 10per cent CO_2+12˚C storage temperature; G_6T_1= 10per cent O_2&15per cent CO_2+ambient storage temperature; G_6T_2= 10per cent O_2&15per cent CO_2+12˚C storage temperature; G_7T_1=10per cent O_2&20per cent CO_2+ambient storage temperature; G_7T_2= 10per cent O_2 & 20per cent CO_2+12˚C storage temperature.