Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(2): 1372-1377
Received: 01-01-2018
Accepted: 02-02-2018

Effect of active packaging and refrigerated storage on quality attributes of kiwifruits (*Actinidia deliciosa* Chev)

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Abstract
Kiwifruit has high nutritional value, as well as popularity with regard to taste and aroma. Nutritionally it has very high chlorophyll, dietary fiber, β- carotene, lutein, phenolics, flavonoids, provitamins- A, B_1, B_2, B_3, B_6, and vitamin B_9 and zeaxanthin having very high functional properties. Various phytochemicals present in the fruits aid in prevention of certain types of cancer, cardiovascular diseases, stroke, atherosclerosis and cataracts and is of particular importance for the diabetics. Rapid flesh softening and high sensitivity of the fruits to ethylene are the major concerns of commercial kiwifruit handling which increase its susceptibility to injuries and leads to various fruit rots and ultimately deterioration in quality of fruits. In the present study effect of active packaging conditions and refrigerated storage (2±1ºC) on different quality attributes of kiwifruit was studied. Fresh and healthy kiwifruits cv. Allison were packed in Low Density Polyethylene (LDPE 100 gauge) bags along with sachets of ethylene, oxygen and carbon dioxide scavengers alone or in combinations. Observations on changes in fruit weight (PLW), fruit firmness, TSS, sugars (total and reducing), titratable acidity, respiration rare and enzymes activity were recorded after every one month of refrigerated storage. Results revealed that all the treatments significantly influenced quality parameters of kiwifruit during storage however, LDPE packaging in containing potassium permanganate sachet alone, or in combination rendered most significant effect after 7 month refrigerated storage. The study indicated that kiwifruit could be stored up to 7 months when packed in LDPE bags with sachets of potassium permanganate (@ 5g/kg fruit) with highest fruit quality.

Keywords: active packaging, scavengers, refrigerated storage, physic-chemical and sensory changes

Introduction
Kiwifruit (*Actinidia deliciosa* Chev.) belongs to Actinidiaceae family and a deciduous, woody fruiting vine growing in deep sandy loam soils (Singletary, 2012) [33]. In 1906 it was introduced in New Zealand which first started to export fruits in 1953. United States started to cultivate kiwifruit commercially in 1960. In 1970-75 it was introduced in Southern Europe and early 80's in Greece. Its importance in India has been realized only in the last decade (Rathore and Pandey 2006) [30]. There has been a sizeable increase in area and production of the fruit in the states like Himachal Pradesh, Jammu and Kashmir and North East region. Kiwifruit has gained enormous popularity in the past two decades owing to its refreshing delicate texture, flavour, high nutritive values, abundant antioxidants, not very high sugar, health benefits and economic viability (Nishiyama, 2007) [23]. The nutritional value and functional importance of kiwifruits has gained popularity among masses of consumers, however typical growth conditions of the vine restricts its cultivation to only temperate regions of India. This poses a challenge for the researchers to develop safe storage technologies so as to ensure unrestricted availability of the fruits from a very limited production in far flung areas. Ripe fruit contains significantly very high amount of biologically active compounds with abundance of chlorophyll, dietary fiber, β- carotene, lutein, phenolics, flavonoids, provitamins- A, B_1, B_2, B_3, B_6, and vitamin B_9 and zeaxanthin having very high functional properties (Vaidya *et al*. 2009, Nishiyama, 2007, Celik *et al*, 2007, Hunter *et al*., 2007) [35, 23, 7 10]. The kiwifruit is a typical climacteric fruit and shows a triple sigmoidal growth curve, apparently a unique pattern in fruit development (Pratt and Reid 1974) [26]. The fruit produces negligible amount of ethylene during ripening and storage however, are very sensitive to exogenous application of ethylene. Rapid flesh softening and sensitivity to ethylene are the major concerns of commercial kiwifruit handling and storage which increase its susceptibility to handling injuries and leads to various fruit rots and ultimately deterioration in quality of fruits. It is therefore of utmost importance to protect the fruit from exposure to ethylene and restrict the respiration to minimum so as to provide more flexibility to the players of supply chain (farmers, whole sellers and retailers) and ensure year round availability of fruits to consumers.

Storage of fruits in proper packaging materials is necessary as it helps in curtailing the post-harvest losses and at the same time can result in a commodity-generated modified atmosphere which diminishes dehydration and preserves freshness (Ben-Yehoshua *et al*. 1994) [5] while, such modification in the package can also be mediated rapidly by using various active ingredients. Active packaging the most recent and relevant approach to increase the shelf life of fresh horticultural produce in which the product, packaging material and environment interacts in a positive way to extend the shelf life of produce along with the incorporation of many different active agents into the packaging material to improve its functionality (Ramos *et al*. 2013) [28]. The present investigation was therefore, undertaken with the goal to prolong the storage life of kiwifruits by using active packaging technology.

Materials and Methods

Freshly harvested Kiwifruits cv. Allison from the experimental orchard of Department of Food Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP), were transported to the Postharvest Physiology Laboratory of the Department of Food Science and Technology. Healthy disease free fruits were randomly distributed into sample lots 1kg fruits each. The fruits gently packed in LDPE bags along with sachets prepared from woven fabric material containing oxygen (Fe), carbon dioxide (activated charcoal) and ethylene scavengers ($KMnO_4$) either alone or in combinations and were kept under refrigerated condition (2±1ºC). The experiment was laid out in completely randomized design (CRD) with 12 treatments and every treatment was carried out in triplicate. The treatment details are given below:

Treatments	Treatment details
T1	LDPE+ 1g Iron Powder/kg of fruit
T2	LDPE+ 2g Iron Powder/kg of fruit
T3	LDPE+ 3g Iron Powder/kg of fruit
T4	LDPE+ 3g Activated Charcoal/kg of fruit
T5	LDPE+ 4g Activated Charcoal/kg of fruit
T6	LDPE+ 5g Activated Charcoal/kg of fruit
T7	LDPE+ 5g Zeolite/kg of fruit
T8	LDPE+ 5g $KMnO_4$/kg of fruit
T9	LDPE+ 2g Iron Powder+ 4g Activated Charcoal/kg of fruit
T10	LDPE+ 2g Iron Powder+ 4g Activated Charcoal+ 5g Zeolite/kg of fruit
T11	LDPE+ 2g Iron Powder+ 4g Activated Charcoal+ 5g $KMnO_4$/kg of fruit
T12	LDPE (control)

Observation on PLW, fruit firmness, TSS, sugars, titratable acidity, respiration rate and enzymes activity (PG and PME) were recorded at a regular interval of 1 month as per prescribed methods (AOAC 1990) [1]. Fruit firmness was recorded by Effigi penetrometer (FT-327) as pressure required to force a plunger of 11 mm diameter into the flesh samples. TSS contents of kiwifruit were measured by hand refractometer. Sugars were estimated by Lane and Eynon method as given by Ranganna (1997) [29]. The Enzyme activities (PG and PME) were determined by the methods described by Mahadevan and Sridhar (1982) [17] and Mazumdar and Mazumdar (2003) [20] respectively. Respiration rate of the fruits was determined by Gas data analyzer (GFM series 30-1/2/3, Gas Data Ltd. Coventry UK) and expressed as ml of CO_2/kg/hour.

Results and Discussion

The changes in fruit weight during storage has been depicted in Table 1 which reveals significant difference among various treatments over the storage of 7 months under refrigerated conditions. It is clear from the data that and highest PLW (13.85%) occurred in control while, lowest PLW (10.38%) was recorded in treatment T_8 (LDPE+ 5g $KMnO_4$/kg of fruit) after 7 month of refrigerated storage. Interestingly, PLW in control fruit was as high as 16.30 per cent after 5 months of storage which further increased to 20.95 per cent after 7 months. PLW generally increases continuously and significantly during postharvest period irrespective of the treatments and storage conditions primarily due to transpiratory (Jacobi *et al.* 2000, Barman *et al*. 2015) [12, 3] and to some extent the respiratory changes (Vandana *et al.* 2015) [36]. Active packaging has been shown to reduce weight loss mainly by restricting respiration by reducing the availability of free oxygen (Mcdonald and Harman, 1982) [21] and effectively by scrubbing off the ethylene from the vicinity of fruits (Pranamornkith *et al.* 2012) [25]. The findings of present investigation have been supported by those previously reported by Bhushan *et al.* (2002) [6] and Emadpour *et al.* (2008) [8] in kiwifruit and Shahroodi variety of apricot where use of different active packaging conditions effectively reduced PLW of the fruits during storage.

The increase in storage duration form 1 to 7 months resulted in progressive decrease in the fruit firmness under all the treatments. Such a decrease however occurred at a rapid pace in untreated fruit samples. LDPE bags containing 5g $KMnO_4$ sachet (T_8) retained highest fruit firmness (4.52 kg/cm^2) while, control fruits had lowest firmness (3.62 kg/cm^2) after 7 months of storage. The reduction in fruit firmness with the passage of time was probably due to the ripening changes initiated by pectic enzymes, pectinmethyle esterase (PME) and polygalacturonase (PG), which disturbed cell integration (Sharma *et al*. 2010) [31]. Retention of higher firmness in fruits packed in LDPE with ethylene absorbent sachet could be due to absorption of ethylene by $KMnO_4$ from the package thereby, prohibiting its activity which might trigger the enzyme systems (Lidster, 1995) [16]. The effectiveness of $KMnO_4$ for retaining fruit firmness have been reported earlier by Rahemi and Saiary (2002) [27] in Golden Delicious variety of apple and Bal and Celik (2010) [2] in kiwifruits.

Moisture loss is well regarded as a factor leading to deterioration of quality, particularly appearance, texture and nutritional quality (Jayathunge *et al.*, 2011) [13]. In the present study moisture loss increased significantly with the prolongation of storage period. Treatment T_8 (LDPE + 5g $KMnO_4$ sachet) however, proved to be the most effective in retaining higher moisture contents (84.34%) and it can be attributed to the barrier properties of LDPE and reduced activity of ethylene which might have restricted respiration and ripening changes and at the same time maintained high

RH inside packages and therefore, prevented the loss of moisture from fruits during storage.

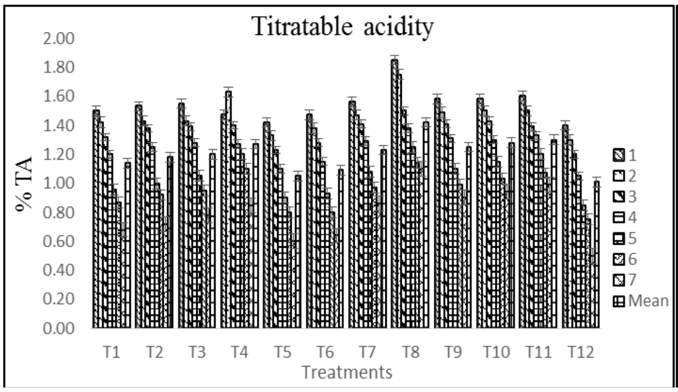
Fruit TSS was significantly affected by different active packaging conditions and followed a typical climacteric pattern (Table 2). Control fruits recorded sharp increase in TSS from 8.69 ºB to 16.01 ºB as the storage progressed from 1st to 5th month then declined to 12.22 ºB on completion of 7 months of storage. Treatment T_8 (LDPE + 5g $KMnO_4$) however, exhibited steady increase in TSS from 1st month (7.58 ºB) to 6th month of storage (16.93 ºB) and then declined to a minimum value (15.97 ºB) which was however higher than other treatments. Slower increase in TSS of the fruits packed in LDPE bags along with $KMnO_4$ sachet during initial storage might be due to restricted respiration and ripening due to inactivation of ethylene from the storage atmosphere of the fruits. The initial increase in TSS during storage was probably due to the breakdown of complex carbohydrates like starch into simpler sugars by the action of hydrolytic enzymes (Bartley and Knee, 1982) [4]. The decrease in TSS during later stages of storages, might be due to the utilization of sugars as respiratory substrates, especially when all the complex carbohydrates have been broken down completely (Wills *et al*. 1980) [38]. Slower increase in fruit TSS in response of potassium permanganate based active packaging have been recorded earlier in apricot (Ishaq *et al*. 2009) [11] and mango (Heydari *et al*. 2011) [9].

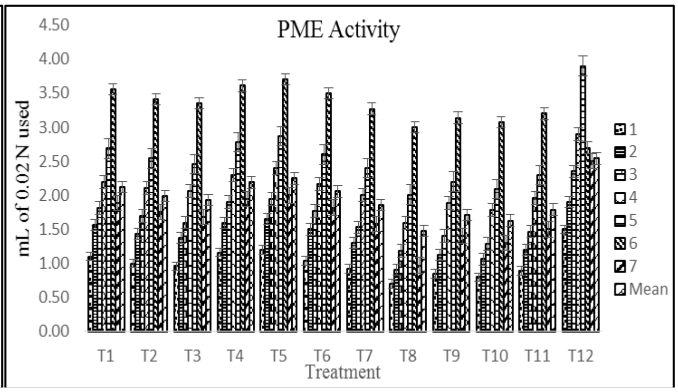
The sugars (total and reducing) followed a trend identical to TSS with a gradual increase up to a period of 6 months in all treatments except the control which exhibited an increase up to 5 months of storage before declining to a minimum level. treatment T_8 (LDPE + 5g $KMnO_4$) retained maximum mean reducing and total sugars (9.60% and 12.10%) after 7 month storage while, control fruits retained minimum mean reducing and total sugars (5.86% and 7.10%) respectively (Table 2). The initial increase in sugar content of the fruits was attributed to breakdown of starch and complex carbohydrates into simpler sugars while, the decrease in later stages might be due to the utilization of sugars as a substrate in respiration (Wills *et al*. 1998) [39]. Further, delayed respiration by inclusion of $KMnO_4$ in the LDPE led to a slow and gradual increase in sugars during storage. The findings of present investigation have also been supported by the results obtained by Mohla *et al.* (2005) [22] in sand pear.

A continuous decrease in titratable acidity of the fruits was observed during storage however, fruits packed in LDPE bags with 5 g $KMnO_4$ sachet (T_8) significantly retained highest acidity (1.10%) while, control exhibited minimum acidity (0.50%) after 7 months of storage under refrigerated conditions (Fig.1(a)). The continuous decrease in acidity of the fruits was correlated with the progression of ripening as during the climacteric maxima organic acids are generally utilized as respiratory substrates to meet high energy demand of the fruits. Similar trends indicating the reduction in fruit acidity with progression of storage have been reported earlier by Sharma and Singh (2010) [31] in apple and Mandal *et al.*, (2016) [18] in banana.

Most of the changes in fruit physiology during ripening process are accomplished by the activation of different enzyme systems and two such most important enzymes are polygalacturonase (PG) and pectin methyl esterase (PME). There was a progressive increase in PME and PG activity during initial 5 month storage before declining during next 2 months. Treatment T_8 (LDPE + 5 g $KMnO_4$) however, exhibited least mean enzyme activity (PME and PG) (0.97 ml NaOH used and 20.70% loss of viscosity) as compared to control fruits which reported highest mean enzyme activity (PME and PG) (2.50 ml NaOH used and 22.03% loss of viscosity) after 7th month of the storage under refrigerated conditions (Fig.1 (b and c)). Polygalacturonases are responsible for the major cell wall disassembly during fruit ripening in many fruits and is known to be induced by ethylene (Payasi and Sanwal 2005). PME activity increases initially and leads to de-esterification of pectin molecules the decline in PME activity thereafter might be attributed to the fact that pectin is the substrate on which PME acts and after solubilization of pectin, no further increase in activity is observed (Tieman *et al.* 2001) [34]. The increase in PME and PG activity during ripening has also been reported by earlier in mango (Vishnu Prasanna *et al.* 2003) [37] and pear (Kaur *et al.* 2014) [14, 15].

The respiration rate increased during storage under all the treatments initially brfore declining towards the completion of storage, although the fruits packed in LDPE along with 5 g $KMnO_4$ sachet exhibited a slower respiration and exhibited climacteric maxima after 6 months of storage (17.19 ml CO_2/kg/hour) before it started to decline whereas. The control fruits on the other hand reached climacteric maxima after 5 months of storage (19.67 ml CO_2/kg/h) followed by a sharp decline in respiration thereafter (Fig.1 (d)). Polyethylene film liners along with scavengers of oxygen and ethylene might have resulted in a modified atmosphere with lower O_2 and higher CO_2 concentrations thereby, reducing the respiration rate of fruits inside such packages (Manolopoulou and Papadopoulou 1997) [19].





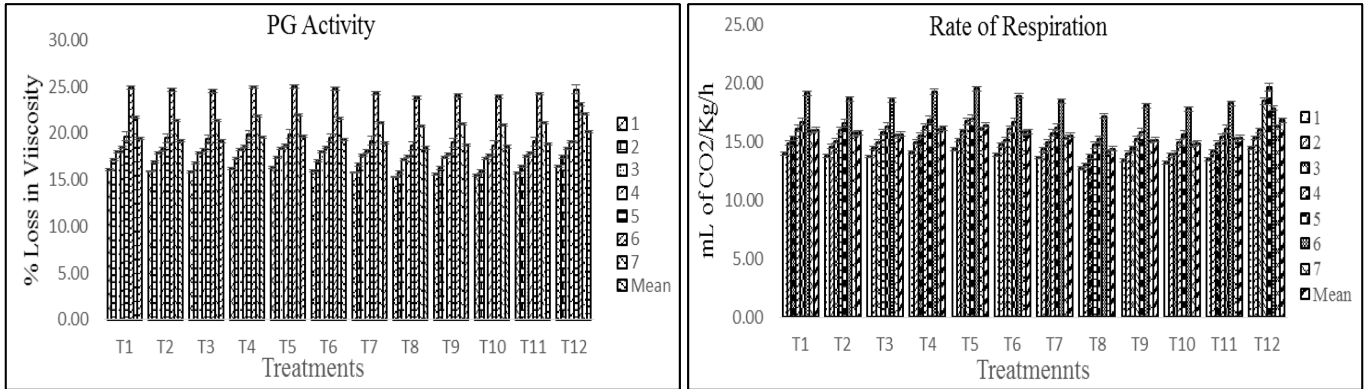


Fig 1: Effect of different active packaging treatments on (a) acidity (b) enzyme activity (PME) (c) PG (d) respiration rate in kiwifruit stored under refrigerated condition

Table 1: Effect of different active packaging treatments on PLW and Fruit firmness of kiwifruit stored under refrigerated condition

Treatments	Physiological Loss In Weight (%)								Fruit Firmness (kg/cm^2)								Moisture Content (%)							
	Storage intervals (I) in months								Storage intervals (I) in months								Storage intervals (I) in months							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**MEAN**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**MEAN**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**MEAN**
T_1	5.55	7.10	10.40	11.40	15.60	16.50	17.70	12.04	6.90	6.00	4.96	3.80	2.90	2.67	0.60	3.98	85.20	84.28	83.88	83.30	82.92	79.70	79.44	82.67
T_2	5.40	6.90	10.30	11.20	15.50	16.40	17.60	11.89	7.00	6.10	5.04	3.90	2.90	2.75	0.70	4.05	85.50	84.70	84.30	83.70	83.18	81.00	79.60	83.14
T_3	5.35	6.78	10.30	11.20	15.40	16.20	17.40	11.79	7.10	6.10	5.09	4.00	3.00	2.80	0.80	4.11	85.60	84.88	84.50	83.92	83.30	81.20	79.79	83.31
T_4	5.60	7.18	10.50	11.50	15.70	16.70	17.80	12.13	7.20	6.10	5.13	4.00	3.00	2.86	0.90	4.17	85.00	84.09	83.68	83.10	82.70	79.55	79.00	82.45
T_5	5.70	7.28	10.60	11.60	15.80	16.80	17.10	12.11	6.80	5.80	4.83	3.80	2.70	2.50	0.40	3.82	84.80	83.87	83.50	79.79	82.47	79.20	78.77	81.77
T_6	5.50	7.00	10.40	11.30	15.60	16.40	17.70	11.98	6.90	5.90	4.92	3.80	2.80	2.52	0.50	3.90	85.30	84.40	84.00	83.48	83.00	79.80	79.58	82.79
T_7	5.25	6.70	10.10	11.00	15.40	16.20	17.40	11.71	7.20	6.20	5.17	4.10	3.00	2.89	0.90	4.21	85.90	85.00	84.60	84.00	83.55	81.30	79.90	83.46
T_8	4.50	5.90	9.45	10.00	13.20	14.10	15.50	10.38	7.50	6.40	5.40	4.20	4.00	3.09	1.90	4.52	86.67	85.96	85.22	84.89	84.15	82.00	81.50	84.34
T_9	5.07	6.50	9.92	10.80	15.20	16.10	17.10	11.52	7.30	6.20	5.21	4.10	3.10	2.94	1.00	4.26	86.21	85.35	84.90	84.66	83.86	81.70	81.19	83.98
T_{10}	5.00	6.40	9.96	10.80	15.10	16.00	17.00	11.44	7.40	6.20	5.27	4.10	3.80	3.00	1.00	4.40	86.40	85.82	85.05	84.75	84.00	81.89	81.45	84.19
T_{11}	5.18	6.57	10.00	10.90	15.30	16.10	17.30	11.63	7.50	6.30	5.31	4.20	3.90	3.03	1.10	4.46	86.10	85.20	84.77	84.34	83.70	81.57	81.30	83.85
T_{12}	7.00	8.99	11.30	13.90	16.30	18.50	21.00	13.85	6.70	5.60	4.76	3.60	2.40	2.00	0.30	3.62	84.40	83.50	82.90	82.20	79.45	78.88	78.50	81.40
$CD_{0.05}$																								
Storage (S)	0.05								0.04								0.15							
Treatment (T)	0.07								0.05								0.11							
S×T	0.18								0.14								0.39							

Table 2: Effect of different active packaging treatments on TSS, reducing and total sugar content of kiwifruit stored under refrigerated condition.

Treatments	Total Soluble Solid (ºB) (MONTHS)								Reducing Sugar (%) (Months)								Total Sugar (%) (Months)							
	Storage intervals (I) in months								Storage intervals (I) in months								Storage intervals (I) in months							
	1	2	3	4	5	6	7	Mean	1	2	3	4	5	6	7	Mean	1	2	3	4	5	6	7	Mean
T_1	8.24	9.92	11.90	14.00	15.10	15.80	13.30	12.61	4.40	5.60	6.79	7.80	8.80	10.10	7.20	7.25	6.50	7.23	7.90	8.99	9.70	11.60	9.90	8.83
T_2	8.12	9.84	11.70	13.90	14.90	16.20	14.10	12.67	4.40	5.50	6.68	7.80	8.70	10.30	7.50	7.27	6.40	7.18	7.81	8.90	9.60	11.90	10.20	8.85
T_3	8.09	9.81	11.60	12.80	14.80	16.20	14.30	12.53	4.30	5.50	6.63	7.70	8.70	10.40	7.80	7.28	6.40	7.18	7.75	8.90	9.60	12.20	10.30	8.89
T_4	8.28	10.10	11.90	14.00	15.10	15.60	13.10	12.58	4.50	5.60	6.85	7.90	8.80	10.10	6.80	7.22	6.60	7.35	8.00	9.12	9.90	11.10	9.20	8.75
T_5	8.48	10.20	12.00	14.10	15.10	15.10	12.50	12.51	4.50	5.70	6.91	7.90	8.90	10.00	6.30	7.18	6.60	7.28	7.94	9.04	9.80	11.30	9.50	8.77
T_6	8.18	9.88	11.70	13.90	15.00	16.10	13.80	12.65	4.40	5.50	6.74	7.80	8.80	10.20	7.40	7.26	6.50	7.23	7.86	8.95	9.70	11.70	9.98	8.84
T_7	7.73	9.71	11.60	13.80	14.80	16.50	14.80	12.70	4.30	5.40	6.58	7.70	8.60	10.40	8.00	7.29	6.30	7.11	7.69	8.83	9.50	12.30	10.70	8.91
T_8	7.58	9.48	11.40	13.60	14.60	16.90	16.00	12.80	4.10	5.30	6.37	7.50	8.40	11.10	9.60	7.46	6.10	6.78	7.45	8.67	9.30	12.90	12.10	9.04
T_9	7.66	9.63	11.50	13.70	14.70	16.80	15.30	12.74	4.20	5.40	6.48	7.60	8.50	10.70	8.70	7.35	6.20	6.96	7.56	8.75	9.30	12.60	11.30	8.96
T_{10}	7.59	9.50	11.40	13.60	14.60	16.90	15.80	12.77	4.20	5.30	6.43	7.50	8.40	10.80	9.10	7.39	6.10	6.86	7.52	8.70	9.30	12.80	11.60	8.98
T_{11}	7.68	9.65	11.50	13.70	14.80	16.80	15.00	12.73	4.30	5.40	6.53	7.60	8.60	10.60	8.30	7.31	6.20	7.04	7.63	8.75	9.40	12.50	11.00	8.93
T_{12}	8.69	10.30	12.20	14.20	16.00	13.70	12.20	12.48	4.70	5.70	7.10	8.10	10.00	6.50	5.90	6.87	6.80	7.51	8.69	9.65	12.00	8.19	7.10	8.57
$CD_{0.05}$																								
Storage (S)	0.03								0.04								0.02							
Treatment (T)	0.04								0.05								0.03							
S × T	0.11								0.13								0.07							

Conclusion

The findings of present investigation indicates that active packaging technology consisting of packaging kiwifruits in LDPE bags containing sachets of $KMnO_4$ @ 5g/kg fruit was the most effective treatment for extending the shelf-life and retaining the storage quality of kiwifruit under refrigerated conditions at least by one month i.e. for 7 months compared to 6 months in other treatments without losing much of its acceptability

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