Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 2018-2023
Received: 17-11-2018
Accepted: 21-12-2018

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Effect of plant growth regulators and plastic films on the shelf life of bitter gourd (*Momordica charantia* L.) fruits

Donal Bhattacharjee, Payel Panja and Rabi Shankar Dhua

Abstract
A study was undertaken to envisage the effect of plant growth regulators *viz.* Benzyl adenine (BA) and Gibberellic acid (GA_3) (25 and 50 ppm respectively) packed in LDPE, HDPE and PP 50μ bags on post-harvest quality and shelf life of bitter gourd fruits and stored at ambient room temperature (27.4-32.3°C and 70-81% RH). There were seven treatments, replicated thrice and experiment was laid out in completely randomized design. The sensory score was maximum in BA 50 ppm treated fruits packed in PP bags. The fruits packed in PP bags and treated with BA 50 ppm recorded lesser weight loss in storage compared to control among three plastic films. Amid two growth regulators, BA 50 ppm documented lowest (2.53 %) spoilage in storage. By the end of storage, maximum DRI in fruits was recorded in BA 50 ppm (85.43) followed by minimum in control. Among the three plastic films, PP bags recorded high DRI values (85.43) followed by LDPE and HDPE respectively. Significant differences in chlorophyll contents were found in BA treated fruits compared to GA_3 and control. Among three plastic films, PP polybags helped to retain better storage properties. Hence, it was concluded that bitter gourd fruits treated with 50 ppm Benzyl adenine and packed in 50μ PP bags can preserve the major post harvest attributes.

Keywords: Benzyl adenine, bitter gourd, gibberellic acid, plastic films, storage

Introduction
India is the second largest country globally in respect of production of vegetables, next only to China. In spite of such huge area and production, about 20 to 30% of the produce is lost annually due to lack of adequate infrastructure and less use of modern post harvest technologies. Such post harvest losses of vegetables increases many fold during rainy season, which is a matter of grave concern for India’s horticulture sector. Being perishable in nature, vegetables deteriorate in the presence of air and lose their freshness due to continuous respiration, metabolic processes that continue even after harvest, microbial decay and inadequate post harvest management practices. Since, the quality of vegetables remains best at harvest and cannot be improved after it so maintenance of the quality is necessary especially when it is not meant to be consumed soon after harvest. So, it is essential to minimize post harvest damage to fresh produce in order to obtain optimal shelf-life. The use of suitable packaging is vital in this respect (Thompson, 1996) [1]. Modified atmosphere (MA) storage is a well-proven technology for preserving natural quality of vegetables in addition to extending the storage life (Jayas and Jeyamkondan, 2002) [2]. MA packaging of fresh vegetables refers to the technique of sealing actively respiring produce in polymeric film packages to modify the O_2 and CO_2 levels within the package atmosphere. It is often desirable to generate an atmosphere low in O_2 and/or high in CO_2 to influence the metabolism of the product being packaged, improves moisture retention or the activity of decay-causing organisms to increase storability and /or shelf life. In addition, MA technology can be applied to prevent browning, retard enzyme activity, protect colour of green vegetables and to inhibit microbial growth. It also reduces incidence of chilling injury (Rivera *et al.*, 2005) [3].
Post-harvest treatment of fruits and vegetables with various plant growth regulators has been used to delay the ripening to reduce losses and to improve and maintain the colour and quality by slowing down the metabolic activities of the produce which results in increased shelf life and marketability for a longer time. Growth regulators are an integral component of vegetable production. These regulators can be used as post harvest treatments for the vegetables to increase various physical and biochemical properties so as to enhance its keeping quality. Generally, gibberellic acid is known for its anti-senescing properties which results in delaying ripening of fruits (Tsomu *et al.*, 2015) [4]. The fruits keep firmer when treated with gibberellic acid. On the other hand, the cytokinins are derivatives of N^6-substituted adenine which have been used, both natural and synthetic form, to affect plant growth.

N^6- benzyladenine delays the senescence of many harvested crop plants. Benzyl adenine acts as an anti-senescent and arrests the metabolic break down deterioration caused by various biochemical activities in the fruits (Bhardwaj *et al*., 2005) [5]. The effect of post-harvest treatment with benzyl adenine on quality of fruits was evaluated by Jiang and Fu (1998) [6] for litchi, Jayachandran *et al*. (2003) [7] for guava, Nagar *et al*. (2004) [8] for lime, Bhardwaj *et al*. (2005) [5] for mandarin cv. Nagpur Santra. Bitter gourd (*Momordica charantia* L., Family: Cucurbitaceae) is an important vegetable grown in the states of Uttar Pradesh, Bihar, West Bengal, Orissa, Assam, Maharashtra, Gujarat, Rajasthan, Punjab, Tamil Nadu, Kerala, Karnataka, and Andhra Pradesh. This nutrient rich vegetable cannot be stored for longer time and it is require maintaining the quality and extending the shelf life with appropriate post harvest management techniques. With this background, the present study analyzes the effect of plastic films in combination with plant growth regulators on shelf life attributes of bitter gourd fruits at ambient storage.

Materials and Methods

The experiment was carried out in the laboratory conditions of the Department of Post-Harvest Technology of Horticultural Crops, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India. Fresh fruits of bitter gourd cv. Meghna 2 were used for the present experiment. Fruits of uniform colour, size and maturity, without injuries were selected. The fruits were washed with chlorine (100 ppm) water for 10 minutes using sodium hypochlorite (4.4 % w/w, as a source of chlorine). Then they were surface dried by keeping under fan in an airy place. The fruits of bitter gourd were treated with different concentrations of Benzyl adenine (BA) and Gibberellic acid (GA_3) for 10 minutes. For control fruits were treated with distilled water. All the treatments were kept on trays under fan to remove the excess water. All the treatments were pre-packed separately in three types of plastic bags *viz*. low density polyethylene (LDPE), high density polyethylene (HDPE) and polypropylene (PP) (20 x 17 cm) of 50 μ thicknesses respectively. 0.25% of perforation was maintained for all three bagging materials. After placing the treated fruits in bags as above the bags were closed. A set of treatments were kept in normal room condition. The temperature and relative humidity of the atmosphere during the study period ranged from 27.4-32.3 °C and 70-81% respectively. There were five treatments *viz*., T_1-Control, T_2- Benzyl adenine 25 ppm, T_3- Benzyl adenine 50 ppm, T_4- Gibberellic acid 25 ppm, T_5- Gibberellic acid 50 ppm. The analysis of data obtained in the experiment was analyzed by Completely Randomized Design with three replications, by adopting the statistical procedures of Gomez and Gomez (1984) [9]. The means between treatments were compared by Duncan's multiple range tests (DMRT) (Duncan, 1955) [10].

Sensory evaluation

During the period of study, observations on sensory properties were estimated by using 9-point Hedonic scale for their sensory characteristics like appearance, texture and overall acceptability. The scores were assigned from extremely liked (9) to disliked extremely (1) (Kaur and Aggarwal, 2015) [11].

Physiological loss in weight (PLW)

The weight of individual fruit in the experiment was taken on the day of observation and the percentage of loss in weight on the day of observation was calculated on the basis of the initial weight and expressed in percentage (Koraddi and Devendrappa, 2011) [12].

$$\text{PLW (\%)} = \frac{\text{Initial fruit weight} - \text{Weight of fruit on observation day}}{\text{Initial fruit weight}} \times 100$$

Spoilage

Spoilage percentage was observed after every 48 hours and was calculated as described below (Bhat *et al*., 2014) [13].

$$\text{Spoilage (\%)} = \frac{\text{Number of decayed fruits at the time of sampling}}{\text{Initial number of fruits}} \times 100$$

Disease reduction index (DRI)

The disease reduction index was estimated from the numbered fruits of each experimental lot at each date of observation and disease reduction index was calculated by the following formula (Gutter, 1969) [14].

$$\text{DRI} = \frac{\text{Percent disease in control} - \text{Percent disease in treatment}}{\text{Percent disease in control}}$$

Chlorophyll content

Chlorophyll a, b and total chlorophyll was extracted in 80% acetone and absorption was measured at 663 nm and 645 nm by spectrophotometer (Systronics Spectrophotometer 166) and expressed as mg chlorophyll per gram of fresh tissue at regular time interval. Using the absorption coefficients, the amount of chlorophyll is calculated using the following equations (Sadasivam and Manickam, 1996) [15]:

$$\text{Mg chlorophyll a/ g tissue} = 12.7\ (A_{663}) - 2.69\ (A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{Mg chlorophyll b/ g tissue} = 22.9\ (A_{645}) - 4.68\ (A_{663}) \times \frac{V}{1000 \times W}$$

And

$$\text{Mg total chlorophyll/ g tissue} = 20.2\ (A_{645}) + 8.02\ (A_{663}) \times \frac{V}{1000 \times W}$$

Where,
A = absorbance at specific wavelengths
V = final volume of chlorophyll extract in 80% acetone
W = fresh weight of tissue extracted.

Results and Discussions

Sensory properties during the storage of bitter gourd fruits is shown in Table 1. The sensory quality gradually decreased during storage at ambient room temperature in all the treatments. Post-harvest treatment with benzyl adenine appreciably reduced loss of sensory properties compared to gibberellic acid treatments particularly during later part of storage. PP packing had better effect than HDPE and LDPE on maintaining the superior sensory score. Better performance was detected with post harvest treatment of benzyl adenine at 50 ppm (T_3) as indicated by highest sensory score (9.00) packed in all three grades of plastic films on 2nd day of storage. By the end of storage, the value of T_3 (Benzyl adenine 50 ppm) reached 8.00 followed by T_2 (Benzyl adenine 25 ppm), T_5 (Gibberellic acid 50 ppm), T_4 (Gibberellic acid 25 ppm) and control with the lowest sensory score (3.33) packed in PP polybags compared to HDPE and LDPE 50μ thickness bags. Post-harvest factors that affect the sensory qualities of fresh produce include respiration rate, the presence of ethylene and storage conditions; temperature, relative humidity, light and the composition of the surrounding atmosphere (Jacobsson *et al*., 2003a) [16]. These factors results in promoting degradation, such as the loss of colour and texture and are the limiting factors of shelf life. Pre-packaging plays an important role in maintenance of sensory qualities by slowing down the biochemical changes and reducing the moisture loss, thus increasing the shelf life of fresh produce (Naik *et al.*, 1993) [17]. Exogenous application of cytokinins results in delay in senescence, maintenance of chloroplast activity, decline chlorophyll degradation (Wingler *et al*., 1998; Clarke *et al*., 1994) [18, 19].

Table 1: Changes in the sensory properties of bitter gourd at different days in storage as affected by PGRs and plastic films

Treatments	Sensory properties								
	LDPE-50			HDPE-50			PP-50		
	Days in storage			Days in storage			Days in storage		
	2	4	6	2	4	6	2	4	6
T_1	7.00 a	5.00 a	1.67a	6.67a	5.33a	2.00a	7.67a	5.00a	3.33a
T_2	8.33 ab	7.67bc	5.33cd	8.67 c	8.00b	7.00c	9.00b	8.33bc	7.67b
T_3	9.00 b	8.33c	6.67d	9.00c	8.33b	7.33c	9.00b	8.67c	8.00b
T_4	7.67ab	6.33ab	3.33b	7.00ab	5.67a	4.67b	8.33ab	7.33b	7.00b
T_5	8.33 ab	7.00bc	4.00bc	8.33bc	7.67b	6.67c	8.67b	8.33bc	7.33b
C.D. (0.05)	N/A	1.427	1.505	1.427	0.952	1.843	0.824	1.259	1.427
S.Em ±	0.447	0.447	0.471	0.447	0.298	0.577	0.258	0.394	0.447

(Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%) (T_1- Control, T_2- Benzyl adenine 25 ppm, T_3- Benzyl adenine 50 ppm, T_4- Gibberellic acid 25 ppm, T_5- Gibberellic acid 50 ppm)

The physiological loss in weight of bitter gourd fruits packed in LDPE, HDPE and PP 50µ thickness bags with 0.25 % perforation influenced by different concentrations of benzyl adenine and gibberellic acid showed steady rise in weight loss of fruits at different days in storage as compared to control (Table 2). On 2nd day of storage, physiological loss in weight was least in T_3 (Benzyl adenine 50 ppm). Among the three plastic films, physiological loss in weight was recorded minimum when packed in PP 50µ bags (1.70 %) followed by HDPE (2.53 %) and LDPE (3.09 %) bags. However, per cent increment in weight loss was observed significantly low in BA 50 ppm (T_3) (5.74 %) treated bitter gourd fruits followed by BA 25 ppm (T_2) (9.63 %) compared to control in all three grades of plastic films during 6th day of storage. The bitter gourd fruits treated with BA recorded lesser weight loss in different days in storage at a concentration of 50 ppm packed in PP 50µ thick polybags compared to control among three plastic films. The physiological loss in weight of fresh bitter gourd is primarily due to transpiration and respiration. In the present investigation, weight loss was significantly higher in LDPE bags (50 µ thickness) than the HDPE and PP bags. High temperatures increased the rates of respiration and other metabolic processes that caused depletion of substrates like sugars and proteins resulting into further weight loss (Buescher, 1979) [20]. As water evaporates from the tissue, turgor pressure decreases and the cells begin to shrink and collapse thus leading to loss of freshness (Wills *et al*., 1998) [21]. Lowest weight loss is due to the confinement of moisture around the produce by polypropylene bags. This increases the relative humidity and reduces vapour pressure deficit and transpiration. In addition, packaging creates a modified atmosphere with higher concentration of carbon dioxide and reduced oxygen around the produce, which slows down the metabolic processes and transpiration (Thompson, 1996) [1]. The present findings are in agreement with the previous findings of Rahman *et al*. (2009) [22], Sandhu and Singh (2000) [23] and Baszczyk and Ysiak (2001) [24].

Table 2: Changes in the physiological loss in weight of bitter gourd at different days in storage as affected by PGRs and plastic films

Treatments	Physiological loss in weight (%)								
	LDPE-50			HDPE-50			PP-50		
	Days in storage			Days in storage			Days in storage		
	2	4	6	2	4	6	2	4	6
T_1	9.67c (3.27)	17.22 c (4.27)	23.84d (4.98)	8.52d (3.08)	14.63 d (3.95)	20.51e (4.64)	7.62d (2.93)	10.37c (3.37)	15.55 d (4.07)
T_2	4.40a (2.32)	10.92 b (3.45)	15.84b (4.10)	3.72b (2.17)	9.05 b (3.17)	12.71b (3.70)	2.64a (1.90)	6.77b (2.78)	9.63 b (3.26)
T_3	3.09a (2.01)	7.41 a (2.90)	11.38a (3.52)	2.53a (1.87)	6.14 a (2.67)	9.80a (3.28)	1.70a (1.64)	3.54a (2.13)	5.74 a (2.59)
T_4	8.61c (3.10)	16.35 c (4.16)	20.44c (4.63)	7.68d (2.94)	15.29 d (4.04)	17.91d (4.35)	6.34c (2.71)	11.59c (3.55)	14.96 d (3.99)
T_5	6.33b (2.71)	14.97 c (3.99)	17.89b (4.34)	5.47c (2.54)	12.91 c (3.73)	15.81c (4.10)	4.35b (2.31)	10.44c (3.38)	12.09 c (3.62)
C.D. (0.05)	0.332	0.340	0.245	0.245	0.236	0.246	0.279	0.299	0.219
S.Em ±	0.104	0.106	0.077	0.077	0.074	0.077	0.087	0.094	0.068

* Figures in parenthesis indicates square root transformed values (Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%) (T_1- Control, T_2- Benzyl adenine 25 ppm, T_3- Benzyl adenine 50 ppm, T_4- Gibberellic acid 25 ppm, T_5- Gibberellic acid 50 ppm)

The data presented (Table 3) on spoilage of bitter gourd fruits as influenced by different concentrations of BA and GA_3 showed increase spoilage of fruits with advancement of storage. Among the three plastic films, PP bags recorded less spoilage during the storage. The bitter gourd fruits bagged in LDPE bags indicated spoilage from 2nd day of storage whereas, fruits in HDPE and PP bags recorded no spoilage. Among two growth regulators, BA 50 ppm (T_3) documented lowest (2.53 %) spoilage followed by BA 25 ppm (T_2) (8.63 %) and GA_3 50 ppm (T_5) (9.62 %). The fruits which were not given any treatments recorded highest spoilage (49.63 %) by the end of storage period. The results indicated more spoilage in control and GA_3 treated fruits. The fruit spoilage due to rotting also increased as the storage period advances irrespective of treatments. This might be due to condensation of moisture in the surface of fruits during storage, anaerobic condition, and break down of enzymes etc., which helped in multiplication of micro flora. The reduced loss due to decay in PP 50 µ thickness bags might be attributed to limited permeability of gases (CO_2 and O_2) and water vapour, which can interplay with physiological processes of fruit (Tijskens and Vollebregt, 2003; Soliva and Martin, 2003) [25, 26]. The results of this finding are in agreement with the reports of Sandhu and Singh (2000) [23] and Drake and Gix (2000) [27].

Table 3: Spoilage of bitter gourd fruits as influenced by PGRs and plastic films

Treatments	Spoilage (%)								
	LDPE-50			HDPE-50			PP-50		
	Days in storage			Days in storage			Days in storage		
	2	4	6	2	4	6	2	4	6
T_1	11.18b (19.47)	21.27e 27.44)	49.63e 44.77)	0.00 a (0.81)	13.24b (21.29)	39.45d (38.90)	0.00 a (0.81)	10.60d 18.97)	31.86c 34.35)
T_2	0.00a (0.81)	9.36b (17.80)	15.90b (23.47)	0.00 a (0.81)	5.73a (11.36)	14.47b (22.34)	0.00 a (0.81)	2.32b (8.73)	8.63b (17.07)
T_3	0.00a (0.81)	0.00a (0.81)	8.40a (16.79)	0.00 a (0.81)	0.00a (0.81)	7.98a (16.39)	0.00 a (0.81)	0.00a (0.81)	2.53a (9.09)
T_4	0.00a (0.81)	16.55d (23.98)	26.29d (30.83)	0.00 a (0.81)	6.36a (11.99)	19.51c (26.19)	0.00 a (0.81)	5.50c (13.53)	10.39b 18.78)
T_5	0.00 a (0.81)	12.83c (20.95)	21.15c (27.36)	0.00 a (0.81)	6.06a (14.21)	19.46c (26.16)	0.00 a (0.81)	4.64c (12.38)	9.62b (18.05)
C.D. (0.05)	1.593	1.938	2.110	-	11.936	1.772	-	1.899	1.717
S.Em ±	0.499	0.607	0.661	-	3.740	0.555	-	0.595	0.538

* Figures in parenthesis indicates angular transformed values (Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%) (T_1- Control, T_2- Benzyl adenine 25 ppm, T_3- Benzyl adenine 50 ppm, T_4- Gibberellic acid 25 ppm, T_5- Gibberellic acid 50 ppm)

The data (Table 4) on the effect of growth regulators and different plastic films in bitter gourd fruits revealed that the application of BA 50 ppm (T_3) maintained lower incidence of diseases during storage followed by treatment with BA 25 ppm (T_2). The disease incidence started from 2nd day onwards in LDPE bagged fruits whereas, no incidence of diseases was reported in HDPE and PP bags. However, by end of storage period, maximum DRI was recorded in T_3 (Benzyl adenine 50 ppm) (85.43) followed by minimum in control (0.00). The fruits in control and that treated with GA_3 showed a steady loss of protective ability to reduce the decay caused by spoilage organisms. Among the three plastic films, PP bags recorded high DRI values (85.43) followed by LDPE (82.98) and HDPE (70.73) respectively. The highest disease incidence observed with non-perforated packaging may be due to high relative humidity and water condensation around the produce, which promote the development of post-harvest decay (Coates *et al*., 1995) [28]. The changes in physical properties of cell membrane leads to the release of metabolites such as amino acids, sugars and mineral salts from cells that together with the degradation of the cell structure provide an excellent substrate for the growth of pathogenic organisms, especially fungi (Wills *et al*. 1998) [21]. The results of this finding are in agreement with the reports of Shi Juan *et al*. (2002) [29] and Drake and Gix (2000) [27].

Table 4: Disease reduction index at different days of storage of bitter gourd

Treatments	Disease reduction index								
	LDPE-50			HDPE-50			PP-50		
	Days in storage			Days in storage			Days in storage		
	2	4	6	2	4	6	2	4	6
T_1	0.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
T_2	100.00	55.88	45.49	100.00	68.31	55.98	100.00	71.76	67.62
T_3	100.00	100.00	82.98	100.00	100.00	70.73	100.00	100.00	85.43
T_4	100.00	21.88	19.26	100.00	50.10	26.92	100.00	51.79	46.38
T_5	100.00	38.89	29.79	100.00	53.98	50.53	100.00	54.11	48.62

(T_1- Control, T_2- Benzyl adenine 25 ppm, T_3- Benzyl adenine 50 ppm, T_4- Gibberellic acid 25 ppm, T_5- Gibberellic acid 50 ppm)

The changes in pigment concentration of bitter gourd fruits as influenced by benzyl adenine and gibberellic acid under LDPE, HDPE and PP polybags illustrated significant differences between the treatments (Table 5). Among the two growth regulators, benzyl adenine recorded significantly higher chlorophyll a (12.13 mg/g), chlorophyll b (5.79 mg/g) and total chlorophyll (17.97 mg/g) in PP bags followed by HDPE and LDPE bags on 2nd day of storage. The same trend prevailed on 4th day as well as on 6th day after storage with highest retention of chlorophyll a (10.23 mg/g), chlorophyll b (4.87 mg/g) and total chlorophyll (15.10 mg/g) in T_3 (Benzyl adenine 50 ppm) and lowest chlorophyll a (6.63 mg/g), chlorophyll b (3.15 mg/g) and total chlorophyll (9.79 mg/g) in control as presented in Table. Thus, significant differences in chlorophyll contents were found in BA treated fruits compared to GA_3 and control. Among three plastic films, PP 50 μ polybags helped to retain maximum chlorophyll contents compared to HDPE and LDPE bags. In the present study it was observed that plant growth regulators had profound influence on chlorophyll content. Significant differences were observed among the treatments with respect to chlorophyll a, b and total chlorophyll contents. An increment in activities of some enzymes (chlorophyllase and Mg-dechelatase) is responsible for chlorophyll catabolism and as a result yellowing of fruits (Costa *et al*., 2005) [30]. Current results showed that exogenous application of BA significantly delays chlorophyll degradation and yellowing. These results are supported by Siddiqui *et al*. (2011) [31], Costa *et al*. (2005) [29] and Zaicovski *et al*. (2008) [32].

Table 5: Chlorophyll a, chlorophyll b and total chlorophyll content of bitter gourd fruits at different days of storage in LDPE, HDPE and PP-50μ thick films

Treatments	Pigment content (mg/g)								
	LDPE-50μ thick films								
	Days in storage								
	2			**4**			**6**		
	Chlorophyll a	**Chlorophyll b**	**Total chlorophyll**	**Chlorophyll a**	**Chlorophyll b**	**Total chlorophyll**	**Chlorophyll a**	**Chlorophyll b**	**Total chlorophyll**
T_1	7.77a	3.69 a	11.47 a	5.71 a	2.72 a	8.43 a	4.57 a	2.18 a	6.75 a
T_2	10.72d	5.11c	15.83c	8.91d	4.24d	13.15d	7.07d	3.37d	10.44c
T_3	11.54e	5.50d	17.04c	10.72e	5.10e	15.82e	8.89e	4.23e	13.12d
T_4	9.13b	4.35b	13.48b	7.08b	3.37b	10.46b	5.48b	2.61b	8.09ab
T_5	9.52c	4.53b	14.05b	7.99c	3.81c	11.80c	6.39c	3.04c	9.43bc
C.D. (0.05)	0.357	0.329	1.259	0.374	0.334	1.255	0.226	0.235	1.427
S.Em ±	0.112	0.103	0.394	0.117	0.104	0.393	0.071	0.074	0.447
	HDPE-50μ thick films								
T_1	8.23 a	3.92 a	12.16 a	7.08 a	3.37 a	10.45 a	5.71 a	2.72 a	8.42 a
T_2	10.96 d	5.22 c	16.18 c	9.82 d	4.68 bc	14.50 c	8.45 d	4.02 bc	12.48 c
T_3	11.74 e	5.59 d	17.33 d	10.85 e	5.17 c	16.03 d	9.82 e	4.67c	14.49 d
T_4	9.52 b	4.53 b	14.05 b	8.45 b	4.03 ab	12.48 b	6.41 b	3.05 a	9.46 ab
T_5	9.83 c	4.68 b	14.51 b	8.68 c	4.13 ab	12.82 b	7.09 c	3.38 ab	10.47 b
C.D. (0.05)	0.258	0.240	1.043	0.223	0.845	0.974	0.178	0.804	1.066
S.Em ±	0.081	0.075	0.327	0.070	0.265	0.305	0.056	0.252	0.334
	PP-50μ thick films								
T_1	8.71 a	4.15 a	12.86 a	7.78 a	3.71 a	11.49 a	6.63 a	3.15 a	9.79 a
T_2	10.98 d	5.23 d	16.20 d	10.29 d	4.90 c	15.19 c	9.81 cd	4.67 bc	14.49 c
T_3	12.13 e	9.80 e	17.97 e	11.42 e	5.44 d	16.87 d	10.23 d	4.87 c	15.10 c
T_4	9.62 b	4.58 b	14.20 b	8.69 b	4.14 b	12.83 b	8.45 b	4.03 b	12.48 b
T_5	10.29 c	4.90 c	15.20 c	9.89 c	4.68 c	14.18 c	9.14 bc	4.35 bc	13.16 b
C.D. (0.05)	0.248	0.208	0.477	0.406	0.340	1.168	0.754	0.655	1.181
S.Em ±	0.078	0.065	0.150	0.127	0.107	0.366	0.236	0.205	0.370

(Means in the column followed by the same alphabet do not differ significantly by DMRT at 5%) (T_1- Control, T_2- Benzyl adenine 25 ppm, T_3- Benzyl adenine 50 ppm, T_4- Gibberellic acid 25 ppm, T_5- Gibberellic acid 50 ppm)

Conclusion

The present investigation revealed that the post-harvest storage behaviour of bitter gourd fruits can be enhanced by packaging in plastic films with application of plant growth regulators. It could be concluded that 50 ppm Benzyl adenine was efficient in delaying ripening, reducing the weight loss, decay incidences, maintaining pigment concentration and enhanced the shelf-life of bitter gourd fruits during storage when packed in 50 μ Polypropylene bags. Benzyl adenine can be easily applied, cost effective and hence can be used commercially to prolong the shelf life of bitter gourd fruits.

References

1. Thompson AK. Post-harvest technology of fruits and vegetables. Blackwell, Oxford, 1996.
2. Jayas DS, Jeyamkondan S. Modified atmosphere storage of grains, meats, fruits and vegetables. Bio systems Eng. 2002; 82:235-251.
3. Rivera LJ, Vazquez OFA, Ayala ZJF, Sotelo MRR, Gonzalez AGA. Cutting shape-cut papaya cv. Maradol. J Food Sci. 2005; 70:482-489.
4. Tsomu T, Patel HC, Thakkar RM, Ajang M, Vasara RP. Response of post-harvest treatments of chemical and plant growth regulators on biochemical characteristics of sapota fruit cv. Kalipatti. The Bio scan. 2015; 10(1):33-36.
5. Bhardwaj RL, Sen LN, Mukherjee S. Effect of Benzyl adenine on physico-chemical characteristics and shelf life of mandarin cv. Nagpur Santra. Indian J Horti. 2005; 62:181-183.
6. Jiang Y, Fu J. Effect of post harvest treatment with N6-benzyl adenine on quality of litchi (*Litchi chinensis* sonn.) fruit. Trop Sci. 1998; 38:161-164.
7. Jayachandran KS, Srihari D, Reddy YN, Rai S. Influence of post-harvest treatments with preservatives on the shelf life and biochemical composition of guava fruits. In: Souvenir, Int. Food Convention (IFCON 2003) on Innovative Food Technology and Quality Systems Strategies for Global Competitiveness Association of Food Scientists and technologist (India) Mysore, 2003, 193.
8. Nagar BL, Dashora LK, Dhaka RS. Effect of different post harvest treatment on shelf life and quality of Kagzi lime (*Citrus aurantifolia* Swingle). Udyanika. 2004; 10:11-17.
9. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research (2nd Ed.).Wiley Inter Science Publication (John Wiley and Sons) New York, USA, 1984.
10. Duncan DB. Multiple range and Multiple F-Tests. Biometrics, 1955; 11:1-42.
11. Kaur S, Aggarwal P. Effect of addition of dehydrated potato flour on the quality of rice papad. The Ecoscan. 2015; 9(1&2):305-310.
12. Koraddi VV, Devendrappa S. Analysis of physiological loss of weight of vegetables under refrigerated conditions. J Farm Sci. 2011; 1:61-68.
13. Bhat A, Kaul RK, Reshi M, Gupta N. Effect of polyamines on shelf life and chilling injury of mango cv. Dashehari. The Bio scan. 2014; 9(3):1097-1100.
14. Gutter Y. Comparative effectiveness of benomyl, thiabendazole and other antifungal compounds for postharvest control of *Penicillium* decay in Sharmouti and Valencia oranges. Plant Dis Reptr. 1969; 53:474-478.

15. Sadasivam S, Manickam A. Biochemical Methods (2ndEdn.) New Age International Publisher, New Delhi, 1996, 187-188.
16. Jacobsson A, Nielsen N, Sjoholm I. Effects of type of packaging material on shelf-life of fresh broccoli by means of changes in weight, colour and texture. Eur Food Res Technol. 2003; 218:157-163.
17. Naik DM, Mulekar VG, Chandel CG, Kapse BM. Effect of prepackaging on physico-chemical changes in tomato (*Lycopersicon esculentum* Mill.) during storage. Indian Food Packer, 1993, 9-13.
18. Wingler A, Schaewen AV, Leegood RC, Lea PJ, Quick WP. Regulation of leaf senescence by cytokinin, sugars, and light effects of NADH-dependent hydroxyl pyruvate reductcase. Plant Physiol. 1998; 116:329-355.
19. Clarke SF, Jameson PE, Downs C. The influence of 6-benzylaminopurine on post-harvest senescence of floral tissues of broccoli (*Brassica oleracea* var. *Italia*). Plant Growth Regul. 1994; 14:21-27.
20. Buescher RW. Influence of high temperature on physiological and compositional characteristics of tomato fruits. LWT Food Sci. Technol. 1979; 12:162-164.
21. Wills R, McGlasson B, Graham D, Joyce D. Postharvest: An Introduction to the Physiology and Handling of Fruits, Vegetables and Ornamentals. 4th Edition. CAB International, Wallingford, Oxen 10 8 DE, 1998, 262.
22. Rahman MM, Shahjahan MD, Miaruddin MD, Chowdhury MDG. Effect of packaging techniques and chlorination on the quality and shelf life of country bean (*Lablab niger*). Bangladesh J Agril. Res. 2009; 34:623-631.
23. Sandhu SS, Singh AP. Effect of harvesting dates and individual seal packaging on the pear fruit cv. Le Conte during cold storage. Haryana J Hortic. Sci. 2000; 29:48-52.
24. Baszczyk J, Ysiak G. Storage properties of Czech pear cultivars “Erica” and “Dicolor”. J Fruit Ornam Plant Res. 2001; 9:71-76.
25. Tijskens LMM, Vollebregt HM. Passive and semi-active modified atmosphere packaging of prickly pear cactus stems (*Opuntis* spp.). Acta Hortic, 2003; 604:665-668.
26. Soliva FRC, Martin BO. Microbiological and biochemical changes in minimally processed fresh-cut Conference pears. Eur Food Res Technol. 2003; 217:4-9.
27. Drake SR, Gix RD. Response of d’Anjou pears to controlled atmosphere storage in elevated temperature and carbon dioxide. Good Fruit Grower. 2000; 51:55-57.
28. Coates L, Cooke T, Persley D, Beattie B, Wade N, Ridgway R. Post-harvest of Horticultural Produce, Tropical Fruits, Department of Primary Industries, Queensland, Briesbane, 1995, 2.
29. ShiJuan D, KunSong C, LuJun Liang, Zheng JT. Effects of different postharvest treatments on storage of Huanghua pear fruit (*Pyrus pyrifolia* Nakai) and its physiological basis. Scientia Agricultura Sinica. 2003; 36:82-88.
30. Costa ML, Civello PM, Chaves AR, Martinez GA. Effect of ethephon and 6-benzyl aminopurine on chlorophyll degrading enzymes and a peroxidase-linked chlorophyll bleaching during postharvest senescence of broccoli (*Brassica oleracea* L.) at 20°C. Postharvest Biol. Technol. 2005; 35:191-199.
31. Siddiqui MdW, Chakraborty I, Ayala-Zavala JF, Dhua RS. Advances in minimal processing of fruits and vegetables: a review. J Sci Ind Res. 2011; 70:823-834.
32. Zaicovski CB, Zimmerman T, Nora L, Nora FR, Rombaldi CV. Water stress increases cytokinin biosynthesis and delays postharvest yellowing of broccoli florets. Postharvest Biol. Technol. 2008; 49:436-439.