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Evaluation of postharvest quality of four local chilli (*Capsicum frutescens*) genotypes of Tripura under zero energy cool chamber

S Shil, J Mandal and SP Das

Abstract
Four high yielding local chilli genotypes were grown at intrsuction farm of KVK, Khowai in the year 2015-16. After harvesting green chiilies were stored under ambient and zero energy cool chamber. Significant differences were observed among cultivars and storage conditions in changes in quality of chilli. Storage at ambient conditions resulted in high weight loss, moisture content loss and rapid deterioration in appearance. The maximum and minimum PLW were recorded in G1 and G4, respectiveof storage condition. Irrespective of chilli genotype, fresh green chilli can be store successfully in zero energy cool chamber upto 6th day whereas under ambient temperature chillies can be store only for two days. And among these four genotype G1shows positive result in physiological loss in weight, retaining moisture content, decay % and maintain firmness and appearance followed by G3 irrespective of storage condition.

Keywords: evaluation, chilli, zero energy, cool chamber, Tripura

Introduction
Chilli [*Capsicum annuum* L.] is an important spice crop in India and is grown in the tropical, subtropical and temperate regions of the world. The demand for chilies is increasing day by day both in local and international markets. The high nutritive and culinary value of pepper gives them a high demand in the market throughout the year. The main producing region in the world is Asia. Chilli occupies an area and production of 287 '000 hectare, 3406 '000 MT respectively during 2016-17 (NHB 2016-17). The major chilli growing states are Andhra Pradesh, Karnataka, Maharashtra, Bihar, Tamil Nadu, Madhya Pradesh, West Bengal and Rajasthan. However, in Tripura chilli is cultivated in 2.12 thousand hectare area with total annual production of 19.60 thousand tones (NHB 2016-17). Most of the varieties grown in the country are pungent varying from very pungent to mild pungency. Green chillies are rich source of Vitamin A and Vitamin E. It is widely used in the curry powder, curry paste, all kinds of pickles and preparing sauce, soups, etc.

In spite of high production, in a sub-tropical country like India, it is difficult to maintain the quality and storability of Chilli after harvest. Fresh green chillies are characterized by high moisture content and active metabolism as a consequence, significant losses resulting in senescence, desiccation, physiological disorders, mechanical injuries and microbial spoilages occur at any point from harvest through utilization (Edusei *et al*. 2012) [5]. Chilli usually needs to be transported from the production region to the remote market and generally not directly sale to the consumers. The most common market chain observe in chilli is farmers wholesaler retailer consumer. It is estimated that there is about 6.7–17.1% loss of chilli occurs during marketing (Sharma *et al*., 2005) [15]. The problem may be aggravated during peak production periods when farmers may be tempted to store their produce for short periods to avoid distress sales.

Fresh produce needs low temperature and high relative humidity (RH) during storage and transportation. Therefore, reducing the temperature and increasing the RH are primary means of maintaining product quality during storage and transportation. (A. Samira *et al*., 2013) [13]. But, most of these cooling methods are unaffordable by the small-scale farmers. High humidity storage in evaporative cool chamber as developed at IARI, New Delhi has been reported to minimize the dessication, dehydration and subsequent yellowing and spoilage and suitable for short term storage of fruits and vegetables (Khurdiya and Roy, 1986) [8].

Zero energy storage structures are generally employed by small farmers with small landholdings, for the storage of fresh fruits and vegetables over a one to two week period. As the name suggests, these structures do not require any energy for operation.

Their operation is based on the principle of evaporative cooling whereby the temperature is decreased and the relative humidity increased, creating an environment suited to maintaining the freshness of fruits and vegetables. Thus, present investigation was undertaken to study the efficacy of different storage conditions for the local chilli genotypes of Tripura.

Materials and Methods

To study the storage behaviour four numbers of local high yielding chilli genotypes coded as G1, G2, G3, G4 were taken. The present study was carried out at krishi Vigyan Kendra khowai, Tripura during 2015-2016. The climate of the region is semi-arid and sub tropical having winter and summer. Khowai is a monsoon influenced humid subtropical climate with large amount of rain almost the year. And the soil of the experiment field was sandy loam in texture. It was medium in organic matter and had good water holding capacity. Seeds of local chilli genotypes were grown at the institutional farm of the KVK, Khowai following the standard package of practices to obtain the fresh green chilli. The green mature chilli fruits of selected genotypes were harvested early in the morning and then keep for storage in two different storage conditions namely Zero energy cool chamber and ambient temperature. The study design will be Factorial CRD (Completely randomized design) with two factors (genotypes and storage condition).

Observations recorded

Physiological loss of weight (PLW) %

For determining PLW of chillies during storage, the weight of the chilli was recorded and the total loss of physiological weight was then calculated by subtracting the final weight of the chillies from the initial weight. The results were then expressed in percentage using following formula:

$$\% \text{ PLW} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{ X } 100$$

Moisture content %

This parameter was determined using 10 g sample from each treatment that was cut into pieces, dried in micro oven at 70 °C to a constant weight as described by (Antoniali *et al*. 2007) [1] and the results were expressed in percentage.

Decay/Rotting (%): It is the percentage of the damaged chilies. It was also determined by the quality parameters of the chilies like rotting, shriveling, incidence of disease, etc.

$$\textbf{Decay (\%)} = \frac{\text{Quantity of spoiled Chilli}}{\text{Total quantity of Chilli}} \times 100$$

Shelf Life (Days)

Shelf life is the length of time for which a produce remains effective, presentable and free from deterioration, and thus saleable.

Appearance and Firmness

Based on visual observations on shrinkage, freshness and color changes appearance was recorded. For this a nine point hedonic scale was developed.

Firmness changes rapidly during storage and become softer. Excessive loss of moisture may also affect the texture of crops. These textural changes are detected by touch. Textural measurements were performed on harvest day and during postharvest storage. For the measurement of firmness also a nine point hedonic scale was used.

Result and Discussion

Table 1: Physiological loss in weight (%) during storage.

Genotype (G)	**Zero Energy Cool Chamber (ZECC)**					**Ambient Temperature**				
	Storage duration (B)									
	0 day (B1)	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**	**0 day (B1)**	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**
G1	0	4.747	10.270	15.783	21.163	0	16.033	25.070	33.127	-
G2	0	4.420	10.093	17.610	25.650	0	18.227	27.867	35.797	-
G3	0	4.630	10.457	17.620	25.033	0	16.877	25.927	34.147	-
G4	0	5.667	13.060	17.477	25.847	0	18.860	29.243	36.130	-
Storage condition (S)		ZECC				Ambient				
Mean		14.345				19.831				
SEm		0.120								
CD		0.338								
Genotype (G)		G1	G2	G3	G4	B1	B2	B3	B4	B5
Mean		15.774	17.483	16.836	18.261	0	11.183	18.998	25.961	12.212
SEm		0.169				0.169				
CD		0.479				0.479				
Interaction		S × B			B × G			S× B × G		
SEm		0.240			0.339			0.479		
CD		0.677			0.957			1.354		

Data pertaining to physiological loss in weight (PLW) of green chilli during storage, as affected by various storage condition are presented in Table 1. A perusal of the data reveals that there was a progressive and continuous increase in PLW of green chilli with an increase in storage duration in both the storage condition. During the initial storage period (day 2), G2 and G4 stored at ambient condition were found to have the highest percentage of weight loss of 18.22% and 18.86%, respectively. However, G2 stored in the zero energy cool chamber showed the lowest percentage weight loss (4.42%) on the same date. On the subsequent days of storage, mean percent weight loss of fruits stored at ambient condition had more percent of weight loss, than the fruits stored in the zero energy cool chamber. In the later stage, however, the difference in the weight loss of fruits under the two storage environments tended to narrow down. On day 4th, nearly all pepper fruits stored at ambient condition were unmarketable, while those stored in the zero energy cool chamber remained marketable up to 6 days. After 8 days of storage in zero energy cool chamber, the maximum weight loss was recorded in G4 (25.84%) and minimum loss in G1 (21.16%). In both storage condition chilli genotype G1 shows lowest weight loss throughout the storage period.

The higher percentage physiological weight loss in chilli stored at ambient conditions compared to those stored in the zero energy cool chamber appeared to be related to the RH and temperature surrounding the produce. The zero energy cool chamber had more air humidity as well as cooler than the ambient storage conditions, there by capable of reducing excessive moisture loss from the produce (A. Samira *et al.* 2013) [13]. The types of surfaces and underlying tissues of fruit may also have a marked effect on the rate of water loss (Wills *et al.* 1989) which could be seen as reasons for the differences observed among the chilli genotypes.

Quality of fresh horticultural produce is affected by water loss during storage, which depends on the temperature and RH of the storage environment (Perez *et al*. 2003) [10]. Hardenburg *et al*. (1986) [7] mentioned that storage under low temperature is the most efficient method to maintain quality of fruits and vegetables due to its effects on reducing respiration rate, ethylene production, ripening, senescence, and rot development. High temperature increases the vapour pressure difference between the fruit and the surrounding, which is the driving potential for faster moisture transfer from the fruit to the surrounding air (Ryall and Pentzer 1982; Hardenburg *et al*. 1986; Salunkhe *et al*. 1991) [11, 7, 12]. In the present study too, the lower temperature and higher relative humidity maintained by the Zero energy cool chamber as compared to the ambient condition could be the reason for the low percentage of weight loss possibly through reducing respiration and transpiration rate. The weight loss in crop not only lead to physical weight loss, but also results change in appearance of the produce like change in texture make it shrivelled, colour etc., which causes reduction in consumer acceptance.

Table 2: Changes in Moisture content % during the storage period

Genotype (G)	Zero Energy Cool Chamber (ZECC)					Ambient Temperature				
	Storage duration (B)									
	0 day (B1)	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**	**0 day (B1)**	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**
G1	91.237	88.140	84.390	83.620	79.537	91.237	85.153	82.327	79.157	0.000
G2	88.977	86.250	83.390	82.760	80.537	88.977	84.220	77.693	77.190	0.000
G3	87.733	85.270	84.830	85.250	80.070	87.733	83.540	80.617	78.750	0.000
G4	89.633	88.350	85.057	84.450	82.817	89.633	85.630	83.010	78.830	0.000
Storage condition (S)	ZECC					Ambient				
Mean	85.115					66.685				
SEm	0.113									
CD	0.319									
Genotype (G)	G1	G2	G3	G4		B1	B2	B3	B4	B5
Mean	76.439	74.999	75.420	76.741		89.395	85.819	82.664	81.251	40.370
SEm	0.160					0.179				
CD	0.451					0.505				
Interaction	S × B			B × G				S× B × G		
SEm	0.254			0.359				0.507		
CD	0.714			1.009				1.428		

Moisture content of chilli fruits of four genotypes (G1, G2, G3, G4) stored under two storage conditions showed significant variation during the storage periods (Table 2). At initial day of storage, chilli genotype G1 and G2 had more moisture content of 91.23 and 88.97 respectively.

During the storage period of 2 to 8 days in zero energy Cool Chamber, genotype G1 retained more moisture whereas genotype G3 showed less moisture retention. At ambient conditions, chilli of G1 had relatively more moisture content compared with the other genotypes and under the same storage condition, genotype G2 exhibited less moisture content. There was a general decreasing trend in the moisture content of the varieties with storage time under both storage conditions. However, the percent decrease in moisture content was pronounced in green chilli stored at ambient condition. This may be due to the ripening process that undergo throughout the storage period as ripening of chilli fruit causes changes in the permeability of cell membranes, making them more sensitive to loss of water (Goodwin and Mercer 1972; Suslow 2000; Antoniali *et al*. 2007) [6, 16, 1].

Significant differences among the cultivars were observed throughout the storage period. This could be due to differences in fruit tissues of the skin wax contents of cultivars. Maalekuu *et al*. (2006) [9] noted that the difference in water loss rate among different genotypes could be attributed to factors such as their cuticlular wax content, difference in cell membrane degradative enzymes and their effects on membrane integrity and membrane lipid composition.

The difference in moisture contents of fruits under the two storage conditions could be attributed to the lower temperature and higher relative humidity in the evaporative cooler than in ambient conditions which could have reduced the amount and rate of moisture loss. Moreover, the lower temperature in the evaporative cooler could have reduced respiration rate and thus delayed fruit ripening and subsequently lowered permeability to moisture loss (Atta-Aly and Brecht 1995) [2].

Decay %

Table 3: Decay % recorded during the storage period

Genotype (G)	Zero Energy Cool Chamber (ZECC)					Ambient Temperature				
	Storage duration (B)									
	0 day (B1)	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**	**0 day (B1)**	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**
G1	0	0	3.483	13.413	18.767	0	0	7.760	18.257	-
G2	0	0	3.523	13.497	18.840	0	0	8.350	19.523	-
G3	0	0	3.493	13.467	18.810	0	0	7.507	18.730	-
G4	0	0	4.047	13.867	19.127	0	0	8.453	20.087	-
Storage condition (S)	ZECC					Ambient				
Mean	7.217					5.253				
SEm	0.143									
CD	0.403									
Genotype (G)	G1	G2	G3	G4		B1	B2	B3	B4	B5
Mean	6.208	6.373	5.801	6.558		0	0	5.827	15.905	9.443
SEm	0.203					0.227				
CD	NS					0.638				
Interaction	S × B			B × G			S× B × G			
SEm	0.320			0.453			0.641			
CD	0.902			NS			NS			

Data presented on Table no. 3 reflecting the extent of spoilage of chilli fruits at different storage intervals, as influenced by various storage condition. The presented data indicates that the extent of fruit spoilage varied considerably under different storage condition at different storage intervals. Till the 2nd day of storage, no visual signs of spoilage were observed under both the storage condition. However, on 3rd day onward the spoilage symptoms started showing in both the storage condition irrespective of genotypes. On 4th day of storage the minimum decay % was recorded in genotype G1 (3.48%) stored in zero energy cool Chamber, whereas, maximum was observed in G4 (8.45%) stored at ambient temperature. On day four, nearly all chilli fruits stored at ambient condition were unmarketable, with maximum decay % in genotype G4 (20.08%) and lowest in G1 (18.25%) However those stored in the zero energy cool chamber remained marketable up to 6 days with maximum decay % in genotypeG4 (13.86%) and lowest in G1 (13.41%)

Firmness: (9 point Hedonic scale)

Table 4: Changes in Firmness % during the storage period

Genotype (G)	Zero Energy Cool Chamber (ZECC)					Ambient Temperature				
	Storage duration (B)									
	0 day (B1)	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**	**0 day (B1)**	**2nd Day (B2)**	**4th Days (B3)**	**6th Days (B4)**	**8th days (B5)**
G1	9.000	8.863	8.760	8.380	7.717	9.000	8.143	7.187	6.930	-
G2	9.000	8.857	8.337	8.070	7.663	9.000	7.913	7.427	6.667	-
G3	9.000	8.763	8.450	7.863	7.527	9.000	8.000	7.103	6.709	-
G4	9.000	8.607	8.257	7.730	7.203	9.000	7.597	7.250	6.307	-
Storage condition (S)	ZECC					Ambient				
Mean	7.942					6.196				
SEm	0.052									
CD	0.146									
Genotype (G)	G1	G2	G3	G4		B1	B2	B3	B4	B5
Mean	7.267	7.073	7.070	6.865		9.000	8.229	7.771	6.968	3.376
SEm	0.073					0.230				
CD	0.206					0.082				
Interaction	S × B			B × G			S× B × G			
SEm	0.117			0.169			0.231			
CD	0.326			0.388			0.993			

One of the important factors used to determine the quality and postharvest shelf-life is the loss of firmness during storage. According to the results, fruit deformation was affected by storage condition, period and genotype. Thus, firmness decreased with prolonged storage. On 8th day of storage in zero energy cool chamber genotype G1 retained highest firmness and genotype G4 shows lowest firmness. Same incase of ambient temperature storage, G1 and G4 shows maximum and minimum firmness respectively on 6th day of storage period. The fruits stored at zero energy cool chamber were more firm than fruits stored at ambient temperature irrespective of chilli genotypes. It may be due to lower metabolic activities at cool environment which retained fruit quality (firmness) for a long time. These results are in conformity with Chae *et al*. (2008) [3] who indicated that fruit firmness was highest at low temperature.

Firmness is correlated to weight loss and the degree of injury due to decay or microbial growth. In this study, the firmness value measured dropped slightly as storage time increased. The radicals (superoxide and nitric oxide) generated by aerobic respiration loosen the cell wall organization and render the wall pectins accessible to the pectinases, causing loss of firmness during postharvest life of the commodity (Chitravathi *et al*. 2015, Selvaraj and Kumar, 1989) [4, 14].

Appearance, quality (9 point Hedonic Scale) and shelf life

Table 5: Changes in Appearance, quality during the storage period

Genotype (G)	Zero Energy Cool Chamber (ZECC)					Ambient Temperature				
	Storage duration (B)									
	0 day (B1)	2nd Day (B2)	4th Days (B3)	6th Days (B4)	8th days (B5)	0 day (B1)	2nd Day (B2)	4th Days (B3)	6th Days (B4)	8th days (B5)
G1	9.000	8.457	8.357	7.450	6.660	9.000	8.213	6.763	6.423	-
G2	9.000	8.357	8.267	7.350	6.567	9.000	8.183	6.730	6.383	-
G3	9.000	8.387	8.307	7.390	6.527	9.000	8.183	6.743	6.397	-
G4	9.000	8.287	8.183	7.300	6.527	9.000	8.103	6.690	6.353	-
Storage condition (S)		ZECC				Ambient				
Mean		7.919				6.058				
SEm		0.017								
CD		0.046								
Genotype (G)		G1	G2	G3	G4	B1	B2	B3	B4	B5
Mean		7.032	6.984	6.993	6.944	9.000	8.271	7.505	6.880	3.28
SEm		0.023				0.026				
CD		0.089				0.073				
Interaction		S × B			B × G			S× B × G		
SEm		0.037			0.052			0.074		
CD		0.104			NS			NS		

To record the appearance and quality 9 point hedonic scale was used. From the data presented on Table 5 it can be revealed that appearance and quality gradually decreases in both the storage condition irrespective if genotype. It is observed that G1 and G3 maintain the appearance in comparison with other genotype throughout the storage period.

From the above discussion it can be conclude that irrespective of chilli genotype, fresh green chilli can be store successfully in zero energy cool chamber upto 6th day whereas under ambient temperature chilli can be store only for two days. And among these four genotype G1 shows positive result in physiological loss in weight, retaining moisture content, decay % and maintain firmness and appearance followed by G3 irrespective of storage condition.

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