POSTHARVEST LIFE EXTENSION AND QUALITY EVALUATION OF BITTER GOURD AND CAPSICUM UNDER LOW TEMPERATURE STORAGE DURING SUPPLY CHAIN

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Abstract

Fruits and vegetables play an important role in human nutrition. Collector, wholesaler, retailer, and transporter are the key players responsible for the perishable supply chain in Sri Lanka. Perishable nature, bulkiness, and seasonality are some of the challenges that reduce a supply chain's effectiveness and efficiency, resulting in significant post-harvest losses. Cold storage is a common method for handling perishables in bulk. In Sri Lanka, the implementation of cold storage has not been fruitful yet due to the unavailability of a well-functioning cold chain. Therefore, this research was conducted to study the shelf life extension and quality evaluation of bitter gourd and capsicum under low temperatures and to identify the conditioning requirements before sending them to the local retail market. Vegetables were kept under cold storage (8±2 °C, 90-95% RH) and ambient (30±2 °C, 60-70% RH) conditions, and quality was evaluated as follows: physiological weight loss (PWL), spoilage, pH, total soluble solids, titratable acidity, colour, firmness, and visual quality ratings. Results revealed that shelf life extensions of bitter gourd (an additional 10 days) and capsicum (an additional 16 days) were achieved under cold storage. Comparatively lower PWL and spoilage values were achieved for both vegetables under cold storage. However, better quality was obtained by transferring vegetables stored in cold storage to an air-conditioned (A/C) environment (20 °C, 80% RH) rather than releasing them directly to normal retail conditions followed by immediate sale. Therefore, cold storage is a technology that ensures quality, nutritional value, economic value, and food safety.

Keywords: bitter gourd, capsicum, cold storage, perishable supply chain

Introduction

Fruits and vegetables play an important role in human nutrition, contributing to the food security of a country. As a tropical country, Sri Lanka is blessed with a rich variety of fruits and vegetables, which are cultivated either commercially or domestically by farmers. Before fruits and vegetables reach consumers, they pass through a chain of interconnected players that includes a farmer, collector, whole seller, retailer, and consumer (Fernando, 2005).

Moderate climate conditions throughout the year, a fairly distributed irrigation system, fertile soil, and various agricultural technologies and applications have blessed Sri Lanka with year-round fruit and vegetable production. However, having two major cultivation seasons named *Yala* and *Maha* causes short or long-term surpluses/shortages in fruit and vegetable supplies, resulting in price fluctuations in the country (Rajapaksha et al, 2021; Gunarathna & Bandara, 2020). As a result, post-harvest life extension during times of surplus and maintaining continuous supply during times of shortages can be a solution to reduce post-harvest losses and increase profit.

However, tropical climatic conditions shorten the shelf life of fruits and vegetables, resulting in serious post-harvest losses. Rajapaksha et at (2021) claim that the postharvest loss with regard to vegetables is around 20-40% and 30-40% for fruits under Sri Lankan conditions. High temperature is the most important factor influencing the deterioration rate of these vegetables and fruits (Kitinoja, 2013). Cold storage is one of the methods for preserving fruits and vegetables in their fresh state for a longer period of time by controlling temperature and humidity conditions. This method is extensively practised for bulk handling of perishables between production and the marketing channel. The combination of low temperatures and proper relative humidity can extend the shelf life, leading to fewer post-harvest losses (Krishnakumar, 2002). According to Concellón, Añón, and Chaves (2007), cold storage results in reduced respiratory activity, reduced internal water loss, reduced wilting, reduced growth of microorganisms, and delay the production of ethylene.

On the other hand, maintaining a suitable low temperature is critical due to the occurrence of chilling injuries in some tropical crops. As a result, determining the best low temperature conditions for tropical fruits and vegetables is essential for extending shelf life and maintaining product quality. The relative humidity is another interconnected factor that goes parallel with temperature in influencing the post-harvest quality and shelf life extension. Usually, the optimum relative humidity has been identified as 80-90% for most tropical perishables (Ashby, 1987).

Many developed countries in the world have done several studies in this sector with the aim of improving supply chain management by maintaining the cold chain itself. In the Sri Lankan context, the implementation of cold storage has not been fruitful yet due to the unavailability of a well-functioning cold chain. However, initiative steps were taken to construct a temperature and humidity-controlled warehouse complex at Dambulla for storage of perishables (5000 metric tons capacity) by the Ministry of Economic Reforms and Public Distribution in recent years. (MERPD, 2019). Therefore, it is necessary to evaluate the shelf life, quality and effectiveness of storing perishables under low-temperature storage. Bitter gourd (a low-country vegetable) and capsicum/*malu miris* (an up-country vegetable) were selected as test crops. This study was conducted with the objective of evaluating the shelf life and quality of selected vegetables at low temperatures and identifying requirements for conditioning stored commodities before sending them to the local retail market.

Literature Review

In the Sri Lankan context, the majority of fruit and vegetable production is done by small-scale farmers who do not have the capacity to reach the consumers directly. Intervention by intermediaries in the supply chain is a common fact. The farmer, collector, wholesaler, retailer, and transporter are the key players in most fruit and vegetable supply chains. However, a higher number of middlemen can result in higher postharvest losses and price increases at the retailer level (Wasala, 2014). Therefore, it is very important to have an efficient and effective supply chain in order to reduce costs, manage redundancy, and increase consumer satisfaction (Vidanapathirana et al, 2018). Perishable nature, bulkiness, and seasonality are some of the reasons challenging the effectiveness and efficiency of a supply chain (Gunaratne & Bandara, 2020). Therefore, cold storage is one of the methods widely practised for bulk handling of perishables between production and marketing processing (Krishnakumar, 2002).

Postharvest losses occur at all the stakeholders involved in the perishable supply chain. It starts in farmers' fields. Harvesting perishables should be done at the correct maturity. Immature produce tends not to ripen naturally and is highly susceptible to injuries during handling, while over-matured produce is highly susceptible to mechanical injuries, microbial contamination, and low consumer preference. Transportation is another important stage in postharvest losses. Losses can occur when perishables are transported from the farm to collection centers, from collection centers to wholesale markets or fairs, and finally to retail shops. Rough handling, poor packaging methods, poor vehicle conditions (opened or closed), excessive loading, etc. further accelerate postharvest losses. Rough handling is a major cause of higher postharvest losses at both retail and wholesale levels (Rajapaksha et al, 2021; Jayathunga et al, 2011; Kitinoja et al, 2011; Kitinoja, 2013).

Temperature is considered the most critical factor in deciding the postharvest life of fruits and vegetables. It directly affects metabolic processes such as respiration, transpiration, ripening, senescence, etc. Low respiration rates cause slower produce deterioration and delay the ripening and senescence processes, which eventually prolong the shelf life of fruits and vegetables (Hardenburg, Watada, & Wang, 1990). The optimal temperature for storing low-temperature fruits and vegetables varies depending on crop species. Sometimes, unsuitable low temperatures can cause chilling injuries, reducing the quality of fruits and vegetables (Ashby, 1987). According to Kitinoja (2013), reduction of respiration; reduction of transpiration; reduction in ethylene production; increase in resistance to ethylene action; decrease in microorganism activity; reducing loss of texture, flavour and nutrients and; delaying ripening and natural senescence are the advantages obtained from subjecting perishables under low temperature.

Most storage crops perform better under high RH (80-95%) conditions. However, high RH conditions cause higher disease incidences, which reduce the quality of fresh produce. On the other hand, low temperatures are responsible for reducing the rates of chemical and biological processes, resulting in slower disease progression. Therefore, a combination of low temperature and high RH conditions is an acceptable way of prolonging shelf life and maintaining the quality of fruits and vegetables (Tilahun, 2010; Wilson, Boyette, & Estes, 1995; Sunmonu, Falua, & David, 2014).

When designing a cold room, temperature and relative humidity are both critical. According to Tassou and Xiang (1998), RH has been defined as the ratio of the partial pressure of water vapour in the air to the partial pressure at saturation at the same temperature. When a particular fruit or vegetable is stored inside a room, a water vapour pressure difference can be observed between the stored environment and the fruits and vegetables. This phenomenon causes the transpiration process and is a major reason for weight reduction during perishable storage. Therefore, it is important to maintain a high RH level (85-90%) inside a cold room during fruit and vegetable storage.

However, cold storage alone cannot extend the longevity of perishables. Having uninterrupted low-temperature while handling of perishables during different postharvest stages should be the most important practice, and it is called a cold chain. The process starts with harvesting and continues through collection, packing, processing, storage, transportation, and marketing until the produce reaches the consumer (Kitinoja, 2013). The Sri Lankan supermarket supply chain practices cold storage facilities at collection centers and transportation is practiced through refrigerated trucks using plastic crates as the packaging material. Finally, these conditions result in very few postharvest losses, around 1–3% in supermarket chains (Perera et al, 2004).

Methodology

Location

The design of the cold store was carried out by the National Engineering Research and Development Center (NERD), Ja-Ela, Sri Lanka, and the quality evaluation of vegetables was done at the National Institute of Post-Harvest Management (NIPHM), Anuradhapura, Sri Lanka, from November 2021 to January 2022.

Materials

Two vegetable species, namely Bitter Gourd (*Momordica charantia*) and Capsicum (*Capsicum annuum*), were used for the study.

Experimentation

Bitter gourd and capsicum were purchased at the correct maturity stage from the local vegetable market at Anuradhapura, and vegetables with mechanical damages, disease incidences, discolourations, or that were overripe were sorted out from the bulk and packed in plastic crates. Bitter gourd and capsicum were selected for this study as they had a similar range of temperature (5-10 °C) and relative humidity (90-95%) during low-temperature storage according to the literature (Weng et al, 2018; Cuadra-Crespo & del Amor, 2010). Then, vegetables were stored under two different storage conditions: cold storage (8±2 °C, 90-95% RH) and ambient (30±2 °C, 60-70% RH). Temperature and relative humidity were measured using sensors inside the cold storage and wet and dry bulb thermometers were used for the ambient.

Quality evaluations were done at four-day intervals for cold storage and at two-day intervals for ambient conditions. Several parameters were evaluated under both conditions, namely physiological weight loss, spoilage, pH, total soluble solid content, titratable acidity, colour, firmness, and overall visual quality of stored vegetables. After the storage period, vegetables stored in the cold store were transferred into an air-conditioned (A/C) environment (20 °C, 80% RH) to identify cold chain behaviour for the selected vegetables.

Figure 1. Storing bitter gourd and capsicum under cold store

Figure 2. Storing bitter gourd and capsicum under ambient condition

Physiological Weight Loss (PWL)

Determination PWL was carried out according to the below equation.

$$\text{PWL \%} = \frac{\text{Initial weight (g)} - \text{final weight (g)}}{\text{Initial weight (g)}} \times 100$$

1.5 kg of each vegetable was kept in separate containers as triplicates under both cold room and ambient conditions. Initial weight was taken on the first day of each trial. Final weights taken on each data measuring point were included in the calculation to obtain PWL % (Horwitz, 2000).

Spoilage

1.5 kg of each vegetable was kept in separate containers as triplicates. The initial weights of the samples were taken on the first day. At each measuring point, weights of spoiled (rotten, diseased, ripened, physically damaged) produce were taken, and the spoilage percentage was calculated using the equation below.

$$\text{Spoilage \%} = \frac{\text{Spoiled weight (g)}}{\text{Initial weight (g)}} \times 100$$

pH

pH was determined with a digital pH meter (Model - Hanna HI11310) using filtered and homogenized juice extracted from mortar and pestle.

Total Soluble Solid (TSS) content

TSS was measured using a portable refractometer (Model: Pocket Refractometer PAL-1), using the juice extracted from vegetables using a mortar and pestle. Homogenized samples were then filtered using a clean muslin cloth. A few drops of the filtrate were placed on the digital refractometer, and readings were obtained as Brix°.

Titratable Acidity (TA)

Vegetables contain more than one type of acid, so the most dominant acid was checked. After filtering and homogenizing, 1 ml of the extracted juice was topped up to 10 ml with distilled water in a conical flask. Then the solution was titrated against a standard N/10 NaOH solution with phenolphthalein as the indicator. The end-point reading of the burette was used in the below equation to calculate TA. Citric acid was considered the dominant acid in both bitter gourd and capsicum, and the conversion factor for citric acid was considered to be 0.064.

$$\text{TA percentage} = \frac{\text{Acid meq. factor x Normality (NaOH)} \times \text{End point of the titration (ml) x 100}}{\text{Juice titrated (ml)}}$$

Colour

A colourimeter (Model: CHROMA METER-CR 400) was used to determine the surface colour of vegetables. Readings were taken as numerical notations (L*, a*, and b* values). L* represents lightness or darkness (0: black and 100: white), and a* represents the hue from green to red. (negative values: greenness and positive values: redness), and b* represents the hue from blue to yellow (negative values: blueness and positive value: yellowness) (Latifah et al, 2007).

Firmness

Firmness was determined using a texture analyzer (Model: GUSS fruit texture analyzer) fitted to a flat, round probe. Readings were expressed in kilograms.

Overall Visual Quality (VQR) of the Produce

It was measured subjectively using a 1 to 9 visual quality rating scale where: 9: “excellent”, essentially no symptoms of deterioration; 7: “good”, minor symptoms of deterioration, not objectionable; 5: "fair", with visible but minor deterioration limiting usability; 3: "poor", with significant deterioration limiting usability; 1: "extremely poor", not usable (Cantwell & Kader, 2006).

Data Analysis

The experimental design was Completely Randomized Design (CRD), and all the treatments were used in triplicates. The data were analyzed using the SPSS statistical package. Means separation was done using the Least Significant Difference (LSD).

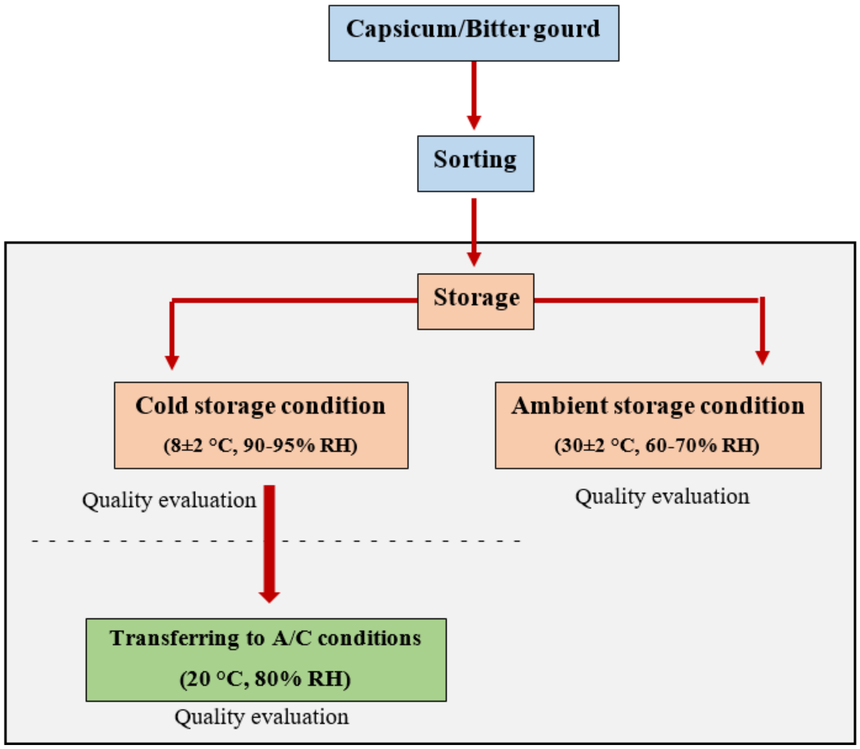


Figure 3. A visual diagram of the study framework

Results and Discussion

Both bitter gourd and capsicum could be stored for an extended period of 16 and 24 days, respectively, under cold storage conditions, but only for 6 days under ambient conditions. As shown in Table 2 and Table 4, the physiological weight loss of both vegetables was high under ambient conditions. Higher temperatures had caused higher rates of metabolic processes such as respiration, transpiration, ripening, and senescence. Increased rates of respiration and transpiration cause higher rates of moisture loss to the external environment. During the respiration process, each cycle causes the loss of one carbon atom, ultimately resulting in a significant weight loss from fruits (Yahia & Carrillo-Lopez, 2018; Chitravathi, Chauhan, & Raju, 2016). Higher RH conditions maintained in the cold store (90-95%) reduced the vapour pressure deficit between the produce and the external environment, resulting in lower moisture loss compared to ambient conditions.

Both the spoilage percentage as well as the rate of spoilage were lower in the cold store (Table 1 and Table 3). Low temperatures had caused lower metabolic rates, reducing the rates of ripening and senescence processes in vegetables. On the other hand, low temperatures also reduce the metabolic rates of pathogens' presence, resulting in slower pathogenesis progression (Brizzolara et al, 2020; Obrępalska-Stęplowska et al, 2015).

Firmness can be considered an indicator of the freshness of a vegetable. Firmness values had reduced over time in both vegetables under both conditions, agreeing with the results of Bourne (1982), due to softening of tissues (Tables 1,2,3,4). However, comparatively lower firmness values could be observed under ambient conditions (Table 2 and Table 4) indicating the softening process has accelerated at higher temperatures. Softening can be defined as a response to the ripening process induced by ethylene synthesis. The synthesis of ethylene is governed by a series of enzymes and other factors that are highly dependent on temperature. At higher temperatures, enzymatic reactions and ripening happen quickly (Saltveit, 1999).

Citric acid is the dominant acid found in both bitter gourd and capsicum, and it tends to decrease with storage time (Gao et al., 2018). Even after storing bitter gourd for 16 days and capsicum for 24 days in cold storage, significant citric acid content was observed (Table 1 and Table 3). pH values of both vegetables tend to increase over time under both conditions (Tables 1,2,3,4). According to Rehman et al (2014) acid hydrolysis of polysaccharides results in the formation of simple monosaccharides, which ultimately reduce the acidity (increasing pH values) and increase TSS values.

Table 1: Storage Quality Evaluation of Bitter gourd under Cold Storage

Parameter	Day 0	Day 4	Day 8	Day 12	Day 16
Weight loss %	-	5.41±0.46[d]	11.2±0.91[c]	12.71±0.96[b]	14.77±1.20[a]
Spoilage %	-	2.58±1.42[e]	9.32±1.09[d]	18.11±2.54[c]	37.56±2.56[b]
Firmness (kg)	4.584±0.312[a]	4.013±0.164[b]	3.732±0.158[c]	3.517±0.180[c]	3.143±0.288[d]
Titratable Acidity % (Citric Acid)	0.206±0.036[a]	0.206±0.036[a]	0.149±0.018[c]	0.198±0.033[b]	0.106±0.018[d]
pH	6.03±0.11[a]	6.06±0.12[a]	6.07±0.10[a]	6.13±0.09[a]	6.23±0.25[a]
TSS (Brix°)	2.36±0.25[a]	2.9±0.37[a]	3.13±0.35[a]	3.46±0.35[a]	4.10±0.72[a]

Data represent in mean ±SD of three replicates. Values followed by the different superscript in each row are significantly different (p<0.05).

Table 2: Storage Quality Evaluation of Bitter gourd under Ambient Condition

Parameter	Day 0	Day 2	Day 4	Day 6
Weight loss %	-	4.25±0.24[c]	10.67±0.34[b]	20.76.66±0.42[a]
Spoilage %	-	8.57±2.2[c]	43.22±1.20 [b]	55.47±4.25 [a]
Firmness (kg)	4.584±0.312[a]	3.974±0.140[b]	3.618±0.153[c]	2.985±0.163[d]
Titratable Acidity % (Citric Acid)	0.206±0.036[a]	0.202±0.018[a]	0.149±0.018[b]	0.138±0.018[b]
pH	6.03±0.11[a]	5.95±0.18[a]	6.16±0.07[a]	6.27±0.06[a]
TSS (Brix°)	2.36±0.25[c]	2.90±0.20[b]	3.30±0.10[a]	3.36±0.15[a]

Data represent in mean ±SD of three replicates. Values followed by the different superscript in each row are significantly different (p<0.05).

Table 3: Storage Quality Evaluation of Capsicum under Cold Storage

Parameter	Day 0	Day 4	Day 8	Day 12	Day 16	Day 20	Day 24
Weight loss %	-	2.35±1.34[e]	3.55±1.4[e]	5.17±0.10[d]	6.86±0.31[c]	8.55±0.47[b]	10.28±0.82[a]
Spoilage %	-	0.89±0.20[d]	3.08±0.13[d]	4.20±0.09[d]	8.59±1.27[c]	12.27±3.14[b]	20.78±3.28[a]
Firmness (kg)	2.120±0.624[a]	1.842±0.280[a]	1.776±0.108[a]	1.765±0.429[a]	1.731±0.164[a]	1.499±0.345[a]	1.431±0.323[a]
Titratable Acidity % (Citric acid)	0.149±0.108[a]	0.149±0.018[a]	0.136±0.018[a]	0.149±0.018[a]	0.149±0.018[a]	0.106±0.018[b]	0.106±0.018[b]
pH	6.14±0.04[c]	6.45±0.03[a]	6.05±0.10[d]	5.73±0.28[e]	6.06±0.15[c]	6.39±0.06[b]	6.44±0.09[b]
TSS (Brix°)	2.46±0.25[c]	2.73±0.40[c]	3.73±0.05[b]	3.50±0.40[b]	4.20±0.17[a]	4.10±0.26[a]	4.15±0.19[a]

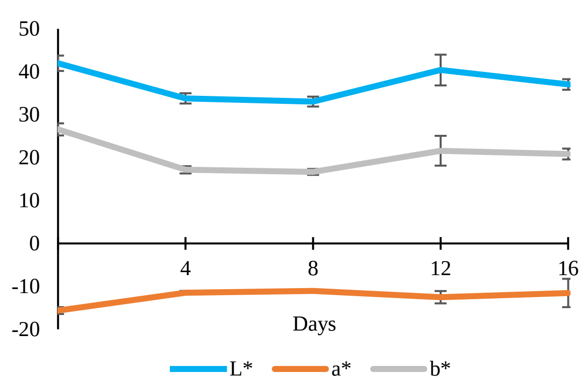
Data represent in mean±SD of three replicates. Values followed by the different superscript in each row are significantly different (p<0.05).

Table 4: Storage Quality Evaluation of Capsicum under Ambient Condition

Parameter	Day 0	Day 2	Day 4	Day 6
Weight loss %	-	7.33±0.37[c]	16.98±2.00[b]	34.03±9.84[a]
Spoilage %	-	3.47±1.33[b]	4.89±1.12[b]	11.63±0.52[a]
Firmness (kg)	2.120±0.624[a]	1.806±0.282[b]	1.506±0.463[b]	1.404±0.327[b]
Titratable Acidity % (Citric Acid)	0.149±0.018[a]	0.136±0.018[a]	0.136±0.018[a]	0.106±0.018[a]
pH	6.14±0.04[a]	6.37±0.20[a]	6.47±0.20[a]	6.06±0.16[b]
TSS (Brix°)	2.46±0.25[b]	2.70±0.95[b]	2.80±0.26[b]	5.40±0.40[a]

Data represent in mean±SD of three replicates. Values followed by the different superscript in each row are significantly different (p<0.05).

According to the results obtained for the surface colour of bitter gourd and capsicum, L* values tend to decrease over time under both conditions (Figures 4,5,6,7). With respect to a* values, an increasing trend could be observed, indicating a reduction in greenness in both vegetables under both conditions. A significant reduction in the chlorophyll content can be experienced as a result of the degeneration of chloroplasts into chromoplasts (Chitravathi, Chauhan, & Raju, 2016). Most vegetables tend to retain chlorophyll at a lower temperature than at higher temperatures, as the results of this study confirm. When considering the b* values of bitter gourd and capsicum, a reducing trend could be observed, indicating an increase in yellowness over time (Toivonen & Brummell, 2008).



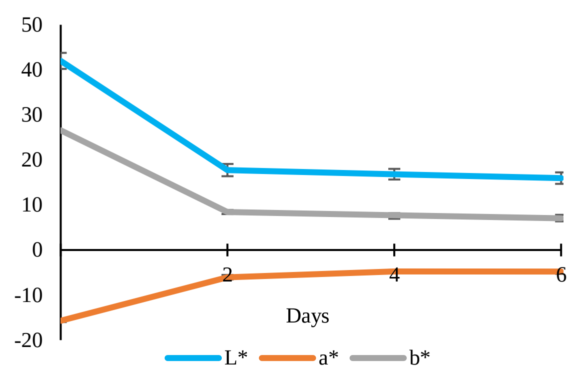


Figure 4. Mean color variation (L a* b*) in bitter gourd under cold storage over storage time (Vertical bars indicate standard error)*

Figure 5. Mean color variation (L a* b*) in bitter gourd under ambient condition over storage time(Vertical bars indicate standard error)*

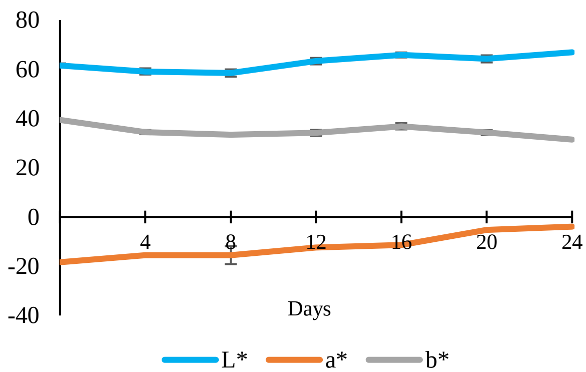


Figure 6. Mean color variation (L a* b*) in capsicum under cold storage over storage time (Vertical bars indicate standard error)*

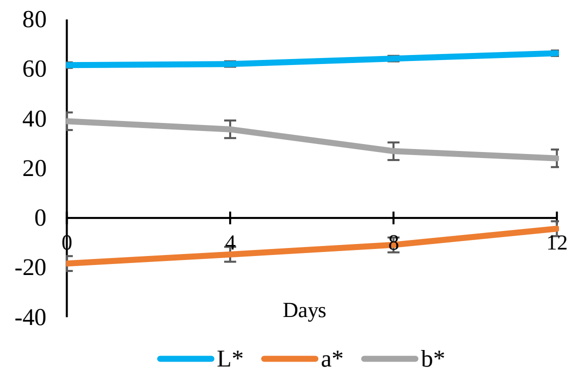


Figure 7. Mean color variation (L a* b*) in capsicum under ambient condition over storage time(Vertical bars indicate standard error)*

The scale adapted for visual quality ranking (Cantwell & Kader, 2006) indicated higher rankings for less deteriorated vegetables and vice versa. According to the results obtained for bitter gourd, the marketable life under cold storage was 14 days, and it was 4 days under ambient conditions (Table 5). Softening, yellowing (ripening), and disease incidences (fungal infection) were observed in bitter gourd during storage.

Table 5: Visual Quality Ratings of Bitter gourd during the Storage Period

	Storage time in days								
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**
Cold store	9	9	9	7	7	5	5	5	3
Ambient	9	7	5	1	-	-	-	-	-

According to the results obtained for capsicum, the marketable life under cold room conditions was 22 days, and it was 6 days under ambient conditions (Table 6). During the storage period of capsicum, shrivelling, ripening, and disease incidences were observed.

Table 6: Visual Quality Ratings of capsicum during the storage period

	Storage time in days												
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
Cold store	9	9	9	9	7	7	7	7	5	5	5	5	3
Ambient	9	7	5	5	-	-	-	-	-	-	-	-	-

Vegetables that were stored in cold storage were then transferred to two different conditions; air-conditioned (A/C) environment (20 °C, 80% RH) and ambient condition (30±2 °C, 60-70% RH). It was done to evaluate the adaptability of vegetables from cold storage to the next most suitable condition for storage. The bitter gourd was transferred on day 14 to new conditions. It was able to be kept for 2 days under A/C environment and only one day under ambient conditions. Under A/C environment, lower physiological weight loss and spoilage values were obtained. Under ambient conditions, comparatively lower firmness values and higher TSS and pH values were obtained due to the commencement of ripening.

On the other hand, capsicum was transferred on day 22 to new conditions. It was able to be kept for 3 days under A/C environment and only one day under ambient conditions. Under A/C environment, lower physiological weight loss values and higher firmness values were obtained, as was the case with bitter gourd. Comparatively higher TSS and pH values were obtained under ambient conditions due to the commencement of ripening under those conditions.

Therefore, vegetables that were kept under A/C showed comparatively better results as the most suitable condition after being removed from cold storage. However, the marketable period, even under A/C, is very low for both vegetables. Therefore, it is advisable to sell the vegetables stored in cold storage immediately.

Figure 8. Transferring vegetables from cold store to A/C and ambient conditions

Conclusions and Implications

Reducing postharvest losses while extending the shelf life of bitter gourd and capsicum could be achieved by storing them under low temperature (8±2 °C, 90-95% RH) conditions. Extended marketable storage periods were 14 days for bitter gourd and 22 days for capsicum. Selected vegetables were short-lived under ambient conditions (30±2 °C, 60-70% RH) whereas they could only be kept for 6 days. Therefore, cold storage is a technology that ensures quality, nutritional value, economic value, and food safety. However, a better quality could be obtained by releasing the vegetables in the cold storage into an A/C environment (20 °C, 80% RH) rather than releasing them directly into ambient conditions. Immediate sale of vegetables is advisable once the vegetables are removed from cold storage.

The current study revealed that electricity consumption for the cold store was ~700 kWh for 22 days (capacity: 1600 kg). Considering the prevailing high electricity charges, cold stores may not be the best solution to prolong the shelf life of perishables at the smallholder farmer's level. However, considering the number of days that can be prolonged, cold storage is an ideal solution for medium- or large-scale farmers or farmer associations, especially when there is surplus production.

Inside a cold store, it is not advisable to mix different perishable types because the sensitivity towards ethylene (which ultimately causes ripening) is different. Therefore, it is more effective to compartmentalize cold storage so that one type of perishable can be stored in one compartment. Although cold storage can prolong the shelf life of perishables, negative factors that have occurred in previous operations like harvesting, transporting, and handling can accelerate ethylene generation, which could ultimately jeopardize the whole objective of cold storage. Therefore, it is important to optimize all the possible postharvest operations before storing perishables in the cold store. For example, practices such as harvesting at the correct maturity stage, field sanitation, removal of field heat, use of suitable packaging materials, careful handling of perishables, correct transportation methods, sorting and grading, maintaining a cold chain throughout the supply chain, etc. help to maximize the effectiveness of using a cold store.

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