Determination of the Shelf Life of Chili (*Capsicum annuum* L.) in Cold Store and Ambient Room Temperature Conditions Harvested at Different Maturity Stages

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Abstract

In Bhutan, different varieties of chili (Capsicum annuum L.) are grown in all the twenty Dzongkhags. Chili being a warm-season crop is produced in the summer but during the winter months, the plant growth is retarded due to low temperatures. During the chili season, there are huge supply in the market but a deficit during the winter months while the demand from the consumers is constant. Storing the last harvest of the summer chili production for the winter months in the cold store could be one possible way to make domestic chilies available during the winter months. This study was conducted to determine the storage shelf life of chili of different maturity stages in ambient room and cold store conditions at the National Post Harvest Sub-centre, Lingmethang. The experiment design was a factorial arrangement with a complete randomized design with two treatments, ambient room temperature and cold storage conditions with five replications. Under each treatment, three maturity stages such as red, light, and dark green chilies were studied. Physiological weight loss, shrinkage, decay, and shelf life data were recorded at weekly intervals. The results indicate dark green chilies could be stored for eight weeks, light green chilies for six weeks, and red chilies for five weeks in the cold store at 8 to 10°C in 90-95% relative humidity. While in the ambient conditions, chilies could be stored for two weeks. Significant physiological weight losses ($p<0.05$) were observed across different chili maturity stages in the cold storage. The dark green maturity stage can be stored for the longest duration. Storing fresh green chilies from the last harvest of the local Bhutanese chili in the cold store could make chilies available during the winter months, when there is a scarcity of local Bhutanese chili in the market.

Keywords: *Physiological weight loss; Shrinkage; Decay; Shelf life*

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1 Introduction

Chilli (*Capsicum annuum* L) is commonly known as pepper, chili, and chile depending on its location. It is an important crop that is cultivated throughout the globe both for consumption and for commercial use. The major producers are India, China, Thailand, Ethiopia, and Indonesia (Agricultural Market Intelligence Centre, 2021). The crop belongs to the Solanaceae family and it is most commonly consumed in horticultural crops in its fresh form. It is cultivated in tropical, sub-tropical, and temperate regions (Kapoor, Sidhu, Tandon, Jindal, & Mahajan, 2022). It is most commonly used as spices, vegetables, ornamental, and medicinal purposes as it contains vitamin B, vitamin C, carotene, antioxidants, and flavonoids (Villa-Rivera & Ochoa-Alejo, 2021). It is also one of the fundamental ingredients in many cuisines, adding spice and flavor to dishes. It is consumed fresh, dried, powder, pickles, sauces, and as a paste.

Five species of chili such as *Capsicum annuum* L.*, Capsicum frutescens* L.*, Capsicum baccatum* L.*, Capsicum pubescens* Ruiz and Pav, and *Capsicum chinense* Jacq., are cultivated under the genus Capsicum (Bosland & Votava, 2000). The most popular and cultivated is the *Capsicum annuum* L. In Bhutan, chili is grown in all the twenty *Dzongkhags*. Different varieties of chilies are cultivated such as *Sha Ema, Baegap Ema, Nubi Ema*, Super Solo, Indian chili IR-8, and hybrid varieties HPH 1069, Sitara Gold, SHP 4884, and SV 2319 (Department of Agriculture [DoA], 2024). The Department of Agriculture under the Ministry of Agriculture and Livestock, so far released about eight varieties of chili and one variety of sweet peppers for cultivation (DoA, 2024). In the year 2023, Bhutan produced about 4848.12 MT of chilies from an area of about 2888.53 acres with an average yield of 1678 kg/acre. Paro Dzongkhag was the highest producer with 1005.07 MT, followed by Wangduephodrang with 467.59 MT and Punakha Dzongkhag with 434.95 MT (National Statistics Bureau [NSB], 2024). Chili is one of the main cash crops of the farmers which provides higher returns with a season and with the higher returns, farmers in the western part of the country have started to cultivate on a large scale (National Biodiversity Centre [NBC], 2015). However, chili being a warm-season crop it is produced only in the summer season and during the winter months the plant growth is retarded due to low temperatures. During the chili season, there are huge supply in the market but a deficit during the winter months while the demand from the consumers remains constant.

According to Poudel, et al., (2021), the demand for this fresh chili is year-round but due to being perishable in nature, it can only be stored for 4-7 days at ambient conditions. It is important to study the storage shelf life of chili to determine the causal factor and provide the

ways and means to reduce the losses, suitable postharvest handling technology development in chili is necessary to fetch a good market price after certain weeks or months of storage when there is lean period of its availability in the market. There are great roles of the harvesting technique, pre-cooling, sorting, packaging, and storage facilities in the quality maintenance of chili for a longer period.

In Bhutan, post-harvest losses of chili hinder the income of the farmers. On the contrary, the domestic production of chili is very low during the winter months due to unfavorable climatic conditions for production. Storing the last harvest of the summer chili production for the winter months in the cold store could be one possible way to make domestic chilies available during the winter months. A study on post-harvest losses of chilies in Bhutan found that 84% of chili farmers avoided storing chili produce for more than a night, as storage for multiple days resulted in increased post-harvest losses due to decay, wilting, and discoloration (Wangmo & Dendup, 2021). The storage practices were usually in the farmhouses without temperature, moisture, or ventilation control.

However, with Bhutan's progress in storage practices by introducing cold storage facilities in various strategic regions of the country by the Food Corporation of Bhutan (Food Corporation of Bhutan Limited [FCBL], 2025), the storage losses in the nearby location could be minimized. The cold store facilities were established to store perishable commodities such as fruits, vegetables, and livestock products to ensure a longer shelf life and maintain their quality thereby reducing postharvest losses. This advanced technology will prove to be an advantage over the ambient stores that the farmers practice at the household level. However, there is still a lack of research on prolonging the shelf life of perishable commodities, such as chili in improving its shelf life in cold store facilities. Previous studies in other parts of the world have shown that different maturity stages of crops can significantly impact their shelf life (Guijarro-Real, et al., 2023; Tolasa et al., 2021 and Tsegay et al., 2013), and to validate these results this study was conducted with the objective to determine the storage shelf life of chili of different maturity stages in ambient room conditions and cold store.

2 Materials and method

2.1 Sample Collection Area

The different maturity stages of chilies (local big chili) varieties were harvested and collected from Wama village located at 1724 masl 27°07'56.74" N and 91°02'42.16" E under Silambi

Geog, Mongar *Dzongkhag*. The chilies were transported to the National Post Harvest Sub-centre, Lingmethang on the same day. The village produces a variety of vegetables and supplies to the nearby schools and markets. In the Silambi *Geog*, Wama village produces maximum chilies till the end of November month. The chilies for the study were collected from the last harvest from the Wama village on November 4, 2023.

2.2 Study Area

The study on the determination of the shelf life of chili in cold store and ambient conditions was conducted at the cold store facilities of National Post Harvest Sub-centre, Lingmethang from November 5, 2023, to January 5, 2024. The chilies were sorted and graded based on their size, shape, and color quality, and at different maturity stages. The damaged, bruised, punctured, rotten, and pest damage were removed.

2.3 Experiment design

Factorial arrangement with a Complete Randomized Design (CRD) with two treatments, treatment 1 (T_1) ambient room temperature storage and treatment 2 (T_2) under cold storage conditions. Under each treatment, three factors were studied. Factor one chilies that had turned to dark green colour, factor two light green colour chilies, and factor three chilies that had turned red.

The fresh chilies were sorted into red chili, light green chili, and dark green chili and were further divided into two treatments. For each treatment, there were five replications. In each replication, 15 kg of chilies were weighed. A total of 450 kg of chilies (150 kg of red chili, 150 kg of light green, and 150 kg of dark green chili) were stored. The chilies were stored using the plastic crates.

The cold store temperature was set to 8°C to 10° C and 90-95% humidity (Walker, 2010). A data logger was placed for ambient room conditions to record the room temperature and humidity. The data on physiological weight loss, chili shrinkage, and decay were recorded every one-week interval.

2.4 Physiological weight loss

The weight of the chilies was measured before the storage and at every weekly interval using a high-precision electronic digital weighing balance (Blue Star). The recorded weight was then calculated in percentage. The physiological weight loss was measured using a standard precision weighing scale and recorded the data. The physiological weight loss was expressed

in percentage using the following equation (Tsegay, Tesfaye, Mohammed, Yirga, & Bayleyegn, 2013) and mean in different maturity stages of stored chili.

$$Physiological\ weight\ loss\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} X\ 100$$

2.5 Decay

A random sample of 100 numbers of chilies from each storage crate was taken and the number of chilies decayed was recorded. The decayed chilies quantity was then determined in percentage from the number of samples collected randomly. The decayed chilies were assessed visually based on the symptoms of decay developed on the chili fruits at the different storage intervals (Tsegay, Tesfaye, Mohammed, Yirga, & Bayleyegn, 2013).

2.6 Shrinkage

The number of chili shrinkage was assessed visually at weekly intervals. Randomly 100 chilies were selected from the crates and then the number of chilies that had shrinkage was recorded based on the surface depression development on the chili fruits (Lowands, Banaras, & Bosland, 1994). The shrinkage of chili in different maturity stages was then determined in percentage from the 100 chilies selected from the lot.

2.7 Shelf life

The shelf life of fruits was decided based on the appearance and spoilage of fruits. When 50% of chili showed symptoms of shrinkage, decay, or spoilage due to pathogens and chilling injury, a lot of chilies were considered to have reached the end of shelf life (Rao, Gol, & Shah, 2011). The shelf life was evaluated based on the number of days at the storage.

2.8 Data analysis

The data collected during the experiment were processed in Microsoft Excel 2013 spreadsheet. It was analyzed using Statistical Tool for Agricultural Research (STAR) version 2.0.1. Both descriptive and inferential analysis were done using the software. Analysis of variance (ANOVA) and Post Hoc test were carried out at a significance level of 0.05.

3 Result and Discussion

3.1 Physiological weight loss of chilies

The results from the experiment showed that the chilies in the ambient room temperature condition could be stored for two weeks. A significant difference *(P-value < 0.05)* was observed among the different maturity stages, dark green, light green, and red chilies which could be stored for two weeks irrespective of the maturity stages. In the first week of the storage

experiment, the maximum weight loss was observed in red chili with a mean weight of 8.58 kg from 14 kg of initial weight, and in the second week, it was 4.20 kg as shown in Table 1. The lowest was in dark green chili with a mean weight of 10.22 kg from 14 kg in the first week and 5.54 kg in the second week of storage in the ambient room temperature condition (Table 1). The chilies in all the stages have shrinkage due to high temperatures of 26^0C to 28^0C and low relative humidity of 40-50% in ambient room conditions and could not be marketed at the end of the two-week storage period. The physiological weight loss of the stored chilies was mostly due to decay and shrinkage.

Table 1. Mean weight of chili stored at an ambient room temperature condition

	Mean weight of chili (Kg) stored at an ambient room temperature condition		
Treatment	Week 0	Week 1	Week 2
Dark green	14	10.22a	5.54a
Light Green	14	9.60b	5.06b
Red	14	8.58c	4.20c
Mean	14	9.47	4.93
CV (%)		3.07	3.33
P-value		0	0

**Means with the same letter in the column are not significantly different at P-value < 0.05*

The chilies in the cold store could be stored for a maximum of two months period. During the storage period a significant difference *(P-value < 0.05)* was observed among the different maturity stages of fresh chilies stored in the cold store conditions. Red chilies could be stored for five weeks while the dark green chilies could be stored for eight weeks in the cold store. The mean weight recorded was 13.76 kg dark green, 13.63 kg light green, and 13.23 kg red chilies in the first week of storage and 5.33 kg for dark green chilies at the end of eight weeks of storage period.

Loss in the weight of chilies gradually increased every week with the rapid weight loss was observed in red and the lowest in dark green chilies during the eight weeks of storage period as shown in Table 2. More than 50% of weight loss was observed from the fifth week in red chilies and from the sixth week onwards in dark green and light green chilies.

Table 2. Mean weight of chili stored in the cold store condition

	Mean weight of chili (Kg) stored in cold store condition								
Treatment	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Dark Green	14	13.76a	13.31a	12.75a	11.86a	11.40a	8.17a	7.19	5.33
Light Green	14	13.63a	13.14a	12.64a	10.18b	9.01b	5.04b		

Red	14	13.23b	12.64b	11.39b	9.38c	5.28c	
Mean	14	13.54	13.03	12.26	10.48	8.57	6.61
CV (%)		1.39	2.31	1.17	1.76	1.15	2.4
P-value		0	0.01	0	0	0	0

**Means with the same letter in the column are not significantly different at P-value < 0.05*

A cold store could have a significant difference in storing fresh chilies compared to the ambient room temperature conditions which could offer for consumption over a longer period (Hameed, et al., 2013). In line with the study by Hameed et al., (2013), chilies stored at 15°C experience maximum quality weight loss, and decay during storing compared to those stored at or below 10°C as more ethylene production and respiration higher at higher temperatures. The weight loss of sweet pepper fruits harvested at fully ripened and full green fruit were significantly higher than fruits harvested at intermediated stages. The physiological weight loss in the ripened fruits could be due to changes in the permeability of cell membranes causing them sensitive to water losses, which is in line with the study conducted by Tsegay, Tesfaye, Mohammed, Yirga, & Bayleyegn, (2013) on the effects of harvesting stage and storage duration on postharvest quality and shelf life of sweet bell pepper. The study also reported that completely ripened and full green chili stages have significantly higher weight loss than the intermediate stages.

3.2 Shrinkage

The number of chili shrinkages was recorded in every hundred chili randomly selected from the stored crate. The shrinkage in red chili was 97%, followed by light green 88% and dark green 70% at the end of two weeks storage in ambient room temperature conditions as shown in Figure 1a. In cold store conditions, red chili has 38% at the end of five-week storage, light green 47% at the end of six-week storage, and 40% dark green at the end of the eight-week storage period as indicated in Figure 1b. Rapid development of shrinkage in the chilies was observed in the red chilies followed by light green and dark green chilies.

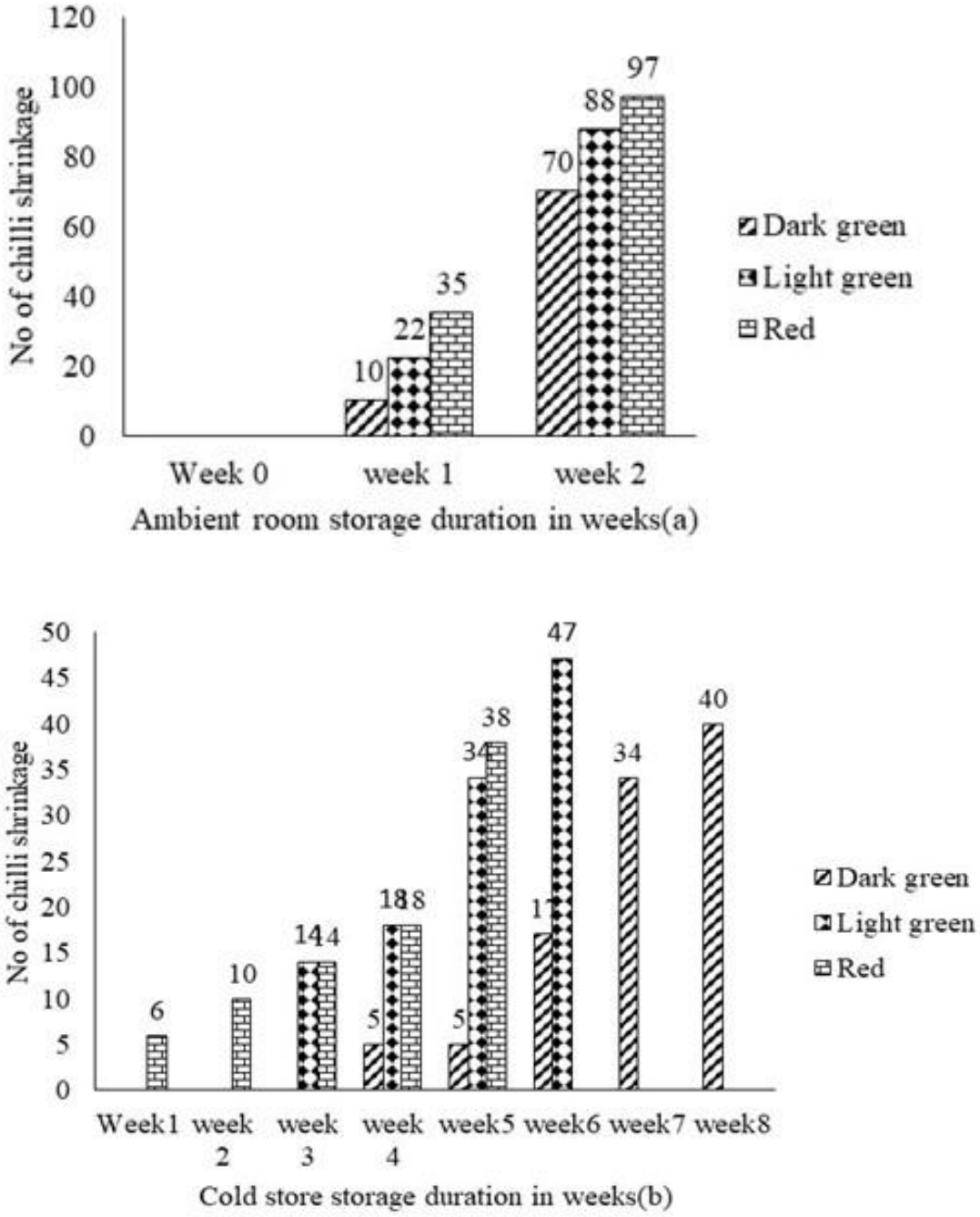

Figure 4. Chilli shrinkage in ambient (a) and cold store (b) during storage

3.3 Decay

The decay of chili fruits at ambient room temperature conditions for the red and light green chilies was 10% each and 9% in dark green chilies at the end of two weeks of storage as shown in Figure 2a. In the cold store conditions in red chilies, there was 25% decay, 15% decay in light green chilies at five-week and six-week storage respectively, and 14% for dark green chilies at the end of eight-week storage in cold store conditions (Figure 2b).

In ripe fruits and vegetables ethylene production continues to increase and increasing ethylene production can result in loss of chlorophyll and decay which in turn decreases the shelf-life and storability capacity of the produce (Watkins & Nock, 2012 and Mope, Adegoroye, Oluwalade, & Adeyelu, 2024).

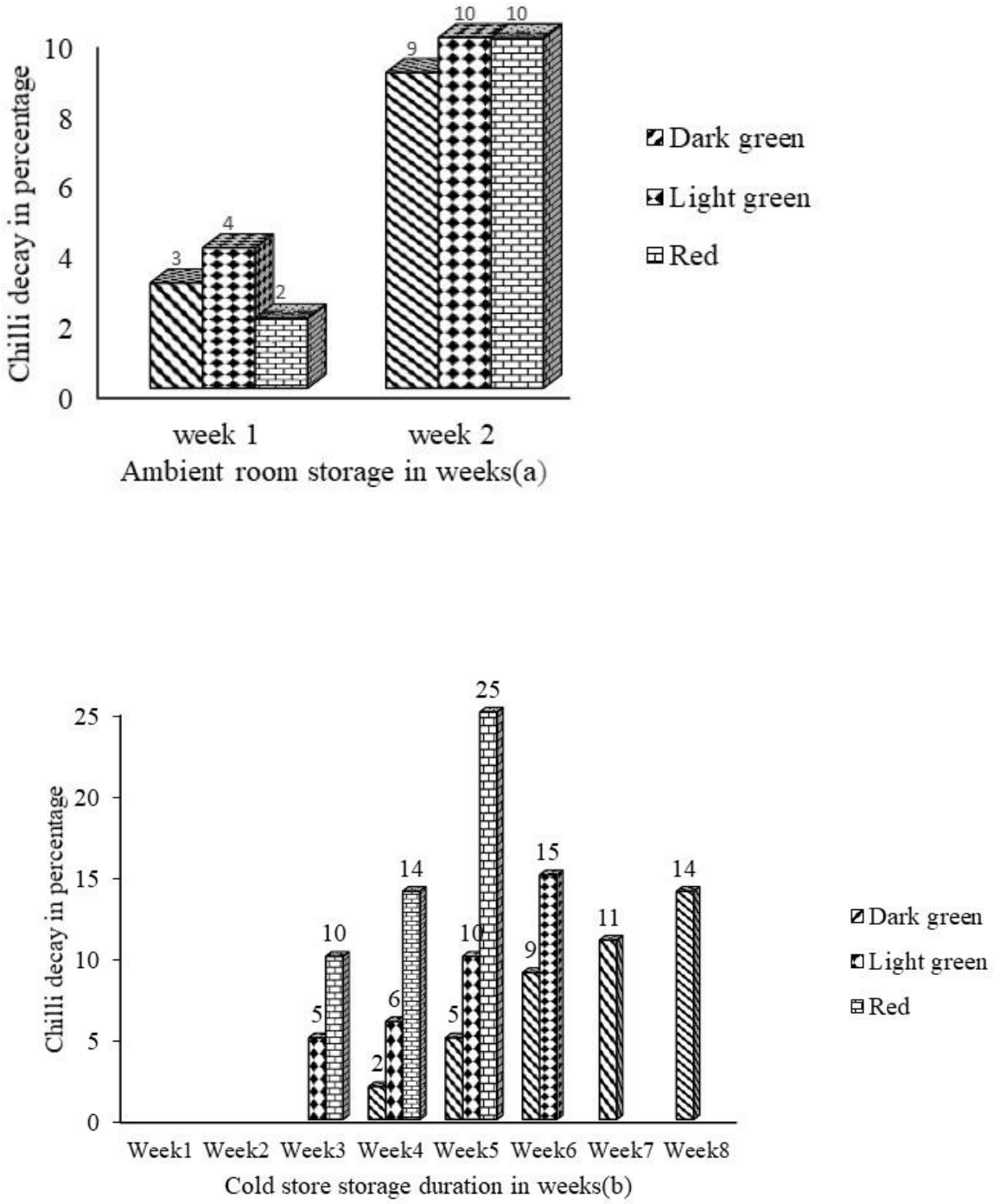

Figure 5. Chilli decay percentage in ambient room (a) and cold store (b)

3.4 Shelf life

Red chilies can be stored for five weeks, light green chilies for six weeks, and dark green chilies for eight weeks in the cold store conditions while in the ambient room temperature conditions, the chilies could be stored for two weeks as quality that are marketable.

The red colour indicates the chilies fruits are ripe and the ripe chilies could be stored for five weeks in the cold store. The maturity stage of chili during storage significantly affects post-harvest quality and shelf life. A study on fruits indicated that as the fruit ripens, it becomes sweeter but exhibits decay rates, highlighting a trade-off between sweetness and shelf life (Rahman et al., 2016). In addition, the research revealed that the type of pepper and its ripening stage greatly affect sugar and capsaicinoid levels, with sugars increasing significantly as the peppers ripen, enhancing flavor but also decreasing shelf life (Guijarro-Real et al., 2023). In line with the study by Tsegay, Tesfaye, Mohammed, Yirga, & Bayleyegn (2013), states the sweet peppers showed that increasing harvest maturity and storage duration improved total soluble solids but reduced fruit firmness.

4 Conclusion

The determination of the shelf life of chili in cold storage and ambient room temperature conditions was conducted at the National Post Harvest Sub-centre Lingmethang for the fiscal year 2023-2024 to determine the storage shelf life of chili of different maturity stages in ambient room temperature conditions and cold store. The results indicate that the chilies could be stored in the cold store for about two months after the harvest at 8°C to 10°C. While at ambient room temperature conditions, the chilies could be stored for only two weeks. This could have advantages in storing the fresh green chilies during the surplus chili production periods. The last harvest of the local Bhutanese chili could be harvested in mid-November months, stored in the cold stores, and then marketed during the winter months when local Bhutanese chili supply is scarce in the market. This will also support utilization of the facilities such as cold storage infrastructure currently established by the Food Corporation of Bhutan at various locations of the country for the storage of perishable fruits, vegetables, and other farm products.

This study on chili storage in ambient room temperature and cold store conditions of different maturity stages also showed that the red and light green chili qualities deteriorated faster than the dark green chilies during the storage period. The weight loss, shrinkage, and decay in chili were rapid in red followed by light green and dark green chilies. Sorting of the deteriorated

chili needs to be carried out at frequent intervals to prevent further quality losses in the stored chili. However, the nutrient content changes during the chili storage period need to be studied in future research of the chili storage.

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6 Authors' contribution statement

Kinley Wangmo developed the study conception and design, implementation of the research, data collection, data analysis, interpretation of results, and draft manuscript preparation. Pema Chophel contributed to the development of the study conception and design, as well as the implementation of the research and data collection. Thinley Wangdi carried out the literature review, data analysis, interpretation of results, and draft manuscript preparation.

7 References

Agricultural Market Intelligence Centre, PJTSAU. (2021). Chili Outlook-August 2021. Agriculture Market Intelligence Centre.

Bosland, P. W., & Votava, E. (2000). Peppers: Vegetable and Spice Capsicums. CABI.

Department of Agriculture. (2024). Inventory of Released and De-notified Crops in Bhutan (1988-2024). Thimphu: Agriculture Research and Innovation Division.

Food Corporation of Bhutan Limited. (2025, January 5). New Cold Store Inaugurated to Bolster Farmers' Resilience! Retrieved from Food Corporation of Bhutan Limited: https://www.fcbl.bt/news_events.php?news_id=501

Guijarro-Real, C., Adalid-Martinez, A. M., Pires, C. K., Ribes-Moya, A. M., Fita, A., & Rodriguez_Burruezo, A. (2023). The Effect of the Varietal Type, Ripening Stage, and Growing Conditions on the Content and Profile of Sugars and Capsaicinoids in Capsicum Peppers. *Plants*, *12*(2), 231.

Hameed, R., Malik, A. U., Khan, A. S., Imran, M., Umar, M., & Riaz, R. (2013). Evaluating the effect of Different Storage Conditions on Quality of Green Chilies (Capsicum annuum L.). Tropical Agricultural Research Vol. 24(4), 391-399.

Kapoor, S., Sidhu, K. R., Tandon, R., Jindal, S., & Mahajan, B. (2022). Post Harvest quality of green chilli (*Capsicum anuum*) cultivars under cold and ambient conditions. Indian Journal of Agricultural Science, 70-74.

Lowands, N. K., Banaras, M., & Bosland, P. W. (1994). Postharvest Water Loss and Storage Quality of Nine Pepper (Capsicum) Cultivars. HortScience 29(3), 191-193.

Makonnen, T., Gedamu, F., & Woldetsadik, K. (2021). Impacts of harvesting stages and pre-storage treatments on shelf life and quality of tomato (*Solanum lycopersicum* L.). Cogent Food and Agriculture, 1-27.

Mope, C., Adegoroye, A., Oluwalade, T. A., & Adeyelu, A. A. (2024). Ethylene Management in Fresh Produce Transport. Asian Journal of Food Research and Nutrition, 60-71.

National Biodiversity Centre. (2015). The history of the introduction and adoption of important food crops in Bhutan. Thimphu: National Biodiversity Centre.

National Statistics Bureau. (2024). Integrated Agriculture and Livestock Census of Bhutan, 2023. Thimphu: National Statistics Bureau.

Poudel, S., Gautam, I. P., Ghimire, D., Pandey, S., Dhakal, M., & Regmi, R. (2021). Modified atmosphere packaging of capsicum for extending shelf life under coolbot condition. Journal of Agriculture and Natural Resources, 120-129.

Rao, T. R., Gol, N. B., & Shah, K. K. (2011). Effect of postharvest treatments and storage temperatures on the quality and shelf life of sweet pepper (Capsicum annum L.). Scientia Horticulturae, 18-26.

Tolasa, M., Gedamu, F., & Woldetsadik, K. (2021). Impacts of harvesting stages and pre-harvesting treatments on shelf life and quality of tomato (*Solanum lycopericum* l.). Cogent Food $ Agriculture, 1-27.

Tsegay, D., Tesfaye, B., Mohammed, A., Yirga, H., & Bayleyegn, A. (2013). Effects of harvesting stages and storage duration on postharvest quality and shelf life of sweet bell pepper (*Capsicum annuum* L.) varieties under passive refrigerator system. International Journal for Biotechnology and, 98-104.

Tshegay, D., Tesfaye, B., Mohammed, A., Yirga, H., & Bayleyegn, A. (2012). Effects of harvesting stage and storage duration on postharvest quality and shelf life of sweet bell pepper (*Capsicum annuum* L.) varieties under Passive refrigerator system. Global Journal of Cellular and Molecular Biological, 027-033.

Villa-Rivera, M. G., & Ochoa-Alejo, N. (2021). Transcriptional Regulation of Ripening in Chili Pepper Fruits (Capsicum spp.). International Journal of Molecular Sciences, 1-18.

Walker, S. (2010). Postharvest Handling of Fresh Chilies. New Mexico State University: College of Agricultural, Consumer and Environmental Science.

Wangmo, C., & Dendup, T. (2021). Post Harvest Handling and Losses of Green Chilies: A Case Study from Bhutan. Indonesian Journal Od Social and Environmental Issues (IJSEI), 284-292.

Watkins, C. B., & Nock, J. F. (2012). 2012 Production Guide for Storage of Organic Fruits and Vegetables. Department of Horticulture, Cornell University.