



RESEARCH ARTICLE

Physical and nutritional changes of Ladakhi radish (Gya Labuk) during storage at high altitude trans-Himalayan region of Leh-Ladakh

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Received: 08 September 2025; Accepted: 16 April 2026; Available online: Version 1.0: 09 July 2026

Cite this article: Vivek KT, Somen A, Shailendra KD, Shardulya S, Monisha R, Vishesh P, Hem PV, Khushboo K. Physical and nutritional changes of Ladakhi radish (Gya Labuk) during storage at high altitude trans-Himalayan region of Leh-Ladakh. Plant Science Today. 2026;13(sp2):01–09. <https://doi.org/10.14719/pst.11668>

Abstract

A study was conducted on Ladakhi local radish to determine the effects of *Aloe vera* gel and Chlorpropham [isopropyl N-(3-chlorophenyl) carbamate] (CIPC) treatments on postharvest quality under cold desert conditions of Leh-Ladakh in the year 2019–20. Radish roots were treated with 100 % *Aloe vera* gel and 10 % CIPC before being stored in a zero-energy semi-underground structure for 90 days. Physiological [weight loss, moisture content] and biochemical parameters [total soluble solids (TSS), anthocyanin content, titratable acidity, total antioxidant activity, sugars, minerals and inorganic anions] were measured after 30 days. At the end of the experiment, the maximum weight loss 19.79 % was recorded in the control, while 15.20 % and 13.33 % weight loss were recorded with the application of CIPC and *Aloe vera*, respectively. Total soluble solids, sugars and anions increased initially but declined after 60 days. No significant changes were observed in mineral content across treatments, although sodium levels were slightly lower in treated samples. *Aloe vera* gel showed potential as a natural, biodegradable coating to enhance shelf life & quality of radish under high-altitude cold desert storage, offering a sustainable alternative to synthetic chemicals like CIPC.

Keywords: high altitude; Ladakhi radish; mineral content; sugar profile; winter storage; zero hunger

Introduction

Radish (*Raphanus sativus* L.) is the most common vegetable in the Brassicaceae family (2n = 18). It is grown all around the world and has been the preferred root vegetable in Ladakh for over a century. It originated in Europe and Asia and came to Ladakh in exchange for products (1). It is an annual for consumption and a biennial crop for seed production with cylindrical, globular and tapered roots. The fresh roots can be cooked, pickled, or dried. Radish roots have a high concentration of minerals, including calcium, manganese and phosphorus, as well as crude fibre, dry matter, nitrate, total soluble sugars, carotene and vitamins like thiamine, riboflavin, nicotinic acid and folate (2,3).

However, radish leaves are a significant source of protein. Radish is an excellent source of vitamin C (15–40 mg/100 g of edible portion) (4). It was observed that the radish had excellent therapeutic and nutritional value. Radish roots, leaves and seeds have highly medicinal values and have been scientifically linked to the

prevention of a variety of diseases, including hyperlipidaemia, coronary heart disease, constipation, jaundice, liver problems, urinary complaints and piles (5, 6). The Ladakhi native radish is biannual, cylindrical, huge in size and has a very thick cuticle as compared to the plain region. Ladakh's geographical environment is crucial for agriculture due to its rugged topography and six months of heavy snowfall every year (7). The high altitude (~3000 m) and little humidity result in radiation levels of up to 6–7 kWh/mm. This location is characterised by a longer photoperiod and only one cropping season was observed each year (May to October) (8). Different storage strategies are critical to increasing shelf life and fulfilling the needs of people for five to six months in the cold desert when snowfall is frequent. So, throughout storage, the major focus was on the morphology, quality and nutritional features of Ladakhi native radish. However, greater focus was devoted to increasing the shelf life and consumption of high-quality radish throughout Ladakh's harsh winter season. As a result, nutritional quality indicators should be thoroughly investigated during radish

preservation.

In developing nations, over 30–40 % of vegetables deteriorate owing to a lack of postharvest management for the entire output. Novel, edible coverings are produced to improve the shelf life of fruits and vegetables. *Aloe vera* gel has excellent properties like moisturising, antifungal and antibacterial properties (9). Physiochemical changes during storage, i.e., sprouting, are the most significant static issue that reduces demand and consumption of stored vegetables. *Aloe vera* gel-based edible coatings have been developed, delaying oxidative browning and inhibiting microbe proliferation (10). During storage, Chlorpropham [isopropyl N-(3-chlorophenyl) carbamate] (CIPC) is commonly used to prevent sprouting in potatoes by interfering with cell division (11).

Less research data was available on physiochemical and nutritional changes during the storage of radish in the trans-Himalayan region of Ladakh. Hence, keeping these factors in mind, it is important to ascertain the physicochemical changes of treated radish (*Aloe vera* and CIPC) during storage in the Ladakh region. The present study was undertaken to determine the physical changes, such as weight loss, sprouting, moisture and dry matter content, under controlled temperature and relative humidity (RH). The nutritional analysis, such as total soluble sugar (TSS), mineral analysis and inorganic anions, was also determined. Our study surely opens the research avenue of post-harvest biology of root crop at high altitude region.

Materials and Methods

Experimental location and details

The present investigation was conducted in the Division of Vegetable Science, DIHAR-DRDO, during 2019–2020. Fresh radish (Gya Labuk)

was purchased from local farmers through the State Cooperative Department, Leh. The experiment was carried out in a completely randomised design (CRD) with three replications. Radish samples were treated with *Aloe vera* (100 %) and CIPC (10 %) to inhibit sprouting and increase shelf life.

Preparation of 100 % *Aloe vera*

Select healthy and mature *Aloe vera* leaves. Wash thoroughly with clean water. After that, remove the spines and peel off the green rind, then extract the transparent gel and blend till a uniform liquid is obtained. Finally, a filter through muslin cloth is required to get a clear gel free from fibres.

Preparation of chlorpropham (10 %)

A 10 g of CIPC was dissolved in 70–80 mL distilled water. Constant stirring was required until CIPC was completely dissolved. Once it is completely dissolved, make up the final volume to 100 mL with distilled water.

Details of the storage structure

Zero energy semi underground storage structure with temperature was rectangular in shape with interior depth 3 m (0.8 m above ground level and 2.2 m below ground level), 3.6 m width and 6.7 m length. The roof was constructed with wooden material and masonry walls. Temperature data was recorded with the help of a Tiny tag datalogger, which was mentioned in Fig. 1.

Observations recorded

Total soluble solids (TSS)

Radish juice was extracted from the juicer-grinder machine and filtered through filter paper, Whatman No. 1 and TSS were determined by placing a drop of carrot juice on the prism of the hand refractometer (ERMA). Results were expressed as brix (°Bx) (12).

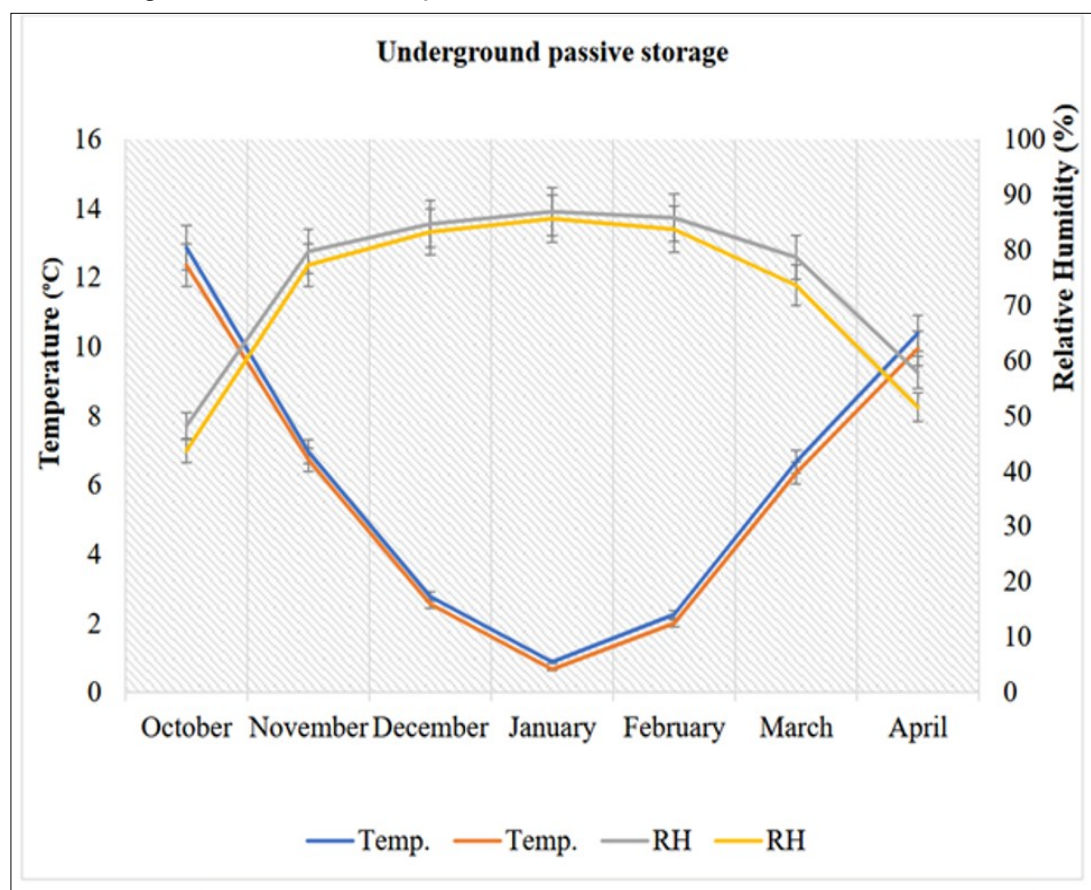


Fig. 1. Underground passive storage temperature and relative humidity data.

Sweetness index and total sweetness index

It was calculated by using the following formulas (13, 14).

Sweetness index (SI) =

$$(\text{Glucose} \times 1.0) + (\text{Fructose} \times 2.30) + (\text{Sucrose} \times 1.35) \quad (\text{Eqn. 1})$$

Total sweetness Index (TSI) =

$$(\text{Glucose} \times 0.76) + (\text{Fructose} \times 1.50) + (\text{Sucrose} \times 1.0) \quad (\text{Eqn. 2})$$

Total acidity

Firstly, 10 mL of juice was extracted and kept in a measuring cylinder and then the volume was made up to 100 mL with distilled water. A 10 mL filtrate was taken and 2–3 drops of phenolphthalein indicator were added. The filtrate was titrated with 0.1 N NaOH until the light pink colour appeared (15). Total titratable acidity can be calculated as follows:

$$\text{Acidity percentage} = (\text{titre value} \times \text{normality of NaOH} \times 64 \times \text{volume made up} \times 100) / (\text{aliquot taken} \times \text{weight of sample} \times 1000) \quad (\text{Eqn. 3})$$

The total titratable acidity was calculated in terms of citric acid and the equivalent weight of citric acid is 64 g. The results were expressed in terms of percentage acidity.

Moisture content

10 g of the sample was dried in a hot air oven at a temperature of 70 °C for 4 hr. The dish with the sample was cooled in desiccators and weighed. This was repeated till the difference in weight between two successive weights became approximately similar. From the weight loss during drying, the amount of moisture was calculated using the following formula and the moisture can be represented in percentage.

Moisture content (%) =

$$\frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100 \quad (\text{Eqn. 4})$$

Physiological weight loss (%)

The weight loss was calculated by measuring the root's initial and final weights using a digital balance and then subtracting the initial weight from the final weight and expressed as a percentage.

Antioxidant:

Radish juice was extracted from a 20 g sample of roots and filtered through Whatman filter paper No. 1. Subsequently, 1 mL of copper chloride solution (1.705 g/L in distilled water) was mixed with 1 mL each of neocuproine solution (1.562 g/L in ethanol), ammonium acetate buffer at pH 7 (19.27 g/250 mL in distilled water), distilled water and 0.1 mL of the extracted juice in a test tube. The volume was maintained at 6 mL by adding distilled water. The test tubes were then kept at room temperature for 30 minutes. A UV-Visible Spectra Max i3x Spectrophotometer was used to determine absorbance at 450 nm in comparison to a blank reagent. Trolox was used to develop the standard curve for determining total antioxidants, which are represented as Mm TE/L.

Anthocyanin:

Anthocyanin content was determined by using pH differential method, where sample extract absorbance is measured at 520 and 700 nm in pH buffers of 1.0 and pH 4.5. The difference in absorbance is used to calculate total anthocyanin content (mg cyanidin-3-glucoside per 100 g sample).

Mineral content (sodium, magnesium, iron, copper, manganese and zinc):

Different elements were determined using Atomic Absorption

Spectrometry (Analytik Jena) (AAS) with the help of the AAS standard solution of respective elements. About 200 mg of sample was digested by heating in a microwave digester (Analytik Jena) using an 8 mL acid mixture consisting of 6.0 mL nitric acid and 2 mL HCl in a Teflon digestion flask, until a clear digest was obtained. This digest was later cooled and diluted to a volume of up to 50 mL volume and aliquots were used for AAS, using filters that match wavelengths for different elements. Calibration curves were prepared with their standard solution (Sigma Aldrich) for the determination of the concentration of minerals in the samples.

Determination of inorganic anions (nitrate, phosphate and sulphate) and soluble sugar (glucose, fructose and sucrose)

Inorganic anions and sugar were extracted in triplicate based on the following method. 1 g of radish sample was taken and homogenised at 15000 rpm in ultrapure (Type-I) water (DQ3, Millipore Waters, USA) for 2 min using a tissue homogeniser (IKA, T10 basic ULTRA- TURRAX, Germany). Homogenised samples were then sonicated using an ultrasonic bath (Ultrasonic cleaner YJ5120-1, India) (40 °C at 30 min for sugar profiling and 55 °C at 40 min for inorganic anions) and then centrifuged at 15000 rpm for 15 min and filtered through Whatman No. 1 filter paper. Further dilutions were carried out and the final diluted samples were passed through a 0.22 µm microporous membrane filter with a 25 mm diameter. The content of inorganic anions (nitrate, phosphate, sulphate) and sugar profiling (glucose, fructose and sucrose) was analysed by an ion chromatography (IC) system (930 compact IC Flex, Metrohm, Switzerland). Metro Sep A Supp 5-250/4.0 anions column and RCX-30-7 µm-250/4.1 mm column were used for anion and sugar analysis, respectively. In the mobile phase, 3.2 mM Na₂CO₃, 1 mM NaHCO₃ and 5 % acetone were used as eluent for anion analysis with a 0.7 mL/min flow rate. A 100 mM H₂SO₄ solution was used as the suppressor solution for anion analysis. For sugar analysis, 0.1 M NaOH was used as an eluent with a flow rate of 1 mL/min. Nitrate, phosphate and sulphate were detected using a conductivity detector and soluble sugars using an amperometry detector. The conversion of phosphate to phosphorus and sulphate to sulphur is multiplied by 0.436 and 0.333, respectively (16, 17).

Statistical analysis

All experimental data were expressed as mean ± standard deviation using statistical analysis with SPSS 16 (SPSS Corporation, Chicago, Illinois, USA) and MS Excel 2019. Differences between mean values were evaluated using one-way analysis of variance (ANOVA).

Result

After 30 days of storage, none of the treatments indicated any weight loss, while it was recorded a little change after 60 days of storage (Fig. 2). At end of experimentation (after 90 days of storage) the maximum weight loss (19.79 %) was recorded in control while 15.20 % and 13.33 % weight loss were recorded with application of CIPC and *Aloe vera*, respectively. During the storage study, treated radish (*Aloe vera* and CIPC) exhibited significant differences when compared with the control.

It was recorded that among all the treatments, radish treated with *Aloe vera* recorded the highest moisture content 85.74 % at the end of the experimentation after 90 days of storage period. The result indicates that the moisture content gradually decreased during the entire storage period. The lowest moisture

content 78.02 % was recorded in control radish as compared to CIPC-treated radish, which recorded 80.51 % moisture content. The biochemical parameters such as TSS, total antioxidant, anthocyanin and total acidity are shown in Fig. 2. Total soluble solids are expressed as total solids that dissolve in water (18). It was observed that significant changes occurred during the entire storage period. Total soluble solids increased significantly from 7.27 to 10.81 after 90 days of storage. The highest TSS was recorded at 10.81 in the control, followed by application of *Aloe vera* (9.81) and CIPC (9.52), respectively. Results indicated an increasing trend after the peak in TSS value. Significant differences ($p < 0.05$) were found in TSS content in storage between different stages of the experiment, but the values of TSS in *Aloe vera* and CIPC were lower than those of the control during the storage period.

It was depicted in Fig. 2 that there was no significant change

seen in anthocyanin content in control and treated radish even after 30 days of storage. After that a continuous reduction was noticed in anthocyanin content of all treatments upto end of the experiment. At the end of the storage period, the maximum anthocyanin content was recorded in *Aloe vera* (20.84), whereas CIPC and control reported 18.87 and 16.68 mg/100 g anthocyanins, respectively. The titratable acidity consistently reported decreasing up to the end of the experiment. The titratable acidity was reported to be highest (0.32 %) at 0 days and lowest (0.21 %) at 90 days in the treatment where *Aloe vera* was used as surface coating material. The titratable acidity is a measure of the concentration of organic acids present in vegetables that are important in maintaining quality. Titratable acidity was found to decrease during the storage period (19, 20). After 90 days of storage period, non significant differences in total antioxidant activity were recorded in all treatments. A gradual

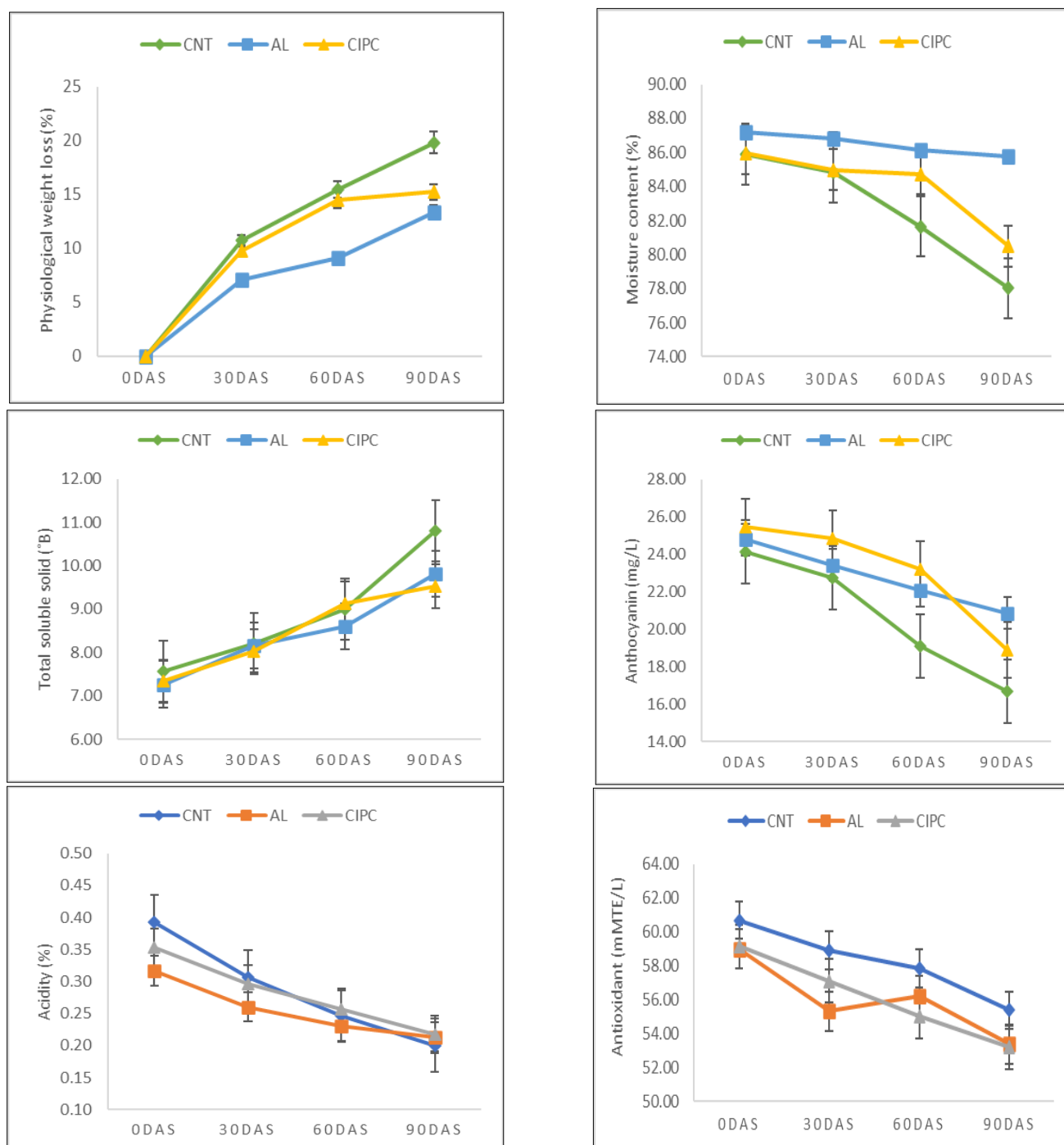


Fig. 2. Changes in physiological weight loss, moisture content, total soluble solids, anthocyanin, acidity and antioxidant content in fresh radish during the storage period. DAS: Days after storage; CNT: Control; AL: *Aloe vera*; CIPC: Chlorpropham

decrease in total antioxidant content was continuously recorded from the first to the last day ($p > 0.05$) of the experimentation. The highest antioxidant content (60.68 mmol/100 g) in radish was recorded at the start of the experiment, i.e., 0 days, while the minimum antioxidant activity (53.19 mmol/100 g) was recorded in CIPC at the end of the experimentation.

The soluble sugar, such as glucose, fructose, sucrose, total sugar, SI and TSI were shown in Table 1. During the storage study, it was observed that up to 60 days of storage, glucose and fructose were found to increase in all treatments and after that, they decreased. The maximum glucose content (g/kg) was found in the control (20.28 g/kg) at the end of the storage (90 days). The non-reducing sugar (sucrose) was exhibited at the highest in *Aloe vera* treatment (10.22 g/kg) after 90 days of storage. The maximum reduction of sucrose content was found in the control compared to other treatments. The highest mean total sugar was found in the control (31.08) at the end of the storage. Non-significant changes in all the treatments of sugars were recorded at the end of the storage period, but significant differences were observed in the duration of storage.

It was clear from Table 2, values of inorganic ions, such as nitrate, phosphate and sulphate, were found to be maximum in the initial period of storage and after that their concentration decreases and were found to be lowest up to 90 days of storage. The highest nitrate (0.31 g/kg) content was reported in control after the end of storage, whereas the phosphate (1.44 g/kg) and sulphate (0.75 g/kg) were reported highest in CIPC treatments at the end of storage. However, the mean amounts of phosphate and sulphate in treated radish roots at different days after postharvest storage were almost similar to the control radish root (21). Nutritional and bioactive components of fresh sprouts of radish and other plant samples at

4 °C cold storage and 2.8 g/kg dry matter nitrate content in radish (22).

The mineral elements such as Magnesium, Iron, Copper, Manganese, Zinc and Sodium were estimated and depicted in Fig. 3. Results indicated that the radish is an excellent source of minerals. Moreover, our results showed that no remarkable changes ($p > 0.05$) in mineral content occurred during the entire storage period. Magnesium was largely well conserved over both fresh and treated radish during storage. Among all the treatments, the highest magnesium (226.91 mg/kg) was reported in *Aloe vera*, followed by control (226.13) after 90 days of storage. Results indicate that radish showed no significant difference in magnesium content between control and treated samples. The general trends were apparent in the retention of manganese in treated and control produce. In radish, there were no significant differences in the manganese content between the two treatments. Iron was one of the best-retained nutrients in the fresh and treated stored commodities evaluated over the course of this study. In all treatments, there were no significant differences between the fresh and treated radish samples and those that were stored fresh. The trends in retention of Zinc in treated radish were similar to those of other minerals. However, the highest amount of Copper was recorded in fresh radish samples. Overall, there was no significant decrease in the mineral composition of radish was observed upto 30 days storage period. After 30 days of storage, the copper content decreased compared to 0 days in the sample. This indicates that there were no losses due to leaching of nutrients. During 90 days of storage, Sodium concentration (258.49 mg/kg) was reported to be maximum in control in all treatments and among treatments found to be lowest (251.94 mg/kg) in CIPC treated. The influence of storage on the all-mineral content was very low. Changes in mineral and trace elements in radish and other crops and reported

Table 1. Sugar profiling (glucose, fructose and sucrose), total sugar, sweetness index and total sweetness index of fresh radish stored for 90 days in a semi-underground store at the cold desert region of Leh-Ladakh

Treatment	Glucose (g/kg)				Fructose (g/kg)				Sucrose (g/kg)			
	0 DAS	30 DAS	60 DAS	90 DAS	0 DAS	30 DAS	60 DAS	90 DAS	0 DAS	30 DAS	60 DAS	90 DAS
CNT	10.7a	17.6a	23.7b	20.28b	5.86a	8.41c	8.55b	3.68±0.48a	17.27a	12.91a	11.04a	7.12a
AL	11.58a	16.50a	17.34a	12.94a	5.28a	5.37a	4.59a	4.17a	17.26a	15.56b	12.84a	10.22b
CIPC	11.40a	20.97b	20.91ab	13.91a	5.77a	7.65b	5.20a	4.07a	17.82a	14.43ab	13.15a	9.11b
Treatment	Total sugar (g/kg)				Sweetness index (g/kg)				Total sweetness Index (g/kg)			
	0 DAS	30 DAS	60 DAS	90 DAS	0 DAS	30 DAS	60 DAS	90 DAS	0 DAS	30 DAS	60 DAS	90 DAS
CNT	33.81a	38.96b	43.28c	31.08a	47.47a	54.41b	58.26c	38.36a	34.18a	38.93b	41.87c	28.05a
AL	34.42a	37.09a	34.78a	27.34a	47.73a	49.08a	45.24a	36.34a	34.44a	35.65a	32.91a	26.32a
CIPC	34.99a	43.05b	39.26b	27.09a	48.73a	58.04b	50.62b	35.58a	35.14a	41.84b	36.84b	25.79a

The values with the different letters within the same column are statistically significant by Duncan's test at $p \leq 0.05$. DAS: Days after storage; CNT: Control; AL: *Aloe vera*; CIPC: Chlorpropham.

Table 2. Changes in nitrate, phosphate and sulphate content of radish during 90 days of storage in a semi-underground store at Ladakh conditions

Treatment	Nitrate (g/kg)				Phosphate (g/kg)				Sulphate (g/kg)			
	0 DAS	30 DAS	60 DAS	90 DAS	0 DAS	30 DAS	60 DAS	90 DAS	0 DAS	30 DAS	60 DAS	90 DAS
CNT	0.46b	0.42b	0.42c	0.31a	1.58a	1.07a	0.98a	0.83a	1.15a	0.86a	0.87a	0.67ab
AL	0.30a	0.29a	0.26a	0.18b	2.29b	1.86c	1.23ab	1.08b	1.27a	1.02b	0.92a	0.60a
CIPC	0.42b	0.39b	0.35b	0.28b	1.78ab	1.70b	1.50b	1.44c	1.12a	0.92ab	0.87a	0.75b

The values with the different letters within the same column are statistically significant by Duncan's test at $p \leq 0.05$. DAS: Days after storage; CNT: Control; AL: *Aloe vera*; CIPC: Chlorpropham.

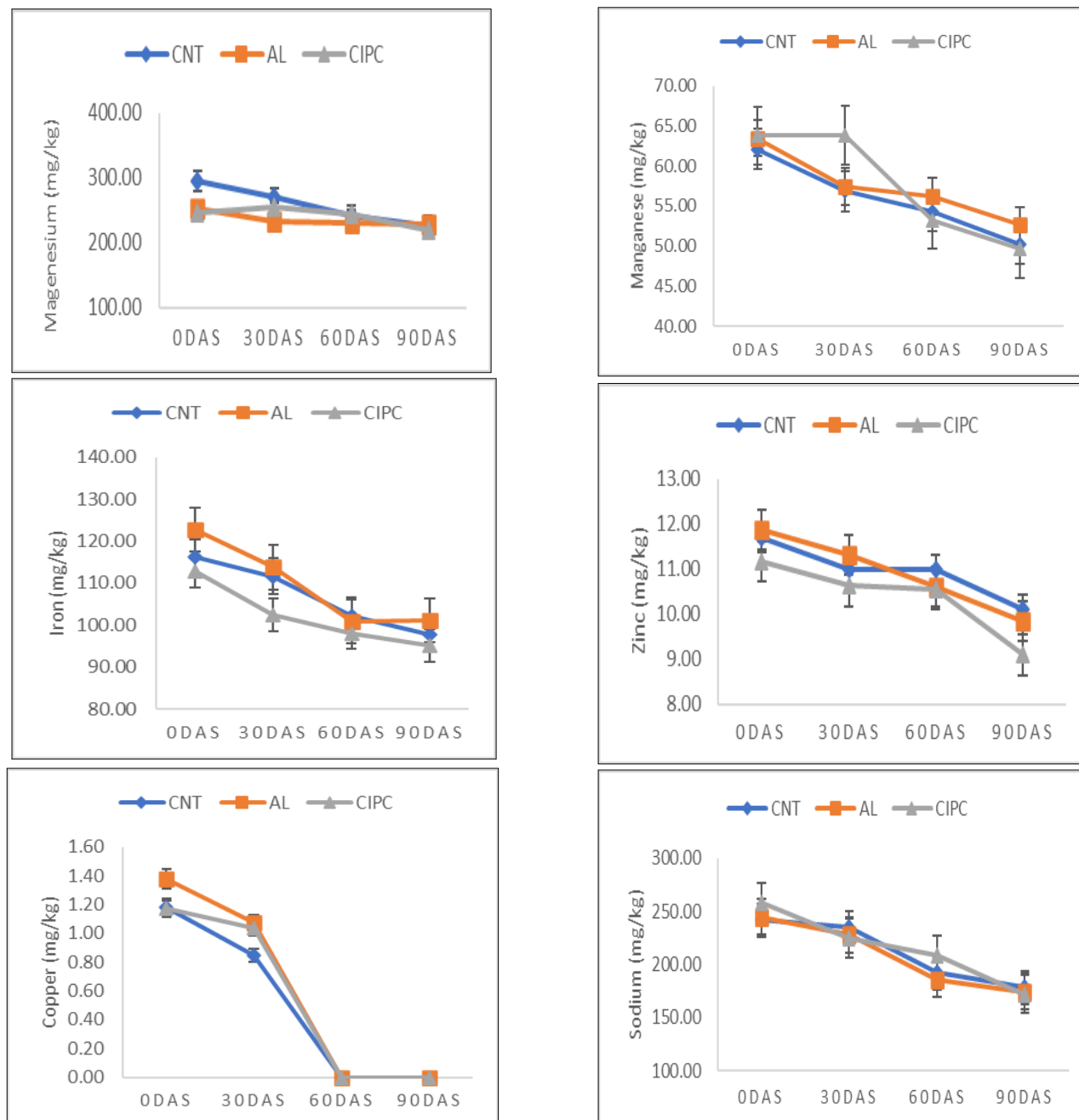


Fig. 3. Changes in mineral composition (Magnesium, Manganese, Iron, Zinc, Copper and Sodium) of radish during 90 days storage period in a semi-underground store at the Ladakh region. DAS: Days after storage; CNT: Control; AL- *Aloe vera*; CIPC - Chlorpropham.

Magnesium (249 mg/100g), Iron (6.5 mg/100g), Copper (0.3 mg/100g), Manganese (1.0 mg/100g) and Zinc (3.1 mg/100g) in radish, which are more or less similar to our results (23). On a dry matter basis, 1.7 mg/g sodium and 3.99 mg/g magnesium were recorded in radish (24).

Discussion

Chlorpropham [isopropyl N-(3-chlorophenyl) carbamate] (CIPC) is an important phenyl carbamate herbicide that is used as a plant growth regulator. The growth retardant activity of CIPC may inhibit the metabolic activity that, in return, may prevent moisture loss, whereas *Aloe vera* inhibits bacterial growth and prevents rotting and softening of tissues. Minimum physiological weight loss was observed when compared to the control. It might be possible that the coating of *Aloe vera* reduces the transpiration rate. The main sources of weight and quality loss are respiration, transpiration and sprouting. The degradation rate of stored fruits and vegetables is

related to their respiratory rate (25). Weight loss in horticultural crops during storage can be described as substrate loss through respiration and transpiration of moisture via a number of methods. Physiological weight loss in vegetables and other horticultural crops is linked to humidity, temperature and metabolic activity changes. No disease indications appeared in *Aloe vera*-coated papaya once the storage period began (26). In twelve short-day onion cultivars that were held for three months at ambient temperatures over three years, weight loss ranged from 21 % to 99 % (27). The increase in dry matter percentage with increasing storage period may be due to evapotranspiration of water from the root. Dry matter relatively increased with the increase in the storage period and our results also follow the same pattern (28).

Chlorpropham inhibits sprouting by interfering with cell division; it is effective in long-term storage. Respiration of tubers during storage leads to breakdown of dormancy that results in sprouting (29). Optimum temperature conditions can prevent weight loss, sprouting and nutritional quality (30). Low-temperature

storage (2–4 °C) inhibits sprouting and rotting, especially in long-term storage (31). Vegetables' TSS increase during storage when starch breaks down into soluble sugars or cell walls are hydrolysed (32). Among the several treatments, *Aloe vera* produced an excellent evapotranspiration barrier, whereas CIPC inhibited sprouting, reduced respiration and eventually sugar metabolism. Coated papaya slowed TSS development because aloe gel reduces sugar respiration and ultimately, metabolism (33). *Aloe vera* gel coating may reduce α -galactosidase, polygalacturonase and pectin methyl-esterase activity (34). Postharvest application of Nimbecidine (1.5 %) on apple gave better results in reducing physiological loss in weight and retaining fruit firmness, whereas neem azal (2.0 %) reported effective in retaining maximum TSS, starch and pectin content at the end of 6 months storage period (35).

Anthocyanin loss may occur because of a lack of moisture or disease infection during storage. The anthocyanin concentration in carrot juice decreased after storage (36). Similar findings were achieved throughout the current experiment. After 8 days of storage, berries treated with 50 % and 75 % gel retained the maximum level of anthocyanin when compared to treatments and control fruits (37). Anthocyanins are water-soluble, which makes them easy to incorporate into aqueous food systems (38). Titratable acidity of apples reduced steadily throughout a nine-month storage period (39). A substantial change was seen in all fresh radish treatments; however, there was no statistical difference after 90 days of storage. Decline of titratable acidity was observed during storage (40).

Phenolics, flavonoids, lycopene, carotenoids and glucosinolates are antioxidants present in vegetables (41). Application of coatings can slow down respiration rate and antioxidant activity can be maintained for a longer storage period in tomato coated with 10 % gum arabic (42). Similar results were observed for radish and carrot when coated with chitosan (0.2 %) compared to uncoated tissue with the same storage conditions (43). During storage, fructose and glucose concentrations increased initially but then decreased. Total sugars were greater in the early phases of storage and remained essentially consistent at the end of storage, which might be due to genotypes (44). The lower total sugar level during storage periods might be attributed to sugar utilisation in respiration and other metabolic processes. Sugar content rose during the first 6 weeks of storage and then gradually decreased. The modest rise in sugar during storage might be caused by the breakdown of complex organic metabolites into simple molecules or by the hydrolysis of starch into sugar (45). Subsequent decline in sugar parameters along with other organic acids that are the primary substrate for respiration, was predictable (46). The increase in sugar concentration is caused by the hydrolysis of starch into sucrose compounds like glucose and fructose (47). The SI and TSI based on the proportion of the individual sugar components are one of the common measures of acceptability of horticultural produce (12).

Cold temperature could strongly reduce the activity of nitrate reductase in leaves of green vegetables by disturbing the internal electron transport of nitrate reductase (48). Nitrite arises from microbiological reduction of nitrate in foods (e.g., vegetables) when stored at room temperature (49). These suggested that the mineral element's properties were stable and unaffected by the external environment. Heat treatments used in ordinary food processing have little effect on minerals (50).

The concentration of mineral components in tuber crops, such as potassium, phosphorus and magnesium, is determined by

the plant genotype, as well as climatic circumstances, crop management techniques and soil properties (51). The minerals exhibited a moderate change that was not significant throughout the storage period (52). Mineral losses were minimal after the veggies were picked and during storage before eating (53).

Conclusion

The present research investigated the efficiency of *Aloe vera* and Chlorpropham [isopropyl N-(3-chlorophenyl) carbamate] (CIPC) treatments in maintaining the postharvest quality of Ladakhi local radish (cv. Gya Labuk) after 90 days in semi-underground storage. The results clearly showed that both treatments substantially prevented physiological weight loss while maintaining higher moisture content than the untreated control. Chlorpropham was extremely successful in the suppression of sprouting, whereas *Aloe vera* increased dormancy for up to 60 days. Biochemically, *Aloe vera*-treated radish had increased anthocyanin concentration and titratable acidity, indicating improved visual and nutritional preservation. Although TSS increased in all treatments, *Aloe vera* and CIPC reduced the increase, indicating delayed metabolic activity. Antioxidant activity decreased progressively, with little variation across treatments being observed. Sugar composition changed during storage, with *Aloe vera* retaining more sucrose, whereas mineral content remained relatively constant across treatments, indicating no major leaching or degradation. The decrease in anion content was modest and treatment-dependent. Overall, *Aloe vera* appeared as an acceptable natural covering for prolonging radish shelf life while preserving nutritional and physiological quality under cold desert storage circumstances, with performance equivalent to or superior to the synthetic growth regulator CIPC.

Acknowledgements

The research was financed and supported by Vegetable Science Division, Defence Institute of High-Altitude Research-DRD.

Authors' contributions

VKT carried out the studies of physical and nutritional changes of Ladakhi radish (Gya Labuk) during storage at high altitude trans-Himalayan region of Leh-Ladakh performed the statistical analysis and drafted the manuscript. KK, SA and MR participated in the design of the study and helped for final manuscript draft. SKD, SS, VP, HPV helped in the data analysis, checking and removal of plagiarism in file. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare

Ethical issues: None

References

1. Chorol S. Antioxidant content in different parts of radish (*Raphanus sativus* L.) from cold arid Ladakh region of trans-Himalaya (Jammu and Kashmir). *Pharmacogn J.* 2010;11(5):1064–70. <https://doi.org/10.5530/pj.2019.11.166>

2. Lu ZL, Liu LW, Li XY, Gong YQ, Hou XL, Zhu XW, et al. Analysis and evaluation of nutritional quality in Chinese radish (*Raphanus sativus* L.). *Agric Sci China*. 2008;7(7): 823–30. [https://doi.org/10.1016/S1671-2927\(08\)60119-4](https://doi.org/10.1016/S1671-2927(08)60119-4)
3. Ramulu P, Rao PU. Total, insoluble and soluble dietary fiber contents of Indian fruits. *J Food Compos Anal*. 2003;16(6):677–85. [https://doi.org/10.1016/S0889-1575\(03\)00095-4](https://doi.org/10.1016/S0889-1575(03)00095-4)
4. Kaur I, Singh R, Singh D. Correlation and path coefficient analysis for yield components and quality traits in radish (*Raphanus sativus* L.). *Agric Res J*. 2017;54(4):484–9. <https://doi.org/10.5958/2395-146X.2017.00093.x>
5. Brintha I, Seran TH. Effect of paired row planting of radish (*Raphanus sativus* L.) intercropped with vegetable amaranthus (*Amaranthus tricolor* L.) on yield components of radish in sandy regosol. *J Agric Sci*. 2009. 4 (1):19–28. <https://doi.org/10.4038/jas.v4i1.1642>
6. Agarwal K, Varma R. Radical scavenging ability and biochemical screening of a common Asian vegetable—*Raphanus sativus* L. *Int J Pharm Sci Rev Res*. 2014; 27(1):127–34.
7. Stobdan T, Angmo S, Anchok D, Paljor E, Dawa T, Tsetan T, et al. Vegetable production scenario in trans-Himalayan Leh Ladakh region, India. *Def Life Sci J*. 2018;3:85–92. <https://doi.org/10.14429/dlsj.3.11661>
8. Singh RK, Acharya S, Chaurasia OP. Effects of mulching and zinc on physiological responses and yield of sweet pepper (*Capsicum annum*) under high altitude cold desert condition. *Indian J Agric Sci*. 2019;89(2):300–6. <https://doi.org/10.56093/ijas.v89i2.87088>
9. Panwar S, Mishra B, Goyal P. Permeability of *Aloe vera* composite coatings and their effect on quality of peeled carrots. *Curr Sci*. 2016;111(12):2031–5. <https://doi.org/10.18520/cs/v111/i12/2031-2035>
10. Marpudi SL, Abirami LSS, Pushkala R, Srividya N. Enhancement of storage life and quality maintenance of papaya fruits using *Aloe vera* based antimicrobial coating. *Indian J Biotechnol*. 2011;10(1):83–9.
11. Kerstholt RPV, Ree CM, Moll HC. Environmental life cycle analysis of potato sprouts inhibitors. *Ind Crops Prod*. 1997;6(3–4):187–94. [https://doi.org/10.1016/S0926-6690\(97\)00007-1](https://doi.org/10.1016/S0926-6690(97)00007-1)
12. Javanmardi J, Kubota C. Variation of lycopene, antioxidant activity, total soluble solids and weight loss of tomato during postharvest storage. *Postharvest Biol Technol*. 2006;41(2):151–5. <https://doi.org/10.1016/j.postharvbio.2006.03.008>
13. Magwaza LS, Opara UL. Analytical methods for determination of sugars and sweetness of horticultural products—A review. *Sci Hortic*. 2015;184:179–92. <https://doi.org/10.1016/j.scienta.2015.01.001>
14. Beckles DM. Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biol Technol*. 2012;63 (1):129–40. <https://doi.org/10.1016/j.postharvbio.2011.05.016>
15. Garner D, Crisosto CH, Wiley P, Crisosto GM. Measurement of pH and titratable acidity [Internet]. Central Valley Postharvest Newsletter. 2008;17(2):1–11 [cited 2026 May 10].
16. Association of Official Analytical Chemists. Official methods of analysis of the Association of Official Analytical Chemists. 15th ed. Arlington (VA): Association of Official Analytical Chemists. 1990. p. 1–50.
17. Naryal A, Acharya S, Bhardwaj AK, Kant A, Chaurasia OP, Stobdan T. Altitudinal effect on sugar contents and sugar profiles in dried apricot (*Prunus armeniaca* L.) fruit. *J Food Compos Anal*. 2009;76:27–32. <https://doi.org/10.1016/j.jfca.2018.11.003>
18. Gemma A, Chope L, Terry A, White J. Effect of untreated atmosphere storage on abscisic acid concentration and other biochemical attributes of onion bulbs. *Postharvest Biol Technol*. 2006;39:233–42. <https://doi.org/10.1016/J.POSTHARVBIO.2005.10.010>
19. Upadhyay IP, Noomhorm A, Ilangantileke SG. Effects of gamma irradiation and hot-water treatment on the shelf life and quality of Thai mango cv. Rad. ACIAR Proc. 1994. p. 348–51.
20. Sharma RR, Singh D, Singh R. Studies on transportation losses and quality parameters in apple packed in different containers. *Indian J Hortic*. 2009;66(2):245–8.
21. Hertz J, Baltensperger U. Determination of nitrate and other inorganic anions (NO_3^- , PO_4^{3-} , Cl^- , SO_4^{2-}) in salad and vegetables by ion chromatography. *Fresenius Z Anal Chem*. 1984;318(2):121–3. <https://doi.org/10.1007/BF00533680>
22. Raimondi G, Rouphael Y, Kyriacou MC, Di Stasio E, Barbieri G, De Pascale S. Genotypic, storage and processing effects on compositional and bioactive components of fresh sprouts. *LWT Food Sci Technol*. 2017;85:394–9. <https://doi.org/10.1016/j.lwt.2017.01.005>
23. Ekholm P, Reinivuo H, Mattila P, Pakkala H, Koponen J, Happonen A, et al. Changes in the mineral and trace element contents of cereals, fruits and vegetables in Finland. *J Food Compos Anal*. 2007;20(6):487–95. <https://doi.org/10.1016/j.jfca.2007.02.007>
24. Vijayarangan P, Uthayam MC. Changes in nutrients content of Radish (*Raphanus sativus*) under copper toxicity. *Int J Adv Res Biol Sci*. 2017;4(4):88–93. <https://doi.org/10.22192/ijarbs.2017.04.04.012>
25. Tiwari VK, Verma VC, Khushboo, Avantika, Kumar K, Tsewang T, et al. Edible coating for postharvest management of fruits and vegetables. *J Pharm Innov*. 2022;11(3):970–8.
26. Brishti FH, Misir, Sarker A. Effect of bio preservatives on storage life of papaya fruit (*Carica Papaya* L.). *Int J Food Stud*. 2013;2(1):126–36. <https://doi.org/10.7455/ijfs/2.1.2013.a10>
27. Ko SS, Chang WN, Wang JF, Cherng SJ, Shanmugasundaram S. Storage under high temperature and high relative humidity and its relationship with disease incidence and bulb characteristics. *J Am Soc Hortic Sci*. 2002;127(5):848–54. <https://doi.org/10.21273/JASHS.127.5.848>
28. Sengül M, Keles F. The effects of storage conditions on physical and chemical properties of potato. *Food*. 2005;30(2):103.
29. Suhag M, Nehra BK, Singh N, Khurana SC. Storage behaviour of potato under ambient condition affected by curing and crop duration. *Haryana J Hortic Sci*. 2007;35:357–60.
30. Singh V, Hedayetullah M, Zaman P, Meher J. Postharvest technology of fruits and vegetables: an overview. *Postharvest Biol Technol*. 2014;2(2):124–35.
31. Burton WG, Wilson AR. The sugar content and sprout growth of tubers of potato cultivar record, grown in different localities, when stored at 10, 2 and 20 °C. *Potato Research*. 1978;21:145–62. <https://doi.org/10.1007/BF02361616>
32. Sharma P, Shehin VP, Kaur N, Vyas P. Application of edible coatings on fresh and minimally processed vegetables: a review. *Int J Veg Sci*. 2019;25(3):295–314. <https://doi.org/10.1080/19315260.2018.1510863>
33. Sharmin MR, Islam MN, Alim MA. Shelf-life enhancement of papaya with aloe vera gel coating at ambient temperature. *J Bangladesh Agric Univ*. 2015;13(1):131–6. <https://doi.org/10.3329/jbau.v13i1.28729>
34. Nunan KJ, Sims IM, Bacic A, Robinson SP, Fincher GB. Changes in cell wall composition during ripening of grape berries. *Plant Physiol*. 1998;118(3):783–92. <https://doi.org/10.1104/pp.118.3.783>
35. Chauhan SK, Thakur KS, Dwivedi SK, Bhanot A. Storage behaviour of apple as affected by pre- and post-harvest treatments of neem based formulations, plant extracts and leaves. *J Food Sci Technol*. 2008;45(6):484–9.
36. Turker N, Aksay S, Ekiz Hİ. Effect of storage temperature on the stability of anthocyanins of a fermented black carrot (*Daucus carota* var. L.) beverage: shalgam. *J Agric Food Chem*. 2004;52(12):3807–13. <https://doi.org/10.1021/jf049863s>
37. Hassanpour H. Effect of Aloe vera gel coating on antioxidant capacity, antioxidant enzyme activities and decay in raspberry fruit. *LWT Food Sci Technol*. 2015;60(1):495–501. <https://doi.org/10.1016/j.lwt.2014.07.049>
38. Dwivedi SK, Joshi VK, Mishra V. Extraction of anthocyanins from plum pomace using XAD-16 and determination of their thermal stability. *J Sci Ind Res*. 2014;73:57–61.
39. Erkan M, Pekmezci M, Gübbük H, Karashin I. Effects of controlled atmosphere storage on scald development and postharvest physiology of Granny Smith apples. *Turk J Agric For*. 2004;28(1):43–8.

40. Girardi C, Corrent A, Luciano L, Marico Z, Tatiane C, Brackmann A, et al. Effect of ethylene, intermittent warming and controlled atmosphere on postharvest quality and the occurrence of woolliness in peach (*Prunus persica* cv. Chiripá) during cold storage. *Postharvest Biol Technol.* 2005;38(1):25–33. <https://doi.org/10.1016/j.postharvbio.2005.05.007>
41. Kaur C, Kapoor HC. Antioxidants in fruits and vegetables—the millennium's health. *Int J Food Sci Technol.* 2001;36(7):703–25. <https://doi.org/10.1111/j.1365-2621.2001.00513.x>
42. Ali A, Maqbool M, Alderson PG, Zahid N. Effect of gum arabic as an edible coating on antioxidant capacity of tomato (*Solanum lycopersicum* L.) fruit during storage. *Postharvest Biol Technol.* 2013;76:119–24. <https://doi.org/10.1016/j.postharvbio.2012.09.011>
43. Pushkala R, Raghuram PK, Srividya N. Chitosan based powder coating technique to enhance phytochemicals and shelf-life quality of radish shreds. *Postharvest Biol Technol.* 2013;86:402–8. <https://doi.org/10.1016/j.postharvbio.2013.07.025>
44. Zhang Z, Wheatley CC, Corke H. Biochemical changes during storage of sweet potato roots differing in dry matter content. *Postharvest Biol Technol.* 2002;24(3):317–25. [https://doi.org/10.1016/S0925-5214\(01\)00149-1](https://doi.org/10.1016/S0925-5214(01)00149-1)
45. Sharma K, Ko EY, Assefa AD, Nile SH, Park SW. A comparative study of anaerobic and aerobic decomposition of quercetin glucosides and sugars in onion at an ambient temperature. *Front Life Sci.* 2015;8(2):117–23. <https://doi.org/10.1080/21553769.2014.998298>
46. Kishor A, Narayan R, Brijwal M, Attri BL, Kumar A, Debnath S. Storage behaviour of apple cultivars under ambient conditions. *Indian J Hort.* 2018;75(2):319–25. <https://doi.org/10.5958/0974-0112.2018.00054.3>
47. Asgar A. Effect of storage temperature and type of packaging on physical and chemical quality of carrot. *IOP Conf Ser Earth Environ Sci.* 2020;443(1):012002. <https://doi.org/10.1088/1755-1315/443/1/012002>
48. Chung JC, Chou SS, Hwang DF. Changes in nitrate and nitrite content of four vegetables during storage at refrigerated and ambient temperatures. *Food Addit.* 2004;21(4):317–22. <https://doi.org/10.1080/02652030410001668763>
49. Phillips WEJ. Changes in the nitrate and nitrite contents of fresh and processed spinach during storage. *J Agric Food Chem.* 1968;16(1):88–91. <https://doi.org/10.1021/jf60155a012>
50. Bouzai A, Holstege D, Barrett DM. Mineral, fiber and total phenolic retention in eight fruits and vegetables: a comparison of refrigerated and frozen storage. *J Agric Food Chem.* 2015;63(3):951–6. <https://doi.org/10.1021/jf504890k>
51. Dresow JF, Krause T, Haase NU, Loges R, Heß J, Böhm H. Effect of different defoliation systems of Ryegrass-Clover on yield and selected quality parameters of organic potatoes (*Solanum tuberosum* L.) for industrial processing at harvest and after storage. *Eur Potato J.* 2013;56(3):179–204. <https://doi.org/10.1007/s11540-013-9239-8>
52. Jood S, Kapoor AC, Singh R. Mineral contents of cereal grains as affected by storage and insect infestation. *J Stored Prod Res.* 1992;28(3):147–51. [https://doi.org/10.1016/0022-474X\(92\)90033-M](https://doi.org/10.1016/0022-474X(92)90033-M)
53. Zhang WE, Wang CL, Shi BB, Pan XJ. Effect of storage temperature and time on the nutritional quality of walnut male inflorescences. *J Food Drug Anal.* 2017;25(2):374–84. <https://doi.org/10.1016/j.jfda.2016.05.010>

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