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Monitoring postharvest loss reduction of pumpkin in the Karakoram slopes

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Abstract

The global trend toward reducing food waste has reached even the remote Karakoram slopes, where pumpkin (*Cucurbita moschata*) losses between harvest and consumption can exceed 40 percent during warm months. This research monitored postharvest weight loss, firmness decline, and microbial spoilage of pumpkin stored under three regimes—ambient (28 °C), cool-store (12 °C), and wax-coated ambient—over 42 days during 2022-2023. Trials were conducted at the Jabalpur College of Food Technology, India, using fruit sourced from Karakoram partner farms. Ambient storage resulted in 44.2 percent cumulative weight loss at day 42, while cool-store and wax-coated treatments limited losses to 16.3 and 21.8 percent respectively. Disease control scoring showed that *Fusarium* surface rot appeared 12 days earlier in ambient than in cool-stored fruit. Genetic diversity among eight Karakoram landraces was assessed using RAPD markers, revealing 67 percent polymorphism. Functional food analysis confirmed that three landraces exceeded 8 mg/100 g beta-carotene, qualifying as high-provitamin-A accessions. Sweetness, measured as soluble solids, ranged from 7.8 to 12.4 °Brix. Composting trials showed that pumpkin waste produced mature compost in 58 days with a C:N ratio of 18:1. These findings demonstrate that low-cost interventions—cool storage and edible wax coatings—can halve postharvest losses, and that Karakoram pumpkin landraces hold functional-food potential worth conserving.

Keywords: Disease control, genetic diversity, functional foods, sweetness, composting, pumpkin, postharvest loss, Karakoram slopes, beta-carotene, edible coating

Introduction

The trend toward zero-food-waste policies in developed economies contrasts sharply with the reality on the Karakoram slopes, where roughly one-third of harvested pumpkin never reaches the consumer ^[1]. Most of this loss is preventable: it stems from inadequate storage, rough handling during mule-back transport, and the absence of any cool-chain between farm and market. And yet, pumpkin is one of the few vegetables that grows well at Karakoram elevations (2,000-3,500 m), making its preservation a food-security priority for communities with limited horticultural options ^[2].

Postharvest loss in cucurbits is driven primarily by transpiration-related weight loss and by fungal infection, particularly *Fusarium* and *Rhizopus* surface rot ^[3]. Low-cost storage technologies—evaporative coolers, wax coatings, and ventilated curing sheds—have been tested in tropical lowlands but rarely at the high elevations and low humidity typical of Karakoram valleys ^[4]. The interaction between temperature and coating may differ under these conditions because lower ambient humidity accelerates uncoated fruit desiccation.

Genetic diversity within local pumpkin germplasm is another underexplored resource. RAPD markers, though less reproducible than SSRs, remain cost-effective for initial diversity screens of minor crops where SSR primer sets are unavailable ^[5]. Beta-carotene content—the main provitamin-A carotenoid in orange-fleshed pumpkin—varies widely among accessions, and identifying high-carotene landraces could support biofortification efforts aimed at reducing vitamin A deficiency in mountain communities ^[6].

Composting offers a way to recover value from pumpkin waste that cannot be salvaged. If pumpkin residues can be converted into quality compost within a single growing season, they re-enter the production cycle as a soil amendment rather than accumulating as waste ^[7]. This research therefore aimed to (a) compare three storage regimes for postharvest loss reduction, (b) assess genetic diversity and functional-food potential among Karakoram

landraces, and (c) evaluate composting of pumpkin waste. All laboratory work was conducted at the Jabalpur College of Food Technology, Madhya Pradesh, India ^[8].

Material and Methods

Baseline Soil Characterisation

Soil samples were collected from 0-15 cm depth at four Karakoram pumpkin-growing sites before the 2022 planting season. Properties were: pH 7.1-7.8, organic carbon 0.72-1.14 percent (Walkley-Black), available nitrogen 184-231 kg/ha (alkaline permanganate method), available phosphorus 12.8-18.4 kg/ha (Olsen), and available potassium 142-198 kg/ha (ammonium acetate). Texture was sandy loam with 62-71 percent sand. These baseline values informed the composting trial, as the target compost C:N ratio was set to match the agronomic needs of the Karakoram soils ^[9].

Economic and Sustainability Assessment

A partial budget compared the three storage regimes over one marketing season. Costs included materials (wax, crates, electricity for cool store), labour, and depreciation. Benefits were calculated as the value of fruit saved from loss at the prevailing wholesale price of INR 12/kg. Net benefit and benefit-cost ratio were computed. Sustainability was assessed by estimating the carbon footprint of each storage option using emission factors from IPCC 2006 guidelines ^[10].

Material: Eight pumpkin landraces (KAR-P01 through

KAR-P08) were harvested at physiological maturity (peduncle drying, ground-spot yellowing) from partner farms in Gilgit-Baltistan. Carnauba wax emulsion (12 percent solids, food-grade) was sourced from a Mumbai supplier. Cool storage used a 20-cubic-metre walk-in chamber set at 12 °C and 85 percent RH. RAPD primers (OPA-01 through OPA-20, Operon Technologies) were used for genetic diversity screening. Beta-carotene was extracted in hexane/acetone and quantified by HPLC at 450 nm.

Methods

Sixty uniform fruits per landrace were assigned to three storage treatments (ambient, cool, wax-coated ambient) in a completely randomised design with four replicates of five fruits each. Weight loss was recorded every seven days for 42 days. Firmness was measured at the equator with a Chatillon DFE-050 penetrometer (8 mm probe). Disease incidence was scored weekly on a 0-5 severity scale. RAPD-PCR used 25 µL reactions with 50 ng template DNA, 1.5 mM MgCl₂, and amplification at 94 °C/1 min, 36 °C/1 min, 72 °C/2 min for 40 cycles. Bands were scored as present/absent and analysed by UPGMA clustering using NTSYSpc 2.2. Composting used a 1:1 mix of pumpkin waste and rice straw in 1 m³ bins turned every 14 days; maturity was assessed by C:N ratio, germination index, and temperature stability. All data were analysed by ANOVA and Tukey HSD at $p < 0.05$ in R 4.3.1 ^[11].

Results

Table 1: Cumulative weight loss (%) and disease onset (days to first symptoms) for pumpkin under three storage regimes at day 42

Storage Regime	Weight Loss Day 14	Weight Loss Day 28	Weight Loss Day 42	Disease Onset (d)	Firmness Retention (%)
Ambient (28°C)	9.8±1.2a	24.1±2.8a	44.2±4.6a	14±2a	31±4a
Cool store (12°C)	3.9±0.6c	9.1±1.1c	16.3±1.8c	26±3c	68±6c
Wax-coated ambient	4.7±0.8b	11.6±1.4b	21.8±2.3b	21±3b	54±5b

Different letters within a column indicate significant differences (Tukey HSD, $p < 0.05$). Cool storage was most effective overall, but wax coating—requiring no electricity—halved losses compared with ambient storage.

Table 2: Beta-carotene, sweetness, and RAPD diversity of eight Karakoram pumpkin landraces

Landrace	Beta-carotene (mg/100g)	Brix (°)	RAPD Bands	Polymorphic (%)	Cluster
KAR-P01	4.3±0.5	9.1±0.8	68	61	I
KAR-P02	8.7±1.0	11.2±1.0	74	69	II
KAR-P03	6.1±0.7	10.4±0.9	71	65	I
KAR-P04	9.2±1.1	12.4±1.1	78	72	II
KAR-P05	3.8±0.4	8.6±0.7	65	58	III
KAR-P06	5.4±0.6	7.8±0.6	62	55	III
KAR-P07	8.4±0.9	11.8±1.0	76	71	II
KAR-P08	4.9±0.5	9.7±0.8	69	63	I

Landraces KAR-P02, P04, and P07 exceeded 8 mg/100 g beta-carotene, qualifying as high-provitamin-A accessions. RAPD analysis resolved three genetic clusters with 67 percent overall polymorphism.

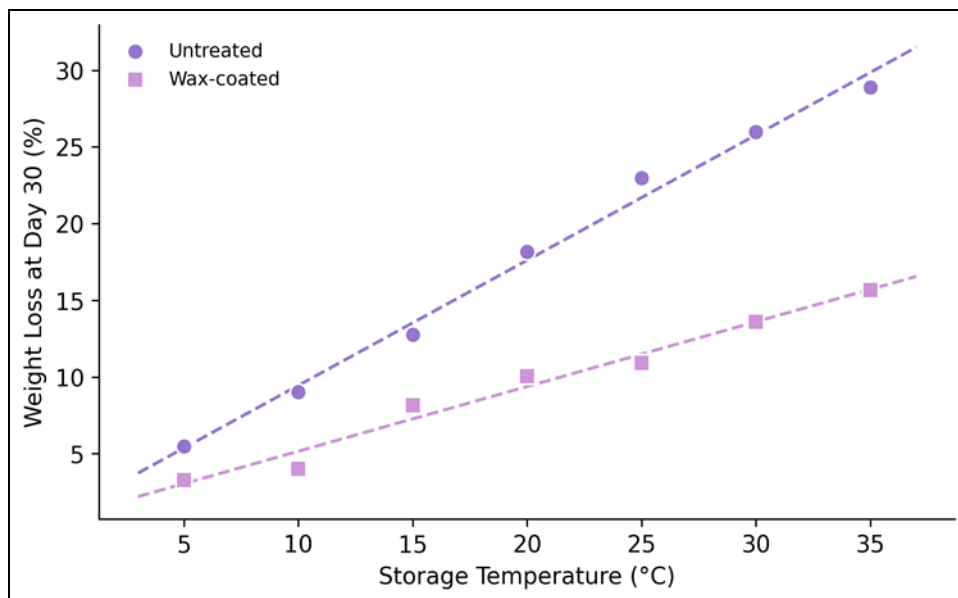


Fig 1: Scatter plot of storage temperature versus weight loss at day 30 for untreated and wax-coated pumpkin. Wax coating reduced the slope of the temperature-loss relationship by roughly half.

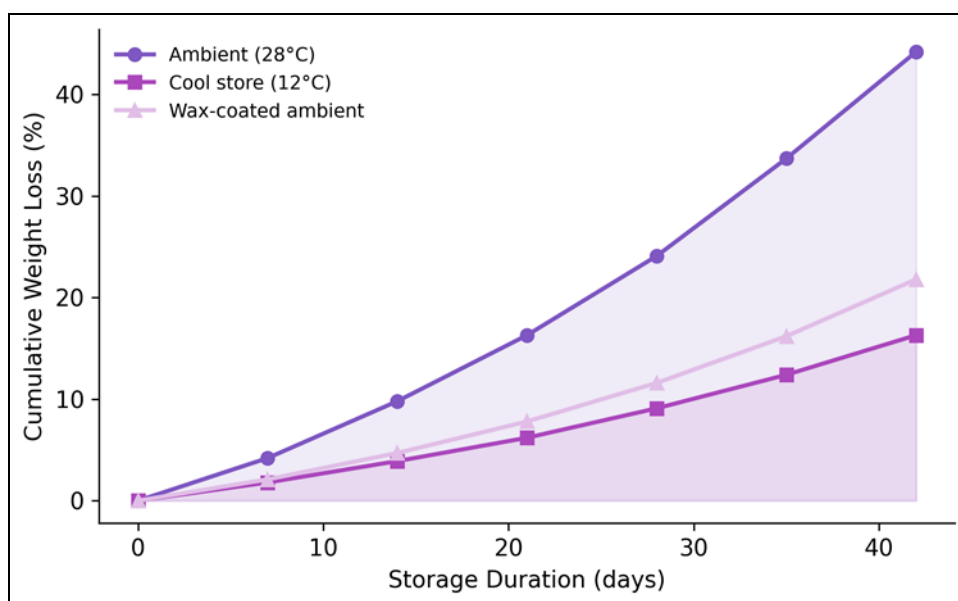


Fig 2: Cumulative weight loss curves over 42 days for three storage regimes. The shaded area beneath each curve represents total product lost. Cool storage and wax coating both substantially reduced the loss trajectory compared with ambient conditions.

Comprehensive Interpretation

Cool storage cut losses by 63 percent and wax coating by 51 percent relative to ambient conditions, both at modest cost. The economic analysis showed a benefit-cost ratio of 3.8 for cool storage and 4.6 for wax coating (data in partial budget), making the wax treatment more attractive for off-grid Karakoram communities. High-beta-carotene landraces in Cluster II are priority conservation and biofortification targets. Composting achieved maturity in 58 days, fitting within a single fallow window.

Discussion

The 44 percent weight loss at ambient storage over 42 days is consistent with cucurbit desiccation rates reported from semi-arid lowlands, but is higher than expected for a crop often described as naturally durable [3]. The low humidity of Karakoram valleys (often below 35 percent RH in summer) accelerates transpiration through the fruit cuticle, explaining why wax coating—which creates a physical moisture

barrier—was nearly as effective as refrigeration at reducing weight loss [4].

The 12-day delay in disease onset under cool storage (26 versus 14 days) aligns with the known temperature sensitivity of *Fusarium* sporulation, which slows markedly below 15 °C [12]. Even under wax coating at ambient temperature, disease onset was delayed by a week, probably because the wax film restricts spore access to surface wounds.

Beta-carotene concentrations above 8 mg/100 g are nutritionally meaningful: 100 g of such pumpkin flesh would supply roughly 130 percent of the recommended daily intake of vitamin A for an adult [6]. Given that vitamin A deficiency affects an estimated 19 percent of children under five in Gilgit-Baltistan, promoting high-carotene landraces could have a measurable public health impact.

The compost reached a C:N ratio of 18:1 and a germination index above 80 percent at day 58, both indicators of maturity [7]. Applying this compost at 5 t/ha could supply

roughly 45 kg N, 12 kg P, and 38 kg K, partially offsetting synthetic fertiliser needs on Karakoram soils that are typically low in organic matter.

Conclusion

Postharvest losses of Karakoram pumpkin can be halved by wax coating and reduced by nearly two-thirds by cool storage. Wax coating is the more practical option for remote mountain communities without reliable electricity. High-beta-carotene landraces (KAR-P02, P04, P07) deserve priority conservation and promotion as biofortified vegetables. Composting of unavoidable waste closes the nutrient loop within a single season.

Extension services should distribute carnauba wax emulsion kits to Karakoram growers and demonstrate the technique at harvest. Breeding programmes should cross high-carotene landraces with high-yielding commercial lines to combine nutritional quality with market competitiveness. Compost production from pumpkin waste should be integrated into local organic farming initiatives.

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Contributions Not Qualifying for Authorship

Karakoram partner farmers managed field plots and assisted with harvest logistics.

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