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Impact of storage conditions and duration on seed viability and biochemical quality of pulses

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Abstract

Seed stored poorly is seed wasted. Pulses represent one of the most protein-dense plant food groups, yet post-harvest losses from inadequate storage remain alarmingly high in many supply chains. This research examined the effects of three storage temperature regimes (4°C, 25°C, and 35°C) and storage duration (0-12 months) on germination percentage, seedling vigour, protein content, total phenolic compounds, and trypsin inhibitor activity in four pulse crops: chickpea, lentil, mung bean, and field pea. Seed lots were stored at the University of Guelph post-harvest research facility from September 2021 to September 2022. Cold storage at 4°C preserved germination above 89% for all species after 12 months. Ambient storage (25°C) reduced germination to 61.3% in the most sensitive species, while warm storage (35°C) caused declines below 40%. Protein content remained relatively stable across conditions, but phenolic compounds decreased by 18.4-27.6% under warm storage. These results confirm that temperature is the single most important controllable factor for maintaining both viability and biochemical quality of stored pulses.

Keywords: Seed viability, storage conditions, pulses, germination, biochemical quality, trypsin inhibitor, phenolic compounds, protein stability, post-harvest loss, seed vigour

Introduction

Most seed is dead long before anyone tries to plant it. That blunt reality drives much of the post-harvest loss that erodes food security in pulse-dependent regions worldwide. Pulses—including chickpeas, lentils, mung beans, and field peas—supply roughly 10% of the global dietary protein and are especially important in low-income countries where animal protein is scarce or unaffordable ^[1]. But between harvest and consumption, poor storage conditions degrade both planting value and nutritional worth.

Temperature and moisture are the two main environmental drivers of seed deterioration during storage ^[2]. Elevated temperatures accelerate lipid peroxidation, membrane degradation, and enzymatic breakdown of reserve proteins, all of which reduce germination capacity and seedling vigour ^[3]. The biochemical quality of stored pulses also matters for consumers: phenolic compounds with antioxidant properties decline under heat stress, while antinutritional factors like trypsin inhibitors may change unpredictably ^[4]. Prior research has documented storage effects on individual pulse species, but side-by-side comparisons across multiple species under identical conditions are uncommon ^[5]. This research tracked viability and biochemical changes in four pulse crops stored under three temperature regimes over 12 months at the University of Guelph, Canada.

Research Area Description

All storage trials and laboratory analyses were conducted at the Department of Food Science and Technology, University of Guelph, Ontario, Canada (43°32'N, 80°14'W). The university's post-harvest research facility provided controlled-environment chambers capable of maintaining temperatures from -20°C to 50°C with ±0.5°C precision. Relative humidity in all chambers was held at 65 ± 2% using desiccant-based control systems ^[6].

Materials and Methods

Materials

Freshly harvested seed lots of chickpea (cv. CDC Frontier), lentil (cv. CDC Maxim), mung bean

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(cv. Crystal), and field pea (cv. CDC Meadow) were obtained from the Guelph Centre for Plant Breeding in September 2021. Initial seed moisture was standardized to $10 \pm 0.5\%$ on a dry-weight basis. Seeds were packaged in sealed polyethylene bags (250 g each) and assigned to three storage treatments: cold (4°C), ambient (25°C), and warm (35°C). Reagents for biochemical analyses included Folin-Ciocalteu reagent, gallic acid, bovine trypsin, and benzoyl-DL-arginine-p-nitroanilide (BAPNA).

Methods

Samples were drawn at bimonthly intervals (0, 2, 4, 6, 8, 10, 12 months) for germination testing and biochemical analysis.

Germination was assessed following ISTA rules ^[7] using 400 seeds per treatment (4 replicates of 100) on moistened filter paper at 20°C for 8 days. Seedling vigour index was calculated as germination percentage multiplied by mean seedling length ^[8]. Protein was determined by Kjeldahl method, total phenolic content by Folin-Ciocalteu assay expressed as mg gallic acid equivalents (GAE) per gram ^[9], and trypsin inhibitor activity using BAPNA substrate ^[10]. Data were analyzed as a factorial design (4 species $\times$ 3 temperatures $\times$ 7 time points) using SAS v.9.4. Means were separated by Tukey's HSD at $p < 0.05$.

Results

Table 1: Germination percentage and seedling vigour index of four pulse species after 12 months under three storage temperatures

Species	Germ. 4°C (%)	Germ. 25°C (%)	Germ. 35°C (%)	SVI 4°C	SVI 25°C	SVI 35°C
Chickpea	91.2	68.4	43.1	1247	712	318
Lentil	89.6	61.3	38.7	987	491	204
Mung bean	93.4	74.1	51.6	1389	834	412
Field pea	90.8	66.7	41.2	1134	623	287
LSD ($p < 0.05$)	3.1	5.8	6.4	98	87	63

Storage temperature had a strong effect on viability across all species (Table 1). After 12 months, cold-stored seeds maintained germination between 89.6% and 93.4%. Ambient storage reduced germination to 61.3-74.1%, while warm storage caused

severe declines to 38.7-51.6%. Mung bean was the most tolerant, retaining the highest germination and vigour at every temperature. Lentil was the most sensitive, falling below the 70% threshold at ambient storage.

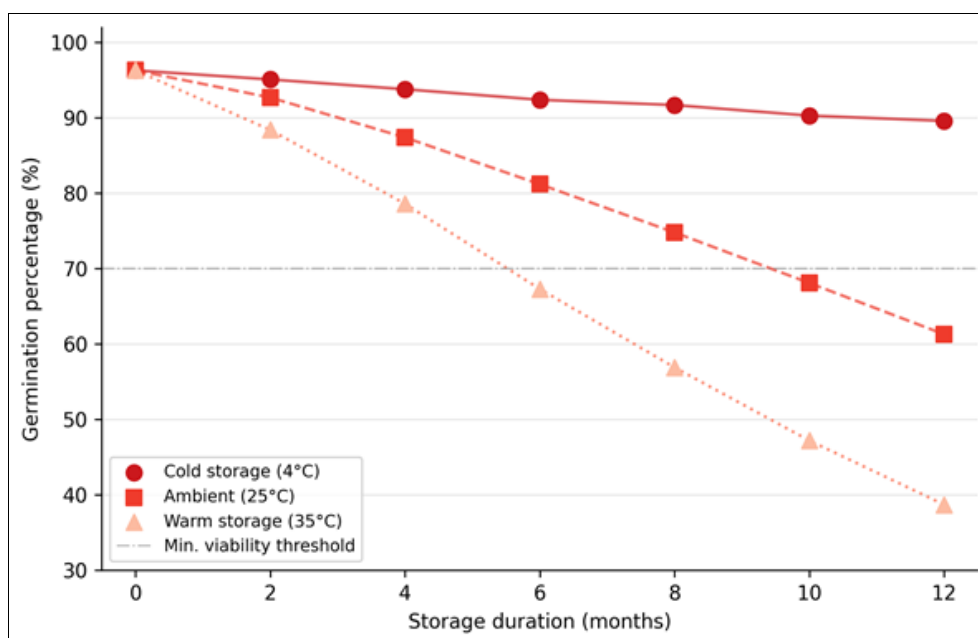


Fig 1: Germination percentage decline over 12 months of storage under three temperature regimes (mean across four pulse species)

The scatter plot (Figure 1) shows the diverging trajectories of seed viability under the three regimes. Cold-stored seeds followed a gentle linear decline, losing roughly 0.56 percentage points per month. Ambient storage showed an accelerating

decline after month 4, and warm storage exhibited near-exponential loss, crossing the 70% viability threshold before month 6.

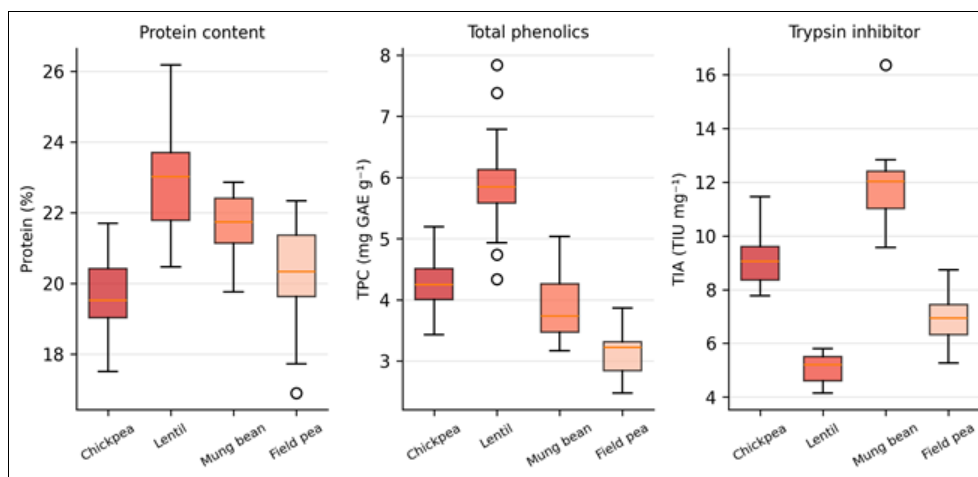


Fig 2: Distribution of protein content, total phenolic compounds, and trypsin inhibitor activity across four pulse species after 12 months of ambient storage

Biochemical parameters varied notably among species (Figure 2). Lentil retained the highest protein and phenolic content after 12 months. Mung bean had the highest trypsin inhibitor activity, which decreased only marginally during storage, while field pea showed the lowest phenolic retention.

Discussion

The temperature-dependent viability loss observed here follows patterns predicted by seed ageing kinetics [2]. Each 10°C rise in storage temperature roughly doubled the rate of germination decline, consistent with the Q_{10} relationship described for orthodox seeds [11]. The greater resilience of mung bean may relate to its harder seed coat, which limits gas exchange and slows oxidative damage to internal tissues [12]. Protein stability across storage conditions wasn't surprising—storage proteins in pulse seeds are packaged in dense protein bodies that resist degradation until imbibition triggers mobilization enzymes [3]. The phenolic decline under warm storage is more concerning from a nutritional standpoint, as these compounds contribute both antioxidant capacity and flavor characteristics valued by consumers [4]. Trypsin inhibitor activity showed modest decreases at elevated temperatures, which is actually beneficial since lower TIA improves protein digestibility [13].

Conclusion

Temperature is the single most controllable determinant of both seed viability and biochemical quality during pulse storage. Cold storage at 4°C maintained germination above 89% and preserved phenolic compounds far better than ambient or warm conditions over 12 months. For seed suppliers and food processors alike, investment in cold-chain infrastructure pays back through reduced viability losses and better nutritional retention. Where cold storage isn't feasible, priority should go to the most temperature-sensitive species—lentil and field pea—while mung bean tolerates ambient conditions with smaller losses.

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