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Enhancing postharvest shelf life of potato (*Solanum tuberosum* L.) using ethyl isothiocyanate

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Abstract
Potato (*Solanum tuberosum* L.) is a globally important food crop, but its postharvest storage is often challenged by sprouting, weight loss, and spoilage, leading to substantial economic losses. The present study evaluated the effect of ethyl isothiocyanate on extending the shelf life of potato tubers during storage. Five treatments (T_1-T_5) were assessed for their impact on physiological weight loss, sprouting behavior, spoilage percentage, and shrinkage intensity over a 30-day storage period. The results indicated that potatoes treated with ethyl isothiocyanate (T_1 and T_2) showed significantly lower weight loss compared to untreated controls, with final values of 6.95% and 7.34% respectively, against 16.37% in T_4. Sprouting was effectively inhibited in treated tubers, with T_1 showing complete suppression throughout the 30-day period, while T_5 recorded a maximum of three sprouts per tuber. Spoilage percentage was also lowest in treated tubers, with T_1 (29.60%) and T_2 (40.60%) showing significantly reduced decay compared to untreated controls (up to 91.00% in T_4). Shrinkage intensity followed a similar pattern, with treated tubers maintaining better firmness and marketable quality. Overall, ethyl isothiocyanate treatment was found to be effective in minimizing postharvest losses by reducing sprouting, delaying spoilage, and maintaining tuber quality. These findings suggest that ethyl isothiocyanate can be a promising alternative to conventional sprout suppressants for extending the storage life of potatoes, thereby ensuring higher marketability and reducing food waste.

Keywords: *Solanum tuberosum* L., ethyl isothiocyanate, shelf-life extension, postharvest management, chemical treatments

Introduction

The potato (*Solanum tuberosum*) holds a prominent position among global food crops, ranking immediately behind staples like rice, wheat, and maize in terms of total production. It surpasses all other tuber crops-including cassava, sweet potatoes, and yams-for global importance. Known for its remarkable productivity, potatoes yield more calories per hectare and mature more rapidly than most cereals. They are also comparatively water-efficient, making them especially valuable in areas with limited irrigation (Reddy *et al*., 2018) [7]. Native to the Andean region of South America, potatoes were domesticated thousands of years ago. Following the Spanish conquest, they were introduced to Europe in the 16th century before eventually spreading worldwide-including to India via Portuguese sailors, with cultivation expanding further under British influence. Today, India is among the leading potato producers, with major output from states such as Uttar Pradesh, West Bengal, Bihar, Punjab, and Gujarat (Singh *et al*., 2019) [8].

The quality of agricultural products is defined by a range of attributes that influence both their overall condition and commercial acceptability. These include nutritional composition, physical properties, and mechanical characteristics, among others. For potatoes, large-scale storage is vital to ensure continuous availability for household use as well as for processing industries. Nevertheless, storage losses are inevitable and generally result from water depletion, disease infection, and sprouting. These losses are categorized into natural weight reduction, decay due to pathogens, and biomass allocated to sprouts (Visse-Mansiaux *et al*., 2022) [10]. Among these factors, sprouting represents one of the most serious postharvest issues because it reduces both the quality and marketable volume of tubers, leading to financial setbacks along the supply chain (Gumbo *et al*., 2021) [3]. The emergence of sprouts alters the physical structure of potatoes by decreasing turgidity, increasing shrinkage, and accelerating weight loss (Gumbo *et al*., 2021) [3].

In addition, sprouting adversely affects texture, reduces nutritional and processing quality, and induces the accumulation of toxic alkaloids, collectively causing substantial economic losses (Alexandre *et al*., 2015) [1].

Different approaches are employed to prolong potato shelf life. Traditional methods rely on low-temperature storage combined with the use of chemical sprout inhibitors, such as maleic hydrazide, α-naphthalene acetic acid, isopropyl N-(3-chlorophenyl) carbonate, and tetrachloronitrobenzene (Murigi *et al*., 2021) [4]. However, concerns have been raised about the safety of such chemicals. For example, regulatory agencies have progressively reduced the permissible residue limits for chlorpropham (CIPC), reflecting growing awareness of its potential health risks, particularly its metabolites (Paul *et al*., 2016) [5]. Cold storage at 2-4 °C can effectively slow sprout development, but it often leads to undesirable sweetening of tissues, limiting its practical use. The high cost of refrigeration and the possibility of chilling or freezing injury further restrict its application (Chourasia & Goswami, 2001) [2]. Alternative treatments, such as γ-irradiation, have been tested and shown to cause structural changes in starch granules and cell walls, which contribute to tuber softening (Wu *et al*., 2023) [11]. Although CIPC has been used as a sprout suppressant for more than four decades due to its ability to disrupt cell division, the extensive and indiscriminate use of synthetic chemicals in agriculture has created environmental concerns. Consequently, several countries have banned or restricted the use of certain sprout inhibitors, prompting the search for safer and more sustainable alternatives (Thoma *et al*., 2022) [9].

This investigation aimed to assess the influence of ethyl isothiocyanate on extending the storage life and suppressing sprouting in potato (*Solanum tuberosum* L.).

Materials and Methods

Plant Material

Uniform-sized and healthy potatoes were procured from the local market for the experiment. The work was carried out in the Microbiology Laboratory, ASPEE Shakilam Biotechnology Institute, during February-March 2022.

Treatments and Experimental Design

The experiment was laid out in a Completely Randomized Design (CRD) with five treatments and five replications. The treatments consisted of different concentrations of ethyl isothiocyanate:

- T_1: 80 µl
- T_2: 90 µl
- T_3: 100 µl
- T_4: 110 µl
- T_5: Control (no chemical treatment)

A total of 75 uniform potatoes were selected, with 15 potatoes assigned to each treatment. For application, airtight plastic jars were used, each containing 15 potatoes. A Whatman filter paper strip was affixed to the inner side of the jar lid, and the designated concentration of ethyl isothiocyanate was applied (except in control). The jars were sealed immediately for 3 hours to allow treatment exposure. Afterward, the lids were removed, and the treated potatoes were placed on blotting paper under ambient conditions for subsequent observations.

Observations

Observations were recorded at 5-day intervals up to 30 days for the following parameters:

- **Sprouting:** Expressed as the average number of sprouts per tuber in each treatment.
- **Weight loss:** Potatoes were weighed at the start and at subsequent intervals. Weight loss (%) was calculated relative to the initial weight.
- **Shrinkage intensity:** Evaluated visually and scored as (+) = no shrinkage, (++) = low, (+++) = high, (++++) = very high.
- **Spoilage percentage:** Determined based on changes in color, aroma, and overall acceptability of tubers.

Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) under the CRD. Treatment means were compared using the critical difference (CD) test at 5% significance ($p \leq 0.05$).

Results

The effect of ethyl isothiocyanate treatment on potato weight loss during storage is presented in Table 1.

Table 1: Effect of chemical ethyl isothiocyanate on weight loss (%) of potato during storage

Treatment	5 Day	10 Day	15 Day	20 Day	25 Day	30 Day
T_1	2.13	2.80	3.98	4.64	5.65	6.95
T_2	2.50	3.13	4.54	5.64	6.22	7.34
T_3	3.05	5.58	7.35	8.55	9.12	10.44
T_4	3.41	6.19	8.85	11.54	13.98	16.37
T_5	3.44	6.21	8.90	10.99	13.29	16.19
SEm±	0.02	0.01	0.01	0.04	0.04	0.06
CD ($p \leq 0.05$)	0.05	0.02	0.04	0.13	0.12	0.17
CV%	1.32	0.34	0.49	1.17	0.96	1.12

A progressive increase in weight loss was observed in all treatments with the advancement of storage duration from 5 to 30 days. Among the treatments, T_1 consistently recorded the lowest weight loss throughout the storage period (2.13% at 5 days and 6.95% at 30 days), followed by T_2. In contrast, T_4 and T_5 exhibited the highest weight loss, reaching 16.37% and 16.19% respectively at 30 days. T_3 showed intermediate values, with 10.44% weight loss at the end of the storage period.

The differences among treatments were found to be statistically significant ($p \leq 0.05$). The low standard error of mean (SEm) and coefficient of variation (CV%) values further indicate the reliability and precision of the experimental data.

The influence of ethyl isothiocyanate on sprouting of potatoes during storage is shown in Table 2.

Table 2: Effect of chemical ethyle isothiocynate on sprouting of potato during storage

Treatment	5 Day	10 Day	15 Day	20 Day	25 Day	30 Day
T_1	0	0	0	0	0	0
T_2	0	0	0	0	0	1
T_3	0	0	0	1	1	2
T_4	0	0	0	1	1	2
T_5	0	0	1	1	3	3

No sprouting was recorded in any treatment up to 10 days of storage. Thereafter, variation among treatments became apparent. T_1 exhibited complete suppression of sprouting throughout the 30-day storage period, while T_2 showed only 1% sprouting at the end of storage. In contrast, higher sprouting percentages were observed in T_3, T_4, and T_5, with T_5 recording the highest incidence (3%) by 30 days.

The data clearly indicate a strong inhibitory effect of ethyl isothiocyanate on potato sprouting, particularly at lower treatment levels (T_1 and T_2), whereas higher concentrations (T_3-T_5) were comparatively less effective.

The effect of ethyl isothiocyanate on spoilage percentage of potatoes during storage is presented in Table 3.

Table 3: Effect of chemical ethyle isothiocynate on spoilage percent (%) of potato during storage

Treatment	20 Day	25 Day	30 Day
T_1	20.00	25.60	29.60
T_2	30.00	39.80	40.60
T_3	45.20	50.00	63.80
T_4	60.20	80.20	91.00
T_5	48.00	60.80	80.20
SEm±	0.44	0.44	0.45
CD ($p \leq 0.05$)	1.30	1.30	1.32
CV%	2.43	1.93	1.64

A progressive increase in spoilage was observed across all treatments as storage time advanced from 20 to 30 days. T_1 consistently recorded the lowest spoilage, with 20.00% at 20 days, 25.60% at 25 days, and 29.60% at 30 days. T_2 followed, with spoilage reaching 40.60% by 30 days. In contrast, the highest spoilage was observed in T_4 (91.00%), followed by T_5 (80.20%) at the end of the storage period. T_3 showed intermediate levels, with 63.80% spoilage by day 30.

The differences among treatments were statistically significant ($p \leq 0.05$). The relatively low values of SEm and CV% indicate that the data were consistent and reliable.

The qualitative assessment of potato weight loss under ethyl isothiocyanate treatment is presented in Table 4.

Table 4: Effect of chemical ethyle isothiocynate on weight loss (%) of potato during storage

Treatment	5 Day	10 Day	15 Day	20 Day	25 Day	30 Day
T_1	+	+	+	+	+	+
T_2	+	+	+	+	+	++
T_3	+	+	++	++	+++	+++
T_4	+	++	++	+++	++++	++++
T_5	+	+	+	++	+++	+++

The symbols "+" to "++++" indicate increasing levels of weight loss.

- T_1 consistently showed the lowest qualitative weight loss ("+") throughout the 30-day storage period.
- T_2 exhibited a slight increase by day 30 ("++"), suggesting moderate weight loss.
- T_3 and T_5 showed progressive increases, reaching "+++" by 25-30 days.
- T_4 demonstrated the highest qualitative weight loss, progressing from "+" at day 5 to "++++" by day 25-30, indicating severe weight reduction.

This qualitative scoring aligns closely with the quantitative weight loss data (Table 1), validating the trend that lower concentrations of ethyl isothiocyanate (T_1, T_2) are more effective in minimizing storage weight loss.

Discussion

Postharvest losses of fresh produce represent a major challenge to global food security, driving the search for safe, sustainable, and effective preservation strategies. Synthetic chemical preservatives, while effective, raise concerns regarding environmental impact, food safety, and consumer acceptance. As a result, natural bioactive compounds such as essential oils have emerged as promising alternatives. Among these, isothiocyanates, volatile compounds derived from the enzymatic hydrolysis of glucosinolates in Brassicaceae plants, have gained considerable attention. ITCs are of interest due to their natural origin, biodegradability, and broad-spectrum antimicrobial properties (Zhu *et al*., 2023) [12].

Weight loss in potato tubers during storage is primarily attributed to physiological processes such as respiration, transpiration, and sprouting. The present results demonstrate that treatment with ethyl isothiocyanate, particularly at the lower concentrations (T_1 and T_2), was effective in minimizing weight loss compared to untreated or higher-dose treatments (T_4 and T_5). These findings suggest that controlled use of ethyl isothiocyanate can help maintain tuber freshness and reduce postharvest losses. The reduced weight loss in T_1 and T_2 could be due to the compound's ability to suppress sprouting and retard metabolic activity, thereby lowering respiration and water loss. Similar observations have been reported by Gumbo *et al*. (2021) [3], who noted that sprout inhibition is directly linked with reduced shrinkage and weight reduction in stored potatoes. On the other hand, higher doses (T_4 and T_5) were associated with greater weight loss. This may be due to possible phytotoxic effects at elevated concentrations, which could disrupt normal tuber physiology and accelerate deterioration. Rastogi *et al*. (2004) [6] also observed that exposure to certain treatments can alter tuber cell structure, resulting in increased softening and weight reduction.

Sprouting is one of the major physiological processes responsible for quality loss and reduced marketability of stored potatoes. In this study, ethyl isothiocyanate was found to be highly effective in suppressing sprout emergence, particularly in treatments T_1 and T_2. The complete inhibition of sprouting in T_1 up to 30 days suggests that the compound can successfully interfere with meristematic activity and delay bud outgrowth. These results align with the findings of Alexandre *et al*. (2015) [1], who reported that sprout suppression helps maintain tuber texture, reduces shrinkage, and prevents the buildup of toxic glycoalkaloids such as solanine. Gumbo *et al*. (2021) [3] also emphasized the strong relationship between sprout growth and increased postharvest losses, including weight reduction and deterioration in quality. Interestingly, the higher doses (T_3, T_4, and T_5) did not enhance sprout inhibition beyond what was observed in lower doses; instead, they allowed moderate sprouting by the end of storage. This could be due to possible concentration-dependent physiological stress that limited the compound's efficiency or induced adaptive metabolic changes in tubers. A similar trend has been noted in studies where excessive application of sprout inhibitors led to inconsistent results or phytotoxic effects (Rastogi *et al*., 2004) [6].

Spoilage of potato tubers during storage is influenced by microbial infections, sprouting, and associated physiological deterioration. In this study, treatments with ethyl isothiocyanate at lower concentrations (T_1 and T_2)

significantly reduced spoilage compared to higher concentrations (T_3, T_4, and T_5). The lowest spoilage percentage in T_1 suggests that the compound effectively inhibited microbial activity and sprouting, both of which are key contributors to postharvest deterioration. The increase in spoilage with higher doses (T_4 and T_5) may be attributed to phytotoxic stress or compromised tuber physiology, which could make the potatoes more susceptible to microbial invasion. This agrees with findings by Rastogi *et al*. (2004) [6], who reported that certain treatments at elevated concentrations can disrupt cell wall integrity and promote softening, thereby accelerating spoilage. The lower spoilage levels in T_1 and T_2 are also consistent with their reduced weight loss and sprouting percentages (Tables 1 and 2), indicating that suppression of physiological and microbial activity collectively enhances storage quality. Similar results have been documented by Alexandre *et al*. (2015) [1], who highlighted the importance of sprout suppression in reducing microbial spoilage and maintaining marketable quality.

The qualitative scoring confirms the trends observed in quantitative measurements: lower concentrations of ethyl isothiocyanate effectively restricted weight loss, while higher concentrations allowed progressive deterioration. The minimal weight loss in T_1 suggests that the treatment efficiently maintained tuber turgidity and prevented excessive moisture loss. In contrast, T_4 and T_5, which showed higher qualitative weight loss, may have experienced partial stress-induced deterioration due to elevated chemical concentration, consistent with prior findings that over-application of sprout inhibitors can accelerate physiological damage (Rastogi *et al*., 2004; Gumbo *et al*., 2021) [6, 3].

The results indicate that ethyl isothiocyanate at lower concentrations (T_1 and T_2) is promising as a sprouting suppressant and can extend storage life by minimizing weight loss and spoilage. However, higher doses may be detrimental, highlighting the importance of optimizing treatment levels for practical application. The qualitative evaluation reinforces the conclusion that optimized ethyl isothiocyanate application (T_1, T_2) is suitable for maintaining postharvest potato quality, whereas excessive levels may reduce storage stability.

Conclusion

The present study demonstrated that ethyl isothiocyanate effectively influences the postharvest behaviour of potato (*Solanum tuberosum* L.). Its application was found to extend storage life by reducing physiological deterioration and suppressing premature sprouting, thereby maintaining tuber quality for a longer duration. These findings highlight the potential of ethyl isothiocyanate as a promising, eco-friendly alternative to conventional sprout suppressants. Further research on dosage optimization, residual effects, and large-scale applicability is recommended to ensure safe and sustainable integration into potato storage systems.

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