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Effectiveness of Neem Leaf Extract And Packaging Types On The Quality of Cilembu Variety Sweet Potato

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ABSTRACT

Proper postharvest handling is a critical factor in maintaining the quality of sweet potatoes (Ipomoea batatas L). This research evaluated the effectiveness of neem leaf (Azadirachta indica A. Juss) extract concentration and packaging type in inhibiting sprouting, reducing infestation by the sweet potato weevil (Cylas formicarius), and maintaining weight loss, starch content, and total dissolved solids in Cilembu variety sweet potatoes during storage. This experiment used a Completely Randomized Design with three replications, consisting of neem extract concentrations (0, 10, 20 ml/L) and packaging types (jute sacks, polinet nets, bamboo baskets). Neem leaves contain azadirachtin compounds which can preserve the physiological quality of sweet potatoes from pest attacks. The higher the concentration, the higher the level of effectiveness in maintaining and preserving the physiological quality of sweet potatoes during storage therefore, this study tested neem leaf extract concentrations of (0, 10, 20 ml/L). Results showed that the combination of 10 ml/L and 20 ml/L neem leaf extract with poly-net packaging yielded the best overall quality. This treatment significantly reduced sweet potato weevil infestation by up to 99.4% and suppressed weight loss by up to 33.8%, while maintaining more stable starch content and total soluble solids. The 10 ml/L and 20 ml/L neem leaf extract demonstrated optimal insecticidal properties, while the poly-net packaging provided the best ventilation for releasing respiratory heat and controlling moisture accumulation compared to jute sacks and bamboo baskets. In conclusion, the combination of 10 ml/L and 20 ml/L neem leaf extract with poly-net packaging is effective in maintaining the quality of Cilembu variety sweet potatoes during storage.

Keywords: neem extract, physicochemical, postharvest, storage, sweet potato

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L) is a vital global food commodity, ranking as the sixt most important staple crop after rice, maize, cassava, wheat, and potatoes (Monostori and Azarvas, 2015; Drapal et al., 2019; Donyina et al., 2025). One of Indonesia's superior varieties is the cilembu sweet potato, which obtained Geographical Indication (GI) status in 2013 as a distinctive product from Sumedang, West Java (Suharyon and Edi, 2020; Tanjung and Nurfadliela, 2023). Despite its high productivity, reaching 15 – 30 tons/ha, and significant export value, national sweet potato production has experienced fluctuations and decline, partly due to suboptimal postharvest handling (Choir and Akbar, 2023; Center for Agricultural Data and Information Systems, 2024).

A major constraint in sweet potato storage is its high moisture content (59 – 69%), making it susceptible to physiological and weight loss of up to 25% during storage can diminish its market competitiveness (Harnowo and Utomo, 2020; Pratiwi, 2020). Appropriate postharvest handling is

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key to preserving sweet potato quality. Good quality sweet potatoes are characterized by optimal physiological maturity, uniform size, absence of physical defects, and freedom from contamination by pests, diseases, and foreign matter such as soil, stems, leaves, or debris (Rembulani and Rahmadhia, 2023). However, at the farmer level, postharvest handling often relies on traditional methods, such as storage in jute sacks or bamboo baskets with limited air circulation, which are less effective in preventing pathogen attack (Herawati et al., 2024). Futhermore, the application of chemical pesticides, while effective, raises concerns about toxic residues, pathogen resistance, and environmental impact (Sardi and Magfirah, 2024).

As a sustainable alternative, neem leaf extract (*Azadirachta indica* A. Juss) offers an innovative solution. This plant is renowned for containing over ≥140 bioactive compounds, including azadirachtin, nimbin, salanin, and flavonoids, which have been scientifically proven to prossess antimicrobial, antifungal, and antioxidant properties (Azwana and Kuswardani, 2023). Additionally, neem leaf extract is biodegradable and has low toxicity, aligning with the principles of sustainability and food safety. The Food and Agriculture Organization (FAO) has recommended neem as a sustainable biopesticide with efficacy equivalent to 70 – 90% of synthetic pesticides but without ecotoxicological risks (Javandira et al., 2022).

Neem leaves contain azadirachtin compounds, which are known to disrupt the growth and development of insect larvae. The extract acts by being absorbed through the insect's cuticle, inducing neurotoxicity that leads to paralysis and mortality. Additionally, the bioactive compounds in neem leaves interfere with insect digestive processes. A positive correlation exists between concentration and efficacy, higher concentrations deliver a greater toxic load to the insects, resulting in significantly higher mortality rates (Wahyudiarto, et al., 2023). This established dose-response relationship provides the rationale for evaluating neem leaf extract concentrations of 0 ml/L, 10 ml/L, and 20 ml/L in this study.

This approach is further supported by existing literature Herawati, et al. (2024) confirmed that a 10 ml/L neem concentration was optimal for mitigating quality loss in sweet potatoes and deterring sweet potato weevil infestation. In a separate study on peaches Li, et al. (2025) reported that a 20% neem extract concentration effectively maintained the fruit's physicochemical properties throughout storage, underscoring the potential of higher concentrations for preserving postharvest quality.

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Another critical aspect is the selection of appropriate packaging. Packaging plays a vital role in controlling respiration rate, humidity, and air ventilation, all of which influence the freshness and shelf life of sweet potatoes. Jute sacks have high porosity but are less effective at retaining moisture; poly-net bags facilitate optimal gas exchange but pose a risk of external contamination while bamboo baskets offer a balance between aeration and mechanical protection, with added value for environmental sustainability (Fakhruzy, 2018; Fernando, 2022; Chaudhary et al., 2024).

Based on these problems, this research aims to examine the effectiveness of combining neem leaf extract with various packaging types in suppressing pest infestation, inhibiting sprouting, reducing weight loss, and maintaining the physiological quality of cilembu variety sweet potatoes during 30 days of storage at room temperature.

2. RESEARCH METHOD

Location of experiment and duration

The experiment was conducted in a controlled storage room located in Haurngombong Village, Pamulihan District, Sumedang Regency, West Java, Indonesia. The storage conditions were maintained at an average temperature of 21°C – 24°C and 78% relative humidity, monitored by a thermo-hygrometer installed in the storage room throughout the 30-day storage period. The research was carried out from March to September 2025, encompassing the preparation, experimental execution, and data analysis phases. The trial consisted of nine treatment combinations, factoring neem leaf extract concentrations (0 ml/L, 10 ml/L, 20 ml/L) and packaging types (jute sacks, poly-net bags, and bamboo baskets). Each treatment combination was replicated three times in a Completely Randomized Design (CRD), resulting in 27 experimental units. Each unit contained 12 sweet potatoes, bringing the total number of tubers used in the study to 324 (equivalent to 54 kg).

Sample collection

Cilembu variety sweet potatoes (*Ipomoea batatas* L) were sourced from farmers in Cilembu Village, Sumedang. Grade A tubers, free from pests and diseases and at four months of harvest age, were selected. Sorting was conducted to ensure the selected sweet potatoes were free from physical defects and diseases. The tubers were cleaned of adhering dirt and soil using clean water and then transported to the storage room for air-drying at ambient temperature.

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Preparation of neem leaf extract (*Azadirachta indica* A. Juss)

The neem leaf extract was prepared at the Biomedical Laboratory, Faculty of Medicine, University of Swadaya Gunung Jati Cirebon, Indonesia, using the maceration method. Fresh neem leaves obtained from farmers in Situbondo Regency, East Java, were cleaned and air-dried, then grounded using a blender. The powder was placed into a jar, and 96% ethanol was added at a ratio of 1:5 (1 kg of neem leaf powder to 5 liters of ethanol). The mixture was stored in a dark, sealed container for three days (maceration). The macerated result was filtered using whatman filter paper to separate the filtrate from the residue. The filtrate was then heated to 40°C at a speed of 60 rpm using a rotary evaporator to isolate the ethanol and dissolved substances. The final product was a concentrated neem leaf extract, stored in a sealed jar in a refrigerator for use according to the treatments. The extraction was prepared using identical materials and ratios for all samples. However, in application, the extracts were differentiated according to the specified treatment concentrations. This methodology was employed specifically to test the hypothesis that a higher azadirachtin content would lead to greater effectiveness in preserving the physicochemical properties of sweet potatoes (Wahyudiarto, et al., 2023). The process of neem leaf extract preparation is shown in Figure 1.

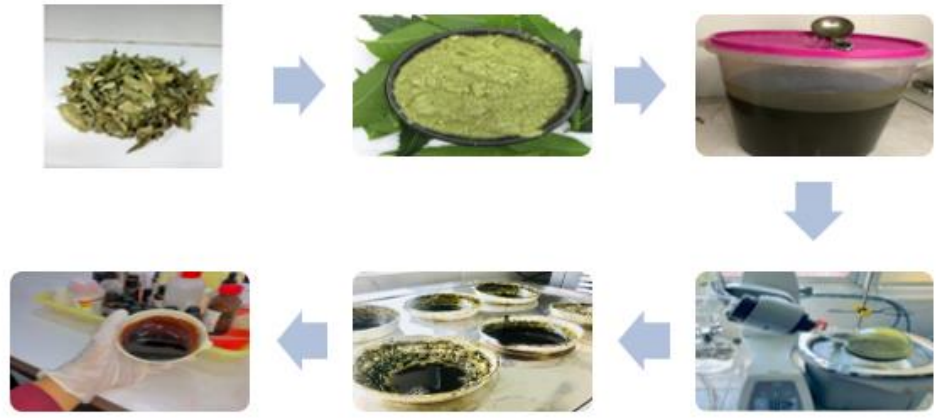

Figure 1. Neem leaf extract preparation process

Packaging preparation

Packaging was prepared in the storage room, with sizes adjusted to contain three sweet potato tubers weighing approximately 500 grams. The packaging materials were obtained from a wholesale store in Indonesia. Each package was labeled according to its treatment. The types of packaging used were jute sacks, poly-net bags, and bamboo baskets.

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(a) (b) (c)

Figure 2. Types of packaging used, jute sack (a); poly-net bag (b); bamboo basket (c)

Sample treatment

Sweet potatoes were divided into three groups, each consisting of 108 tubers, for immersion in neem leaf extract concentrations (0 ml/L, 10 ml/L, and 20 ml/L) for 10 minutes. The samples were then air-dried and packaged in the three types of packaging (jute sack, poly-net bags, and bamboo basket). The samples were stored in the storage room for 30 days in a dark environment (temperature: 21°C – 24°C, relative humidity: 78%) on a wooden table.

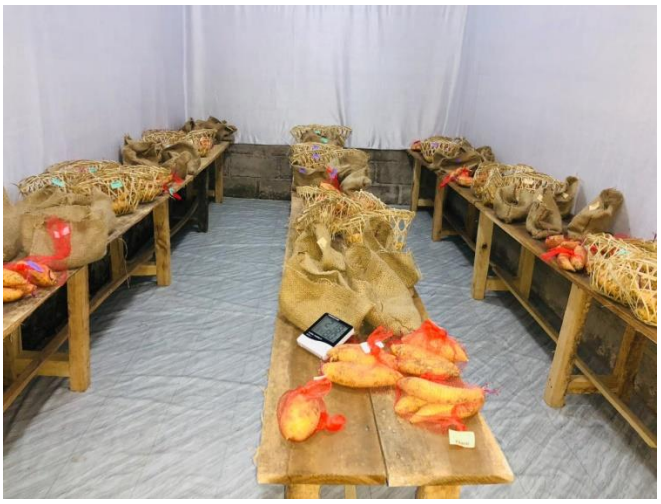

Figure 3. Sample layout in the storage room

Observation parameters

Sprout growth (cm)

Observation was conducted by examining changes on the tuber surface. If sprouts were present, they were counted and their length measured using a ruler or tape measure. Sprout growth was observed according to the changes in each sweet potato under each treatment. A sprout was counted if its length was ≥ 0.5 cm to ensure accurate identification and avoid misclassification.

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Indication of sweet potato weevil (*Cylas formicarius*) infestation %

Observation was performed by examining the tuber surface for signs of sweet potato weevil infestation, characterized by the presence of black holes, particularly near the stem end. Each hole typically contains a single hatched egg, and the larvae tunnel into the tuber. These small boreholes are often covered by frass, which is green to black in color and has a distinct odor. If consumed, the tuber tastes bitter (Sutrisno et al., 2017). In this study, destructive sampling was conducted by indicated with weevil infestation. The percentage was calculated as the total tuber weight (grams) minus the weight of the tuber part indicated to be infested (grams). The formula for calculating infestation frequency is as follows:

$$Infestation\ Frequency = \frac{X}{Y} x\ 100\%$$

Where:

X = Number of infested tubers

Y = Total number of tubers observed

The assessment of infestation level was based on the percentage of infested tubers as follows:

Table 1. Percentage scale for infestation level

Percentage	Classification of Infestation Level
≤ 10%	Very low
10 – 50%	Low
51 – 75%	Moderate
≥ 75%	High

The following formula is used for calculating infestation intensity:

$$I = \frac{\Sigma(ni\ x\ vi)}{N\ x\ Z} x\ 100\%$$

Where:

I = Pest infestation intensity (%)

ni = Number of tubers infested by sweet potato weevil

vi = Damage severity scale value

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Z = Highest value of the established damage scale

N = Total number of tubers observed

The following is the rating scale for infestation intensity based on the percentage of damaged tubers:

Table 2. Scale values for each damage category

Scale Value (Z)	Damage Category
0	No damage
1	Light damage (≤ 25%)
2	Moderate damage (25% - 50%)
3	Severe damage (50% - 75%)
4	Very severe damage (75% - 100%)

Weight loss (%)

Observation was conducted using a digital scale. The initial weight of sweet potatoes was measured before storage, and final weights were recorded at 10, 20, and 30 days of storage. The following formula was used to calculate weight loss:

$$weight\ loss = \frac{initial\ weight\ (gr) - final\ weight\ (gr)}{initial\ weight\ (gr)} x\ 100\%$$

Starch content (%)

Analysis was performed through destructive sampling of each specimen. Starch content was determined by cleaning the sweet potatoes, grating them, and adding water. The grated mixture was filtered to separate the pulp from the filtrate. The extract was allowed to settle for five hours for starch precipitation. After sedimentation, the supernatant was discarded, and the settled starch was dried in a microwave at 40°C for five minutes. The dried starch was weighed using a digital scale.

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Figure 4. Starch content determination process

Total Soluble Solids (TSS) °Brix

Measurement was conducted using a refractometer (Atago model PR 201α) with a measurement scale of 0 – 60% °Brix. Samples were prepared by extracting juice from grated sweet potatoes, which was then dropped onto the refractometer lens for reading. The TSS value was directly displayed on the instrument. After each measurement, the lens was cleaned with distilled water and calibrated before subsequent readings. Each sample was measured three times as replicates.

(a) (b)

Figure 5**.** Total soluble solids measurement method. Sample extraction (a); Sample extraction observation using °Brix refractometer lens (b)

Data analysis

The data obtained from the observations in this study were analyzed using a linear model Analysis of Variance (ANOVA). Where significant differences were found, the analysis was followed by a post-hoc test using the Least Significant Difference (LSD) at the 5% significance level. The general linear model for the Completely Randomized Design (CRD) is as follows:

$$\boldsymbol{Yij = \mu + \alpha i + \varepsilon ij}$$

Where:

Yij = Observed value from the *i* treatment and the *j* replication

μ = Grand mean

αi = Effect of the *i* treatment

i = Treatment

j = Replication

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εij = Experimental error for the *i* and the *j* replication

The obtained data were compiled into an analysis of variance (ANOVA) table to determine the significance level of the F-test, as shown in the following table.

Table 3. Analysis of variance

Source of variation	DF	SS	MS	F_{cal}	$F_{0,05}$
Treatment	8	$\frac{\Sigma Yi^2}{j} - CF$	$\frac{SST}{dft}$	$\frac{MST}{MSE}$	3,07
Error	18	SS(T) – SS(T)	$\frac{SSE}{dfe}$		
Total	26	$\Sigma Yij2 - CF$			

The hypothesis decision rule is based on the F-calculated value, as follows:

Table 4. Decision rule for hypothesis testing

Analysis Result	Analysis Conclusion	Description
$F_{cal} \leq F_{0,05}$	No significant	There is no significant difference in the effect among the treatments.
$F_{cal} \geq F_{0,05}$	Significant	There is a significant difference in the effect among the treatments.

If the analysis results show a significant effect, a post-hoc test was conducted using the Least Significant Difference (LSD) test at the 5% significance level, calculated with the following formula:

$$BNT = t\alpha(5\%) \times \sqrt{\frac{2\,KTgalat}{n}}$$

Where:

$t_{\alpha(5\%)}$ = t-table value at the 5% significance level with error degrees of freedom

MSe = Mean square of error obtained from the ANOVA table

n = The number of replications for each treatment

3. RESULTS AND DISCUSSION

Effect of treatment on sprout growth (cm)

Sprout are new vegetative organs emerging from the buds on tubers. Based on observation results, sprout growth in sweet potatoes became visible on the 8th day of storage. This indicates

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that the physiological dormancy phase has ended and the tubers have entered the active growth phase. The storage conditions (temperature: 21°C – 24°C, relative humidity: 78%) were proven to support the cellular metabolic activity required for sprout growth.

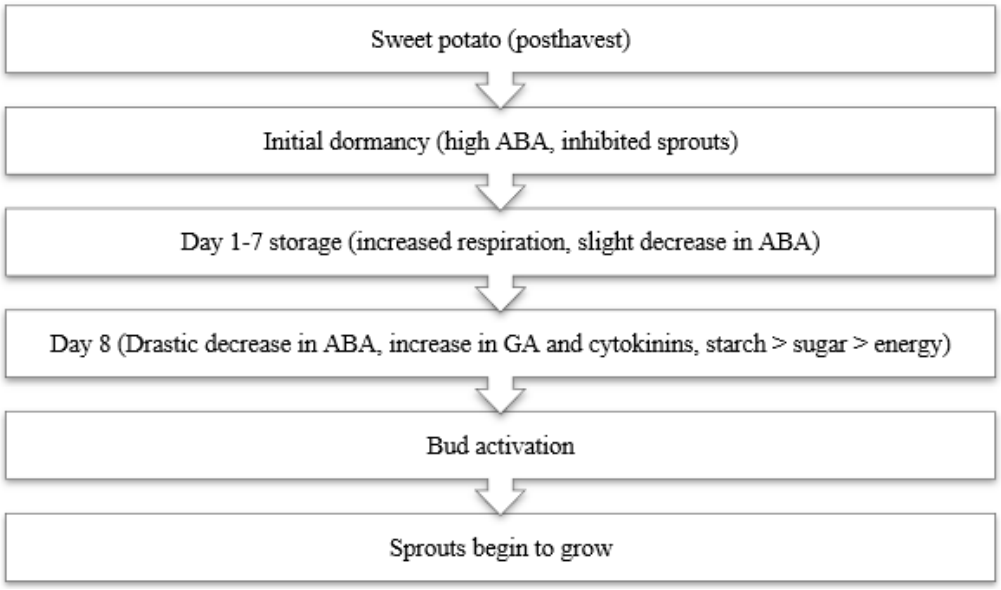

Figure 6. Sprouting mechanism

During the storage period, enzymatic degradation of starch into simple sugars (glucose and maltose) occurs, serving as the primary energy substrate for cell division and elongation in sprouts. The increase in the number and length of sprouts over storage time indicates elevated respiratory activity. The respiration process produces carbon dioxide (CO_2), water vapor, and heat as secondary metabolites from carbohydrates, proteins, and other organic, compounds (FAO, 2001; Narullita et al., 2013). The increased respiration rate during storage leads to weight loss in sweet potatoes due to mass loss through the release of water and respiratory gases (Xanthopoulos et al., 2024; Pedrosa et al., 2025). Physiologically, the energy generated from starch degradation is used to support sprout growth activities, particularly during the dormancy-breaking phase. The transformation of carbohydrates into simple sugars provides sufficient energy supply for meristematic cells to undergo intensive division (Narullita et al., 2013; Haider et al., 2022; Di et al., 2024).

Besides biochemical factors, growth hormones also play a crucial role in the sprouting process. Cytokinin hormones function to break dormancy and stimulate cell division in the bud areas, while gibberellins are responsible for cell elongation, promoting longitudinal sprout growth.

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During room temperature storage, increased levels of both hormones have been proven to accelerate the sprouting process (Desta and Amare, 2024; Donyina et al., 2025). Gibberellin hormones, particularly GA_3, play an important role in accelerating dormancy breakdown and enhancing carbohydrate mobilization, although this is associated with increased weight loss due to high metabolic activity (Qayyum et al., 2025). The increased activity of starch-degrading enzymes occurs when the dormancy perio ends, ensuring energy supply for sprout growth (Di et al., 2024). Furthermore, environmental factors such as temperature, humidity, and packaging type influence the physiology of sprout growth. The room conditions (temperature: 21°C – 24°C, relative humidity: 78%) are considered optimal for activating metabolic processes, increasing hydrolase enzyme activity, and accelerating the breakdown of starch into simple sugars (Sun et al., 2025). This physiological activity signifies that the sweet potatoes have transitioned from the dormancy phase to the active vegetative growth phase.

Table 5. LSD test of treatment effects on sprout growth (cm)

Treatment	Sprout Growth		
	10 Days	20 Days	30 Days
K0P1 (0 ml/L, jute sack)	1,33 a	2,33 a	9,33 a
K0P2 (0 ml/L, poly-net bag)	0,67 a	2,00 a	10,33 a
K0P3 (0 ml/L, bamboo basket)	0,33 a	1,00 a	3,67 a
K1P1 (10 ml/L, jute sack)	0,67 a	1,33 a	4,67 a
K1P2 (10 ml/L, poly-net bag)	0,33 a	1,00 a	5,44 a
K1P3 (10 ml/L, bamboo basket)	1,00 a	2,67 a	8,67 a
K2P1 (20 ml/L, jute sack)	1,33 a	3,33 a	8,67 a
K2P2 (20 ml/L, poly-net bag)	0,00 a	1,33 a	6,33 a
K2P3 (20 ml/L, bamboo basket)	0,00 a	0,00 a	5,00 a

Description: Data in the same column followed by the same lowercase letter are not significantly different based on LSD test at 5% level.

Based on table 5, sprout growth across all treatments showed no significant differences. Sprouts were able to grow and develop in all treatments, including those treated with neem leaf extract (K1 and K2). The treatments with neem leaf extract K1 (10 ml/L) and K2 (20 ml/L) resulted in sprout growth due to the role of bioactive compounds contained in neem leaf extract, such as azadirachtin, nimbin, and salanin, which possess physiological inhibitor activity (Prasad et al., 2022; Mu et al., 2024). These compounds function to regulate plant growth hormones involved in dormancy breaking and cell division in sprouts, particularly cytokinin and gibberellin hormones (Leng and Reddy, 2014; Javandira et al., 2022). Therefore, increasing neem leaf extract

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concentration inhibits the enzymatic metabolism responsible for breaking down starch into simple sugars, which are the primary energy source for sprout growth. This inhibition reduces energy availability for cell division and elongation activities in sprouts, consequently suppressing sprout growth in treatments K1 (10 ml/L) and K2 (20 ml/L) compared to treatment K0 (0 ml/L).

(a) (b) (c)

Figure 7. Sprout growth of sweet potatoes in each packaging type. Sprout growth in jute sack packaging (a); Sprout growth in poly-net bag packaging (b); Sprout growth in bamboo basket packaging (c)

Effect of treatment on sweet potato weevil (*Cylas formicarius*) infestation %

Analysis results indicate that during storage, Cilembu variety sweet potatoes underwent significant changes in their physical and chemical properties. This is evident from the visual changes and damage observed in the sweet potatoes during storage. This phenomenon commonly occurs due to postharvest physiological activities such as respiration, transpiration, and interactions with microorganisms and insects repetation (Narullita et al., 2013; Leng and Reddy, 2014; Capinera, 2014; Han et al., 2019). One of the primary causes of this damage is infestation by the sweet potato weevil (*Cylas formicarius*), known as a major pest of sweet potatoes. This pest not only attacks during the cultivation phase but can also persist and develop during storage, leading to quality deterioration and reduced market value of the tubers. Infestation by this pest causes quality decline in tubers, flavor changes, and the emergence of unpleasant odors resulting from the metabolic activities of larvae inside the tubers. In this study, sweet potatoes treated with neem leaf extract (*Azadirachta indica* A. Juss) extract were proven to reduce postharvest losses by up to 99,4% across all packaging types compared to those without neem extract.

Table 6. LSD test of treatment effects on sweet potato weevil infestation (%)

Treatment	Sweet Potato Weevil		
	10 Days	20 Days	30 Days

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K0P1 (0 ml/L, jute sack)	0,00 a	33,33 b	66,67 b
K0P2 (0 ml/L, poly-net bag)	33,33 b	66,67 b	86,67 c
K0P3 (0 ml/L, bamboo basket)	0,00 a	66,67 b	86,67 c
K1P1 (10 ml/L, jute sack)	0,00 a	0,00 a	0,00 a
K1P2 (10 ml/L, poly-net bag)	0,00 a	0,00 a	0,00 a
K1P3 (10 ml/L, bamboo basket)	0,00 a	2,00 a	4,00 a
K2P1 (20 ml/L, jute sack)	0,00 a	0,00 a	0,00 a
K2P2 (20 ml/L, poly-net bag)	0,00 a	0,00 a	0,00 a
K2P3 (20 ml/L, bamboo basket)	0,00 a	1,33 a	2,67 a

Description: Data in the same column followed by the same lowercase letter are not significantly different based on LSD test at 5% level.

Based on table 6, the data reveal a trend of increasing sweet potato weevil (*Cylas formicarius*) infestation over the storage period (10-30 days), which was particularly evident in the K0 treatment (0 ml/L neem extract). In contrast, the K1 (10 ml/L) and K2 (20 ml/L) treatments demonstrated significantly superior protective efficacy. Observational results indicated that the most severe weevil infestations occurred in the K0 treatment across all packaging types, with damage intensity ranging from moderate (33.3%) to very severe (86.6%). Meanwhile, the K1 and K2 treatments using P3 packaging (bamboo baskets) maintained minimal infestation levels (<25%), classifying them in the uninfected category.

This is attributed to the biochemical activity of secondary metabolite compounds in neem leaves, such as azadirachtin, nimbin, salanin, and meliantriol, which function as antifeedants, contact poisons, and insect growth inhibitors (Leng and Reddy, 2014; Isman, 2020). Phytochemical studies have identified that neem leaves contain primary compounds including azadirachtin, saponins, steroids, phenols, triterpenoids, reducing sugars, alkaloids, phenolic compounds, flavonoids, and tannins, which possess natural antibacterial and insecticidal activity (Bhamare et al., 2020; Modi and Soni, 2023).

Based on observation results, neem leaf extract can inhibit the infection rate of sweet potato weevils in sweet potatoes because neem leaves contain secondary metabolites with antibacterial activity. Azadirachtin, the main compound in neem leaf extract, acts as an antifeedant, inhibits insect development, and serves as a contact poison, disrupting the pest's life cycle until they fail to develop and die (Pavela and Benelli, 2016; Kortse et al., 2023). Additionally, other compounds possess insecticidal and antimicrobial activity, such as nimbin, salanin, and meliantriol (Wylie and Merrell, 2022). This method presents an innovative, environmentally friendly solution to maintain sweet potato quality during storage against pest infection and can extend the shelf life

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of sweet potatoes. Observation of tuber damage was conducted manually using destructive methods, involving evaluation of infestation symptoms on the surface and inside of the tubers (Figure 8). The results reinforce evidence that neem leaf extract treatment, particularly at high concentrations, significantly suppresses sweet potato weevil activity and maintains the physiological quality of sweet potatoes during storage (Capinera, 2014; Minista et al., 2017).

Figure 8**.** Indication of cilembu variety sweet potatoes infested by sweet potato weevil

Effect of treatment on treatment on weight loss (%)

During storage, sweet potatoes undergo weight loss characterized by water loss through transpiration and the evaporation of gases resulting from the breakdown of glucose into carbon dioxide (CO_2) during respiration (Narullita et al., 2013). Weight loss is indicated by a decrease in the weight of sweet potatoes when measured periodically during storage. This weight loss reflects the transpiration rate of the stored produce. Transpiration is the process of water mass transfer from the sweet potato tissues to the surrounding air. This process can lead to changes in nutritional content and weight loss, influenced by internal and external factors such as tuber skin thickness, physiological maturity of the tuber, temperature, and humidity. Respiration, meanwhile, is the breakdown of complex materials within cells with the help of oxygen (O_2) into simpler molecules (Widjanarko, 2012; Chilungo et al., 2019; Han et al., 2019). The occurrence of physiological processes like respiration and transpiration during storage can increase weight loss in sweet potatoes (Herawati et al., 2024

Table 7. LSD test of treatment effects on weight loss (%)

Treatment	Weight Loss		
	10 Days	20 Days	30 Days
K0P1 (0 ml/L, jute sack)	17,67 a	18,33 a	28,33 c
K0P2 (0 ml/L, poly-net bag)	16,33 a	17,33 a	24,33 b
K0P3 (0 ml/L, bamboo basket)	18,67 b	20,67 b	22,00 b

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K1P1 (10 ml/L, jute sack)	9,67 a	13,3 a	20,00 b
K1P2 (10 ml/L, poly-net bag)	9,33 a	12,67 a	14,00 a
K1P3 (10 ml/L, bamboo basket)	15,67 a	15,67 a	16,33 a
K2P1 (20 ml/L, jute sack)	9,33 a	12,67 a	19,33 b
K2P2 (20 ml/L, poly-net bag)	10,33 a	12,67 a	15,00 a
K2P3 (20 ml/L, bamboo basket)	12,67 a	14,33 a	14,67 a

Description: Data in the same column followed by the same lowercase letter are not significantly different based on LSD test at 5% level.

Based on table 7, sweet potatoes exhibited weight loss during storage across all treatments. The highest weight loss percentage was recorded in treatment K0P3 (0 ml/L, bamboo basket packaging) on day 10 and on day 20 and again in treatment K0P1 (0 ml/L, jute sack packaging) on day 30. This weight reduction occurred due to the combined processes of transpiration and respiration in the sweet potatoes, exacerbated by infestation from the sweet potato weevil (*Cylas formicarius*) that particularly affected the K0 (0 ml/L) treatments during storage.

The neem leaf extract treatments also exhibited weight loss across all packaging types however, the magnitude was consistently and significantly lower than in the K0 (0 ml/L) control. This phenomenon is likely attributed to the bioactive properties of the neem extract, which functions as an antibacterial and insecticidal agent. By effectively suppressing sweet potato weevil (*Cylas formicarius*) infestation, the extract mitigates physical damage to the tubers, thereby decelerating the rate of moisture loss. Furthermore, the reduction in weevil infection leads to a decrease in secondary catabolic processes that would otherwise trigger an elevated respiration rate and increased weight loss. The substantial weight loss in the K0 (0 ml/L) treatment is a direct consequence of severe weevil infestation that affected the sweet potatoes in all packaging types during storage. In contrast, the K1 (10 ml/L) and K2 (20 ml/L) treatments successfully and significantly suppressed weevil infestation, resulting in markedly lower weight loss throughout the storage period.

The efficacy of botanical insecticides from the neem plant against the sweet potato weevil has been documented in field and laboratory studies on various commodities and has been comprehensively reviewed to support the use and application of neem extract as an environmentally friendly alternative for various agricultural commodities during storage (Alzohairy, 2016; Wylie and Merrell, 2022; Kortse et al., 2023; Modi and Soni, 2023; Herawati et al., 2024). Regarding packaging, poly-net bags provided superior air ventilation compared to bamboo baskets and jute sacks. This effective ventilation helps suppress the transpiration process

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by allowing moisture from tuber water loss to escape, preventing a buildup of temperature and humidity inside the packaging. Both poly-net bags and bamboo baskets facilitate the release of heat generated from the respiration process, wherein starch breaks down into energy (producing CO_2 + H_2O and releasing heat that can accelerate tissue deterioration). In contrast, jute sacks tend to retain this respiratory heat, contributing to their higher associated weight loss compared to poly-net bags and bamboo baskets.

Packaging plays a crucial role in the postharvest physiology of sweet potatoes. Respiration and transpiration processes can lead to substantial weight loss (5 – 10%) and degradation of nutrients such as vitamin C and beta-carotene (Pahlevi et al., 2016). These changes occur as carbohydrates, proteins, and vitamins break down or transform during respiration releasing carbon dioxide, heat, and water vapor (Narullita et al., 2013). A faster respiration rate depletes the food reserves in sweet potatoes more quickly, converting them into new compounds and releasing heat into the environment, thereby shortening shelf life. Therefore, the combination of well-ventilated packaging like poly-net bags with neem leaf extract treatment creates a synergistic effect, effectively reducing weight loss and maintaining the physiological quality of sweet potatoes during storage (Prasad et al., 2022; Herawati et al., 2024).

Effect of treatment on starch content (%)

Starch content refers to the amount of polysaccharides stored in sweet potato tissues, serving as the primary energy reserve during storage, expressed as a percentage. During storage, sweet potatoes undergo biochemical changes where starch is enzymatically broken down by maltase into maltose, which is further hydrolyzed by amylase into glucose as an energy source for metabolic activities (Widjanarko, 2012; Li et al., 2021; Sun et al., 2025). This process results in sweet potatoes becoming sweeter over storage time.

Table 8. LSD test of treatment effects on starch content (%)

Treatment	Starch Content		
	10 Days	20 Days	30 Days
K0P1 (0 ml/L, jute sack)	24,33 b	18,00 a	11,67 a
K0P2 (0 ml/L, poly-net bag)	20,67 a	16,67 a	12,00 a
K0P3 (0 ml/L, bamboo basket)	18,33 a	18,00 a	10,00 a
K1P1 (10 ml/L, jute sack)	30,33 c	25,67 b	13,67 b
K1P2 (10 ml/L, poly-net bag)	23,00 b	17,00 a	12,00 a
K1P3 (10 ml/L, bamboo basket)	20,67 a	18,00 a	11,67 a
K2P1 (20 ml/L, jute sack)	24,67 b	18,00 a	13,33 a

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K2P2 (20 ml/L, poly-net bag)	25,67 b	21,67 b	14,33 b
K2P3 (20 ml/L, bamboo basket)	18,33 a	15,67 a	12,00 a

Description: Data in the same column followed by the same lowercase letter are not significantly different based on LSD test at 5% level.

Based on table 8, starch content showed a decreasing trend with prolonged storage duration. Treatment K1P1 (10 ml/L neem extract, jute sack packaging) demonstrated the highest starch content on day 10 compared to other treatments, while treatments K1P1 and K2P2 (20 ml/L neem extract, poly-net packaging) showed significant differences (denoted by 'b') on days 20 and 30 compared to other treatments (denoted by 'a'). This decline in starch content indicates ongoing enzymatic hydrolysis during storage, converting starch into simple sugars such as glucose and maltose, which serve as energy substrates for respiration and sprout development. Treatments K1P1 and K2P2 showed statistically significant differences compared to the K0 control (0 ml/L), demonstrating that neem leaf extract significantly influences sweet potato starch content during storage. The higher starch content maintained in treatments K1P1 and K2P2 compared to the K0 control provides evidence that neem leaf extract components can effectively preserve the physiological quality characteristics of sweet potatoes during storage.

This phenomenon aligns with reports by Li et al. (2021) and Sun et al. (2025), stating that the activity of α -amylase and maltase enzymes increases as starch content decreases in sweet potatoes during storage, especially under room conditions (temperature: 21°C – 24°C, relative humidity: 78%). Starch degradation is a normal physiological mechanism in sweet potatoes due to the transition from the dormancy phase to the active metabolic phase. According to Han et al. (2019), the respiration process in sweet potatoes involves the oxidation of carbohydrates, producing carbon dioxide (CO_2), water vapor, and heat, thereby reducing the starch reserves in sweet potatoes. This activity is influenced by increased temperature and humidity in the storage room environment, which accelerates the respiration rate (Mu et al., 2024; Sun et al., 2025).

Effect of treatment on total soluble solids (°Brix)

Total soluble solids represent all solid materials present and dissolved in water within the tuber, including reducing sugars, sucrose, organic acids, and water-soluble vitamins (Narullita et al., 2013). The measuring instrument used in this study was a refractometer (Atago model PR 201α) with a measurement scale of 0 – 60% °Brix. The higher the percentage value, the higher the sweetness level contained in the sweet potato.

Table 9. LSD test of treatment effects on total soluble solids (°Brix)

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Treatment	Total Soluble Solids		
	10 Days	20 Days	30 Days
K0P1 (0 ml/L, jute sack)	24,33 b	18,00 a	11,67 a
K0P2 (0 ml/L, poly-net bag)	20,67 a	16,67 a	12,00 a
K0P3 (0 ml/L, bamboo basket)	18,33 a	18,00 a	10,00 a
K1P1 (10 ml/L, jute sack)	30,33 c	25,67 b	13,67 b
K1P2 (10 ml/L, poly-net bag)	23,00 b	17,00 a	12,00 a
K1P3 (10 ml/L, bamboo basket)	20,67 a	18,00 a	11,67 a
K2P1 (20 ml/L, jute sack)	24,67 b	18,00 a	13,33 a
K2P2 (20 ml/L, poly-net bag)	25,67 b	21,67 b	14,33 b
K2P3 (20 ml/L, bamboo basket)	18,33 a	15,67 a	12,00 a

Description: Data in the same column followed by the same lowercase letter are not significantly different based on LSD test at 5% level.

Based on table 9, the total soluble solids (TSS) value in sweet potatoes fluctuated during storage. On day 10, the K1P1 treatment (10 ml/L, jute sack) showed the highest values and were significantly different (denoted by 'c'). Meanwhile, on days 20 and 30, the TSS values continued to fluctuate, with the highest value ultimately recorded in treatment K1P1 (10 ml/L, jute sack packaging), K2P1 (20 ml/L, jute sack packaging), and K2P3 (20 ml/L, bamboo basket packaging). In the K0 control treatment (0 ml/L), the decrease in TSS value resulted from sweet potato weevil (*Cylas formicarius*) infestation, which damaged tuber tissues and consequently reduced total soluble solids. Conversely, the K1 (10 ml/L) and K2 (20 ml/L) treatments effectively minimized tissue damage and maintained relatively stable TSS levels. The influence of azadirachtin and flavonoid compounds contained in neem leaves has been proven to exhibit antimicrobial and antioxidant activity, thereby suppressing the loss of sugars and other organic components during storage (Wylie and Merrell, 2022; Modi and Soni, 2023).

This increase indicates the conversion of starch into simple sugars in sweet potatoes due to the activity of amylase and maltase enzymes during storage (Mu et al., 2024; Sun et al., 2025). The higher the soluble sugar content, the sweeter the taste of the sweet potato, resulting from the accumulation of glucose and maltose from starch hydrolysis (Han et al., 2019). The rise in TSS value is also influenced by the decrease in water content in sweet potatoes due to transpiration and respiration processes. According to Narullita et al. (2013) and Mu et al. (2024), water loss causes an increase in the concentration of dissolved substances in sweet potatoes, such as sugars and organic acids.

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Therefore, the higher the weight loss due to transpiration, the greater the measured TSS value. This is consistent with the research of Bhattarai et al. (2021), which reported that storage under well-ventilated and controlled temperature conditions can suppress water loss, thereby maintaining the stability of soluble solids.

4. CONCLUSIONS

Based on the research results, it can be concluded that the combining neem leaf extract at a concentration of 10 ml/L and 20 ml/L with poly-net bag packaging is the most effective treatment for maintaining the quality of Cilembu variety sweet potatoes during storage. This combination significantly suppresses excessive sprout growth, reduces sweet potato weevil (*Cylas formicarius*) infestation by up to 99,4%, minimizing weight loss by an average of 33,8%, and maintaining significantly more stable starch content and total soluble solids compared to other treatments. Poly-net bag packaging provides optimal ventilation that supports the release of respiratory heat and suppresses the transpiration rate, while the 10 ml/L and 20 ml/L neem leaf extract acts as a natural, environmentally friendly insecticide and antibacterial agent that inhibits weevil infestation and damage to the sweet potatoes. This combination proved superior to other treatments in maintaining the physiological viability and postharvest quality of Cilembu variety sweet potatoes. Therefore, this solution is expected to benefit farmers and entrepreneurs by maintaining the quality and extending the shelf life of Cilembu sweet potatoes during the storage period.

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