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RESEARCH

Effect of Selected Plant Extracts and Curing on Post-Harvest Quality of Onion (*Allium cepa* L.)

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Abstract

Onion (*Allium cepa* L.) suffers a rapid deterioration in quality during storage due to physiological changes and pathological damage. This experiment evaluated the effects of different plant extracts and curing days on the postharvest quality of onion. The experiment was laid out in a two-factor complete randomized design with three replications. One factor was the curing, 0, 5, and 10 days; and another factor was botanical extracts, coconut (*Cocos nucifera* L.) (2%) oil, neem oil (*Azadirachta indica* L.) (2%), and aloe vera gel (*Aloe vera* L.) (2%). At 80 days of storage, the use of neem extract showed the minimum loss in physiological weight (10.57%), the minimum sprouting (38.88%), the minimum rotting (35.55%), minimum sprout length (12.89 cm), maximum total soluble solids content (8.43%), minimum titratable acidity (0.50 g/L), and minimum visual color rating (1) due to minimum loss in original color followed by coconut oil and aloe vera gel. Additionally, curing for a duration of 5 days yielded improved outcomes. Consequently, onions that underwent a 5-day curing process and were treated with neem extract exhibited superior quality and an extended shelf life. This approach can be advocated as the optimal method to uphold quality standards and enhance the longevity of onions.

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Statement of Sustainability: The research focuses on sustainable agriculture, incorporating plant extracts such as coconut oil, neem oil, and *Aloe vera* gel for resource efficiency and to reduce synthetic inputs. This approach is consistent with sustainable practices aimed at mitigating the negative effects of chemical-intensive agriculture. The study also emphasizes optimizing post-harvest handling for resource conservation, minimizing storage resources and energy consumption. The use of plant extracts aligns with growing consumer preferences for organic and natural products, contributing to a shift toward sustainable and health-conscious food choices. The findings could inform long-term sustainable agricultural practices, promoting environmental health and food security.

1. Introduction

Onion (*Allium cepa* L.) is an important cash crop in Nepal, both economically and nutritionally. Onion is very popular in Nepalese cuisine due to its flavor and taste-enhancing properties (Thapa et al., 2016). Physiologically, onion is a long-day plant belonging to the Amaryllidaceae family and can be grown in almost all hilly and terai districts of Nepal. In Nepal, onion is generally planted in October and November (Rabi season) and harvested in May and June (Gautam et al., 2006). However, increasing population, health consciousness, and awareness have increased the demand for onion bulbs throughout the year. One of the best measures to supply fresh and healthy onions to the market is to increase the shelf life of onions through proper curing techniques (Bahram and Lim, 2018). Curing is the process of removing excess moisture from the outer skin, roots, and neck tissues of onion bulbs at the time of harvest to improve storage quality and reduce disease and pest infestation during storage (Gorreapti et al., 2017). The perishability of onions is directly proportional to their respiration rate; less moisture present at the time of storage results in longer shelf life and reduced postharvest loss (Sargent et al., 1988). Storage of onion bulbs without a curing process can result in significant post-harvest loss, mainly due to high humidity and temperature during the summer season (Chandrashekar, 2014). Different studies have shown 49.9% storage loss of onion without curing onion bulbs and 31.9% post-harvest loss even after curing over 4 months of storage (Tripathi and Lawande, 2019). Some studies have even shown that post-harvest losses range from 50 to 90% and a major part of the loss occurs during the storage period due to diseases, physiological weight loss, germination, and decay (Gorreapti et al., 2017). The main cause is a fungal infection (Hussien et al., 2021). Four major fungal groups have been identified as the primary cause of decay and post-storage losses; *Aspergillus niger*, *A. flavus*, *Penicillium* sp., and *Rhizopus stolonifer*. *A. niger* and *Penicillium* sp. are the most dominant and common fungi (Hussien et al., 2021). In addition, curing the outer skin of the onion bulb provides a dry barrier that seals against water loss to prevent fungal infection and provides mechanical protection against external injury (Gorreapti et al., 2017). In Nepal, research on extending the shelf life of onions to reduce postharvest losses is lacking. Recent studies have found a 45% loss in physiological weight of onion bulbs stored without curing and a 32% loss even after curing over four months (June to September) in Nepal (Kaini, 2020).

Low-cost technologies, which should be readily available, economically viable, and feasible in terms of health and environmental concerns, need to be standardized. Among the various low-cost technologies, the application of edible coating has received increasing attention from farmers as this coating protects perishable onion bulbs from deterioration by reducing transpiration and respiration, improving textural quality, retaining color and volatile flavor compounds, and reducing microbial growth (Mahfoudhi et al., 2014). The edible coating of fruits with pure coconut oil has gained interest for its anti-aging properties by controlling the respiration rate, transpiration rate, and binding of the ethylene biosynthesis process (Lieberman et al., 2006). Coconut oil is a natural food rich in lauric acid. There is evidence that some of this acid is endogenously converted to monolaurin, which is known to have a broad spectrum of antiviral, antibacterial, and antifungal activities (Lieberman et al., 2006). Neem leaf oil contains at least 35 biologically active compounds, is the most potent fungicidal and insecticidal ingredient, and can be used as a coating ingredient (Mondal et al., 2009; Meena, 2012). *Aloe vera* (AV) gel coating has an antifungal activity that significantly inhibits mycelial growth and spore germination, reduces disease incidence and severity, and also delays changes in weight loss, firmness, total soluble solids concentration, and titratable acidity (Khaliq et al., 2019). With the growing concern of consumers regarding the use of synthetic chemicals, this study aims to investigate the effects of the use of different curing durations and bio-extracts on the shelf life of onions.

2. Material and Methods

The experiment was conducted to study the post-harvest quality of onions by subjecting them to different treatments. The onions were planted on January 23, 2021, under field conditions and harvested on May 19, 2021. Onions were harvested when more than 40% of the leaf tips were bent downwards (Khokhar and Jilani, 2000).

2.1. Experimental Site

The experiment was conducted in the rural community of Bishnupur, Saptari District, Nepal, located at 26.52° N latitude and 86.69° E longitude, at an altitude of 76 m asl. Storage was conducted in a well-ventilated, aerated mud floor covered with jute sacks at a temperature of approximately 28 °C and a humidity of 85%.

2.2. Experimental Design and Data Collection

The experiment was designed as a two-factor completely randomized design (CRD) with three replications. Among the two factors, one factor was curing days, no curing (0 days control), curing I (curing for 5 days) and curing II (curing for 10 days) and another factor was plant extracts, coconut oil (2%), neem oil (2%) and *Aloe vera* gel (2%). Onion of the *Nasik red* variety grown in the farmer's field under uniform cropping practices was harvested on May 19, 2021.

2.3. Observations Taken

The data was recorded at 20-day intervals up to 80 days of storage. Ten healthy onion bulbs for each experimental unit with a weight greater than 40 grams were collected from the farmer's field for observation. Data were recorded for parameters physiological loss in weight (PLW), rotten percentage, color rating, total soluble solid (TSS), titratable acidity (TA), and TSS: TA ratio.

- **Physiological loss in weight (PLW%):** A digital-sensitive balance was used to determine fruit weight. The weight loss was calculated according to the formula (Sharma et al., 2020):

$$\text{PLW\%} = \frac{\text{Wo} - \text{Wt}}{\text{Wo}} \times 100$$

  Where, PLW is the percentage of weight loss, Wo is the weight of the initial bulb, and Wt is the weight of the bulb at the designated time.

- **Rotten percentage:** The surface appearance of the samples was visually inspected at each sampling time. Samples showing soft rot, discoloration, or fungal growth were considered decayed. Three different assays were performed in triplicate. Results were expressed as the ratio of the number of decayed samples to the total amount of samples (Soomro et al., 2016).

- **Color rating (Change in peel color):** Peel color ratings were made for all treatments from the first day of treatment through storage at twenty-day intervals. The peel color rating chart was used to categorize the color into the different indices (Figure 1). The onion color palette has 5 colors which are Philippine Brown (1), Deep Carmine (2), Popstar (3), Spanish Pink (4), and Queen Pink (5).

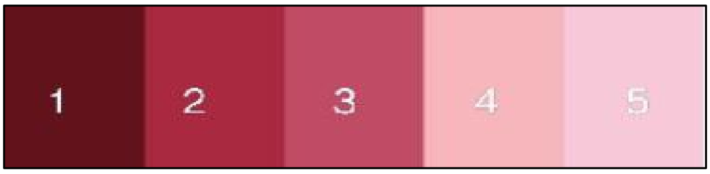

Figure 1. Color chart showing the color change rating with storage.

- **Total soluble solid (TSS: °Brix):** The total soluble solids (°Brix) were determined using a portable refractometer. After measuring the weight of these sampled fruits, the peel was removed, the bulb was crushed sieved, and squeezed in a muslin cloth, and the juice was obtained. Two drops of homogenized juice were placed on the prism of the refractometer and the reading was taken. Calibration was performed before recording the observation. These readings were averaged as per treatment and replicates.

- **Titratable acidity (TA):** The TA of the bulb pulp was measured by using the following formula:

$$\text{Titratable Acidity (TA)} = \frac{\text{ml of NaOH consumed} \times \text{Acid factor}}{\text{ml of juice consumed}} \times 100$$

$$\text{TSS/ TA ratio} = \frac{\text{TSS}}{\text{TA}}$$

2.4. Statistical Analysis

The data obtained were entered into MS Excel 2016 (Microsoft, USA), and the graphs were generated. Analysis of variance for all parameters was performed using R-Studio version 4.1.1 (Open-Source, Boston Massachusetts, USA). A Duncan's Multiple Range Test (DMRT) at a 5% significance level was performed (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Effect on Physiological Weight Loss of Onion Bulb

There was a significant effect on the physiological weight loss of the onions. At 20, 40, 60, and 80 DAS, the highest bulb weight loss was observed with distilled water followed by coconut oil, aloe gel, and neem extract showed the least weight loss (Figure 2). The highest weight loss was observed in bulbs without curing and the lowest weight loss was observed with curing II (for 10 days). Weight loss of onion bulbs during storage is due to loss of moisture by respiration (Ward, 1976). The coconut oil coating closed the openings of stomata and lenticels, thereby reducing transpiration and respiration rate, resulting in less weight loss (Bisen et al., 2012). Coconut oil has a tremendous effect on reducing respiration, ethylene production, and weight loss during storage (Nasrin et al., 2020). Neem leaf extract has the most potent fungicidal and insecticidal components that reduce weight loss (Mondal et al, 2009; Meena, 2012). *Aloe vera* gel coating has an antifungal activity that delays changes in weight loss (Khaliq et al, 2019).

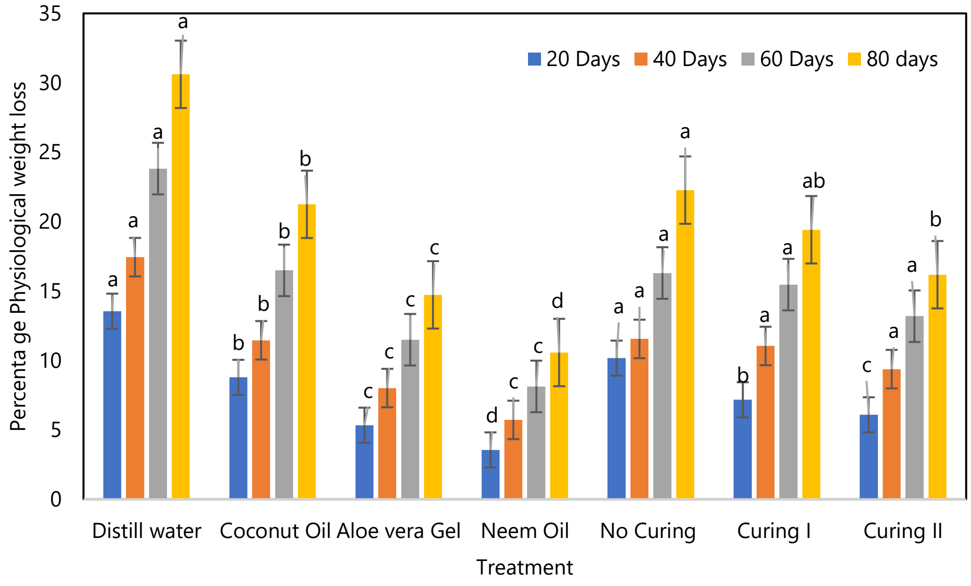

Figure 2. Physiological loss in weight of onions under different post-harvest treatments during storage at ambient room temperature (28°C).

3.2. Effect on Bulb Sprouting of Onion

Results revealed highly significant differences among bio-extract treatments for sprouting percentages at 20, 40, 60, and 80 days. the lowest sprouting (7.78%) was found in bulbs treated with neem extract, followed by coconut oil, which was statistically similar to *Aloe vera* gel (Figure 3). The maximum sprouting (25.55%) was recorded in bulbs treated with distilled water. The minimum sprouting (59.166%) was found in 5 days of cured onions. The coconut oil coating closed the opening of stomata and lenticels, which reduced the sprouting of the bulbs (Bisen et al., 2012). Coconut oil has an immense effect in reducing respiration and ethylene production and preventing sprouting during storage (Nasrin et al., 2020). Neem leaf extract also reduces germination (Mondal et al, 2009). *Aloe vera* gel coating has an antifungal activity that delays sprouting (Khaliq et al, 2019).

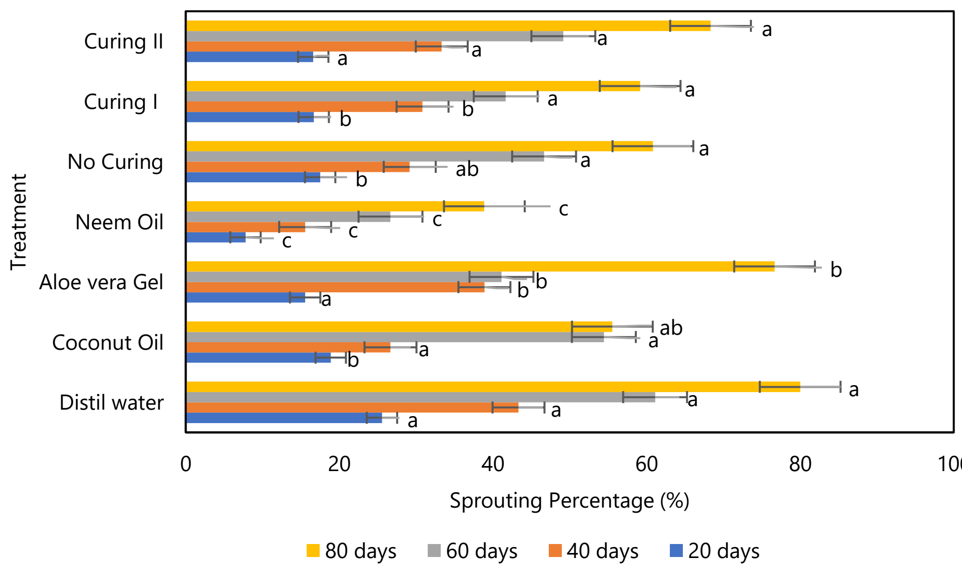

Figure 3. Sprouting percentages of onions under different post-harvest treatments during storage.

3.3. Effect on Bulb Rotting of Onion

A highly significant difference in bulb damage was found among bio-extract treatments at 20, 40, 60, and 80 days. The minimum bulb rot (5.55%) was found in bulbs treated with neem extract (Figure 4), which was statistically similar to

Aloe vera gel (10.00%) and coconut oil (11.11%). The maximum bulb decay was found in onion bulbs treated with distilled water (24.44%). ANOVA showed that there was a statistically significant difference ($p \leq 0.01$) in germination during the first 80 days, which ranged from 47.50% to 55.833%. The minimum onion rot (59.166%) was found in 5 days of cured onion. The minimum sprouting (47.50%) was found in 5-day cured bulbs, which were statically similar to the sprouting bulb of no curing (50.833%). The maximum sprouting (55.83%) was found in 10-day cured bulbs. This study is supported by Lieberman et al. (2006), who state that coconut oil possesses lauric acid, which is endogenously converted to monolaurine, which is known to possess a broad spectrum of antiviral, antibacterial and antifungal activities that prevent bulb damage. Coconut oil also has an immense effect on quality retention, reducing respiration, ethylene production, and damage during storage (Nasrin et al, 2020). Similarly, Neem oil contains at least 35 biologically active compounds with potent fungicidal and insecticidal properties that prevent onion damage (Mondal et al, 2009; Meena, 2012). *Aloe vera* gel coating has an antifungal activity that significantly inhibits mycelial growth and spore germination and reduces bulb damage (Khaliq et al., 2019).

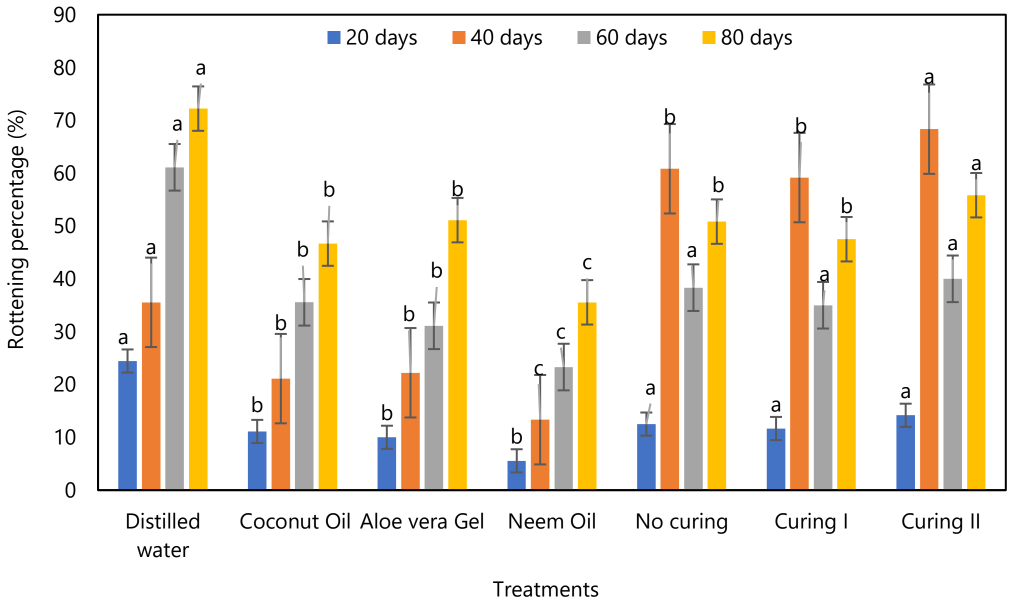

Figure 4. Rotting percentages of onion bulb.

3.4. Effect on Sprout Length of Onion

ANOVA revealed highly significant differences among bio-extract treatments for sprout length at 20, 40, 60, and 80 days. The minimum sprout length was observed in onion bulbs treated with neem extract (Table 1), which was statistically similar to coconut oil and statistically significant with aloe gel. Maximum sprout length was observed in onion bulbs treated with distilled water. Analysis of variance revealed that curing was statistically significant in sprout length at 20 and 40 days where control showed maximum sprout length and curing for 5 days showed minimum which was indifferent with curing for 10 days. This study is supported by Lieberman et al. (2006) who state that coconut oil prevents sprouting of onion. Similarly, neem oil inhibits germination (Mondal et al., 2009; Meena, 2012).

3.5. Effect on Visual Color Change of Onion

There was a gradual increase in the color rating as the color of the bulb faded as the number of days in storage increased. The color rating is on a scale of 1 to 5 as shown in Table 2. In the first 20 days, the rating was 1 similar in all treatments. At 60 days, ANOVA revealed highly significant differences among bio-extract treatments for color treatment at storage. The onion treated with neem bio-extract shows the maximum color retention with a minimum rating of 1, followed by aloe gel and coconut oil with a similar rating of 2 showing deep carmine color at 60 days. The onion bulb treated with distilled water shows the maximum color fading with a rating of 4 (Spanish Pink). At 80 days, the onion treated with neem bio-extract showed the maximum color retention with a minimum rating of 2 (deep carmine), which shows the minimum quality loss, followed by coconut oil (3) and aloe gel (4). The maximum loss of color occurs in the onion bulb treated with distilled water with a rating of 5 (Queen Pink). Coconut oil has a tremendous effect on maintaining the original peel color (Nasrin et al, 2020). This study is supported by Lieberman et al. (2006) who mentioned that coconut oil prevents the fading of the original peel color. Similarly, neem oil inhibits the loss of peel color (Meena, 2012).

Table 1. Sprouting length of onions under different post-harvest treatments during storage.

Treatment	Sprouting length (cm)			
Bio-extract	20 days	40 days	60 days	80 days
Distilled water	5.44[a]	9.22[a]	20.11[a]	30.55[a]
Coconut Oil (2%)	1.66[c]	4.11[b]	8.78[c]	12.89[c]
Aloe vera Gel (2%)	3.77[b]	10.11[a]	17.44[b]	24.89[b]
Neem Oil (2%)	1.77[c]	5.56[c]	13[d]	21.11[d]
LSD (0.05)	1.05	2.03	2.23	3.042
SEm	0.32	0.60	0.66	0.90
F test	***	***	***	***
CV, %	4.11	6.29	5.44	3.98
Curing				
0 Days	3.17[a]	8.58[a]	14.92[a]	20.75[a]
5 Days	3.67[ab]	7.25[ab]	15[a]	23.5[a]
10 Days	2.67[b]	5.92[b]	14.58[a]	22.83[a]
LSD (0.05)	0.91	1.75	1.93	2.63
SEm	0.36	0.69	0.76	1.04
F test	*	*	ns	ns
CV (%)	3.37	8.71	8.913	6.852
Interaction	ns	ns	ns	ns

Note: the common letter(s)within the column indicates a non-significant difference based on Duncan multiple range tests (DMRT) at a 5% level of significance (Significance. codes: '***'= 0.01; '**' = 0.05; '*'= 0.1 for F-test).

Table 2. Color rating of visual change of onions under different post-harvest treatments during storage.

Treatment	Color Rating (1 to 5 Scale)			
Bio-extract	20 days	40 days	60 days	80 days
Distilled water	1[a]	2[a]	4[a]	5[a]
Coconut Oil (2%)	1[a]	1[b]	2[b]	3[b]
Aloe vera Gel (2%)	1[a]	2[a]	2[a]	4[a]
Neem Oil (2%)	1[a]	1[a]	1[c]	2[c]
LSD (0.05)	4.32e-16	0.71	0.58	0.54
SEm	1.28e-16	0.21	0.17	0.16
F test	ns	*	***	***
CV (%)	4.44e-14	34.87	20.60	15.31
Curing				
0 Days	1[a]	2[a]	3[a]	4[a]
5 Days	1[a]	1[b]	2[b]	4[b]
10 Days	1[a]	2[a]	2[b]	3[b]
LSD (0.05)	3.74e-16	0.61	0.51	0.47
SEm	1.5	0.24	0.20	0.18
F test	ns	*	*	*
CV (%)	4.44e-14	34.871	20.60	15.31
Interaction	ns	ns	ns	ns

Note: the common letter(s)within the column indicates a non-significant difference based on Duncan multiple range tests (DMRT) at a 5% level of significance (Significance. codes: '***'= 0.01; '**' = 0.05; '*'= 0.1 for F-test).

3.6. Effect on Total Soluble Solid (°Brix) of Onion

ANOVA revealed highly significant differences among plant extract treatments for TSS at 20, 40, and 60 days. The minimum TSS was found in onion bulbs treated with distilled water (Table 3). The maximum TSS was found in onion bulbs treated with neem extract, which was statistically similar to the onion treated with aloe gel. During curing, the maximum TSS was found in onion bulbs cured for 10 days, which was statistically similar to curing for 5 days. The minimum was found in the uncured onions. At 80 days, the maximum TSS was found in onion bulbs treated with neem extract (8.433 °Brix) which was statistically similar to aloe gel and coconut oil. The minimum, 4.088 °Brix, was found in the bulbs treated with distilled water. The maximum TSS was found in onion bulbs treated with Curing II (7.575 °Brix), which was statistically similar to Curing I. The minimum, 5.841°Brix, was found in uncured onions. Several studies have shown that the total soluble solids decreased during the postharvest period (Nasef, 2018; Kahramanoğlu and Usanmaz, 2019). These results were supported by Han et al. (2016) for fresh-cut Welsh onions, where the soluble solids content decreased after 7 days of storage at 4 °C. Application of edible coatings delayed the change in the soluble solids content of fresh and minimally processed onions (Medina et al., 2022). *Aloe vera* gel coating delayed changes in soluble solids concentration and TA (Khaliq et al., 2019).

Table 3. TSS of onions under different post-harvest treatments during storage.

Treatment	Total Soluble Solid			
Bio-extract	20 days	40 days	60 days	80 days
Distilled water	12.31[c]	8.12[a]	6.033[c]	4.088[c]
Coconut Oil (2%)	13.44[b]	10.12[a]	8.911[b]	6.455[b]
Aloe vera Gel (2%)	13.666[ab]	12.65[a]	10.47[a]	8.433[a]
Neem Oil (2%)	14.066[a]	12.71[c]	10.23[a]	8.433[a]
LSD (0.05)	0.4589	0.578	0.866	0.676
SEm	0.1361	0.198	0.257	0.20
F test	***	***	***	***
CV (%)	3.52	6.29	9.99	10.15
Grand Mean	13.37	10.90	8.913	6.852
Curing				
0 Days	13.20[b]	10.57[b]	7.825[a]	5.841[b]
5 Days	13.28[ab]	10.783[ab]	9.183[a]	7.141[a]
10 Days	13.63[a]	11.35[a]	9.733[b]	7.575[a]
LSD (0.05)	0.397	0.578	0.75	0.586
SEm	0.157	0.228	0.297	0.231
F test	*	*	***	***
CV (%)	3.52	6.29	9.99	10.15
Grand Mean	13.37	10.90	8.913	6.852
Interaction	ns	ns	ns	ns

Note: the common letter(s)within the column indicates a non-significant difference based on Duncan multiple range tests (DMRT) at a 5% level of significance (Significance. codes: '***'= 0.01; '**' = 0.05; '*'= 0.1 for F-test).

3.7. Effect on Titrable Acidity of Onion

ANOVA revealed highly significant differences among plant extract treatments for TA at 20, 40, and 60 days. The maximum TA was found in onion bulbs treated with neem extract, which was statistically significant with coconut oil and aloe gel, and the minimum was found in bulbs treated with distilled water (Table 4). Among the curing days, maximum TA was found in onion bulbs cured for 10 days which was statistically similar to curing for 5 days and minimum was found in uncured bulbs. At 80 days, ANOVA revealed highly significant differences among the plant extract treatments for TA at storage. The maximum TA was found in onion bulbs treated with neem extract at 0.508 g/l. The minimum, 0.33 g/L was found in the bulbs treated with distilled water. The maximum TA was found in onion bulbs treated with Curing II at 0.425 g/L, which was statistically similar to Curing I, 0.40 g/L, and the minimum, 0.33 g/L, was found in no curing. Each variety has a unique total TA and total TSS, and the method of curing affects these characteristics (Grangeiro et al., 2008). *Aloe vera* gel coating delays changes in TA (Khaliq et al., 2019). The results were supported by Han et al. (2016) for fresh-cut Welsh onions, where the TA content decreased after 7 days of storage at 4 °C. Application of an edible coating delayed the change in TA (content of fresh and minimally processed onions (Medina et al., 2022).

3.8. Effect on TSS/TA Ratio of Onion

ANOVA revealed highly significant differences among plant extract treatments for TSS/TA at 20, 40, and 60 days. The maximum TSS/TA was found in onion bulbs treated with aloe gel, which was statistically significant for onions treated with coconut oil and neem extract (Table 5). The minimum was found in bulbs treated with distilled water. Analysis of variance revealed that curing was not statistically significant. At 80 days, ANOVA revealed highly significant differences among plant extract treatments for TSS/TA at storage. The maximum TSS/TA was found in onion bulbs treated with aloe gel at 26.07, which was statistically significant with onions treated with coconut oil at 18.50 and neem extract at 16.73. A minimum of 14.02 was found in bulbs treated with distilled water. *Aloe vera* gel coating delayed the changes in TSS/TA ratio (Khaliq et al., 2019). Several studies revealed that the total soluble solids decreased during the postharvest period (Nasef, 2018; Kahramanoğlu and Usanmaz, 2019). The application of edible coatings delayed the change in the TSS/TA ratio content of fresh and minimally processed products (Medina et al., 2022).

Table 4. TA of onions under different post-harvest treatments during storage.

Treatment	Titrable Acidity			
Bio-extract	20 days	40 days	60 days	80 days
Distilled water	0.77^{a}	0.63^{c}	0.63^{c}	0.33^{a}
Coconut Oil (2%)	0.83^{a}	0.83^{a}	0.81^{a}	0.37^{b}
Aloe vera Gel (2%)	0.67^{a}	0.55^{b}	0.558^{b}	0.33^{a}
Neem Oil (2%)	0.7^{b}	0.67^{c}	0.81^{a}	0.51^{a}
LSD (0.05)	0.0842	0.069	0.093	0.062
SEm	0.033	0.027	0.036	0.024
F test	*	***	**	***
CV (%)	3.09	2.37	3.99	1.15
Grand Mean	0.76	0.665	0.55	0.38
Curing				
0 Days	0.775^{a}	0.64^{a}	0.496^{a}	0.33^{a}
5 Days	0.733^{a}	0.66^{a}	0.558^{ab}	0.4^{a}
10 Days	0.783^{a}	0.686^{a}	0.61^{b}	0.425^{b}
LSD (0.05)	0.097	0.069	0.093	0.062
SEm	0.033	0.27	0.036	0.024
F test	ns	ns	*	*
CV (%)	3.09	2.37	3.99	1.15
Grand Mean	0.76	0.665	0.55	0.38
Interaction	ns	ns	ns	ns

Note: the common letter(s)within the column indicates a non-significant difference based on Duncan multiple range tests (DMRT) at a 5% level of significance (Significance. codes: '***'= 0.01; '**' = 0.05; '*'= 0.1 for F-test).

Table 5. TA/TSS ratio of onions under different post-harvest treatments during storage.

Treatment	TSS/TA			
Plant extract	20 days	40 days	60 days	80 days
Distilled water	16.02^{b}	12.986^{c}	11.69^{c}	14.02^{c}
Coconut Oil (2%)	17.51b^{b}	15.52b^{b}	17.53^{b}	18.50^{b}
Aloe vera Gel (2%)	20.87^{a}	23.31^{a}	22.01^{a}	26.07^{b}
Neem Oil (2%)	16.986b^{b}	15.67b^{b}	15.61^{b}	16.738^{b}
LSD (0.05)	2.327	2.2821	3.33	4.47
SEm	0.69	0.677	0.98	1.328
F test	**	***	***	***
CV (%)	13.39	13.90	20.491	24.227
Grand Mean	17.85	16.87	16.71	18.99
Curing				
0 Day	17.36^{a}	16.75^{a}	15.954^{a}	18.767^{a}
5 Days	18.567^{a}	16.84^{a}	17.208^{a}	19.47^{a}
10 Days	17.62^{a}	17.023^{a}	16.98^{a}	18.74^{a}
LSD (0.05)	2.0153	1.9763	2.88	3.877
SEm	0.7972	0.7818	1.1416	1.53
F test	ns	ns	ns	ns
CV (%)	13.398	13.90	20.491	24.227
Grand Mean	17.852	16.87	16.71	18.99
Interaction F test	ns	ns	ns	ns

Note: the common letter(s)within the column indicates a non-significant difference based on Duncan multiple range tests (DMRT) at a 5% level of significance (Significance codes: '***'= 0.01; '**' = 0.05; '*'= 0.1 for F-test).

3.9. Correlation Studies

Among the observed parameters, weight and decay percentage at 20, 60, and 80 days were positively correlated, and color rating was positively correlated with decay percentage at 80 days (Figure 5). More rotten onion bulbs showed higher color fading. TSS content was negatively correlated with weight and rot percentage. The higher the soluble solids content, the higher the percentage of dry matter, and therefore the bulbs are better preserved (Mallor, 2008). Weight and TSS were linearly correlated and influenced shelf life (Valverde-Miranda et al., 2021). Several studies revealed that the total soluble solids decreased during the postharvest period (Nasef, 2018; Kahramanoğlu and Usanmaz, 2019). The linear relationship between dry matter content (DMC) and TSS of cucumbers (Davies & Kempton, 1976; Verheul et al., 2013).

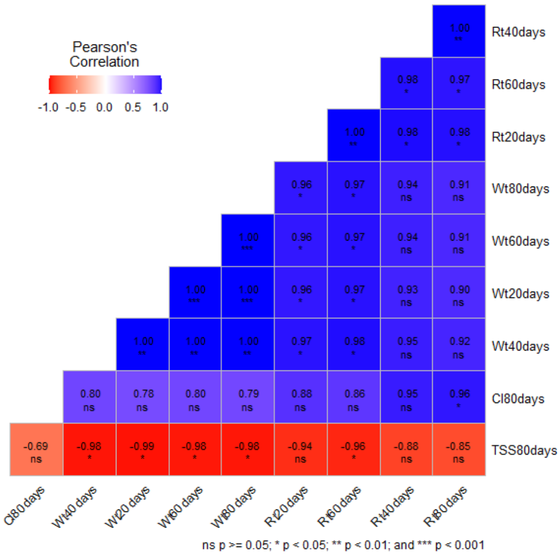

Figure 5. Heat map showing Pearson correlation (r) of different parameters.

4. Conclusion

Based on the evidence and findings of the experimental trial, it was evident that onion bulbs treated with neem extract had longer shelf life, minimum physiological weight loss, minimum sprouting, minimum rotting, minimum sprout length, maximum total soluble solids content with minimum loss of TSS, minimum titrable acidity and minimum visual color rating (1) followed by coconut oil and *Aloe vera*. The shelf life of onions can be improved, and freshness can be maintained for a longer period by using neem extract. Curing for 5 days showed the best quality and shelf life. Thus, based on the above findings, we recommend farmers use Neem extract and curing for 5 days to improve the shelf life of onions and maintain minimum post-harvest losses.

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