Evaluation of Guso (Kappaphycus alvarezii) Seaweeds as Edible Coating to Eggplant (Solanum melongena var. Calixto) Stored under Ambient Conditions

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Evaluation of Guso *(Kappaphycus alvarezii)* Seaweeds as Edible Coating to Eggplant *(Solanum melongena* var. Calixto) stored under Ambient Conditions

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Abstract: *This study investigated the efficacy of guso seaweed (Kappaphycus alvarezii) extract as an edible coating to preserve eggplant quality without refrigeration. Eggplants were coated with guso extract at varying concentrations (1%, 2%, 3%, and 4%) and stored under ambient conditions for 22 days. The results demonstrated significant improvements in key quality parameters, including weight loss, Visual Quality Rating (VQR), shelf life, Phomopsis Rot Index (PRI), firmness, pH, total soluble solids (TSS), and water activity, compared to uncoated control samples. Among the different concentrations, the 4% guso extract treatment provided the most effective preservation of eggplant quality. This study concludes that K. alvarezii extract has substantial potential for use as an edible coating for fresh fruits and vegetables.*

Keywords: seaweeds; eggplant; edible coating; ambient condition; quality parameters

1. INTRODUCTION

Eggplant *(Solanum melongena* L.) is a popular vegetable and economically important crop in Asia [1]. In the Philippines, 13.62 thousand hectares of farmland were cultivated with eggplant in 2023. Production data from the Philippine Statistics Authority [2] indicate that eggplant production reached 102.9 thousand metric tons. Postharvest handling and shelf-life of these produce are major challenges for farmers. The rapid loss of moisture after harvesting causes the peel to shrink, the sepal and pedicel to turn brown, and a decrease in surface glossiness, all of which reduce the fruit's marketability under ambient conditions [3]. Polyphenol oxidases (PPOs) oxidize phenolic compounds, leading to browning and degradation of the eggplant[4]. These fruits often face various quality issues, including rapid surface shrinkage, loss of skin glossiness, reduced color, and drying of the pedicel. These factors dramatically shorten the shelf-life of the fruits to 2–3 days under ambient conditions [4]. Different methods for preserving the shelf life of agricultural products, such as dehumidification systems, have been explored [5].

Moreover, various post-harvest treatment options are available, with edible coatings recognized as one of the most effective alternatives. Edible coatings are thin layers applied to food surfaces to preserve and improve food quality. This method is commonly used after harvesting, especially for perishable foods such as fruits and vegetables [6]. Seaweeds, which are natural marine algae, possess qualities that function as natural preservatives, prolonging the shelf life of perishable goods without causing adverse effects [7]. Studies have explored how seaweed coatings affect the shelf life of fruits and vegetables, including tomatoes and papayas [6,7].

Edible coatings offer a promising approach to extending the shelf life and maintaining the quality of perishable agricultural products. These coatings serve multiple functions, including reducing moisture loss, delaying ripening, and protecting the fruit from mechanical damage and microbial contamination. The application of edible coatings is especially critical for commodities with high perishability, such as fruits and vegetables, which are often susceptible to rapid deterioration.

Seaweeds have emerged as a particularly interesting source for edible coatings due to their natural preservative properties. They contain polysaccharides, such as alginates, carrageenans, and agar, which form a protective layer over the food surface. This layer acts as a barrier to moisture and gas exchange, which helps in slowing down the ripening process and preserving the freshness of the produce. Additionally, seaweed-based coatings can be enriched with bioactive compounds that have antioxidant and antimicrobial properties, further enhancing their preservative effects.

Despite the known benefits, the effectiveness of seaweed coatings can vary based on several factors, including the type of seaweed used, its concentration, and the specific conditions of storage. For example, the optimal concentration of seaweed extract in the coating formulation needs to be determined to balance the coating's effectiveness with its impact on the fruit's sensory attributes, such as taste and texture.

The focus of this study is on eggplants, a widely consumed vegetable that is particularly sensitive to postharvest quality deterioration. By examining the impact of different seaweed concentrations (1%, 2%, 3%, and 4%) on eggplant quality under ambient storage conditions, this research aims to provide valuable insights into optimizing seaweed-based coatings for this specific crop. The findings could contribute to developing effective post-harvest management strategies that enhance the shelf life and market value of eggplants, benefiting both producers and consumers.

2. MATERIAL AND METHODS

2.1 Sample Preparation

This study used 600 eggplants (var. Calixto) that were harvested from Buenavista, Agusan del Norte, and promptly transported to the postharvest laboratory at Caraga State University. They were washed, air-dried, and prepared. Guso seaweeds, procured from Langihan Market in Butuan City, Agusan del Norte, Philippines, were cut, dried at 50°C for 24 hours, and pretreated with distilled water to reduce salt content [9]. After preparation, the seaweeds were stored at room temperature for carrageenan extraction.

2.2 Preparation of Polysaccharide-Based Guso Seaweeds Coating

During the preparation of the coating, the dried guso was boiled in water to extract the gel.

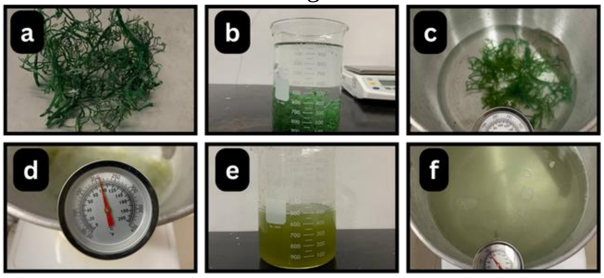

Figure 1. Major procedures for Polysaccharide-Based Edible coating. (a) Weighing dried seaweeds; (b) Immersing in 1000 mL distilled water; (c) Boiling seaweeds; (d) Measuring solution temperature; (e) 500 mL seaweed extracts; (f) Diluting with distilled water

Figure 1 shows the procedure for preparing the polysaccharide-based edible coating. Ten (10) grams of dried guso seaweeds were neutralized by immersing them in distilled water for 10 minutes to remove contaminants such as salt. The seaweeds were then boiled in distilled water for 15 minutes at 100 °C. The seaweed extract was cooled and filtered using a strainer to obtain 500 mL of concentrated seaweed gel. The coating was produced by diluting the concentrated gel with distilled water. Dilution involved mixing 50 mL, 100 mL, 150 mL, and 200 mL of seaweed gel with 5000 mL of distilled water (v/v), resulting in concentrations of 1%, 2%, 3%, and 4%, respectively.

Table 1. Polysaccharides-Based Coating under Different Treatment

TREATMENTS	COMPOSITION
T0 (Control)	Distilled Water
T1	1% Seaweed Extract
T2	2% Seaweed Extract
T3	3% Seaweed Extract
T4	4% Seaweed Extract

2.3 Application of the coating

The experiment used a Complete Randomized Design (CRD) with five treatments and three replications per treatment, involving 10 eggplants per replication. In total, 150 eggplants were used for non-destructive testing and 450 for destructive testing. Samples were dipped for 2 minutes in different treatments: T0 (distilled water), T1 (1% seaweed extract), T2 (2% seaweed extract), T3 (3% seaweed extract), and T4 (4% seaweed extract). The coated samples were air-dried at room temperature. The air-dried samples were placed in labeled plastic trays and crates on rack storage. Measurements of various physicochemical properties were taken every other day until degradation.

2.4 Quality Parameters

2.4.1 *Percent Weight Loss*

Physiological weight loss was determined using a precision electronic balance (Sartorius BSA2202S-CW) before and after storage at two-day intervals. The percent weight loss was calculated according to the standard method of AOAC [10].

2.4.2 Visual Quality and Shelf life

Visual quality rating (VQR) was assessed to gauge the fruit's visual appeal during storage, following Valida et al. [11] .The duration required to achieve a VQR 5 rating indicated the potential postharvest viability of eggplant fruits stored under ambient conditions.

Table 2. Visual Quality Rating, Valida et al. [11]

VQR	DESCRIPTION
9	Excellent, field fresh or no detect
7	Good, defect minor
5	Fair, defects minor, the limit of marketability
3	Poor, defects serious, the limit of edibility
1	Non-edible under usual condition

2.4.3 Color

The LS172 colorimeter model was used to detect color differences in fruit samples, with measurement taken every other day. Measurements were taken at the top, middle, and bottom of the fruit.

2.4.4 Phomopsis Rot Index

Visual observations were conducted for 22 days with assessments made at two (2) days intervals. These evaluations were performed using the Phomopsis Rot Index (PRI) method by Valida et al. [11].

Table 3. Phomopsis Rot Index, Valida et al. [11]

PRI	DESCRIPTION
5	Extensive rotting
4	31-50% rotting
3	11-30% rotting
2	1-10% rotting
1	No symptoms of rot

2.4.5 Firmness

Fruit firmness was evaluated using the Lutron Precision Fruit Sclerometer, Model FR- 5120. Samples from each replication were selected, and the force required for penetration was measured by placing the probe at two opposing points on the equatorial zone of each fruit.

2.4.6 pH

Eggplant fruits from each treatment were sliced, blended, and strained. The pH level of the sample juice was determined using a digital pH meter (Apera Instruments, PH800 Laboratory Benchtop PH Meter Kit).

2.4.7 Total Soluble Solid

TSS content was determined by a Digital Brix and Sucrose Refractometer standardized with the distilled water and placing 1-3 drops of juice samples onto the instrument’s prism, and reading were recorded periodically throughout the storage period.

2.4.8 Water Activity

The water activity measurement of Apriliyani et al. [12] was conducted using a water activity meter (WA-60A).

Subsequently, samples weighing five grams each were sliced, weighed, and inserted into the meter. After a five (5) minutes interval, reading was recorded.

2.4.9 Statistical Analysis

Eggplant quality was analyzed using the open-source Statistical Tool for Agricultural Research (STAR) software developed by the International Rice Research Institute. ANOVA identified variation sources like storage days and treatments. Pairwise comparison of treatment means was determined using Fisher's Least Significant Difference at $p \leq 0.05$.

3. RESULT AND DISCUSSION

3.1 Percent Weight Loss

Figure 2 shows the percent weight loss (PWL) trends observed throughout the experiment, a crucial indicator of post-harvest storage potential for fresh vegetables and fruits. The control sample showed weight loss of 4.53% on day 2 and continuously increased to 23.53% at day 18. The control samples were removed on day 18 due to its severely rotten characteristics. The PWL reflects water and organic matter loss due to metabolic processes like respiration and transpiration, influenced by the storage condition. A similar result was obtained by Ban et al. [13] wherein their research revealed that weight loss in all treated eggplant fruits increased during storage. Though transpiration is the primary process, respiration can considerably contribute to weight loss, particularly at greater humidity levels where transpiration rates are minimal [14] .

Moreover, T4 exhibited the lowest weight loss among the treatments, contrasting with the control samples showing the highest value of weight loss. Based on this, the study of Prabha et al. [15] justifies that *Kappaphycus alvarezii* contain bioactive compounds such as phenolic compound, tannins, terpenes and flavonoids which act as antioxidant. Aligned with this was the statement supported by Nawab et al., [16] those edible coatings act as a semi-permeable barrier to gas exchange and water vapor, altering respiration rate, reducing weight loss, and delaying senescence.

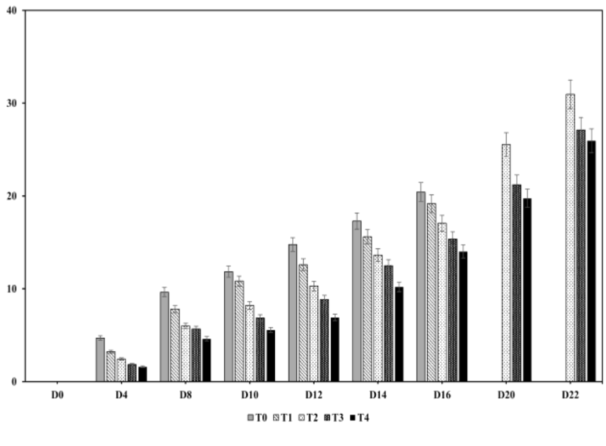

Figure 2. Percent Weight Loss of eggplant on different treatment and stored under ambient condition for 22 days.

3.2 Visual Rating Quality

The shelf life is the period during which a coated product retains its desired qualities, such as freshness and texture. It extends from production until the product begins to deteriorate significantly, affecting its appeal to consumers. Figure 3 illustrates the VQR (Visual Quality Rating) results for coated and uncoated eggplant fruits, which is a subjective grading method. Throughout storage, the control exhibited the lowest VQR scores, while the T4 coating maintained the highest ratings.

Lufe et al. [17] noted that physiological water loss is a significant issue in post-harvest fruit, leading to issues such as shriveling, wilting, browning, texture loss, and reduced flavor. Coating helps to slow ripening and deterioration, thereby improving quality and preserving bioactive compounds [18]. A similar study by Siringul et al. [19] found that seaweed-based edible coatings could reduce weight loss and limit microorganism development compared to untreated samples. Their study demonstrated that certain treatments effectively serve as substitutes for maintaining natural quality and extending shelf life by up to 14 days.

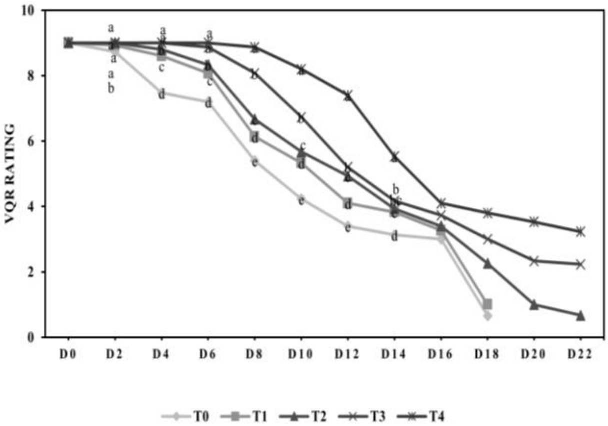

Figure 3. Visual Quality Rating of eggplant on different treatment and stored under ambient condition for 22 days.

3.3 Phomopsis Rot Index

Phomopsis blight, caused by *Phomopsis vexans*, can result in leaf blight and fruit rot in eggplants. Figure 4 presents the Phomopsis Rot Index (PRI) for eggplant fruits with and without edible coatings. Most of the seaweed-coated fruits exhibited a lower PRI compared to the control samples. The control and T1 samples showed the highest PRI throughout the storage period. In dry conditions, diseased fruits tend to become dry, shriveled, and blackened [20]. On the final day (Day 22), the sample coated with 4% *Kappaphycus alvarezii* exhibited a lower PRI, likely due to antimicrobial or antioxidant effects that mitigate moisture loss, oxidation, or tissue damage.

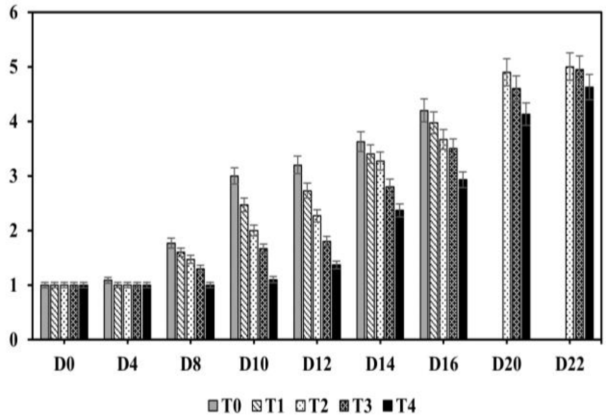

Figure 4. Phomopsis Rot Index of eggplant on different treatment and stored under ambient condition for 22 days.

3.4 Shelf Life

Figure 5 illustrates the shelf-life data for eggplant fruits treated with different concentrations of seaweed-based edible coatings. The study observed a significant extension in shelf life due to the interaction effect of the seaweed extracts. Control samples had a shelf life of 9 days, while treated samples exhibited significantly longer shelf lives. The most effective treatment was T4, which preserved the samples for nearly 15 days. This improvement in shelf life can be attributed to the polysaccharide-based coatings' ability to selectively permeate oxygen and carbon dioxide gases, thereby creating a modified atmosphere around the fruit and prolonging its shelf life [22]. The findings indicate that uncoated eggplants had a shorter shelf life at room temperature due to increased respiration, transpiration, and susceptibility to microbial spoilage. These results are consistent with the findings of Gonzales and Benitez [23], who reported a 10-day extension in eggplant shelf life using alginate and cornstarch as edible coatings.

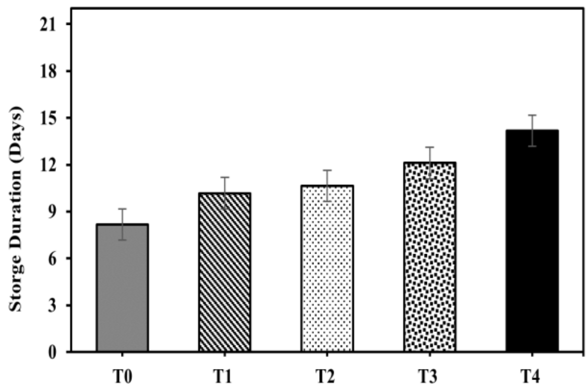

Figure 5. Shelf life of eggplant on different treatment and stored under ambient condition for 22 days.

3.5 Color

In postharvest handling, food processing research, and industry, color is one of the most extensively evaluated quality parameters, significantly influencing consumer choice and preferences [24]. Fresh eggplants are typically bright purple, but ripening or postharvest storage can cause them to turn brown or dull. This color change is often due to oxidative reactions triggered by exposure to light and oxygen, along with enzymatic browning reactions [25]. As shown in Figure 6, from Day 4 to Day 14, all treatments exhibited a consistent increase in color difference. However, from Day 16 to Day 22, no significant differences were observed between treatments. This trend aligns with the findings of Cortbaoui et al. [26] The data indicates that a higher percentage of seaweed extract results in minimal color differences, suggesting its effectiveness in slowing enzymatic browning. Seaweed extract coatings provide a protective barrier against oxygen exposure, delaying browning by inhibiting enzyme activity and thus extending the shelf life of eggplants.

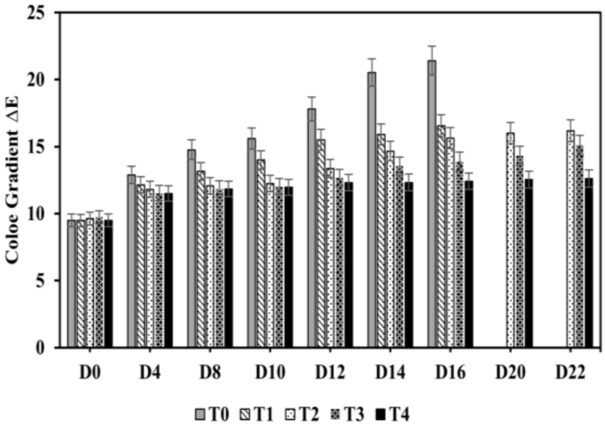

Figure 6. Color difference of eggplant on different treatment and stored under ambient condition for 22 days.

3.6 Firmness

Changes in firmness are crucial for assessing fruit quality and ripening. During eggplant maturation, cell wall modifications occur, facilitated by enzymes such as polygalacturonase, leading to fruit softening. As shown in Figure 7, the control sample exhibited the lowest firmness values, indicating the highest level of softening. This decrease in firmness is attributed to moisture loss [27]. However, the T4 treatment resulted in the smallest decrease in firmness throughout the storage period, likely due to its reduced oxygen permeability and respiration rates, which delay ripening and hydrolysis activities that contribute to fruit softening [8].

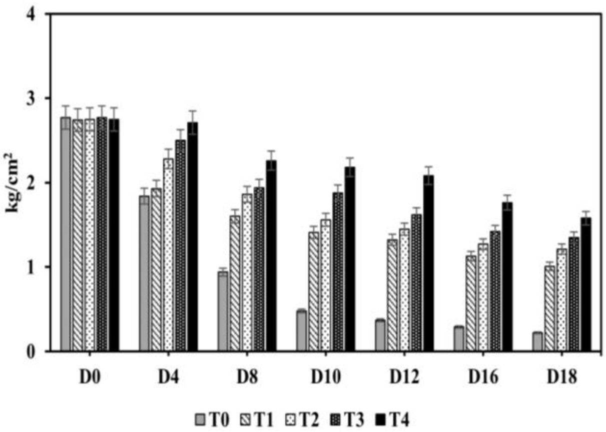

Figure 7. Firmness of eggplant on different treatment and stored under ambient condition for 22 days.

Furthermore, the seaweed coating's concentration effectively reduced oxygen permeability and respiration rates, which delays the ripening process and potentially inhibits hydrolysis activities that lead to softening [28]. Edible coatings serve to mitigate moisture loss and prevent fruit softening by providing a barrier layer around the fruit [29] . These findings are consistent with those of Hamzah et al. [28], who reported that higher seaweed concentrations in papaya coatings better preserved firmness.

3.7 pH

Figure 8 highlights pH measurements for four treatments over 18 days. The control samples exhibited a significant increase in pH, while the T4 samples showed only a slight increase throughout the storage period. This observation is consistent with the study by Moraes [30], which reported that control samples experienced a greater pH increase during storage due to the consumption of organic acids in enzymatic reactions during respiration, leading to rapid respiration rates and a rise in pH. They also observed that pH elevation was more pronounced in uncoated fruit compared to those coated with alginate and carrageenan, suggesting that coatings slow down pH changes in fruit.

Additionally, the rise in pH may be related to a decrease in the availability of organic acids and a lower rate of their synthesis [31]. Radi et al. [32], reported that during ripening, organic acids are used as substrates in respiratory metabolism, resulting in decreased total acidity (TA) and increased pH and total soluble solids (TSS).

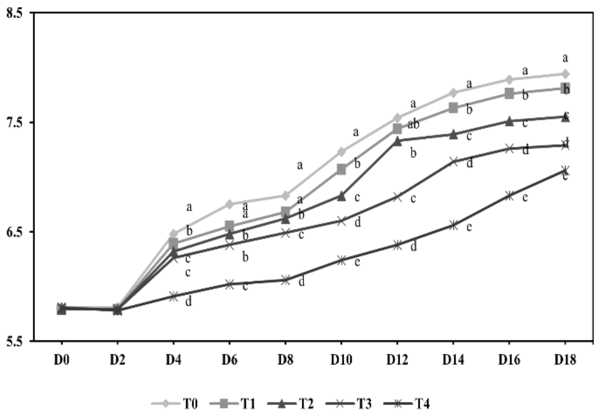

Figure 8. The pH of eggplant on different treatment and stored under ambient condition for 22 days.

3.8 Total Soluble Solid

Total soluble solids (TSS) reflect the concentration of dissolved compounds in a liquid. In eggplant fruits stored under ambient conditions, both coated and control samples showed increasing TSS values as storage days progressed. Figure 9 illustrates that the control samples exhibited the highest TSS values, while the coated samples, particularly the T4 treatment, showed slightly lower TSS values. These findings align with those of Lutipula & Abdullah [33], who observed similar TSS changes in minimally processed mangoes during storage. The increase in TSS may result from sugar synthesis due to the utilization of acids and starches for metabolic activities, leading to moisture loss and the breakdown of cell-wall polysaccharides [34]. A similar study conducted by Suhaimi et al. also observed that the application of the edible coating resulted in a slight reduction in TSS, possibly due to altered gas exchange and reduced respiration [35].

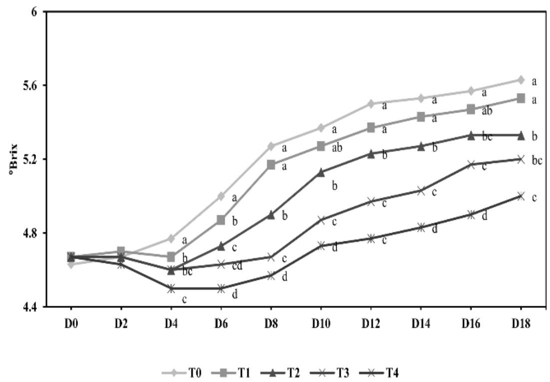

Figure 9. Total Soluble Solid of eggplant on different treatment and stored under ambient condition for 22 days.

3.9 Water Activity

Water activity is an important factor in microbial protection and food preservation, influencing microbial development and metabolic activity [36]. It directly impacts degradation, texture, color, and nutritional retention of food. Water activity estimates the availability of water for enzymatic, chemical, or microbiological actions, which affects food shelf life [37]. Figure 10 shows that the control sample exhibited increasing water activity, indicating potential degradation or rotting. Microbial contamination or enzymatic activity can disrupt cellular structure, leading to increased water activity [38]. The T4 treatment exhibited the lowest water activity value throughout the storage period, indicating effective preservation. Lower water activity reduces the risk of microbial growth [39], demonstrating the efficacy of the T4 (4% guso extract) edible coating in preventing rapid increases in water activity.

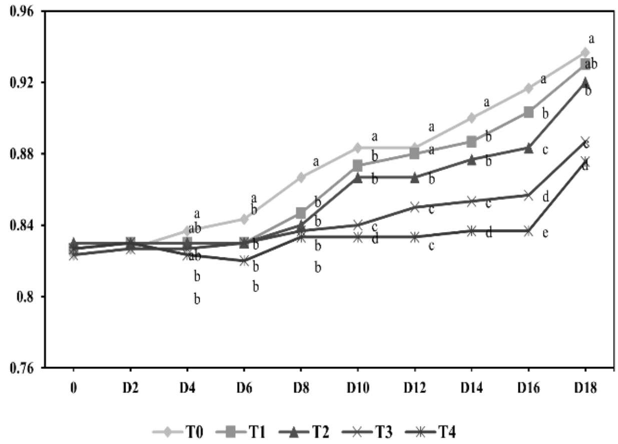

Figure 10. Water Activity of eggplant on different treatment and stored under ambient condition for 22 days.

4. CONCLUSION

This study demonstrated that seaweed-based edible coatings significantly prolong the shelf life of eggplants stored under ambient conditions for 18 days. In terms of weight loss, all samples treated with guso seaweed (*Kappaphycus alvarezii*) extracts exhibited a gradual decrease in weight loss compared to the untreated control samples. Notably, the T4 treatment (4% *K. alvarezii* extract) displayed the lowest weight loss percentage, at 59.95%, over the entire storage period. Additionally, the eggplants treated with 4% *K. alvarezii* (T4) showed the least reduction in firmness. The treated samples also demonstrated enhanced pH and total soluble solids (TSS) levels, achieving significantly lower values than the control samples. The 4% *K. alvarezii* (T4) maintained pH and TSS values of 7.06 and 5 °Brix, respectively, throughout the storage period.

Furthermore, the coated eggplant samples consistently obtained higher mean Visual Quality Ratings (VQR) compared to the uncoated samples until the end of the storage period. Among all treatments, the 4% *K. alvarezii* seaweed extract proved to be the most effective and desirable for preserving eggplant quality during storage. Thus, seaweed polysaccharides from *K. alvarezii* exhibit considerable potential for edible coating development.

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