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Effects of Leek Powder and Sunflower Oil in Guar Gum Edible Coating on the Preservation of Mushrooms (*Agaricus bisporus*)

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Abstract

This study investigated the effects of various guar gum edible coating formulations, incorporating different proportions of waste leek powder and sunflower oil, on weight loss, color parameters (L*, a*, b* values, and ΔE), texture, and shrinkage of Agaricus bisporus mushrooms during a 7-day storage period. The goal was to assess the potential impact of these coatings on preserving the mushrooms' quality over time. The results showed that the coatings had a significant effect on reducing weight loss compared to uncoated samples. The lowest weight loss was observed in the 0.5% leek powder and no sunflower oil, while the highest was in 2.5% leek powder and 0.1% sunflower oil. Shrinkage was also positively affected by the coatings, with 1.5% leek powder and no sunflower oil showing the most promising results. The L* values of the coated samples declined slightly, indicating better color preservation, while the a* values exhibited stable redness/greenness. On the other hand, b* values increased, indicating an increase in yellowness during storage. The ΔE values were lower for the coated samples, suggesting less color deviation compared to uncoated ones. Overall, the study indicates that these edible coatings have the potential to maintain the quality of mushrooms during storage, leading to better preservation and extended shelf life.

Key Words: *Edible coating, Mushroom, Leek powder, Sunflower oil*

Introduction

In Türkiye, the cultivation of edible mushrooms, particularly the Agaricus bisporus species, has shown significant growth in recent years. According to estimates, the production of cultivated mushrooms was around 65,000 tons in 2018, and it is projected to reach 100,000 tons by the year 2025 (Eren and Pekşen, 2019). Among the various mushroom cultivation practices, Agaricus bisporus remains at the forefront due to its popularity and economic significance in the country. This upward trend reflects the increasing interest in mushroom production as a viable and profitable agricultural activity in Türkiye. However, the short shelf life of mushrooms constitutes a major problem in the field of mushroom production and preservation. The short shelf life of mushrooms can be attributed to the absence of a protective cuticle, which leaves them vulnerable to damage and water loss, consequently leading to microbial attacks (Zhang et al., 2019). To solve the problem, edible packaging options can be applied to mushrooms to prolong the freshness. Edible films or coatings create a protective barrier for mushrooms, offering benefits such as gas conditioning, delayed gas transfer, reduced moisture and flavor loss, slower color change, and improved appearance (Nasiri et al., 2018). While films are the structures that can be wrapped around food after molding, coatings involve directly applying liquid edible coating material to protect the food (Ali et al., 2010; Thakur et al., 2021).

Research has focused on preparing edible films and coating by environmentally degradable materials that are derived from plants, animals, and even their by-products or waste. Up to date, xanthan gum, alginate (Jiang 2013), chitosan (Nair et al., 2020), aloe vera (Kumar et al., 2023), and tragacanth gum (Nasiri et al., 2018) are commonly used in the production of edible coatings due to their biodegradability, recyclability, and sustainability. Although biopolymers have advantages, they possess poor mechanical and barrier properties. To address this, certain natural materials can be incorporated to enhance their flexibility, gas barrier, and mechanical properties. Notably, oils can be added to inhibit the growth of microorganisms and improve water-vapor barrier capacity.

The outer leaves of leeks (Allium porrum) can be considered as waste since these parts are typically removed and discarded during the preparation process before cooking or using leeks in recipes. Due to their high phenolic content (262.66 ± 18.05 mg GAE 100 g−1 dry weight) and significant antioxidant activity (48.58 ± 3.84 %) coupled with antibacterial properties (Pellegrini and Ponce, 2020), leek leaves present a potential as an active ingredient in edible coating formulations. Sunflower oil in edible coatings may provide improved barrier properties, including enhanced water vapor resistance and flexibility, while also offering antioxidant benefits, antibacterial activity, and a mild flavor enhancement, making it a valuable addition for preserving and enhancing the quality of food products. Additionally, it serves as a source of essential fatty acids, contributing to the nutritional value of the coated food. In the literature, there have been no studies conducted on the application of edible coating using waste leek powder for the preservation of mushrooms. Thus, in this study, the impact of various guar gum edible coating formulations containing different proportions of waste leek powder and sunflower oil on weight loss, color parameters (L*, a*, b* values, and ΔE), texture and shrinkage of mushrooms (Agaricus bisporus) during storage was investigated.

Materials and Methods

Materials

Leek and sunflower oil were purchased from a local store. Guar gum and glycerol was purchased from Sigma-Aldrich (Merck İlaç Ecza ve Kimya Tic. A.Ş., an affiliate of Merck KGaA, Darmstadt, Germany). Mushrooms (Agaricus bisporus) with consistent sizes, appearance, color, and ripeness level, devoid of any defects, were carefully chosen for the study. Immediately after harvest, the mushrooms were brought to the laboratory and subjected to washing with 0.1% sodium hypochlorite. Following the cleaning process, they were allowed to air dry before the application of the coating.

Edible coating preparation

The outer two layers of leek were peeled. Subsequently, the peeled leek material was subjected to drying in an electric oven (Nuve NO55, Ankara, Türkiye) and then finely ground using a grinder (Kiwi Coffee and Spice Grinder, Türkiye). The ground leek particles were further sieved through a 100-mesh sieve to achieve a consistent and uniform particle size. The guar gum edible coating formulation (Table 1.) was based on method described by Saha et al. (2016) with minor changes. Leek powder was added to the coating formulation at concentrations of 0, 0.5, 1.5, and 2.5 g per 100 ml of coating solution. Ethanol was included in the formulation to dissolve alcohol-soluble ingredients. Glycerol is commonly used in edible coatings as a plasticizer, enhancing the flexibility and mechanical properties of the coating. Its hygroscopic nature helps retain moisture, improving the barrier properties and extending the shelf life of coated food products. Glycerol was incorporated into the coating solution at a concentration of 0.4 g per 100 ml. To assess the impact of sunflower oil in the coating, 0.1 ml of sunflower oil was added to the formulation of samples L0S0.1, L0.5S0.1, L1.5S0.1, L2.5S0.1.

Table 1. Edible coating formulations

Coatings	Guar Gum (g)	Glycerol (g)	Leek powder (g)	Ethanol (ml)	Distilled water (ml)	Sunflower oil (ml)
L0S0*	0.9	0.4	0	0	100	0
L0.5S0	0.9	0.4	0.5	0.75	99.25	0
L1.5S0	0.9	0.4	1.5	2.25	97.75	0
L2.5S0	0.9	0.4	2.5	3.75	96.25	0
L0S0.1	0.9	0.4	0	0	99.9	0.1
L0.5S0.1	0.9	0.4	0.5	0.75	99.15	0.1
L1.5S0.1	0.9	0.4	1.5	2.25	97.65	0.1
L2.5S0.1	0.9	0.4	2.5	3.75	96.15	0.1

* the abbreviations L and S represent leek and sunflower oil, respectively. The subsequent numbers represent the percentage amount of each ingredient in the solution. For example, L0.5 indicates 0.5% (w/v) leek in the coating solution, and S0.1 indicates 0.1% (v/v) sunflower oil in the coating solution.

Guar gum, glycerol, leek powder, sunflower oil and distilled water were stirred at room temperature for 60 min to dissolve adequately. The mushrooms were randomly divided into eight different sections, and immersed in their respective coating solutions for a duration of 2 minutes at a temperature of 20°C. In contrast, the control group was submerged in distilled water.

Following the treatment, the samples were placed on plastic trays and exposed to a fan for 30 minutes to facilitate the drying process. Subsequently, the treated samples were placed on polystyrene trays using toothpicks. The samples were then stored under controlled conditions at 4 ± 1 °C and 85–90% relative humidity for a period of 7 days. Experimental assessments were performed on days 1, 3, and 7 to monitor the effects of the storage and coating on the samples. Each experiment was conducted in three replicates.

Weight loss (%) measurement

To assess weight loss, coated and uncoated mushrooms were initially weighed at day 1 and then weighed again at each storage period. Weight loss was calculated as the percentage of weight reduction relative to the initial mass. The experiment was performed in triplicate to ensure accuracy and reliability of the results. The mushrooms' weight was measured by an analytical scale (KERN PFB 1200-2A, Balingen, Germany). Weight loss was determined using the following equation where W1 represents the initial weight of the mushrooms, and W2 represents the weight after storage for 3 and 7 days.

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$$Weight\ loss\ (\%) = \frac{W_1 - W_2}{W_1} \times 100$$

Color measurement

Color of mushrooms on storage days 1, 3 and 7 were recorded using a handheld colorimeter (TES 135A Color Reader, TES, Taiwan). Color characteristics were evaluated and expressed using the CIE color coordinate system, which includes three components: L*, a*, and b*. The L* component represents lightness, ranging from 0 (black) to 100 (white). The a* component represents the position on the red-green axis, with positive values indicating redness and negative values indicating greenness. The b* component represents the position on the yellow-blue axis, with positive values indicating yellowness and negative values indicating blueness. By using this color coordinate system, the color of the samples could be precisely quantified and compared. Euclidean distance ΔE was obtained by Equation below by taking color data of fresh mushrooms as base (L* =99.6, a* = 3.5 and b* = 14.1)

$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

Hardness measurement

A texture analyzer (Lloyd Ins. TA Plus, Hants, UK) was employed to conduct a penetration test on the mushrooms' caps. A cylindrical probe with a diameter of 5 mm was utilized to determine the hardness. The texture analyzer was set with a loading head speed of 2.0 mm s−1, a trigger force of 50 g, and a probe travel distance of 5 mm. Average value of 6 different measurement for each batch was quantified as hardness value.

Shrinkage ratio (%)

The shrinkage ratio of mushrooms was calculated based on the measurement of cap diameter using a digital caliper, as described by Thakur et al. (2020). The formula for shrinkage ratio is as follows:

$$Shrinkage\ ratio\ (\%) = \frac{D_i - D_f}{D_i} \times 100$$

where Di represents the initial cap diameter of the fresh mushroom in millimeters (mm), and Df represents the cap diameter of the mushroom on 3rd and 7th days of storage. The average value of six different measurements was calculated for each batch of mushrooms.

Statistical analysis

The collected data was subjected to analysis of variance (ANOVA), and subsequently, the means were compared using Tukey Post Hoc Analysis. The statistical analysis was conducted in MINITAB Release 17.1 (Minitab Inc. State College, PA, USA), and a significance level of $p < 0.05$ was employed to determine the statistical significance of the results.

Results and Discussion

Effect of coatings on weight loss of mushrooms

Weight loss is a key parameter in assessing the efficiency of edible coatings, as it directly impacts the preservation and quality of food products. Minimizing weight loss is crucial in extending the shelf life of perishable items, ensuring they remain fresh and marketable for a longer period. Edible coatings can help reduce the rate of weight loss in coated food products. Moreover, weight loss is often associated with moisture loss in fruits and vegetables, leading to undesirable changes in texture, appearance, and taste. Edible coatings may act as a barrier, preventing excessive moisture loss and maintaining the overall quality of the coated food. The weight loss of coated mushrooms ranged from 39.079% ± 0.781% (coating L1.5S0) to 55.055% ± 1.437% (coating L2.5S0.1) between first and seventh days of storage (Table 2). The lowest weight loss was observed in mushrooms coated with L1.5S0, while the highest weight loss was in mushrooms coated with L2.5S0.1. In contrast, uncoated mushrooms exhibited a weight loss of 63.110% ± 5.200%. The coatings significantly reduced weight loss compared to the uncoated mushrooms, with the L1.5S0 formulation showing the most promising results because of the effect of waste leek powder. The addition of oil in the coatings was observed to lead to a significant increase in weight loss. The application of composite coatings consisting of carboxymethyl cellulose alone and in combination with garlic essential oil exhibited a significant delay effect on weight loss (Dong and Wang, 2017). In the study, %1 and %2 garlic essential oil added coatings reduced weight loss, while %3 garlic essential oil increased weight loss. In our research, the use of %0.1 sunflower oil in the coatings may have led to a less pronounced effect of sunflower oil in reducing weight loss.

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Table 2. Weight loss (%) and shrinkage ratio (%) in coated and uncoated mushroom samples between the 1st and 3rd days and the 1st and 7th days of storage

Coatings	Days	Weight loss (%)	Shrinkage ratio (%)
L0S0*	1-3	20.580±0.571^{ij}	11.468±0.0257^{bc}
	1-7	43.090±0.537^{def}	22.84±1.45^{abc}
L0.5S0	1-3	18.751±0.963^{jk}	13.329±0.288^{abc}
	1-7	41.287±0.460^{ef}	28.059±0.998^{a}
L1.5S0	1-3	14.860±0.567^{k}	8.873±1.082^{c}
	1-7	39.079±0.781^{f}	19.02±0.507^{abc}
L2.5S0	1-3	22.153±0.591^{hij}	8.739±0.732^{c}
	1-7	44.875±0.397^{de}	19.107±0.0108^{abc}
L0S0.1	1-3	23.120±0.460^{hij}	8.84±0.516^{c}
	1-7	46.670±1.498^{cd}	19.212±0.533^{abc}
L0.5S0.1	1-3	23.704±0.228^{hi}	9.25±1.94^{c}
	1-7	50.904±0.856^{bc}	21.76±3.06^{abc}
L1.5S0.1	1-3	26.127±0.964^{gh}	15.83±11.76^{abc}
	1-7	52.981±0.578^{b}	23.63±11.14^{abc}
L2.5S0.1	1-3	28.262±0.784^{g}	10.274±0.868^{bc}
	1-7	55.055±1.437^{b}	24.07±2.67^{abc}
Uncoated	1-3	29.125±0.902^{g}	15.95±1.58^{abc}
	1-7	63.110±5.200^{a}	25.838±0.434^{ab}

* the abbreviations L and S represent leek and sunflower oil, respectively. The subsequent numbers represent the percentage amount of each ingredient in the solution. For example, L0.5 indicates 0.5% (w/v) leek in the coating solution, and S0.1 indicates 0.1% (v/v) sunflower oil in the coating solution. Values are expressed as mean±standard deviation. Different superscripts show that values in the same column within each group are significantly different ($p \leq 0.05$)

Effect of coatings on shrinkage ratio of mushrooms

Some edible coatings have been shown to slow down the ripening and senescence processes in fruits and vegetables, which can contribute to reduced shrinkage during storage. Moreover, edible coatings prevent excessive moisture loss from the food. This can lead to reduced shrinkage, as moisture is retained within the product, maintaining its overall size and shape. The minimum shrinkage ratio was observed in sample L1.5S0, with a value of 19.02% ± 0.507%, while the maximum shrinkage ratio was found in sample L0.5S0, measuring 28.059% ± 0.998%. In comparison, uncoated samples exhibited a shrinkage ratio of 25.838% ± 0.434% (Table 2). The application of edible coatings, particularly L1.5S0, appears to have resulted in lower shrinkage ratios, indicating a potential positive effect in reducing the shrinkage of the coated mushrooms compared to the uncoated ones. So, there is approximately a 26.4% reduction in shrinkage ratio when using the coating L1.5S0 compared to the uncoated samples. 1.5% of waste leek powders showed promising results.

Effect of coatings on color values (L*, a*, b* and ΔE) of mushrooms

L*, a*, and b* values are color parameters used to characterize the color of a sample. L* corresponds to lightness, a* indicates the degree of redness (positive values) or greenness (negative values), and b* represents the extent of yellowness (positive values) or blueness (negative values). In many cases, edible coatings are formulated to preserve the natural color of the food, delay color changes, and maintain its visual appeal during storage (Medina-Jaramillo et al., 2020). As expected, L* values exhibited a declining pattern as the mushrooms were stored for longer period. During the 7-day storage period, the lightness (L*) of the uncoated sample decreased from 93.44±4.5 to 82.69±2.67. On the other hand, the best coating based on both weight loss and shrinkage data only slightly decreased from 98.115±1.407 to 94.2±0.933, resulting in a relatively lighter color, thus preserving its original appearance better (Table 3). In a previous study, alginate-based coatings were reported to effectively preserve the lightness of mushrooms, resulting in an L* value of approximately 82.5 (Louis et al., 2021), which is darker compared to the L* value observed in our study. The difference in L* values between the two studies could be attributed to variations in the formulation and application of the coatings, as well as differences in the storage conditions in each study.

Among the color parameters, the a* value exhibited the least change, indicating relatively stable redness/greenness, compared to other color components. Additionally, the coatings had a lesser effect on the a* value when compared to the uncoated samples, suggesting that the coatings had a minimal impact on the redness/greenness of the mushrooms during storage.

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The b* values, representing yellowness/blueness, increased during the 7 days of storage (Table 3). This indicates that the mushrooms became more yellow over time. The increase in yellowness may be attributed to various factors, such as the natural ripening process, chemical reactions, or changes in the structure and composition of the mushrooms during storage. An increase in b* values is often associated with browning reactions, which can occur during the storage of fruits and vegetables. Browning reactions, such as enzymatic browning and Maillard reactions, can lead to the formation of pigments that contribute to a more yellow or brown color in the food. The study by Rokayya et al. (2021) observed a similar increase in b* values of mushrooms, providing further evidence of the occurrence of browning reactions during storage.

ΔE represents the total color difference between two color samples in the CIE Lab color space. It quantifies the perceptual difference between the colors and is used to evaluate how much one color deviates from another. ΔE was calculated with respect to fresh mushrooms CIE Lab color. The least color deviation was observed in samples coated with L0S0, L0.5S0, and L1.5S0, with ΔE values of 8.2202±0.0442, 8.769±0.217, and 9.812±0.945, respectively. These coated samples showed minimal color change and maintained their original color more effectively. In contrast, the uncoated samples exhibited a higher ΔE value of 18.64±2.3, indicating a more significant color deviation and changes during the storage period.

Table 3. Color values (L*, a*, b* and ΔE) of coated and uncoated mushroom samples on the 1st, 3rd, and 7th day of storage

Coatings	Days	L* value	a* value	b* value	ΔE
L0S0*	1	98.85 ± 0.438^{a}	3.296 ± 0.185^{abc}	14.345 ± 0.276^{efgh}	0.853 ± 0.421^{g}
	3	95.845 ± 0.757^{abc}	3.303 ± 0.258^{abc}	17.76 ± 2.39^{cdefgh}	5.32 ± 2.19^{defg}
	7	93.635 ± 0.0495^{abc}	5.325 ± 1.103^{abc}	19.39 ± 0.368^{bcdefg}	8.2202 ± 0.0442^{bcdefg}
L0.5S0	1	99.37 ± 0.368^{a}	1.14 ± 1.054^{c}	13.635 ± 0.134^{gh}	2.453 ± 0.954^{fg}
	3	98.065 ± 1.138^{ab}	5.06 ± 1.77^{abc}	14.1 ± 1.47^{fgh}	2.56 ± 1.77^{fg}
	7	94.295 ± 0.742^{abc}	5.658 ± 0.463^{abc}	20.705 ± 0.46^{bcdef}	8.769 ± 0.217^{bcdefg}
L1.5S0	1	98.115 ± 1.407^{ab}	2.692 ± 0.272^{bc}	11.865 ± 0.615^{h}	2.906 ± 1.117^{fg}
	3	95.89 ± 2.29^{abc}	4.305 ± 1.047^{abc}	19.2 ± 3.18^{bcdefg}	6.37 ± 4.01^{cdefg}
	7	94.2 ± 0.933^{abc}	5.898 ± 0.357^{abc}	21.925 ± 0.431^{abc}	9.812 ± 0.945^{bcdefg}
L2.5S0	1	97.545 ± 0.7^{ab}	3.5875 ± 0.0247^{abc}	14.83 ± 1.174^{defgh}	2.278 ± 1.009^{fg}
	3	92.56 ± 4.21^{abc}	6.32 ± 2.32^{ab}	21.92 ± 4.84^{abc}	10.9 ± 6.79^{abcdefg}
	7	91.03 ± 2.61^{abcd}	6.73 ± 2.08^{ab}	24.915 ± 1.096^{ab}	14.24 ± 2.87^{abcde}
L0S0.1	1	95.76 ± 0.863^{abc}	3.708 ± 0.711^{abc}	14.165 ± 0.219^{fgh}	3.879 ± 0.888^{efg}
	3	93 ± 2.43^{abc}	6.703 ± 1.015^{ab}	22.46 ± 1.81^{abc}	11.14 ± 3.09^{abcdefg}
	7	87.465 ± 0.997^{cde}	6.252 ± 0.449^{abc}	25.535 ± 0.502^{ab}	16.907 ± 0.982^{abc}
L0.5S0.1	1	93.545 ± 0.247^{abc}	4.883 ± 0.456^{abc}	16.88 ± 1.69^{cdefgh}	6.885 ± 0.993^{cdefg}
	3	89.565 ± 0.672^{bcd}	7.15 ± 0.771^{ab}	23.31 ± 1.58^{abc}	14.13 ± 1.305^{abcde}
	7	87.99 ± 0.665^{cde}	7.38 ± 0.658^{ab}	23.22 ± 0.382^{abc}	15.282 ± 0.11^{abcd}
L1.5S0.1	1	94.07 ± 3.99^{abc}	6.12 ± 2.36^{abc}	16.9 ± 0.495^{cdefgh}	6.84 ± 4.33^{cdefg}
	3	91.755 ± 0.728^{abc}	7.25 ± 0.714^{ab}	22.68 ± 0.467^{abc}	12.239 ± 0.359^{abcdef}
	7	88.16 ± 0.424^{cde}	8.023 ± 0.237^{a}	27.79 ± 1.72^{a}	18.41 ± 1.6^{ab}
L2.5S0.1	1	91.94 ± 0.976^{abc}	6.697 ± 0.916^{ab}	20.3 ± 1.032^{bcdefg}	10.37 ± 1.62^{bcdefg}
	3	95.74 ± 4.34^{abc}	5.72 ± 2.3^{abc}	19.09 ± 3.41^{bcdefg}	6.8 ± 5.71^{cdefg}
	7	92.73 ± 3.24^{abc}	5.367 ± 0.916^{abc}	22.81 ± 1.52^{abc}	11.36 ± 2.97^{abcdefg}
Uncoated	1	93.44 ± 4.5^{abc}	5.1 ± 1.63^{abc}	17.77 ± 1.344^{cdefgh}	7.42 ± 4.75^{cdefg}
	3	80.07 ± 2.23^{e}	7.6 ± 2.47^{ab}	21.47 ± 2.08^{abcd}	21.42 ± 1.8^{a}
	7	82.69 ± 2.67^{de}	6.212 ± 0.929^{abc}	21.345 ± 0.643^{abcde}	18.64 ± 2.3^{ab}

* the abbreviations L and S represent leek and sunflower oil, respectively. The subsequent numbers represent the percentage amount of each ingredient in the solution. For example, L0.5 indicates 0.5% (w/v) leek in the coating solution, and S0.1 indicates 0.1% (v/v) sunflower oil in the coating solution. Values are expressed as mean±standard deviation. Different letters show that values in the same column within each group are significantly different ($p \leq 0.05$)

Effect of coatings on hardness of mushrooms

Monitoring the hardness of the coated mushrooms over the storage period is crucial to determine the effectiveness of the edible coating in preserving the desired texture. In general, edible coatings can help maintain the hardness or texture of the coated mushrooms during storage. The application of edible coatings forms a protective layer on the surface of the mushrooms, which can reduce moisture loss and prevent mechanical damage. This protective barrier helps retain the natural moisture content of the mushrooms, thereby minimizing softening or loss of firmness. The hardness values of both the coated and uncoated samples were observed to decrease significantly

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during storage. This reduction in hardness indicates that the mushrooms became softer over time, regardless of whether they were coated or uncoated. the short observation time of 7 days might have limited the ability to detect significant differences in hardness between the coated and uncoated samples. With longer storage durations, the positive effects of the coatings on hardness could become more pronounced. The findings from Mohebbi et al. (2012)'s study support the notion that the texture of mushrooms tends to deteriorate during storage, and this difference in texture becomes more pronounced over time. Therefore, the use of coatings is expected to help maintain the hardness and fresh texture of mushrooms. Initially, during the early days of storage, there might be minimal differences between the coated samples and the uncoated control in terms of preserving the initial texture quality. However, as the storage period extends, the positive effects of the coatings on hardness changes become more evident, particularly for mushrooms treated with gum tragacanth. This indicates that the coatings could provide protective benefits that effectively delay the degradation of hardness and texture in the mushrooms, especially when stored for longer durations.

Table 4. Hardness value of coated and uncoated mushroom samples on the 1st, 3rd, and 7th day of storage

Coatings	Days	Hardness value
L0S0*	1	2.05 ± 0.0866^{bcdefg}
	3	$1.9333 \pm 0.1528^{cdefg}$
	7	1.56 ± 0.0529^{hijk}
L0.5S0	1	$2.1333 \pm 0.0289^{bcdef}$
	3	2.243 ± 0.277^{abcd}
	7	1.57 ± 0.1127^{hijk}
L1.5S0	1	2.6 ± 0.265^{a}
	3	2.3 ± 0.1^{abc}
	7	1.8 ± 0.05^{efghijk}
L2.5S0	1	2.417 ± 0.176^{ab}
	3	1.9 ± 0.1^{cdefghi}
	7	1.5333 ± 0.0577^{hijk}
L0S0.1	1	2.25 ± 0.05^{abcd}
	3	1.8 ± 0.05^{efghijk}
	7	1.5 ± 0.1323^{ijk}
L0.5S0.1	1	$2.0967 \pm 0.0839^{bcdef}$
	3	1.85 ± 0.05^{defghij}
	7	1.38 ± 0.0819^{k}
L1.5S0.1	1	2.2833 ± 0.0289^{abc}
	3	1.587 ± 0.201^{hijk}
	7	1.4667 ± 0.0577^{jk}
L2.5S0.1	1	2.1567 ± 0.0814^{bcde}
	3	1.717 ± 0.362^{fghijk}
	7	1.3833 ± 0.0289^{k}
Uncoated	1	$1.9167 \pm 0.0764^{cdefghi}$
	3	$1.6333 \pm 0.0289^{ghijk}$
	7	1.4033 ± 0.138^{k}

* the abbreviations L and S represent leek and sunflower oil, respectively. The subsequent numbers represent the percentage amount of each ingredient in the solution. For example, L0.5 indicates 0.5% (w/v) leek in the coating solution, and S0.1 indicates 0.1% (v/v) sunflower oil in the coating solution. Values are expressed as mean±standard deviation. Different letters show that values in the same column within each group are significantly different ($p \leq 0.05$).

Conclusions

The study investigated the effects of different guar gum edible coating formulations, which incorporated varying proportions of waste leek powder and sunflower oil, on weight loss, color parameters (L*, a*, b* values, and ΔE), texture, and shrinkage of Agaricus bisporus mushrooms during 7 days of storage. The research explored how these coating formulations could potentially impact the preservation and quality of the mushrooms over time. Overall, the study suggests that edible coatings have the potential to play a crucial role in preserving the moisture, shape and color quality of mushrooms during storage, leading to better quality and extended shelf life.

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