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Evaluating the quality of green asparagus treated with cassava starch-based coating using laser scattering

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ABSTRACT

The presented study investigated the effects of edible coatings with concentration of 2%, 3% and 4% of starch (w/v) on the weight loss and firmness loss of green asparagus during 4 days of storage at room temperature (26 ± 2 °C, 65–70% RH). According to the results, the coated asparagus exhibited significantly slower deterioration rate than the uncoated control samples. This was indicated by the decrease in weight loss and increase in firmness ($P < 0.05$). After the storage period, the samples treated with 4% starch formula retained the highest quality. Furthermore, the assessment of asparagus quality throughout the storage period involved the use of the line laser scattering technique. Extracted parameters of laser

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scattering signal discriminated samples with linear discriminant analysis (LDA), in which the correct recognition rate of the treated groups was 75.26% and the storage time was 70.54%. This study showed the potential of laser scattering as a rapid, non-invasive, and practical optical method for assessing the quality of asparagus during storage.

KEYWORDS

edible coating, non-destructive, machine vision, discriminant analysis

INTRODUCTION

Green asparagus (*Asparagus officinalis* L.) is a valuable and highly demanded fresh vegetable, well-known for distinct taste, and also holding significant economic value in the markets. However, its high respiration rate leads to a short shelf-life after harvesting. This is caused by various biochemical reactions, resulting in a decline in quality that manifests as increased weight loss and hardness (You et al., 2021). Therefore, it is a challenge to ensure extended shelf-life of this vegetable and maintain its quality for commercialization (Zsom et al., 2016). Previous studies have investigated the effects of modified atmosphere packaging (MAP) and hypobaric pressure on the shelf-life of green asparagus (An et al., 2007; Albanese et al., 2007; Wei and Ye, 2011). However, these results indicate that more methods need to be investigated to improve the quality of green asparagus during storage.

The application of edible coatings to extend the shelf-life of fruits and vegetables has attracted attention in recent years. Edible coatings create a gas barrier equivalent to controlled atmosphere storage (Pham et al., 2022). Furthermore, the use of biological packaging as an alternative is also receiving attention due to environmental concerns (Nguyen et al., 2018). However, edible coatings must meet certain requirements to be used at a commercial level (Panahirad et al., 2020). Cassava starch is used as a coating for vegetables due to its availability, low cost and biodegradability. Besides, cassava starch coatings can inhibit gas migration due to their hydrogen bond network structure. These coatings are typically colorless and odorless, and are generally considered safe and nontoxic, making them a popular choice for use as edible coatings. Furthermore, their mechanical properties can be modified for desired improvement (Pham et al., 2023).

Overall, the firmness of green asparagus is an important factor influencing consumer acceptance. Sensory and destructive techniques are commonly used to evaluate the firmness of asparagus. However, this method has a limitation in that sampling is limited to only a few samples in a batch (Sanz et al., 2009; Bodor et al., 2018). To overcome these limitations, optical methods are applied to monitor the physicochemical changes of products during harvest and post-harvest (Zsom et al., 2018; Nguyen et al., 2020; Zsom-Muha et al., 2021). The effectiveness of near-infrared reflectance (NIR) spectroscopy as a non-invasive method for food quality monitoring has been demonstrated (Felföldi et al., 2017; Baranyai, 2011). It offers advantages such as fast speed, measurement reproducibility, and no sample preparation required. NIR is a tool that predicts the chemical properties of foods within a specific wavelength range. However, it does not provide quantitative data on light dispersion in the sample. In NIR techniques, scattering effects are considered noise and are removed or resolved during spectral analysis (Romano et al., 2011). In contrast to NIR, a potential method of increasing interest involves the absorption of photons and diffuse scattered light. The surface scattering properties of food are the result of the interaction between its absorption and scattering. Absorption provides detailed information about chemical constituents while scattering reveals characteristics of cell or tissue structures (Zsom et al., 2014). Many studies have been conducted to explore the potential of light scattering properties in predicting food quality (Zsom et al., 2021; Hencz et al., 2022). However, there is a lack of research evaluating the influence of light scattering properties in predicting or grading asparagus quality.

Therefore, this study was conducted to evaluate the effect of edible coatings with different starch concentrations on quality parameters including weight loss and firmness during storage at room temperature. In addition, laser scattering technique was applied to classify asparagus quality during storage. These classifications were based on the analysis of light propagation characteristics.

MATERIALS AND METHODS

Materials

A total of 200 fresh, uniform, and washed green asparagus were obtained directly from the grower in Csengőd, Hungary. The cassava starch powder, with the minimum purity of 99% on dry basis, was purchased from Hunorganic Ltd., Hungary. Gelatin with a purity exceeding 99%, sorbitol with a purity exceeding 99% and glycerol with a purity over 99% were each bought from different suppliers: Szilasfood Ltd., Hungary; Parma Produkt Ltd., Hungary; and Budai Szent Klara Pharmacy in Hungary, respectively.

Table 1 presents formula of coating that was applied to the different sample groups. Cassava starch was heated to 95 °C and held at this temperature for 30 min to reach complete gelatinization. Gelatin was hydrated for 1 h and then heated to 70 °C, and kept on this temperature for 30 min. The materials were blended in the prescribed sequence, starting with cassava starch, followed by gelatin, sorbitol, and glycerol. Coating of the asparagus was performed by immersing them in the prepared solutions for 15 s at room temperature. Following the coating step, the asparagus were left to gradually dry for 1 h at ambient temperature. After that, the coated samples were placed on plastic trays and stored at room temperature.

Table 1. The constituents included in different coating formulations

Sample group	Components (%, w/v)			
	Cassava starch	Gelatin	Sorbitol	Glycerol
Control	0	0	0	0
S2	2	0.5	3	0.5
S3	3	0.5	3	0.5
S4	4	0.5	3	0.5

Weight loss

The weight loss of asparagus during storage was assessed by periodically measuring the weight using an electronic weighing device (Kern PFB, Kern & Sohn Gmbh, Balingen-Frommern, Germany) with the accuracy of 1 mg. The change in weight was monitored at different intervals, and the results were expressed as the percentage of initial weight (0 d).

Firmness

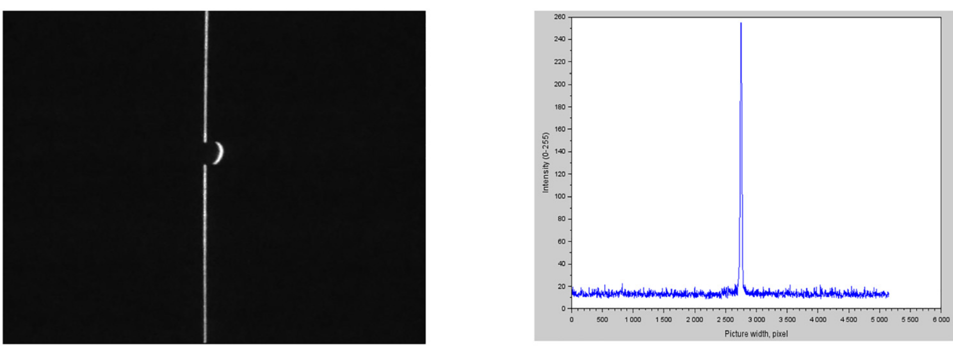
Asparagus firmness was measured by TA.XTplus (Stable Micro Systems, Godalming, UK) as described by Tzoumaki et al. (2009). A cutting test was performed using a TA-TPB probe to make precise cuts at the designated positions on the asparagus. The measurements were performed using a probe with constant speed at 1.0 mm s^{-1}. The Texture Expert software (version 1.0) was used to record the force, penetration depth, and time data. The firmness value was defined as the highest force applied during the cutting test.

Laser scattering

A laser system was developed for the assessment of green asparagus quality throughout storage period. The setup included a dark box with a single line laser module and a digital camera (SONY, DSC-W800, Tokyo, Japan). A single line laser module (635 nm) with the power of 1 mW and the line thickness of 1 mm was used to illuminate the asparagus samples. For the experiment, the lens of the camera and specimen were situated 27 cm apart, while the line laser was adjusted to the angle of 20°. In this study, the general workflow of image processing performed by Scilab is shown in Fig. 1. The intensity profile of the images was analyzed using Scilab software (version 6.1.1) to extract the signal width at 50% (full width half maximum, FWHM), 75% (D75) and 25% (D25).

Statistical analysis

Each measurement was made on 10 pieces of green asparagus and was repeated 3 times. The analysis of the data was performed with the SPSS version 19 (IBM Corp., Armonk, N.Y., USA).



(a) (b)

Fig. 1. Workflow of image processing: a) Image acquisition, b) Features extraction

Two-way ANOVA was conducted to evaluate the data. The data was represented in figures displaying the average value ± standard deviation ($P < 0.05$).

RESULTS AND DISCUSSION

Weight loss

Weight loss is a critical parameter of asparagus during storage due to its direct correlation with negative impact on appearance, resulting in economic losses (Sanz et al., 2009). As illustrated in Fig. 2, weight loss in asparagus gradually increased during storage. This was a result of transpiration, driven by variations in pressure between the asparagus and the surrounding environment, leading to water loss (Tzoumaki et al., 2009). The findings indicated that applying these coatings considerably decreased weight loss by limiting gas permeability on the asparagus surface, thereby decreasing respiration rate and weight loss. After 4 d of storage, the control group exhibited a 48.9% reduction in weight, while the coated asparagus resulted in weight losses ranging from 23.84% to 32.64%. Among the coated samples, S4 demonstrated the highest effectiveness in reducing weight loss. The results suggest that increased amount of starch in the coating formula resulted in increased coating thickness, which improved its effectiveness during storage (Pham et al., 2022).

Firmness

Asparagus quality is evaluated based on its firmness, as it is an important factor for consumers (Lau et al., 2000). It was observed that the firmness of green asparagus increased during storage (Fig. 3). The increase in firmness is probably associated with the increase of crude fiber, specifically lignin, and the enzyme activity of phenylalanine ammonia-lyase (Lau et al., 2000). The data showed that the coated asparagus had lower firmness compared to the control sample.

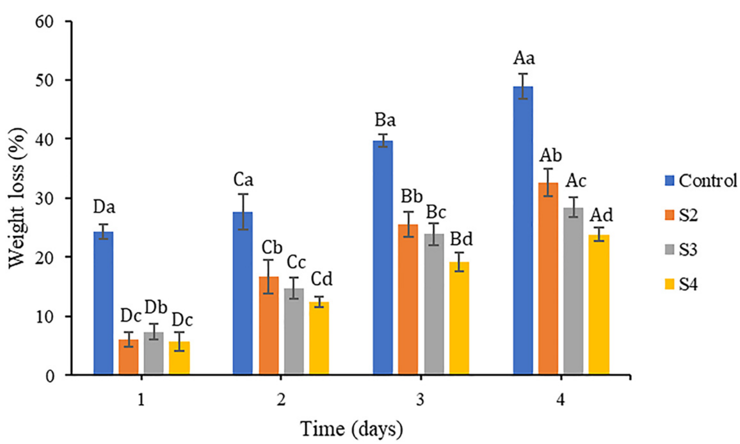


Fig. 2. Asparagus weight loss during storage. Capital letters are time comparisons ($P < 0.05$) while small letters are treatment comparisons ($P < 0.05$)

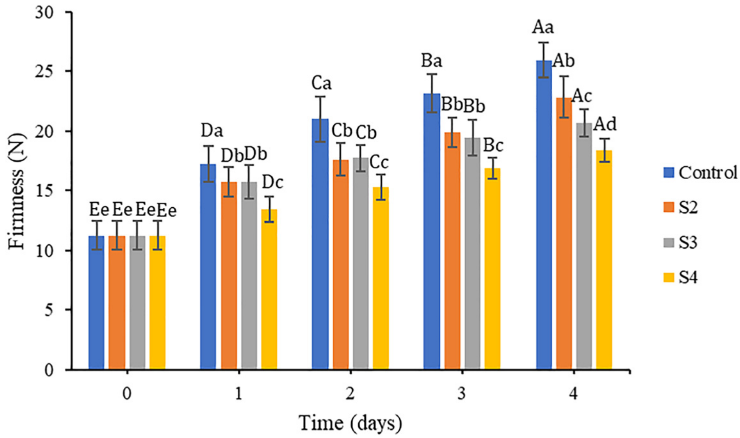


Fig. 3. Asparagus firmness during storage. Capital letters are time comparisons ($P < 0.05$) while small letters are treatment comparisons ($P < 0.05$)

The application of the coating aimed to alter the gas composition within the asparagus by decreasing oxygen while increasing carbon dioxide levels. This modification slowed down the biochemical reactions responsible for firmness changes. These results were consistent with the findings of Tzoumaki et al. (2009) and Qiu et al. (2013). The S4 coating formula was the most effective in slowing the increase in asparagus firmness among the treated samples. The findings indicated that the amount of starch in the coating formula had a significant impact on asparagus firmness. This result was because of the rise in polymer components and the overall dissolved substances within the coating layer, despite its volume remaining constant (Pham et al., 2022).

Laser scattering

Laser scattering has proved to be effective in quality evaluation of solid foods like fruits and vegetables (Baranyai and Zude, 2008). The data presented in Table 2 indicated that changes in the internal quality of asparagus had significant impact on the sensitivity of the signal shape. Compared with coated samples, the control sample exhibited lower FWHM values in the intensity profile. Besides, a decrease in scattering around the incident point was observed as storage time increased. The variations detected in the data extracted from scattering images throughout storage could be attributed to the changes in weight loss and firmness. As the moisture content decreased, the replacement of air in the space between cells led to increase in material density (Romano et al., 2011). Hence, the backscattering region was reduced due to the increase of absorption and the refraction reduction. Firmer vegetables were difficult for light penetration into the tissue, resulting in a sharper gradient (Hashim et al., 2018). This was due to the reduction in distance of gradient around the halo. Besides, a decline in chlorophyll content could lead to the alterations in the backscattering at 635 nm (Mozaffari et al., 2022). Furthermore, ANOVA results indicated that storage time had the primary effect on the intensity profile, followed by the treatment factor, and no interaction amongst factors was observed (Table 3).

Table 2. The parameters extracted from the light scattering signal

Time/treatment	1			2			3			4		
	FWHM	D75	D25	FWHM	D75	D25	FWHM	D75	D25	FWHM	D75	D25
Control	37.23	22.57	51.07	33.87	16.77	47.63	28.73	17.07	39.23	29.70	17.57	40.39
S2	37.20	20.17	51.60	35.73	19.43	49.90	31.47	19.13	42.33	29.39	17.78	38.91
S3	38.20	23.03	54.67	35.03	19.27	48.30	32.30	19.67	45.50	29.87	18.00	40.60
S4	37.63	20.33	54.03	36.10	18.93	51.53	32.93	19.07	44.33	30.93	18.23	41.43

Table 3. F-values from ANOVA analysis of the parameters extracted from the light scattering signal

Parameter	Time	Treatment	Interaction
FWHM	5.288^{***}	3.894^{**}	0.861
D75	2.005^{***}	2.602^{*}	1.522
D25	7.403^{***}	4.649^{**}	0.812

***: $P < 0.001$, **: $P < 0.01$, *: $P < 0.05$.

Furthermore, the effectiveness of laser scattering in classifying the asparagus quality was assessed through LDA. The data were classified into groups according to storage time and the treatment. The finding indicated that the precision of categorization was good for both the time (70.54%) and treatment group (75.26%). In previous research, it was found that the accuracy of categorizing stored bananas exceeded 90% (Zulkifli et al., 2019). Yang et al. (2021) reported that the classification accuracy for "Hayward" kiwifruit was lower (49–61%) in comparison to the findings from this research.

CONCLUSIONS

The study examined the impact of cassava starch-based coating with varying starch content on the quality of fresh green asparagus stored at room temperature. Quality parameters, including weight loss and firmness, were evaluated to assess the efficacy of coating. The findings revealed that the coating with 4% starch content was the most effective in maintaining the asparagus quality and extending its storage duration. Further research is required to explore and optimize additional methods that can enhance the shelf-life of asparagus in combination with coating. The laser scattering technique distinguished the quality classes of asparagus during storage with correct classification rate above 70%. The research indicated the potential of laser scattering technique as a non-destructive method for monitoring the asparagus quality.

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