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EFFECT OF EDIBLE COATING ON THE POSTHARVEST QUALITY AND SHELF LIFE OF SPINACH MICROGREENS

Shahla Karuthedath[1] and S. Thilakavathy [2]

ABSTRACT

Research on the impact of guar gum-and coconut oil-based edible coatings on the postharvest quality and shelf life of spinach microgreens was conducted in January 2024 at the Avinashilingam University, Coimbatore. Premium spinach seeds were planted in plastic containers that were filled with a blend of cocopeat, perlite, and vermiculite. Spinach microgreens were grown in a controlled setting with LED lighting, consistent watering, and temperature monitoring. Harvesting occurred when the plants developed their first true leaves and reached 1-3 inches in height, usually 7-14 days post-germination. The experiment employed a completely randomized block design. Edible coatings for microgreens were created using emulsions of guar gum and coconut oil in various ratios, comprising guar gum, coconut oil, and glycerol. Different variations of coconut oil and guar gum were evaluated alongside an untreated control group to assess quality parameters, including physiological weight loss, respiration rate, ascorbic acid content, instrumental color and overall acceptability at intervals of 0,2,4 and 8 days. By assessing the impact of these edible coatings, this study aimed to expand the understanding of spinach microgreen preservation and to enhance their potential as a sustainable and nutrient-rich food source. Edible coatings markedly decreased the physiological weight loss. The highest loss of 3.15% was observed in the uncoated E0T1 (control) sample on day 8, whereas E1T1C0 (0.25% guar gum) exhibited the lowest loss of 0.10%, showing its efficacy in reducing deterioration. The storage respiration rates in spinach microgreens were significantly lowered by edible coatings (p d" 0.05). The lowest respiration in E1T1C0 (0.25% guargum) started at 22.5 µl CO, g^{-1} h^{-1} and rose to 34.1 µl CO, g^{-1} h^{-1} by day 8. For ascorbic acid, the top-performing coated samples E1T1C0 (0.25% guargum) and E2T1C0 (0.5% guar gum) maintained higher levels at 39.90 mg 100 g^{-1} and 38.90 mg 100 g^{-1}, respectively. E1T1C0-0.25% guargum and E2T1C1-0.5% guar gum exhibited exceptional performance in maintaining the colour attributes. The E1T1C0 (0.25% guar gum) and E1T1C1 (coconut oil 1.0% + guar gum 0.25%) coatings showed good results in the overall acceptability, maintaining high scores (> 7.5) for up to 4 days, and sustaining acceptable levels (> 7.0) even after 8 days. These results may extend the storage duration and can improve the overall quality of spinach microgreens.

INTRODUCTION

In recent years, microgreens have attracted considerable interest because of their high nutritional content and possible health advantages. These young, tender greens are harvested shortly after germination and are known for their concentrated nutrient content and intense flavor (Xiao *et al.,* 2012). Among the various microgreen varieties, spinach (*Spinacia oleracea* L.) has emerged as a popular choice owing to its rich nutrient profile and versatility in culinary applications.

The cultivation of microgreens requires careful attention to factors such as seed quality, growth medium, and environmental conditions. High-quality seeds with excellent germination rates are crucial for successful microgreen production (Kyriacou *et al*., 2016). The use of a balanced growing medium, typically a mixture of components, such as cocopeat, perlite, and vermiculite, provides adequate support, aeration, and moisture retention for optimal growth (Di Gioia *et al.,* 2017).

Controlled environmental conditions, including light exposure, temperature, and humidity, play vital roles in microgreen cultivation. Research has demonstrated that LED lighting can improve the development and nutritional content of various microgreen varieties (Samuoliene *et al.,* 2013). Appropriate harvesting techniques are essential to maintain the quality and shelf life of microgreens, as these delicate plants are highly perishable (Kou *et al*., 2014). Techniques applied after harvesting, including the use of edible protective layers, have shown promise as effective methods for prolonging storage duration and preserving the quality of fresh agricultural products, such as microgreens.

Quality evaluation of spinach microgreens involves a comprehensive assessment of various parameters, including physiological weight loss, respiration rate, nutrient content, color, and overall acceptability. These

1. Ph. D Scholar, Dept. of FSN, Avinashilingam University, Tamil Nadu, India
2. Assoc. Professor, Dept. of FSN, Avinashilingam University, Tamil Nadu, India

measurements provide valuable insights into the post-harvest behavior and shelf life of microgreens under different storage conditions and treatments (Xiao *et al.,* 2014).

This study examined the effects of edible coatings made from guar gum and coconut oil on the quality and longevity of spinach microgreens after harvest. By examining various quality parameters and employing advanced analytical techniques, such as scanning electron microscopy, this research seeks to contribute to the growing body of knowledge on microgreen preservation and enhance their potential as a sustainable and nutritious food source.

MATERIALS AND METHODS

Cultivation of microgreens

High-quality spinach (*Spinacia oleracea* L.) seeds with germination rates exceeding 90% were obtained from the Kerala Agriculture University seed outlets in Thrissur, India. The seeds were scattered in plastic trays measuring 10.75" x 10.75" x 1.50" externally and 10" x 10" x 1.40" internally, filled with a mixture of Cocopeat, perlite, and vermiculite (50:25:25) in three replicates. The trays were stacked for seed germination and water was sprayed twice daily using a spray bottle. 20-watt LED lights were utilized for 10 h, maintaining an average air temperature of 240 °C and 70% relative humidity. After germination, each tray was positioned on another tray without holes, containing water.

The spinach microgreens were harvested when they developed their initial true leaves and reached a height of 1-3", which typically occurred 7-14 days after germination and varied based on soil type. Clean, sharp stainless-steel scissors were used for harvesting, with the spinach microgreens being carefully cut just above the soil surface to avoid bruising. The harvested spinach microgreen samples were then placed in a clean container. Before applying the edible coating, the spinach microgreens were inspected, and any plants with imperfections or discolored foliage were discarded.

Edible coating to the spinach microgreens and quality evaluation

Application of edible coatings with guar gum and coconut oil emulsions

An edible coating using a guar gum emulsion was applied following the method described by Jankar *et al.* (2020). Microgreens were harvested from three randomly selected trays, washed (Sharma *et al*., 2023), and thoroughly drained. To prepare the coating solution, a specified quantity of guar gum was dissolved in 100 ml of heated water. Coconut oil, as specified in Table 1, was incorporated into the guar gum mixture. To enhance stability, 0.4% glycerol was added to each solution. Cleaned spinach microgreens were immersed in the coating solution for three minutes, thoroughly drained, and dried using a fan. Experimental treatments included E0T1 (control without coating), E1T1C0 (0.25% guar gum), E1T1C1 (1.0% coconut oil + 0.25% guar gum), E1T1C2 (2.0% coconut oil + 0.25% guar gum), E2T1C0 (0.5% guar gum), E2T1C1 (0.5% guar gum + 1.0% coconut oil), and E2T1C2 (0.5% guar gum + 2.0% coconut oil).

Quality evaluations

Quality evaluations were performed on storage days 0, 2, 4, and 8. On each sampling day, a quality assessment was conducted on three samples from each treatment group.

Physiological weight loss

Physiological weight loss (PWL) was measured by precisely weighing the samples at the start of the storage period and every 48 h throughout the storage period. The findings were expressed as the percentage of weight reduction compared to the initial fresh weight of the microgreens (Xiao, 2014).

Respiration rate

The spinach microgreen respiration rates were measured in a sealed environment at 48-hour intervals throughout the storage period. The rates were quantified and expressed in µl CO2 g^{-1} h^{-1} (Fonseca *et al*., 2002).

Determination total ascorbic acid content

Extraction and measurement of free, dehydro, and total ascorbic acid were performed following the protocol described by Kampfenkel *et al.* (1995). The DHA/FAA ratio was calculated and documented. A standard curve of l-ascorbic acid, ranging from 100 to 500 µg ml^{-1}, was used to determine the ascorbic acid concentration. The results were expressed in mg 100 g^{-1} of fresh weight (Saad and Mohamed, 2022).

Instrumental colour

A Konica Minolta CR-10 color reader (Minolta Co. Ltd., Osaka, Japan) was used to assess the color of the samples. The device, featuring an 8 mm aperture, was calibrated using a white tile prior to the measurements. Color measurements were performed using the CIELAB coordinates. For spinach microgreen coated varieties, the L* coordinate, which indicates lightness, was recorded. To monitor chlorophyll breakdown in the spinach microgreens, the a* (-) value representing greenness was documented. Additionally, the b* (+) coordinate, signifying yellowness, was measured in spinach microgreens due to the observed leaf discoloration. The sample preparation involved filling a 3-inch petri dish with plucked leaves. The color reader probe was positioned on the upper surface of the leaves in the dish, and the reflectance spectra were directly measured at three distinct points. The averages of these measurements were calculated (Dzurenda, 2023).

Overall acceptability

A panel of 25 women assessed the overall acceptability of the spinach microgreens. The participants were introduced to the samples and scoring method but received no specific training to ensure that their evaluations reflected consumer preferences. The samples were randomly

presented to the panelists with coded labels immediately after package opening. Using a 9-point hedonic scale, the panel members were instructed to rate the samples based on their personal preferences (Prachi *et al*., 2024).

Statistical Analysis

The experiment was conducted using complete randomized block design (CRBD). To assess the impact of various treatments on the quality parameters of spinach microgreens over time, researchers employed Analysis of Variance (ANOVA) for statistical evaluation (Shamsher *et al*., 2024).

RESULTS AND DISCUSSION

Physiological weight loss

Edible coatings offer an effective approach for mitigating physiological deterioration in spinach microgreens during storage. These coatings serve as a barrier against mechanical and microbial harm while also slowing down biochemical degradation processes (Jyothsna and Nair, 2022; Sharma *et al*., 2023). Table 2 shows the application of edible coatings for PWL. Across all treatments, notable differences in physiological loss were evident on days 2, 4, and 8. The highest physiological loss was consistently observed in E0T1(uncoated), reaching 3.15% by day 8, indicating that the lack of coating led to quicker deterioration. Conversely, E1T1C0 (0.25% guargum) exhibited the lowest physiological loss throughout the study, particularly on day 8 (0.10%), highlighting its efficacy in reducing physiological deterioration. E2T1C2 (guargum 0.5% + coconut oil 2.0%) and E1T1C2 (coconut oil (2.0%) + guar gum (0.25%) displayed slightly higher losses over time, but still significantly outperformed the control group. Dhrubo *et al.* (2019) noted that eggplant (*Solanum melongena*) experienced a weight loss of 4.07%.

Respiration rate

Figure 1 illustrates the impact of edible coatings on respiration rate. The type of coating significantly influenced respiration rates during storage ($p < 0.05$). The respiration rates of the two spinach microgreen varieties showed a significant reduction ($p < 0.05$) between the first and fourth days of storage. Following this period, the rate remained relatively constant until storage duration was reached. The coating treatments E1T1C0 (0.25% guargum) exhibited remarkable efficacy in controlling respiration rate, initially the respiration rate was measured at 22.5 µl CO, g^{-1} h^{-1} and showing a modest increase to 34.1 µl CO, g^{-1} h^{-1} by day 8. E1T1C0 (0.25% guargum) consistently displayed the lowest respiration rates throughout the storage period, indicating that this coating significantly ($P \leq 0.05$) reduced respiratory and metabolic activities. This suggests its effectiveness in decelerating the deterioration process (Ghoora and Srividya, 2020). By lowering respiration rates, edible coatings can help maintain the quality attributes of the fresh produce including texture, colour and nutritional value for extended periods. Additionally, a reduced metabolic activity may lead to decrease water loss and slower ripening process, further contributing to the overall longevity. A similar effect was observed in coated shallots, which showed reduction in respiration rates compared to uncoated samples, further supporting the ability of edible coatings to lower respiration rates in fresh produce (Wibisono and Bintoro, 2021).

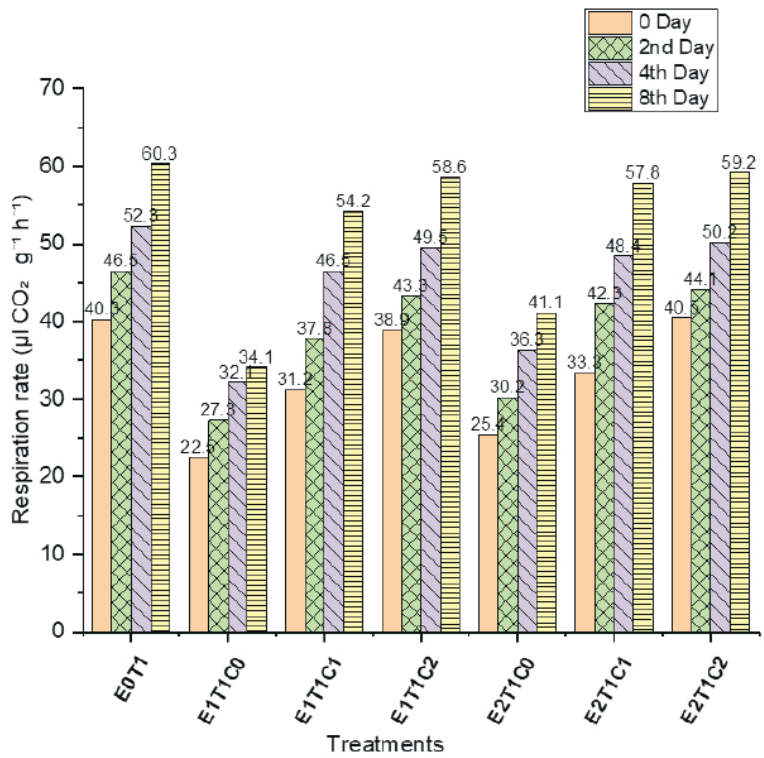

Figure 1. Respiration rate of the coated and uncoated spinach microgreens

Determination of ascorbic acid

The table summarizes the association between different samples of spinach microgreens (E0T1-Uncoated, E1T1C0, E1T1C1, E1T1C2, E2T1C0, E2T1C1, and E2T1C2) and their ascorbic acid contents over 2, 4, and 8 days. One-way ANOVA was used to assess the significance of the differences between the samples over time, and the uncoated sample (E0T1-uncoated) had the lowest ascorbic acid content, suggesting that the absence of a protective coating accelerates nutrient degradation. while the highest was found in the E1T1C0 - 0.25% guargum sample (47.70 mg 100 g^{-1}). This indicates that the application of a coating can helps preserve the nutrient value in the early stages of storage. These findings are consistent with studies that demonstrated the protective effect of polysaccharide-based edible coatings in preserving vitamins and antioxidants in fresh vegetables (González-Aguilar *et al.,* 2009). The uncoated sample decreased to 23.90 mg 100 g^{-1}, whereas E1T1C0 - 0.25% guargum and E2T1C0 - 0.5% guar gum remained higher, at 42.40 mg 100 g^{-1} and 41.40 mg 100 g^{-1}, respectively. The ascorbic acid content in the uncoated sample dropped further to 10.20 mg 100 g^{-1}, while the best-performing coated samples, E1T1C0 - 0.25% guargum and E2T1C0 - 0.5% guar gum, maintained higher levels at 39.90 mg 100 g^{-1} and 38.90 mg 100 g^{-1} ($P \leq 0.05$), respectively. This finding supports previous research showing that edible coatings can reduce oxidation and nutrient loss in fresh produce (Rojas-Grau *et al*., 2009).

Instrumental colour changes

To determine the association between instrumental color changes in spinach microgreens of samples (E0T1 – Uncoated, E1T1C0, E1T1C1, E1T1C2, E2T1C0, E2T1C1, and E2T1C2) and parameters, the values for lightness (L*), a* (red-green), and b* (yellow-blue) were used to describe colors in a standardized manner. The result clearly indicate that coating application substantially affect instrumental color measurements (L*, a*, and b*) of spinach microgreens throughout the storage period. The changes in L* (lightness), a* (red-green), and b* (yellow-blue) suggest that the color stability of the spinach microgreens deteriorated progressively over the 8 days, with the extent of change varying between different coating treatments; on day 0, immediately after coating, there was already a noticeable difference in color between the control (E0T1-uncoated) and coated samples. Samples like (E1T1C0-0.25% guargum and E2T1C1 - 0.5% guar gum) performed better in maintaining color attributes, suggesting better protection against oxidation and moisture loss (Table 4).

The progressive decline in L* (lightness), along with changes in a* and b* values, suggests that oxidation, dehydration, and chlorophyll degradation (Yamauchi and Watada, 1998) occurred more rapidly in uncoated spinach microgreens than in those treated with the coatings. Coatings combining guar gum and coconut oil appeared to provide the best protection, preserving the color stability longer than the other treatments. This study was in line with the study proposed by Nadim *et al.* (2015), where the application of edible methylcellulose coatings on strawberries resulted in darker fruits with less redness, indicating a significant effect on surface color parameters.

Overall acceptability

At the outset, the untreated sample exhibited high sensory ratings, but its quality deteriorated noticeably over time. The acceptability scores decreased to approximately 7.0 by day 8, signifying some quality loss. Coatings E1T1C0 (0.25% guargum) and E1T1C1 (coconut oil 1.0% + guar gum 0.25%) demonstrated superior performance in preserving overall acceptability, maintaining elevated scores (> 7.5) for up to 4 days, and sustaining acceptable levels (above 7.0) even after 8 days. These treatments appear to be effective in conserving the sensory attributes of spinach microgreens over an extended period. Conversely, the E1T1C2 (coconut oil 2.0% + guar gum 0.25%) and E2T1C2 (guargum 0.5% + coconut oil 2.0%) treatments exhibited the most rapid deterioration in sensory acceptability, particularly beyond day 4, with scores falling between 6.0 and 6.8 by the 8th day. These coatings proved to be less successful in maintaining sensory quality. The acceptability scores for spinach microgreens exhibited a gradual decline over the course of 8 days, with most treatments showing a decrease to approximately 7.0 by the end of the observation period. This decline indicates a noticeable loss in overall quality as perceived by sensory evaluators. Among the various coating treatments tested, E1T1C0 (0.25% guar gum) and E1T1C1 (1.0% coconut oil + 0.25% guar gum) emerged as the most effective in preserving sensory attributes. These treatments maintained high acceptability scores (above 7.5) for the initial 4 days and continued to exhibit acceptable levels (above 7.0) even after 8 days of storage. This suggests that these specific coating formulations were particularly successful in retaining the desirable sensory characteristics of spinach microgreens over an extended period.

In contrast, the treatments E1T1C2 (2.0% coconut oil + 0.25% guar gum) and E2T1C2 (0.5% guar gum + 2.0% coconut oil) demonstrated the least favorable outcomes in terms of sensory preservation. These coatings showed a more rapid deterioration in overall acceptability, especially after day 4 of storage. By the 8th day, the acceptability scores for these treatments had declined to between 6.0 and 6.8, indicating a significant loss in sensory quality. The poor performance of these coatings suggests that higher concentrations of coconut oil (2.0%) may have adverse effects on the sensory attributes of spinach microgreens during storage. The utilization of edible coatings, which consist of thin layers of consumable materials, can create a protective barrier that may aid in preserving the quality and extending the shelf life of sensitive plants (Nikhanj, 2023). Similarly, coatings of carboxymethyl cellulose (CMC) and aloe vera gel (AV) on jujube fruits preserved sensory acceptability and improved appearance quality, including color retention (Moradinezhad *et al*., 2018).

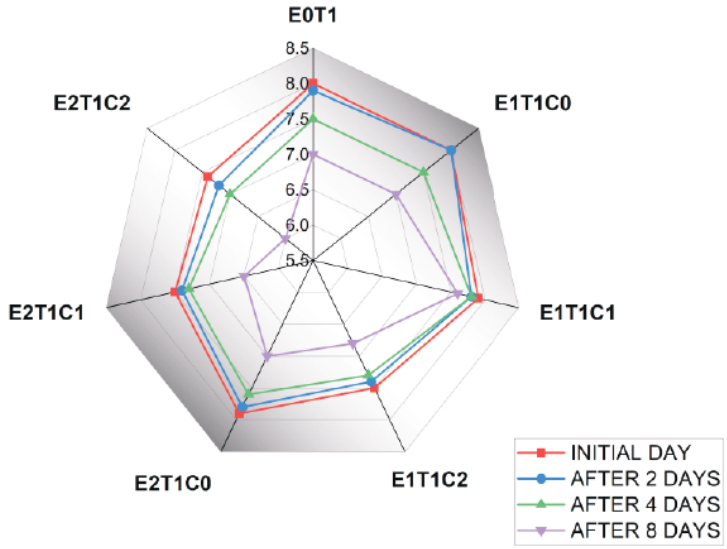

Figure 2. Overall acceptability of coated and uncoated spinach microgreens

In conclusion, this study demonstrated the efficacy of edible coatings in preserving the quality and extending the shelf life of spinach microgreens. The application of guar gum and coconut oil emulsions significantly reduced physiological weight loss, respiration rates, and color changes, while maintaining higher ascorbic acid content compared to uncoated samples. Among the treatments, E1T1C0 (0.25% guar gum) and E1T1C1 (1.0% coconut oil + 0.25% guar gum) exhibited the most promising results in terms of overall acceptability and quality retention throughout the storage period. These findings suggest that the use of edible coatings, particularly those combining guar gum and coconut oil, can be an effective strategy for improving the post-harvest quality and shelf life of spinach microgreens, potentially benefiting both producers and consumers in the fresh produce industry.The study's findings have significant implications for the fresh produce industry, particularly in the context of increasing demand for microgreens and the need for sustainable packaging solutions. The reduction in physiological weight loss, respiration rates, and color changes, coupled with the maintenance of higher ascorbic acid content, suggests that these coatings can help maintain the nutritional value and visual appeal of microgreens for longer periods.

Table 1. Composition of edible coating on spinach microgreens

Treatments	Guargum (%)	Coconut Oil (%)
E0T1	-	-
E1T1C0	0.25	-
E1T1C1	0.25	1.0
E1T1C2	0.25	2.0
E2T1C0	0.5	-
E2T1C1	0.5	1.0
E2T1C2	0.5	2.0

E0T1 (control without coating), E1T1C0 (0.25% guargum), E1T1C1 (coconut oil (1.0%) + guar gum (0.25%), E1T1C2 (coconut oil (2.0%) + guar gum (0.25%), E2T1C0(0.5%guar gum), E2T1C1 (guargum 0.5% + coconut oil 1.0%), and E2T1C2 (guargum 0.5% + coconut oil 2.0%)

Table 2. Physiological weight loss

Treatments	2nd Day	4th Day	8th Day
E0T1	1.70	2.80	3.15
E1T1C0	0.33	0.66	0.10
E1T1C1	0.60	0.73	1.13
E1T1C2	1.00	1.17	1.45
E2T1C0	0.40	0.73	1.00
E2T1C1	1.00	0.90	1.13
E2T1C2	0.90	1.07	1.83
SE (m) ±	0.05	0.07	0.03
CD @5%	0.15	0.20	0.09

Values with different superscripts differ significantly ($p<0.05$)

Table 3. Association between samples and ascorbic acid in 2, 4 and 8 days

Days	Samples	Mean	SE (m) ±	CD @5%
Day 2	E0T1-Uncoated	35.00	**0.06**	**0.174**
	E1T1C0	47.70		
	E1T1C1	45.20		
	E1T1C2	43.50		
	E2T1C0	46.70		
	E2T1C1	44.20		
	E2T1C2	40.50		
Day 4	E0T1-Uncoated	23.90	**0.025**	**0.075**
	E1T1C0	42.40		
	E1T1C1	40.40		
	E1T1C2	38.00		
	E2T1C0	41.40		
	E2T1C1	39.40		
	E2T1C2	35.00		
Day 8	E0T1-Uncoated	10.20	**0.514**	**1.54**
	E1T1C0	39.90		
	E1T1C1	35.80		
	E1T1C2	30.00		
	E2T1C0	38.90		
	E2T1C1	35.00		
	E2T1C2	27.00		

Values with different superscripts differ significantly ($p<0.05$)

Table 4. Association between samples and instrumental colour changes in 0,4,8 days

Samples	Parameters	0Day	4Days	8Days
E0T1-Uncoated	Lightness (L):*	12.19	9.20	9.12
	a* Value (Red-Green)	-3.42	-2.12	-1.10
	Yellow-Blue Axis (b):*	9.24	18.12	25.60
E1T1C0	Lightness (L):*	11.98	10.90	9.05
	a* Value (Red-Green)	-3.12	-2.40	-2.29
	Yellow-Blue Axis (b): *	8.01	27.90	37.53
E1T1C1	Lightness (L): *	10.12	9.18	8.01
	a* Value (Red Green)	-1.31	-1.29	-1.05
	Yellow-Blue Axis (b): *	8.62	17.66	36.45
E1T1C2	Lightness (L): *	11.64	10.23	9.45
	a* Value (Red Green)	-2.31	-2.01	-1.98
	Yellow-Blue Axis (b): *	8.10	17.92	26.84
E2T1C0	Lightness (L): *	12.10	11.87	10.89
	a* Value (Red Green)	-3.62	-3.01	-3.93
	Yellow-Blue Axis (b): *	9.26	28.93	37.90
E2T1C1	Lightness (L): *	11.19	9.10	8.09
	a* Value (Red Green)	-3.32	-3.20	-3.09
	Yellow-Blue Axis (b): *	8.21	7.89	6.83
E2T1C2	Lightness (L): *	12.12	11.91	11.23
	a* Value (Red Green)	-3.39	-3.36	-2.89
	Yellow-Blue Axis (b): *	8.21	17.82	26.99
	SE (m)±	**0.03**	**0.052**	**0.09**
	CD @5%	**0.09**	**0.156**	**0.27**

Values with different superscripts differ significantly ($p<0.05$)

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