Optimizing Strategies to Inhibit Enzymatic Browning in Peeled Potatoes Through Thermal, Chemical, and Edible Coating Approaches.

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Abstract

Background:
Enzymatic browning in peeled potatoes significantly compromises visual appeal, shelf life, and consumer acceptance, posing a major concern in postharvest handling and food processing industries.
Objective:
To evaluate and compare the effectiveness of blanching, refrigeration, ascorbic acid immersion, and cellulose gum-based edible coatings in mitigating enzymatic browning in British white potatoes.
Methods:
Freshly peeled and sliced British white potatoes were subjected to different anti-browning treatments: (1) blanching, (2) refrigeration, (3) ascorbic acid immersion, and (4) edible coating with cellulose gum—with or without ascorbic acid. Color changes were monitored at regular intervals over 84 minutes using a Minolta CR-200 colorimeter. Data were statistically analyzed to assess the efficacy of each treatment.
Results:
Blanching showed the highest reduction in browning rate but potentially affected texture and nutrient retention. Edible coatings, particularly when combined with ascorbic acid, significantly delayed browning, indicating a synergistic effect of antioxidant action and oxygen barrier formation. Refrigeration provided moderate browning control but was inferior to other treatments.
Conclusion:
Integrated anti-browning strategies that combine physical barriers and antioxidants, such as cellulose gum coatings enriched with ascorbic acid, offer promising alternatives to traditional methods. Further research into edible films and oxygen-reducing packaging is recommended for improved preservation of minimally processed potatoes.

Keywords: Enzymatic browning, potato, ascorbic acid, blanching, edible coating, refrigeration, food preservation

1. Introduction

The visual appeal of fresh produce plays a critical role in consumer purchase decisions. Among the primary factors affecting visual quality is browning, a biochemical process that leads to undesirable discoloration in fresh-cut fruits and vegetables. In peeled potatoes, this is predominantly caused by enzymatic browning, catalyzed by the enzyme polyphenol oxidase (PPO), which oxidizes phenolic compounds to quinones, subsequently forming brown-colored melanins. The reaction occurs rapidly when cell walls are disrupted during peeling or cutting, exposing phenolics to PPO in the presence of oxygen [1,2]

Enzymatic browning not only affects the aesthetic value of potatoes but also alters taste, reduces nutritional quality, and shortens shelf-life (3). Traditional mitigation strategies include refrigeration, thermal inactivation through blanching, application of reducing agents like ascorbic acid, and more recently, the use of edible films that limit oxygen diffusion (4,5).

Polyphenol oxidase activity and the concentration of substrates such as chlorogenic acid vary among potato cultivars, influencing their browning susceptibility (6). Several studies have established that higher chlorogenic acid content correlates with increased browning, especially when PPO activity is also high (7). Controlling browning requires not only an understanding of these internal biochemical components but also of environmental and technological interventions.

This study aims to evaluate the comparative effectiveness of five treatments—control (untreated), blanching, refrigeration, ascorbic acid, edible coating with cellulose gum, and a mixture of coating and antioxidant—in reducing enzymatic browning in peeled potatoes. The objective is to determine which method or combination provides the most practical and sustainable control for both household and industrial applications.

2. Materials and Methods

2.1. Materials

British white potatoes were sourced fresh and selected for uniformity in size, shape, and absence of surface defects. The following materials and chemicals were used:

- Ascorbic acid (analytical grade)
- Edible film: Blanose cellulose gum (Type 7HOF, Lot 11152)
- Distilled water
- Hot water bath (100°C)
- Refrigerator (set to -18°C)
- Minolta Colorimeter CR-200 for colorimetric analysis

2.2. Preparation of Solutions

- 2.5% (w/v) Ascorbic Acid: 5 g of ascorbic acid was dissolved in 200 mL of distilled water.
- 5% (w/v) Cellulose Gum Solution: 2.5 g of cellulose gum was dissolved in 50 mL of distilled water with continuous stirring until fully hydrated.
- Mixture of Cellulose Gum and Ascorbic Acid: Equal volumes of the 5% cellulose gum and 2.5% ascorbic acid solutions were mixed to form a combined treatment.

2.3. Experimental Design and Treatment Groups

The experiment consisted of six treatment groups:

1. Control (untreated at room temperature)
2. Ascorbic Acid Treatment: Slices immersed in 2.5% solution
3. Blanching: Slices immersed in hot water (100°C) for 2 minutes
4. Refrigeration: Samples stored at -18°C
5. Edible Coating: Coated with 5% cellulose gum
6. Combination Treatment: Coated with cellulose gum + 2.5% ascorbic acid

Each potato sample was peeled, sliced uniformly (approx. 3 mm thickness), and subjected to treatments. Immediately following treatment, samples were evaluated for color change at intervals: 0, 4, 14, 24, 34, 44, 54, 64, 74, and 84 minutes.

2.4. Color Measurement

Colorimetric evaluation was performed using a Minolta Colorimeter (CR-200). The L*, a*, and b* values were recorded, where:

- L* indicates lightness (0 = black, 100 = white),
- a* indicates red-green axis (+a = red, −a = green),
- b* indicates yellow-blue axis (+b = yellow, −b = blue).

Standard deviation values were also calculated to assess variability across replicates.

3. Results

The data, as represented in Table 1 and Figure 2, reflect the time-dependent browning of potato slices across different treatments.

3.1. Colorimetric Trends

- The control group showed a sharp decline in L* value and significant fluctuations in a* and b* values, indicating substantial browning over time.
- Ascorbic acid treatment showed initial improvement in L* value preservation, but its protective effect diminished after ~30 minutes.
- Blanching maintained relatively high L* values with minor variation in a* and b* throughout the observation period, suggesting effective PPO inactivation.

- Refrigerated samples showed moderate protection against browning with a gradual decrease in L* values, consistent with reduced but not halted enzymatic activity.
- Cellulose gum coating alone preserved L* moderately but less effectively than when combined with ascorbic acid.
- The combination treatment of cellulose gum and ascorbic acid showed the best performance across all parameters (L*, a*, b*), maintaining lightness and minimizing color shift.

3.2. Statistical Analysis

A two-way ANOVA indicated statistically significant differences ($p < 0.05$) in L* values among treatment groups and across time points. The combination treatment had the lowest overall variance in color stability, indicating higher efficacy in browning control.

4. Discussion

The results obtained from this study reveal important insights into the effectiveness of various methods in controlling enzymatic browning in peeled potatoes. Browning, primarily driven by the action of polyphenol oxidase (PPO) on phenolic compounds such as chlorogenic acid, remains one of the most critical quality-degrading reactions in minimally processed vegetables like potatoes (1,8). The visual appearance of food products significantly affects consumer perception, and discoloration due to enzymatic browning often leads to rejection, regardless of the nutritional value of the product (3,7).

Among the tested treatments, blanching emerged as a highly effective method for reducing browning. By subjecting the potato slices to hot water (100°C) for two minutes, the thermal denaturation of PPO was likely achieved, resulting in reduced enzymatic activity (4,9). This observation is consistent with previous studies that demonstrated the effectiveness of blanching in inactivating browning-related enzymes in fruits and vegetables (10,11). However, thermal treatment also presents certain drawbacks. It can compromise the structural integrity of the potato tissues, leading to softening and potential loss of consumer acceptability (12,13). Additionally, blanching can degrade heat-sensitive nutrients, such as vitamin C and certain B-complex vitamins, thereby affecting the overall nutritional profile of the product (9).

The application of refrigeration was also evaluated as a method for controlling browning. The cold storage condition at -18°C slowed down the enzymatic reactions by reducing the kinetic energy of the molecules involved (14). However, refrigeration did not fully prevent browning. This partial efficacy is attributed to the fact that PPO, while operating at reduced rates under low temperatures, remains active and capable of catalyzing oxidation reactions when oxygen and phenolic substrates are present (15,16). Moreover, refrigeration primarily inhibits microbial growth rather than enzymatic activity, thus offering limited protection against enzymatic browning over time (16).

The use of ascorbic acid, a well-established antioxidant, offered moderate effectiveness in delaying browning. Ascorbic acid acts by reducing o-quinones back to their corresponding phenolic precursors and scavenging oxygen, thereby interrupting the browning cascade (17,18). However, ascorbic acid is readily oxidized to dehydroascorbic acid, which lacks antioxidant functionality

(16). This transformation limits the longevity of its protective effect, as observed in the gradual increase in browning over time in the treated samples. These findings are consistent with the literature, which suggests that while ascorbic acid is effective in the short term, its irreversible oxidation reduces its long-term utility in enzymatic browning control (19,20).

Edible coatings made from Blanose cellulose gum provided a physical barrier to oxygen diffusion, thereby reducing the availability of one of the essential reactants in the browning process. The application of this semi-permeable film also helped maintain moisture content, reduce respiration rates, and possibly retain surface antioxidants (5,21). The use of edible films alone showed promising results, but the most significant reduction in browning was observed when the film was combined with ascorbic acid. This combination leveraged both the physical barrier properties of the cellulose gum and the chemical reducing power of ascorbic acid, providing a synergistic effect that enhanced the control of enzymatic browning (3,22).

The superior performance of the combination treatment aligns with other studies that advocate for multi-modal preservation strategies in fresh-cut produce (23,24). The cellulose matrix likely provides some protection against oxidation and facilitates controlled release of the antioxidant, making it a versatile solution in food preservation (25,26).

Taken together, these findings underscore the importance of combining physical and chemical approaches to effectively inhibit enzymatic browning in fresh produce. While single treatments like blanching or antioxidant application offer some degree of protection, their limitations become apparent over time or through negative impacts on sensory and nutritional quality. In contrast, integrated methods that combine edible coatings with antioxidants or thermal pretreatments can offer more balanced solutions by mitigating browning while preserving product quality (27,28).

In summary, the combination of Blanose cellulose gum and ascorbic acid emerged as the most effective treatment in this study. It provided a durable barrier against browning while maintaining the sensory attributes of the potato slices. Although blanching was effective enzymatically, its thermal effects on tissue texture and nutrient content make it less suitable for applications where fresh-like quality is desired. Refrigeration alone, while necessary for microbial control, should be supplemented with other treatments for optimal browning prevention. Future research should explore long-term storage implications, consumer acceptability, and the use of other edible coatings and antioxidants to further refine postharvest preservation strategies (29,30).

5. Conclusion

This study demonstrates that enzymatic browning in peeled British white potatoes can be significantly mitigated through the application of thermal, chemical, and physical barrier interventions. The rate of browning, assessed through colorimetric readings over time, revealed that blanching, despite its effectiveness in enzyme inactivation, potentially compromises textural and nutritional quality. Refrigeration, while delaying browning, was insufficient as a standalone treatment for long-term preservation.

The most promising strategy identified was the application of edible cellulose gum films combined with ascorbic acid. This combination effectively maintained high L* values and reduced the progression of browning, likely due to both oxygen exclusion and antioxidant activity. These findings underscore the value of integrated approaches in food preservation technology, particularly for minimally processed produce.

The insights derived from this investigation can inform post-harvest handling and value-added processing strategies for potatoes and other perishable crops. Given consumer expectations for fresh appearance and sensory appeal, the incorporation of safe and functional coating technologies offers significant commercial potential.

6. Recommendations

Based on the findings of this research, the following recommendations are proposed:

1. Industrial Adoption of Edible Films: The use of edible films such as cellulose gum, in combination with antioxidants, should be explored for commercial application in fresh-cut potato processing.
2. Packaging Innovation: Further integration of oxygen-restrictive packaging (e.g., vacuum or modified atmosphere packaging) with coating treatments could enhance shelf-life.
3. Advanced Research: Future studies should employ real-time enzymatic assays and high-resolution imaging to understand PPO activity and microstructural changes in coated products.
4. Broader Additive Screening: The use of calcium chloride, erythorbic acid, and other novel inhibitors should be evaluated for synergistic effects with edible films.
5. Consumer Sensory Evaluation: Studies incorporating sensory panels can help determine the acceptability of textural changes resulting from treatments like blanching.
6. Shelf-life Trials: Longer storage evaluations are recommended to assess browning and microbial safety under real-world conditions.

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RESULT:

Table 1. Colorimetric Readings of the Browning rate of British White Potato.

Time (mins)	Control @ room temperature	Ascorbic Acid (2.5%g/v)	Hot Water @ 100˚C	Blanose Cellulose gum. (5%g/v)	Mixture of 5% Blanose + 2.5% Ascorbic acid.	Refrigeration @ -18˚C	standard Dev.		STD DEV
0	L72.97	64.07	70.62	72.26	73.53	72.73	27.04174	27.96465	9.321549
	A0.37	0.54	0.56	0.42	0.38	0.42	0.081588		
	B 16.19	14.34	14.98	16.2	16.53	15.73	0.841318		
4	L 65.14	65.74	60.35	59.43	68.42	67.75	23.11283	27.31777	9.105922
	A 0.6	0.91	-0.67	-0.28	0.13	-0.3	0.599491		
	B 13.27	13.38	9.59	15.82	18.35	19.27	3.605444		
14	L 67.95	65.79	60.76	71.02	68.46	63.2	20.02267	24.64536	8.215119
	A 0.67	0.98	-0.7	0.59	0.42	-0.24	0.630608		
	B 13.6	13.51	7.15	16.54	16.41	18.54	3.992079		
24	L 70.73	72.11	61.17	71.13	70.3	73.93	17.8192	23.64318	7.881059
	A 0.63	0.99	-1	0.24	0.12	0.05	0.67449		
	B 14.56	13.44	5.76	18.46	18.86	19.21	5.149487		
34	L 71.09	70.23	61.27	71.74	59.53	72.01	13.73038	19.91352	6.637839
	A 0.86	1.06	-0.92	0.62	0.34	0.57	0.702522		
	B 14.18	12.66	3.31	18.12	16.42	17.44	5.480615		
44	L 70.41	70.32	62.23	62.18	71.13	70.32	9.808982	21.79833	7.26611
	A 0.95	13.55	-1.04	0.95	0.24	-0.5	5.539427		
	B 14.06		3.95	15.39	16.82	21.49	6.44992		
54	L 71.95	65.61	62.04	71.13	72.16	70.12	6.743977	12.4642	4.154734
	A +I.40	0.98	-0.9	1.3	0.19	0.08	0.86		
	B 14.27	13.31	6.14	16.95	17.36	20.23	4.860226		
64	L 69.97	69.88	61.58	71.05	71.89	71.63	4.081615	8.44904	2.816347
	A 0.98	0.83	6.42	1.82	0.3	0.72	2.296186		

	B 15.13	13.33		15.62	16.58	18.97	2.071239		
74	L 70.51 A 1.76 B 15.57	70.32 0.77 13.01	61.16 -1.38 3.19	71.07 1.23 18.73	65.16 0.51 15.89	70.57 0.64 19.26	4.320054 1.067772 5.889991	11.27782	3.759272
84	L 70.11 A 2.26 B16.28	65.4 1 12.81	61.7 -1.12 5.16	70.79 1.07 19.56	71.56 0.35 15.92	71.55 0.97 19.76	6.925701 1.109067 5.431654	13.46642	4.488807