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Impact of Cold Pressed Cardamom Oil (*Elettaria cardamomum*) on The Sensory Attributes and Color Stability of Frozen Chicken Burger

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Abstract

Background: Essential oils' natural antioxidants and antibacterial properties have attracted attention in meat preservation since they offer a good alternative for synthetic preservatives. This study investigated the efficacy of cold-pressed cardamom essential oil (CEO) as a natural preservative for maintaining color stability and sensory quality in frozen chicken burgers stored over three months **Methods:** Burgers were formulated with varying concentrations of CEO (50, 25, and 12.5 ppm) and compared to a synthetic antioxidant, butylated hydroxytoluene (BHT, 200 ppm), and untreated control. **Results:** Instrumental color analysis using CIE Lab*color space showed that CEO-treated samples significantly ($p < 0.001$) maintained higher redness (a*) and lower total color variation (ΔE) than control and BHT samples throughout storage, indicating better oxidative stability. Sensory evaluation (odor, color, texture, taste, overall acceptability) conducted by a trained panel using a nine-point hedonic scale revealed that CEO, especially at 50 ppm, significantly improved sensory stability compared to control and synthetic antioxidant (BHT). **Conclusions:** These findings highlight CEO's potential as a natural preservative in frozen chicken burgers, enhancing both color and sensory stability in meat products, offering manufacturers a viable clean-label alternative. Further research on microbial stability and physicochemical changes could provide deeper insights into preservation mechanisms of cardamom essential oils in meat products.

Keywords: Food quality, Essential oil, Elettaria cardamomum, Sensory evaluation.

1. Introduction

The growing consumer demand for safer, healthier food products has driven significant interest in natural food preservatives as alternatives to synthetic additives [1]. Consumers are increasingly seeking clean-label products, prompting the food industry to explore plant-derived bioactive compounds with antioxidant and antimicrobial properties for meat preservation [2, 3]. Essential oils extracted from various species, such as cardamom, have gained attention because of their ability to enhance food quality, extend shelf life, and improve sensory attributes [4]. Cardamom (Elettaria cardamomum), widely recognized for its aromatic and medicinal properties, is a rich source of bioactive compounds including flavonoids, terpenoids, and phenolic acids, which exhibit strong antioxidant activity [5].

Meat products, particularly frozen poultry, are prone to oxidative deterioration, leading to unfavorable changes in color, texture, and sensory characteristics over time [6]. Synthetic antioxidants such as butylated hydroxytoluene (BHT) have been commonly used to mitigate oxidative degradation; however, concerns regarding their potential health risks have prompted the search for natural alternatives [7]. Cold-pressed essential oils (CEO) obtained without the use of chemical solvents retain a higher concentration of bioactive compounds, making them an attractive natural preservative option [8]. Despite the well-documented antioxidant and antimicrobial properties of cardamom essential oil, its direct application in poultry meat preservation remains largely underexplored. Therefore, this study evaluated the effects of CEO on color stability and sensory attributes of frozen chicken burgers during storage. By comparing different CEO concentrations with synthetic antioxidants, it sought to determine cardamom oil's efficacy in maintaining product quality over time. Understanding natural preservatives' role in meat preservation can contribute to developing healthier clean-label alternatives in the food industry.

2. Materials and Methods

2.1. Ethical Approval

The study protocol was reviewed and approved by the Care and Use Committee for Research Ethics at the Faculty of Veterinary Medicine, Banha University (BUFVTM 01-10-23).

2.2. Essential Oil and Chicken Burger Patty Preparation

Cold-pressed cardamom essential oil (Haraz Ltd., Cairo, Egypt) was purchased from a supermarket in Benha City, Qalyubia Governorate. Approximately 3000 gm of fresh chicken breast meat was obtained from a local market in Benha City, Egypt. Then, the chicken meat was minced using a 5 mm plate grinder (Mainca, Barcelona, Spain) and divided into five groups. The control group (C) contained no additives, while the positive control (BHT) was supplemented with 200 ppm of butylated hydroxytoluene (BHT). Three experimental groups were treated with cardamom essential oil (CEO): 50 ppm (T1), 25 ppm (T2), and 12.5 ppm (T3). After mixing treatments with minced meat, chicken burgers (40 ± 2 g) were formed using a manual mold. Samples were frozen at -18°C and

evaluated initially (0 months) and monthly for three months. This experiment was performed in triplicate.

2.3. Instrumental Color Analysis

The color parameters L*, a*, and b* were measured in chicken burgers using a CR-410 chromometer (Konica Minolta Sensing, Inc., Osaka, Japan). The device was configured to operate within the L*, a*, and b* color space, utilizing illuminant D65 with a 2° observer angle and an 8.0 mm closed cone aperture. Calibration was conducted using a standard white tile prior to the measurement. Color readings were taken across the cut surface of chicken burger patties following a 30-minute blooming period. These measurements were then used to determine color saturation (hue angle) using the equation h° = arctan (b*/a*), and color intensity (chroma) as C = ($a^2 + b^2$)^0.5. The total color variation (ΔE) between fresh and stored chicken burger samples was calculated using the following formula [9].

$$(\Delta E) = [(L^* - L^*_0)2 + (a^* - a^*_0)\,2 + (b^* - b^*_0)2]\,{}^{1}/_{2}$$

2.4. Sensory Evaluation

A trained nine-member panel conducted sensory evaluation of frozen chicken burgers at the Meat Hygiene Laboratory, Faculty of Veterinary Medicine, Banha University. Panelists used a nine-point hedonic scale to assess sensory attributes: odor, color, texture, taste, and overall acceptability. Samples were thawed at room temperature (22 ± 2°C) for 1 hour prior to sensory analysis. Each characteristic was rated from 1 ("dislike extremely") to 9 ("like extremely"). Overall sensory acceptability scores were categorized as very good, good, acceptable, unacceptable, and bad. No additional sample preparation was performed prior to evaluation [10].

2.5. Statistical Analysis

Data analysis was conducted using SPSS software (version 22, SPSS Inc., Chicago, IL, USA). Results are expressed as mean ± standard error. Tukey's b multiple comparison test assessed effects of cardamom essential oil compared to the control group and analyzed differences across time points within the same treatment group. The significance threshold was $P < 0.05$.

3. Results

3.1. Color stability of frozen chicken burgers during storage

The effects of CEO on color stability of frozen chicken burgers during three months of storage were illustrated in Figure 1. and Table 1. L* values (lightness) varied significantly over time ($p < 0.001$), with the highest lightness recorded in T3 on day zero (63.27) and the lowest in the control group (61.655). Over time, the L* values increased in all groups, particularly in the BHT group at the third month (64.70), reflecting the possible oxidative effects of storage. Similarly, a* values (redness) decreased over time in all samples, with T3 exhibiting the lowest redness reduction ($p < 0.001$), indicating its superior oxidative stability compared to the other treatments. The b* (yellowness) and chroma (C*) values followed similar trends, with significant effects observed throughout storage ($p < 0.001$).

Table (1) Color stability of frozen chicken burgers during storage.

Parameter	Storage time	Groups					SEM	*p* value		
		CON	BHT	T1	T2	T3		G	T	G*T
L*	Zero day	61.655^{c}	62.60^{Da}	62.74^{Da}	61.935^{Bc}	63.27^{Aa}	0.009	<0.001	<0.001	<0.001
	1st month	60.01^{d}	63.40^{Ca}	63.41^{Ca}	61.68^{Cb}	61.02^{Cc}				
	2nd month	64.19^{b}	63.83Bc	64.63^{Aa}	63.28^{Ad}	61.12^{Ce}				
	3rd month	61.320	64.70^{A}	64.41^{B}	62.00^{B}	61.90^{B}				
a*	Zero day	8.69^{a}	7.26^{Ab}	4.97^{Ad}	6.27^{Ac}	4.02^{De}	0.014	<0.001	<0.001	0.001
	1st month	6.31^{a}	5.02^{Dc}	3.715^{Ce}	4.71Bd	5.54B^{b}				
	2nd month	3.46^{c}	7.09^{Ba}	3.29^{Dc}	4.83^{Bb}	4.72C^{b}				
	3rd month	7.36	5.86^{C}	4.44^{B}	6.11^{A}	7.06^{A}				
b*	Zero day	17.10^{b}	18.85^{Ba}	18.58^{Ba}	18.31^{Ba}	18.81^{Aa}	0.017	<0.001	<0.001	0.001
	1st month	16.31^{e}	17.79^{Cc}	19.35^{Aa}	18.17^{Bb}	17.30^{Cd}				
	2nd month	19.99^{a}	18.68^{Bc}	19.33^{Ab}	19.30^{Ab}	18.21^{Bd}				
	3rd month	16.68	19.26^{A}	19.32^{A}	17.36^{C}	17.89^{B}				
C*	Zero day	19.18^{b}	20.20^{Aa}	19.23^{b}	19.36^{Bb}	19.23^{Ab}	0.056	0.001	<0.001	0.002
	1st month	18.49	18.49^{C}	19.50	18.77^{C}	18.16^{C}				
	2nd month	20.28^{a}	19.98^{Bb}	19.78^{b}	19.89^{Ab}	18.81^{Bc}				
	3rd month	18.23	20.13^{AB}	19.51	18.40^{D}	19.23^{A}				
Hue angle	Zero day	63.08^{e}	68.94^{Cd}	75.02^{b}	71.10^{Bc}	77.93^{Aa}	0.279	<0.001	<0.001	<0.001
	1st month	65.91^{b}	74.24^{Aa}	76.92^{a}	75.46^{Aa}	72.25^{Cab}				
	2nd	80.19^{a}	69.21^{Cb}	77.84^{a}	76.09^{Aa}	75.47^{Ba}				

	month									
	3rd month	66.19	72.85^{B}	74.14	70.62^{B}	68.48^{D}				
	Zero day		2.49^{ab}	2.25^{b}	1.62^{c}	2.70^{a}	0.014	<0.001	<0.001	<0.001
Δ E	1st month		3.93^{a}	2.03^{c}	2.33^{b}	1.30^{d}				
	2nd month		3.93^{a}	4.00^{a}	2.04^{c}	2.51^{b}				
	month									
	3rd month		4.55^{a}	1.44^{c}	3.53^{b}	1.11^{d}				

$^{a-e}$ means within a row not sharing a common superscript differ significantly when ($p < 0.05$), $^{A-D}$ means within a column not sharing a common superscript differ significantly when ($p < 0.05$), SEM: standard error of mean, CON: control group, BHT: butylated hydroxy toluene treated group, T_1: group treated with 50 ppm cardamom oil , T_2: group treated with 25 ppm cardamom oil, T_3: group treated with 12.5 ppm cardamom oil L*: Lightness, a*: redness, b*: yellowness, C*: chroma, Δ E: Delta E (Total color differences), G: group, T: time of storage, G*T: interaction between group and storage time.

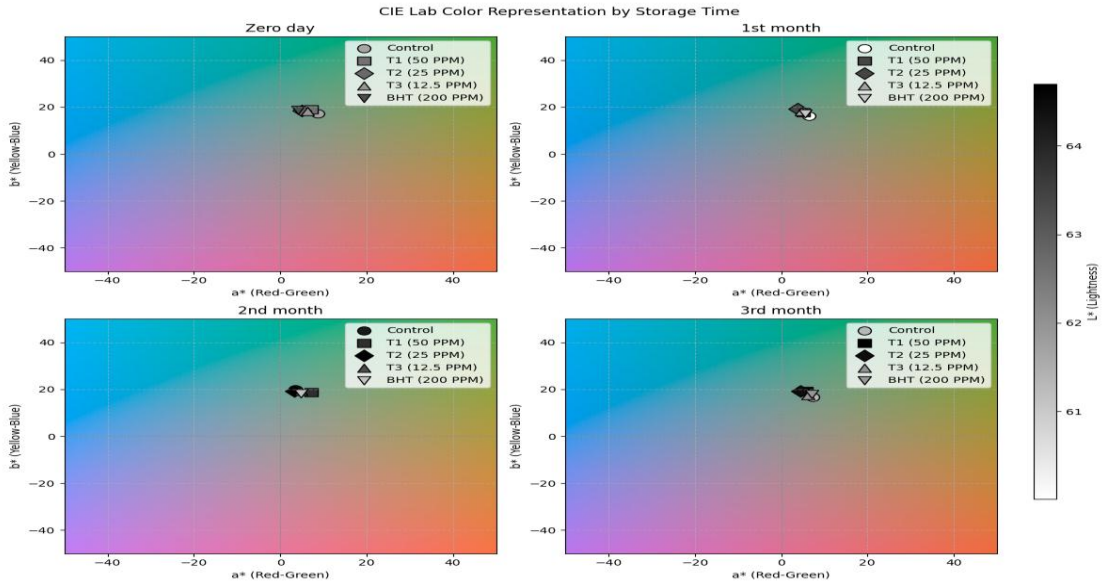

Fig. (1) CIELAB color of the frozen chicken burger treated with cardamom oil at three concentrations (T1, T2, and T3) was compared to that of the BHT and Control groups by storage time. Legend Marks indicate different groups, and color intensity represents L* values aligned with gray scale bars.

The hue angle increased over time, indicating a shift toward a more yellow tone in all groups. The highest hue angle was observed in the T3 group (77.93°) on day zero, while the control group exhibited the lowest hue angle (63.08°). Delta E (ΔE) values also increased with storage, with the highest color changes observed in the control and BHT groups, suggesting that essential oil treatment might offer better color stability (Fig.2).

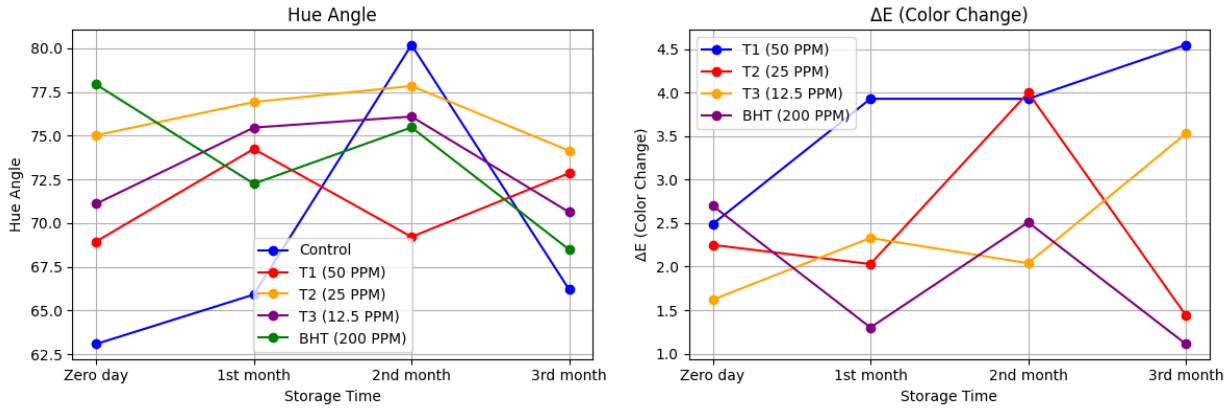

Fig. (2) Hue and Color changes of frozen chicken burgers treated with cardamom oil at three concentrations (T1, T2 and T3) compared to the BHT and Control groups by storage time.

The sensory evaluation of frozen chicken burgers treated with different concentrations of cardamom oil (T1, T2, and T3) was assessed over a three-month storage period, compared to butylated hydroxytoluene (BHT) and a control sample (C). Attributes analyzed included odor, color, texture, taste, and overall acceptability (Figure 3-5). The odor profile declined gradually across all treatments over time (Figure 3). Initially, all samples started at a high rating of 9. After one month, the control sample (C) showed a more pronounced decline than treated samples, with a score of 6. Cardamom oil (T1, T2, and T3) led to a slower decline, suggesting its potential role in maintaining odor stability. By the third month, T1, T2, and T3 retained better odor ratings (5, 4.5, and 4, respectively) than the control (3.25). This trend suggests that cardamom oil may have antioxidant or antimicrobial effects that help retain the fresh odor of chicken burgers during storage.

Color is a key indicator of quality and consumer acceptability (Fig.3). The control sample showed a decline from 9 to 3.75 by the third month, whereas BHT and cardamom-treated samples demonstrated improved color stability. T1, T2, and T3 maintained higher scores than the control, indicating that natural pigments and antioxidant activity of cardamom oil may prevent discoloration. Results suggest that higher concentrations of cardamom oil (T1) were more effective in color preservation, showing similar or better performance than the BHT-treated sample.

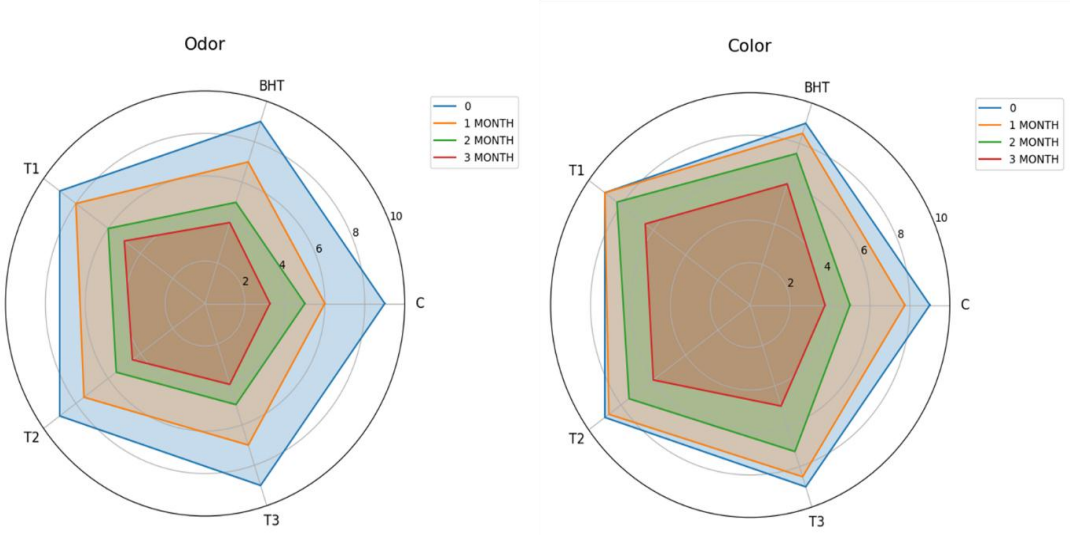

Fig. (3) Odor and Color Sensory Evaluation of Frozen Chicken Burgers Treated with Cardamom Oil and BHT Over Three Months of Storage.

The textural attributes of the chicken burgers followed a similar trend to odor and color, with the control group experiencing the most significant decline over time (Fig. 4). Initially, all samples had a score of 9. After three months, the control dropped to 3.5, whereas T1, T2, and T3 retained scores of 6.5, 6, and 5, respectively. These findings indicate that cardamom oil helped maintain product firmness and reduce structural degradation during storage, potentially due to its antimicrobial properties that prevent protein breakdown.

Taste is crucial for consumer preference. The control and BHT-treated samples showed a significant decline in taste scores over time, with the control dropping from 9 to 2 by the third month (Fig. 4). In contrast, the cardamom oil-treated samples retained higher scores (4.5 for T1 and T2, and 3 for T3). This suggests cardamom oil might have contributed to flavor stabilization by preventing oxidative rancidity, common in stored meat products. T1, with the highest concentration of cardamom oil, exhibited the best taste retention, highlighting the potential of this natural extract for flavor preservation.

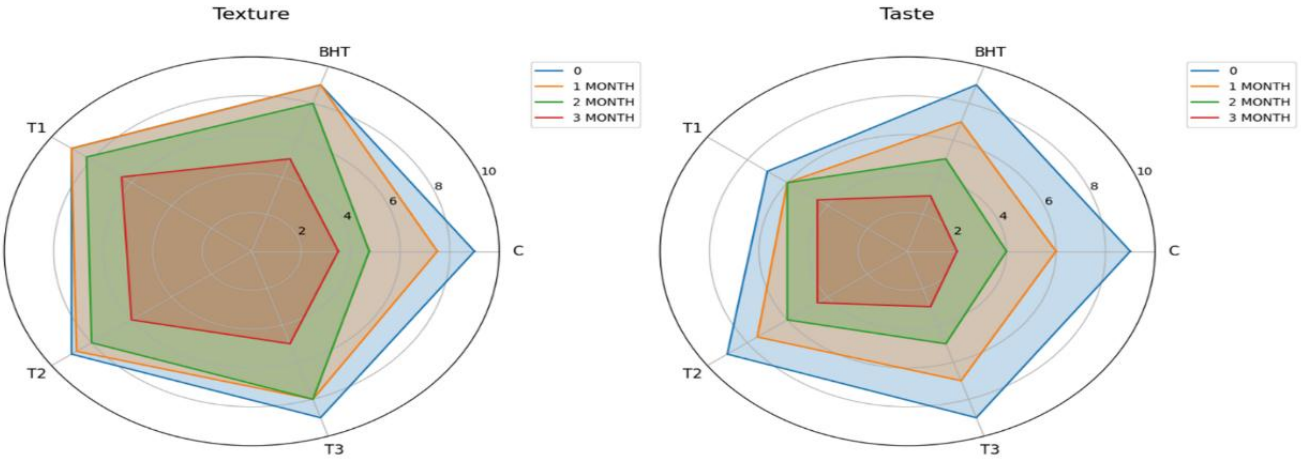

Fig. (4) Texture and Taste Sensory Evaluation of Frozen Chicken Burgers Treated with Cardamom Oil and BHT Over Three Months of Storage.

The cumulative effects of the sensory attributes were reflected in the overall acceptability scores. The control sample showed the steepest decline, decreasing from nine at the start to four at the end of the study. The BHT-treated samples performed slightly better, but T1, T2, and T3 demonstrated superior results, with T1 maintaining the highest acceptability score (6) by the end of the third month. This suggests that cardamom oil, particularly at high concentrations, positively influences the long-term sensory quality of frozen chicken burgers, making it a promising natural preservative.

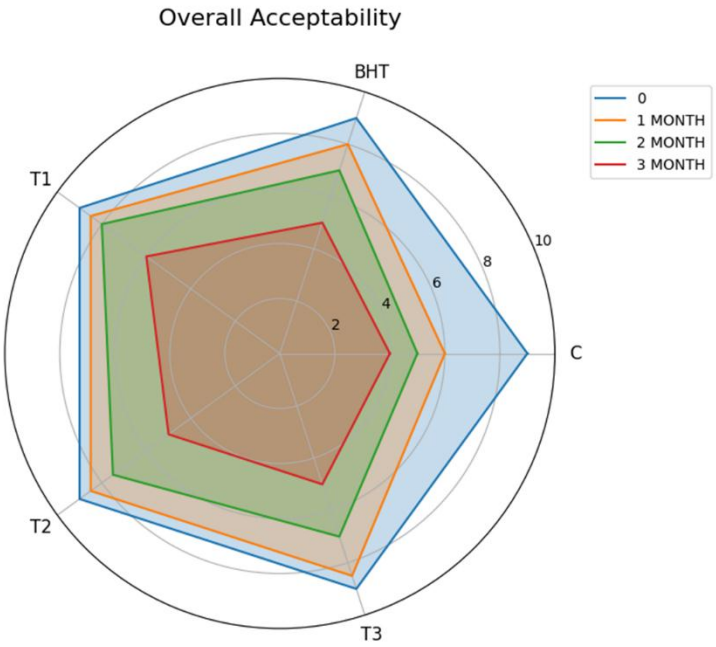

Fig. (5) Overall acceptability of frozen chicken burgers treated with cardamom oil and BHT over three months of storage

4. Discussion

The present study evaluated the effects of cold-pressed cardamom essential oil (CEO) at different concentrations (T1: 50 ppm, T2: 25 ppm, T3: 12.5 ppm) compared to BHT (200 ppm) and a control on the instrumental color parameters and sensory attributes of frozen chicken burgers over a three-month storage period at –18°C.The lightness (L*) of frozen chicken burgers was significantly influenced by both the antioxidant treatment and storage duration. An overall increase in L* values was observed across all groups over time, which is consistent with previous studies attributing such changes to oxidative deterioration of surface proteins and lipids during frozen storage [11]. Studies have shown that natural antioxidants such as cardamom oil can enhance the initial lightness of meat products. Although direct studies on the effect of cardamom oil on chicken meat color are limited, related research provides insights into its potential impact. For instance, the incorporation of essential oil in chicken burgers resulted in improved color stability during frozen storage [12]. This stability is attributed to the antioxidant compounds such as phenolics and terpenes present in essential oils, which inhibit lipid and pigment oxidation [13, 14].

The progressive decrease in redness (a*) observed over a three-month storage period in all treatment groups aligns with the well-established phenomenon of myoglobin oxidation and lipid peroxidation during frozen storage [15–17]. Notably, the T3 group (12.5 PPM cardamom oil) exhibited the least reduction in redness, suggesting that even at lower concentrations, cardamom oil effectively enhanced the oxidative stability. This efficacy is attributed to the high content of bioactive compounds such as phenolic acids and terpenes, which scavenge free radicals, inhibit lipid peroxidation and stabilize myoglobin molecules [18].

Yellowness (b*) increased in all groups during storage, but at a slower rate in CEO-treated samples, suggesting reduced formation of oxidative by-products such as carbonyl compounds [19]. Chroma (C*) values, representing color intensity, were also better maintained in CEO groups, consistent with previous findings on the antioxidative potential of essential oils [20, 21]. Sensory evaluations confirmed the instrumental results. CEO-treated samples maintained higher odor, color, texture, and taste scores compared to the control and BHT groups throughout storage. The antioxidant properties of CEO helped preserve freshness, firmness, and flavor [22, 23]. Overall acceptability remained highest in samples treated with 50 ppm CEO. Thus, cold-pressed cardamom essential oil demonstrated significant potential to serve as a natural preservative, maintaining both sensory quality and oxidative stability in frozen poultry products.

Conclusions

Cold-pressed cardamom essential oil (CEO) effectively preserved the color stability and sensory attributes of frozen chicken burgers during three months of storage at –18°C. CEO treatments, particularly at 50 ppm, significantly reduced oxidative deterioration, as evidenced by higher L*, a*, and C* values compared to both BHT-treated and untreated control samples. Sensory analysis further confirmed that CEO-treated burgers maintained superior odor, texture, taste, and overall acceptability throughout storage. These results highlight the potential of CEO as a natural antioxidant for poultry meat preservation. Future studies should focus on optimizing CEO concentrations and assessing its stability and efficacy under varying storage conditions.

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