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Research Article

The Effect of Sodium Alginate Coating Containing Citrus (*Citrus aurantium*) and Lemon (*Citrus lemon*) Extracts on Quality Properties of Chicken Meat

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The effect of sodium alginate-based edible coating containing 2% citrus (*Citrus aurantium*) and lemon (*Citrus lemon*) extracts was evaluated on the chemical, antimicrobial, and sensory properties of samples during storage at 4°C. The results showed that coating with sodium alginate containing citrus and lemon extracts had a significant effect on the pH, TVN, PV, and TBA values of chicken meat ($P < 0.05$). The lowest PV and TBA values were observed in the coated sample containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + CLE), indicating the antioxidant activity of sodium alginate and extracts. Coating resulted in less growth of microorganisms in the samples. The lowest microbial counts were also observed in the sodium alginate containing 2% citrus and lemon extracts (ALG + CAE + CLE). The coated samples had good overall acceptability similar to the control treatment. In conclusion, sodium alginate containing citrus (*C. aurantium*) and lemon extracts (*C. lemon*) are suggested for coating meat products.

1. Introduction

Chicken meat is rich in protein, energy and vitamins, minerals, and amino acids. Chicken meat and its products, even during refrigerated storage, are exposed to spoilage due to oxidation and microbial growth along with enzymatic and biochemical decomposition [1, 2].

The edible coating can increase the shelf life of foods due to its antimicrobial and antioxidant activity. Edible coatings cause the slow release of these compounds into the meat and can also help maintain high concentrations of antibacterial substances on the surface of the meat, where it is more exposed to bacterial invasion [3].

The edible coatings act as a barrier against the transfer of moisture, gases, and soluble substances, and therefore, can prolong the shelf life of foods [4]. Edible coatings derived from hydrocolloids such as alginate are strong and impermeable films to oils, but due to their hydrophilic nature, they show poor water resistance [5].

Alginate-based coatings have strong properties including consistency, stabilization, suspension, gel formation, and stabilization of emulsions. They react with metal cations, especially sodium and calcium ions, and form strong gels or insoluble polymers [5]. So far, there have been various reports on the use of edible coatings containing sodium alginate in meat products [6–8].

In recent years, herbal products such as essential oils and extracts have also received much attention. Essential oils and extracts are claimed to be safe secondary metabolites (GRAS) and are known as alternatives to synthetic additives due to their antimicrobial and antioxidant effects [9]. Therefore, these healthy and safe substances can be used as

an alternative method to control pathogens and spoilage microorganisms. Extracts are slowly released on the surface of the food when added to the edible coatings, and thus maintain the quality of the food. The antibacterial activity of essential oils and extracts is due to their hydrophobicity, which causes the penetration of these substances into the phospholipids of bacterial cell membranes and causes disruption in their structures and increases permeability, finally leakage, and cell death [10].

Citrus (*C. aurantium*) belongs to the Rutaceae family and grows well in tropical and subtropical regions. There are various biologically active compounds such as phenols, flavonoids, vitamins, and monoterpenes such as limonene, mericin, linalool, linalyl acetate, geranyl acetate, and alpha-terpineol in *C. aurantium* that have led to its use in traditional medicine [11–13]. Some researchers reported the antioxidant, antimicrobial, antifungal, and anti-inflammatory activity of *C. aurantium* [11–15].

Sour lemon (*C. lemon*) belongs to the Rutaceae family and is a powerful antioxidant, perhaps due to its significant amount of vitamin C [16]. The antimicrobial and antioxidant properties of lemon have been reported previously [17–21].

The direct use of these compounds for food preservation is limited, due to organoleptic effects (aroma and flavor) and potential toxicity. So researchers are looking for ways to improve their activity such as incorporating these natural materials into edible coatings [22].

Due to the high rate of oxidation in meat products and the relationship between oxidation and cardiovascular disease [23], the aim of this study was to study the effect of the use of sodium alginate-based edible coating containing 2% citrus (*C. aurantium*) and lemon (*C. lemon*) extracts on the chemical, antimicrobial, and sensory properties of chicken meat during storage at 4°C.

2. Material and Methods

2.1. Materials. Sodium alginate was purchased from Sigma Company (USA). Citrus and sour lemon plants were collected from farms in the Mazandaran province of Iran. All chemicals and culture media were obtained from Merck, Germany.

2.2. Chicken Meat Preparation. The breast meat (300–400 g) was purchased from a local poultry slaughterhouse (Mazandaran province, Iran) and was transferred to the laboratory in ice bags.

2.3. Preparation of Coating Solutions. The maceration method was used to extract aqueous extract of citrus (*C. aurantium*) and lemon (*C. lemon*). After drying at room temperature and grinding, 100 g of the dried powder of each plant was mixed with 1000 cc of water at room temperature (25°C) for 24 hours and then filtered with Whatman paper and dried in a freeze-dryer (Christ, Osterode, Germany) at −70°C for 6 hours. Sodium alginate solution was prepared by dissolving 2% (w/v) sodium alginate in 3% v/v distilled water. Tween 80 (Merck, Germany) was added to sodium alginate at 0.2% (w/w) as a plasticizer. The sodium alginate coating solution was filtered through a Whatman filter paper (No. 3). Then, the citrus (*C. aurantium*) and lemon (*C. lemon*) were mixed with Tween 80. The final coating solution was homogenized with a magnet (IKA, C-MAG HS 10, Germany) under aseptic conditions at 1000 rpm for 2 min [24].

2.4. Treatment of Chicken Meat. Fillet samples were categorized into five treatments consisting of control (uncoated) and four treated samples following: sodium alginate (ALG), sodium alginate + 2% citrus extract (ALG + CAE), sodium alginate + 2% lemon extract (ALG + CLE), and sodium alginate + 2% citrus and lemon extracts (ALG + CAE + CLE). All coated samples were immersed for 2 min in 300 ml of the coating solutions. After that, the fillets were removed and drained for 3 h at 10°C and then stored at 4°C for 16 days. The control sample (Con) was prepared without the addition of coating solutions. The samples were stored in a refrigerator (4°C) and tested for physicochemical, microbial, and sensory changes for 16 days [1].

2.5. Chemical Analyses. The pH of the samples was measured using a digital pH meter (Metrohm Ltd., CH-9101 Herisau, Switzerland). The samples were analyzed for peroxide value (PV) [25] and thiobarbituric acid reactive substances (TBARS) [25] according to AOCS methods (Cd 8–53 and Cd 19–90). The total volatile basic nitrogen (TVB-N) according to the procedures previously described [26].

2.6. Microbiological Analyses. Microbiological counts were determined by homogenizing a 10 g sample in 90 ml of 0.1% peptone water with a stomacher. Total viable bacterial counts were counted by the pour plate method, using plate count agar (PCA, Merk, Germany). The plates were incubated at 30°C for 24–48 hours for the total viable count, and at 7°C for 10 days for the psychrotrophic count. *Pseudomonas* populations were counted using CFC agar (Merk, Germany) and incubated at 20°C for 48 hours. The lactic acid population of bacteria was counted in MRS agar (Merk, Germany) at 25°C for 5 days. To count Enterobacteriaceae, VRBG agar (Merk, Germany) and incubation at 37°C for 24 hours were used. For counting of mold and yeast, potato dextrose agar (PDA, Merk, Germany) and incubation at 25°C for 5 days were used. All microorganism counts were reported as log 10 CFU/g [27].

2.7. Sensory Analyses. Chicken samples were cooked at 85°C for 10–15 minutes and sensory properties (taste, color, odor, texture, and overall acceptance) were evaluated by 8-member panelists based on the 9-point hedonic method. The taste was analyzed until 4 days due to microbial contaminations. Panelists evaluated the sensory characteristics of the sample in terms of using a scoring scale that had 1 extremely unpleasant and 9 extremely pleasant [1].

2.8. Statistical Analysis. All chemical and microbial experiments were performed in 3 replications. In this study, SPSS software (version 23) was used to analyze the results. The significance of the results was determined at the level of 5% by comparing the means with the two-way ANOVA test ($P < 0.05$).

3. Results and Discussion

3.1. Chemical Analyses. As can be seen in Figure 1(a), the control chicken fillet sample had a higher pH value in comparison with coated samples. So the minimum pH value was observed in the coated samples containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + -CLE). The control samples had the highest pH value after 16 days. The pH value of all samples increased with time.

The increase in pH value at the end of storage time can be attributed to the increase in volatile bases such as ammonia, trimethylamine, enzymatic activities of bacteria, and endogenous enzymes [28, 29]. The decrease in pH of coated samples is also due to the inhibitory potential of bacteria and enzymatic proteases by edible coatings i.e., sodium alginate. Similar results have been found in the research of Lu et al. [30] and Yu et al. [8].

As can be seen in Figure 1(b), the control chicken fillet had a higher TVB-N value than the coated samples. The coating had a significant effect on the TVB-N value of the chicken fillet during refrigerated storage ($P < 0.05$). So that, the minimum TVB-N value (37.82 mg/100g) was observed in the coated samples containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + CLE). The control samples had the highest TVB-N value after 16 days (60.34 mg/100g). The results also showed that the TVB-N value of coated and uncoated chicken fillets increased with time.

Total volatile base nitrogen (TVB-N) is a quantitative factor in determining ammonia and amino acids in meat. An increase in this index indicates an increase in the activity of spoilage bacteria and meat enzymes. In general, the edible coating alone and in combination with 2% citrus and lemon extracts decreased the bacterial population of samples and the amount of accumulation of nonamino compounds such as ammonia and amino compounds [31]. The lower TVB-N values of the coated groups can be attributed to reduced bacterial growth and the capacity of bacteria for the oxidative deamination of nonprotein nitrogen [28].

Gimenez et al., [32] proposed a value of 25 mg N/100 g as the highest acceptable level for TVB-N values. In the present research, all TVB-N values remained below this limit of acceptability after 8 days in ALG + CAE + CLE sample (Figure 2). Since TVB-N is generated usually by bacterial decomposition, the higher microbial population could account for the higher TVB-N values of the control group.

As can be seen in Figure 1(c), the control sample had a higher peroxide value (PV) in comparison with coated samples. The coating had a significant effect on the PV value of the chicken fillet during refrigerated storage ($P < 0.05$). So that the minimum PV value (1.06 mEq/kg) was observed in the coated samples containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + CLE). The control samples had the highest PV value after 16 days (3.42 mEq/kg), followed ALG sample (3.36 mEq/kg). The results also showed that the PV value of coated and uncoated chicken fillets increased with time.

The peroxide index measured the hydroperoxides that are produced in the first stages of oxidation. Hydroperoxides are the primary products of lipid oxidation, and increase and then decrease during oxidation and this process continues due to their successive formation and deformation [33]. In the initial stages of oxidation, the formation of peroxides is slow, but in the later stages, their formation increases rapidly. In this stage, determining the peroxide value is a good sign of the oxidation state of the oil [34].

In this research, the lowest amount of peroxide value is related to the coated sample containing sodium alginate and citrus and lemon extracts (ALG + CAE + CLE), which can be attributed to the antioxidant properties of alginate and citrus and lemon extract and their synergistic effects. The increase in peroxide index over time is due to the increase of oxidation with storage time.

The phenolic compounds and antioxidant properties of citrus (*C. aurantium*) and lemon (*C. lemon*) extracts have been reported in many studies [11–15, 19–21]. The antioxidant activity of phenolic compounds is mediated through a variety of mechanisms, including the chain-breaking antioxidant, the decomposition of hydroperoxides, and the bonding of metal ions. Phenolic compounds produce stable and less effective radicals and can neutralize radicals by electron transfer [9].

As can be seen in Figure 1(d), the control chicken fillet sample had a higher thiobarbituric acid (TBA) value in comparison with coated samples. The coating had a significant effect on the TBA value of the chicken fillet during refrigerated storage ($P < 0.05$). So that the minimum TBA value (1.26 mg MDA/kg) was observed in the coated samples containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + CLE). The control and ALG samples had the highest TBA value after 16 days (3.48 mg MDA/kg). The results also showed that the TBA value of coated and uncoated chicken fillets increased with time.

The peroxide index alone does not determine the oxidation of the product. Because this index is an indicator of the primary oxidation products and does not specify the production of oxidation by-products. Therefore, determining the TBA index, which is an indicator of the rate of oxidation development and production of by-products, seems necessary [35]. Malondialdehyde (MDA) is the most important carbonyl produced in the oxidation reaction, which causes changes in the taste of oxidized foods and forms a red complex with TBA [36].

In this research, the TBA value during storage was significantly lower in all coated samples than in the control sample, indicating the protection of chicken meat from oxidation by antioxidants. The antioxidant activity and oxygen barrier properties of sodium alginate may have contributed to lipid oxidation-reduction. The TBA value in ALG + CAE + CLE

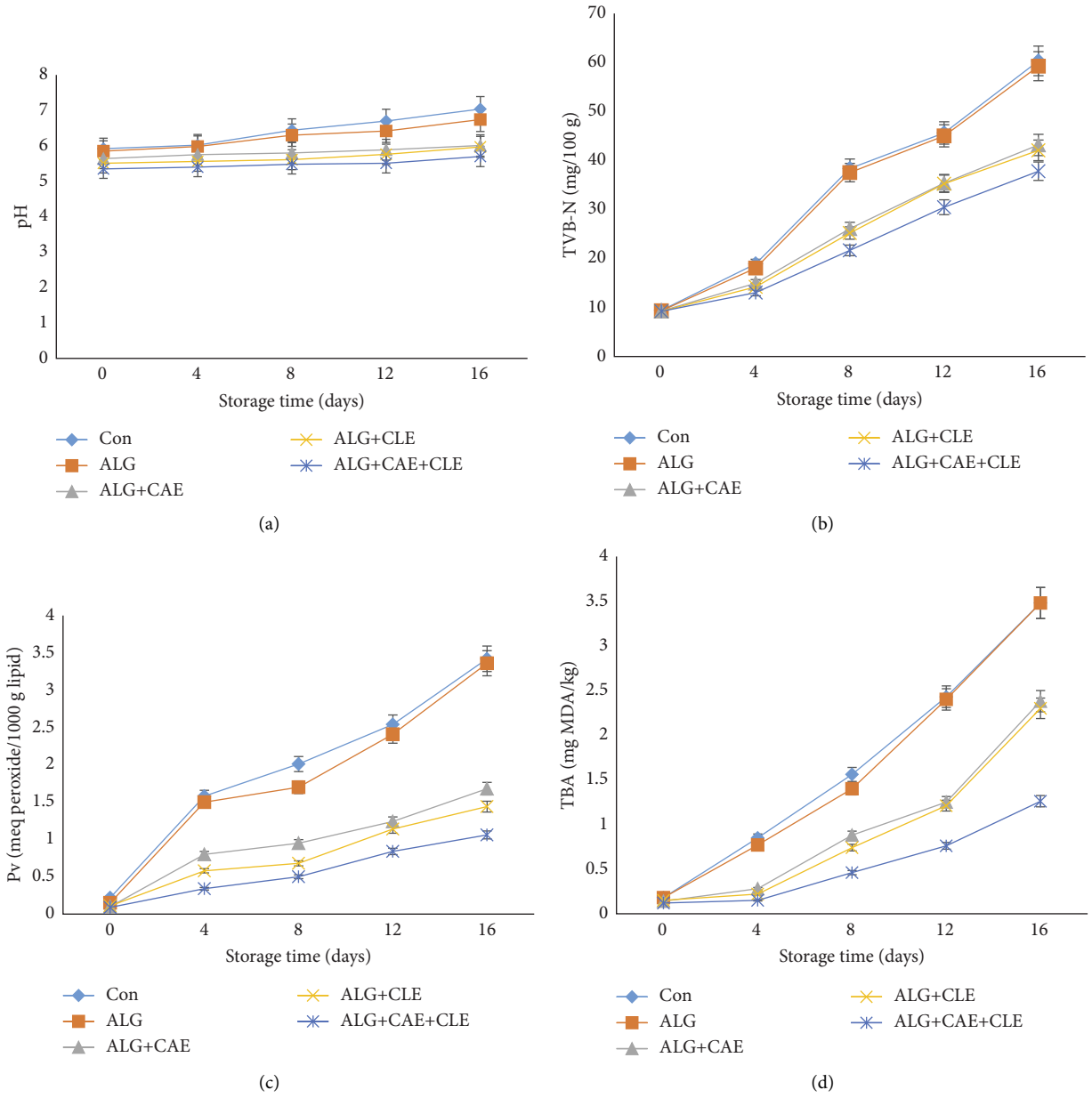

Figure 1: Changes in chemical of chicken fillet samples during refrigerated storage.

treatment was significantly lower than in other treatments, which could be due to the inhibition of oxygen permeation and synergistic effects between sodium alginate and citrus and lemon extracts [29, 30, 37].

The maximum amount of TBA value indicating good quality meat products is 5 mg MDA/kg [38]. In the present study, TBA values in all groups were lower than such proposed limits during storage.

3.2. Microbiological Analyses. As can be seen in Figure 2, the control sample had a higher microbial population in comparison with the coated samples. The coating had a significant effect on the microbial counts of the chicken fillets during refrigerated storage ($P < 0.05$). So that the least microbial counts were observed with a significant difference ($P < 0.05$) in the coated samples containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + CLE). The control samples had the highest microbial counts after 16 days. The microbial counts of coated and uncoated chicken fillets increased with time.

The initial Enterobacteriaceae (log10 CFU/g) in chicken fillet ranged from 2.4 in coated samples to 2.5 in control and reached final counts of 8.61 logs on day 16 (Figure 2(a)). ALG + CAE, ALG + CLE, and ALG + CAE + CLE treatments produced significantly lower ($P < 0.05$). Other researchers have confirmed that sodium alginate coating containing Mentha spicata essential oil inactivated Enterobacteriaceae in the raw silver carp [7].

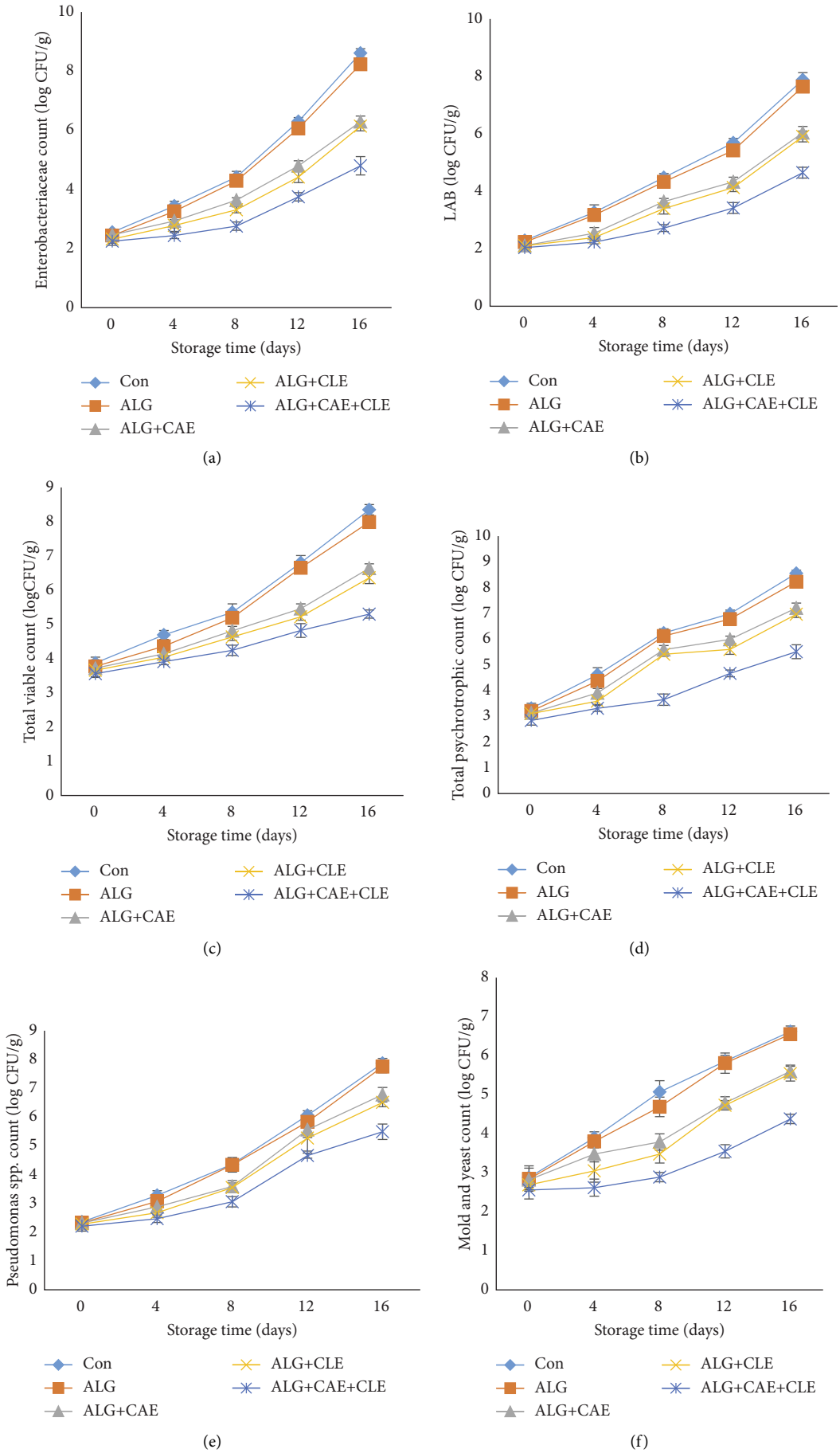

Figure 2: Changes in microbial counts of chicken fillet samples during refrigerated storage.

Table 1: Changes in sensory properties of chicken fillet samples during refrigerated storage.

Sensory attributes	Treatment	Storage time (day)				
		0	4	8	12	16
Taste	Con	8.77 ± 0.24^{Aa}	7.01 ± 0.22^{Bd}			
	ALG	8.81 ± 0.19^{Aa}	7.79 ± 0.30^{Bc}			
	ALG + CAE	8.86 ± 0.14^{Aa}	8.40 ± 0.14^{Bb}			
	ALG + CLE	8.88 ± 0.13^{Aa}	8.56 ± 0.18^{Aab}			
	ALG + CAE + CLE	8.92 ± 0.09^{Aa}	8.91 ± 0.09^{Aa}			
Texture	Con	8.76 ± 0.20^{Aa}	8.67 ± 0.15^{Ac}	7.53 ± 0.14^{Bd}	6.14 ± 0.14^{Cc}	3.82 ± 0.25^{Dd}
	ALG	8.85 ± 0.14^{Aa}	8.72 ± 0.07^{Abc}	7.53 ± 0.20^{Bd}	6.34 ± 0.15^{Cc}	4.04 ± 0.15^{Dd}
	ALG + CAE	8.84 ± 0.14^{Aa}	8.88 ± 0.13^{Abc}	7.95 ± 0.17^{Bc}	6.96 ± 0.20^{Cb}	5.35 ± 0.16^{Dc}
	ALG + CLE	8.79 ± 0.20^{Aa}	8.87 ± 0.14^{Abc}	8.26 ± 0.14^{Bb}	7.04 ± 0.14^{Cb}	5.76 ± 0.14^{Db}
	ALG + CAE + CLE	8.88 ± 0.14^{Aa}	8.95 ± 0.04^{Ab}	8.84 ± 0.16^{Aa}	7.84 ± 0.20^{Ba}	6.32 ± 0.07^{Ca}
Color	Con	8.70 ± 0.29^{Aa}	8.53 ± 0.15^{Ab}	7.57 ± 0.14^{Bc}	5.31 ± 0.15^{Cc}	2.79 ± 0.30^{Dd}
	ALG	8.80 ± 0.18^{Aa}	8.77 ± 0.13^{Aa}	8.04 ± 0.17^{Bb}	6.27 ± 0.14^{Cb}	3.88 ± 0.27^{Dc}
	ALG + CAE	8.82 ± 0.17^{Aa}	8.84 ± 0.15^{Aa}	8.36 ± 0.14^{Bab}	7.24 ± 0.18^{Ca}	5.63 ± 0.15^{Db}
	ALG + CLE	8.81 ± 0.17^{ABa}	8.88 ± 0.12^{Aa}	8.46 ± 0.29^{Ba}	7.25 ± 0.25^{Ca}	5.60 ± 0.20^{Db}
	ALG + CAE + CLE	8.86 ± 0.11^{Aa}	8.93 ± 0.08^{Aa}	8.57 ± 0.13^{Ba}	7.59 ± 0.18^{Ca}	6.68 ± 0.22^{Da}
Odor	Con	8.31 ± 0.19^{Ab}	7.26 ± 0.27^{Bb}	6.54 ± 0.23^{Cc}	5.03 ± 0.21^{Dc}	2.37 ± 0.26^{Ec}
	ALG	8.68 ± 0.12^{Aa}	7.49 ± 0.18^{Bb}	6.86 ± 0.16^{Cb}	5.21 ± 0.25^{Dc}	2.69 ± 0.17^{Ec}
	ALG + CAE	8.85 ± 0.15^{Aa}	8.44 ± 0.29^{Ba}	8.00 ± 0.10^{Ca}	6.82 ± 0.16^{Db}	5.58 ± 0.17^{Eb}
	ALG + CLE	8.79 ± 0.26^{Aa}	8.66 ± 0.15^{Aa}	8.09 ± 0.13^{Ba}	6.80 ± 0.23^{Cab}	5.60 ± 0.24^{Db}
	ALG + CAE + CLE	8.89 ± 0.12^{Aa}	8.82 ± 0.17^{Aa}	8.21 ± 0.10^{Ba}	7.22 ± 0.20^{Ca}	6.43 ± 0.19^{Da}
Overall	Con	8.68 ± 0.23^{Aa}	7.58 ± 0.26^{Bb}	6.21 ± 0.11^{Cc}	4.82 ± 0.28^{Dd}	2.80 ± 0.27^{Ed}
	ALG	8.68 ± 0.26^{Aa}	8.14 ± 0.16^{Ba}	6.78 ± 0.12^{Cb}	5.99 ± 0.12^{Dc}	3.58 ± 0.21^{Ec}
	ALG + CAE	8.81 ± 0.11^{Aa}	8.31 ± 0.20^{Ba}	7.52 ± 0.16^{Ca}	6.87 ± 0.14^{Db}	5.26 ± 0.19^{Eb}
	ALG + CLE	8.71 ± 0.28^{Aa}	8.31 ± 0.12^{Ba}	7.55 ± 0.16^{Ca}	7.22 ± 0.11^{Ca}	5.49 ± 0.29^{Db}
	ALG + CAE + CLE	8.78 ± 0.27^{Aa}	8.28 ± 0.14^{Ba}	7.73 ± 0.20^{Ca}	7.47 ± 0.15^{Ca}	6.33 ± 0.21^{Da}

The mean ± SD (standard deviation) within columns with different capital letters and rows with different small letters differs significantly ($P < 0.05$).

The initial LAB (log10 CFU/g) in chicken fillets ranged from 2 in coated samples to 2.29 in control (Figure 2(b)). The growth prevention of LAB in meat samples is probably due to the antimicrobial activity of sodium alginate, citrus, and lemon extracts.

The initial TVC (log10 CFU/g) in chicken fillet ranged from 3.5 in coated samples to 3.87 in control (Figure 2(c)). TVC for all of the coated treatments was below 8 log10 CFU/g, while that of control attained a count of 8.35 at 16 days, which was higher than the maximal recommended limit, indicating a microbiological shelf life of 12 days for the control sample [26].

The initial psychrotrophic count (log10 CFU/g) in chicken fillets ranged from 2.84 in coated samples to 3.31 in control (Figure 2(d)). The growth pattern of PTC was similar behavior of TVC, with control also being the highest at day 16 (8.35 log10 CFU/g), followed by the ALG sample (7.99 log10 CFU/g), and the lowest count (5.3 log10 CFU/g) was observed in ALG + CAE + CLE treatment.

The initial *Pseudomonas* (log10 CFU/g) in chicken fillet ranged from 2.21 in coated samples to 2.36 in control, increasing during storage to reach a final population of 7.87 log CFU/g (control samples), whereas respective counts for ALG, ALG + CAE, ALG + CLE, and ALG + CAE + CLE were about 7.75, 6.78, 6.51, and 5.49 log CFU/g lower than in the control sample. *Pseudomonas* spp. population in all treatments was significantly ($P < 0.05$) lower than the control. Samples containing extract were the most effective treatments for the inhibition of *Pseudomonas* spp. probably due to the antimicrobial actions of alginate and extracts. These results are contradictory to those obtained by Giatrakou et al., [39] which was reported for a poultry product treated with chitosan and thyme oil.

Mold and yeast species are known as the spoilage of chicken meat. The initial mold and yeast (log10 CFU/g) in chicken fillets ranged from 2.56 in coated samples to 2.88 in control (Figure 2(f)). Antifungal activity of CAE and CLE has been reported previously [11, 14, 17–21].

The low oxygen penetration from the alginate coating and antimicrobial properties of citrus and lemon extracts has an effective effect in decreasing the microbial population in the coated treatments. The results showed that the addition of the extracts increased the antimicrobial properties of the sodium alginate-based edible coating [22].

The antimicrobial activity of the extracts is probably due to the reaction of the extract compounds with the cell membrane, and the cell wall of bacteria that by increasing membrane permeability and leakage from the cell wall, membrane swelling, reduced membrane function due to inhibition of enzyme activity and also the ability of bacteria to absorb nutrients, prevent their growth and prevent bacteria from growing [40]. All these properties and especially the reaction of extracts with the cell wall prevent the growth of microorganisms.

These results are consistent with the results of research by Keshri and Sanyal [24]. The researchers reported a significant reduction in bacterial counts in meat

with sodium alginate coating containing thyme essential oil. In other studies, combinations of sodium alginate with horsemint (*Mentha longifolia*) essential oil [40] and sodium alginate with *Mentha spicata* essential oil [7] led to a reduction of TVC and PTC, PSC, and Enterobacteriaceae in the carp fillets, respectively.

3.3. Sensory Evaluation. As can be seen in Table 1, the coating had a nonsignificant effect on the sensory attributes of chicken fillets ($P < 0.05$). The sensory evaluations showed nonsignificant differences ($P > 0.05$) between samples at day zero. The panelists did not reject any coated sample; in all cases, scores were higher than 7 (acceptable). Overall acceptability scores of coated samples were not similar to the control ones, especially at the end of storage time, but the scores of the coated samples with sodium alginate (ALG) were the lowest and similar to the control ones after 16 days. The results also showed that the sensory properties of coated and uncoated chicken fillets decreased with time.

The trend of changing sensory evaluation in treatments during storage is in line with oxidation changes in the tested treatments, which can be due to fat oxidation, which leads to a decrease in sensory quality and reduction of nutrients, including essential fatty acids and production of toxic products attributed to oxidation [41]. On the other hand, increasing fat hydrolysis leads to a decrease in overall acceptance. Because the accumulation of FFA has been shown to affect protein stability and cause texture destruction through reaction with proteins and protein oxidation occurs [42].

Improving sensory properties can be due to the effect of sodium alginate coating and citrus and lemon extracts and their synergistic effects. Because edible coatings are good oxygen barriers and can delay oxidation and improve taste, odor, color, texture, and overall acceptance [43].

5. Conclusion

Edible coatings are extensively applied in the food industry. In this study, sodium alginate-based edible coating containing 2% citrus (*C. aurantium*) and lemon (*C. lemon*) extracts was used in the chicken fillet. The results showed that coating with sodium alginate containing citrus and lemon extracts due to their barrier properties led to a decrease in the oxidation parameters (PV and TBA) and growth of aerobic mesophilic bacteria, *Pseudomonas*, lactic acid bacteria, Enterobacteriaceae, psychrotrophic, mold, and yeast. The coated samples showed low pH and TVB-N changes compared with the control sample. Sodium alginate in combination with citrus and lemon extracts inactivated the tested microorganisms to an undetectable level in chicken fillets. Among different samples, the coated samples containing sodium alginate with 2% citrus and lemon extracts (ALG + CAE + CLE) were suggested for coating and usage in industrial meat production. Due to the high rate of oxidation in meat products and the relationship between oxidation and cardiovascular disease, the coating can be a good way to consume meat products. It would be useful for the food industry to produce foods with reduced oxidation and spoilage from a more scientific point of view.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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