PAPER

EFFECT OF CHITOSAN COATING ENRICHED WITH CUMIN (*CUMINUM CYMINUM* L.) ESSENTIAL OIL ON THE QUALITY OF REFRIGERATED TURKEY BREAST MEAT

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ABSTRACT

A solution containing 2% chitosan, 1% cumin seeds' essential oils and 1% acetic acid was applied for the coating preparation. In all of the treatments the total viable counts and applied psychrophilic bacteria decreased significantly compared to the control through the storage time. The pH, total volatile basic nitrogen (TVB-N), peroxide value (PV) and sensory attributes in all the treatments were significantly detected lower than the same parameters of the controls. The results of our investigation revealed that chitosan+cumin and ascorbic acid retarded spoilage and oxidative changes in refrigerated turkey breast meat.

Keywords: antibacterial properties, lipid oxidation, meat products, natural antioxidant

1. INTRODUCTION

Products produced by poultry meats are considered as the food products with considerable growing interest in market in many parts of the world due to their low production cost compared to further meat products including beef, lamb and pork meats. They contain low fat, high nutritional value as well as distinct interesting taste and flavor. However, poultry meats due to their nature and composition, (i.e high moisture and protein contents) as well as high pH value (low acidity value), they have ideal and appropriate environments for pathogenic microorganisms' growth (LATOU *et al.,* 2014; VAITHIYANATHAN *et al.,* 2011). The approach to extend and increase the shelf life of raw poultry meats and its products may present a challenge for meat and poultry industries not only in Iran but also in further areas. Microbial growth as well as lipid oxidation reactions may lead to undesirable and unwanted organoleptic alterations through the storage period in meat products (OUATTARA *et al.,* 2000). One of the most commonly used methods to preserve food products safe and increase their shelf life is the addition of natural compounds with antibacterial and antioxidant properties in food products. Since synthetic antioxidants have been reported to behave as carcinogens and mutating agents, more attention has been directed to the employment of natural antioxidants (TAHERI *et al.,* 2012; WANNES *et al.,* 2010). Several studies have been performed in this area including application of essential oils obtained from plant sources (RAEISI *et al.,* 2015; CHEN *et al.,* 2014; TAHERI *et al.,* 2013, ALLAHGHADRI *et al.,* 2010), chitosan obtained from natural origins (OJAGH *et al.,* 2010; NO *et al.,* 2007), and organic acids of natural resources (SHALTOUT *et al.,* 2014; BIN JASASS, 2008) with the aim of retardation of microbial deteriorations and oxidation reactions (LATOU *et al.,* 2014).
Chitosan is categorized as a modified and natural carbohydrate polymer derived from deacetylation of chitin [poly-β-(1 → 4)-N-acetyl -D-glucosamine), and is a major component of the shells of crustaceans including crab, shrimp, and crawfish and is ranked second in the abundance among further natural biopolymers (after cellulose) (NOWZARI *et al.,* 2013; NO *et al.,* 2007). Due to the chitosan's intrinsic antimicrobial and anti-oxidative properties and having appropriate characteristics in film preparation, as well as its biocompatibility and biodegradability properties, chitosan has attracted much attention as a natural additive (preservative) in not only nutraceutical but also in pharmaceutical and cosmetic industries (YUAN *et al.,* 2016; KANATT *et al.,* 2013; FAN *et al.,* 2009). Several studies have been performed on the antibacterial, antioxidant, and potential health benefit properties of the essential oils extracted from spices and herbs particularly from *Apiacea* family (ALLAHGHADRI *et al.,* 2010; ZHANG *et al.,* 2009). One of these valuable plants is cumin (*Cuminum cyminum* L.), named "zira" growing in Middle East particularly in Iran. This plant species is also commonly grown in Cyprus, Lebanon, Morocco, Malta, Turkey, Spain, Russia and India as well as China (ERDENI *et al.,* 2013). Antioxidant and antibacterial activities are detected as one of the most considerable functional properties of cumin seeds. Cumin seeds may have considerable potential to be used as an antioxidant agent in food products; the achieved results of several performed studies have shown that γ-terpinene is a predominant detected compound with potential health benefits in cumin seeds (RAEISI *et al.,* 2015; CHEN *et al.,* 2014; IACOBELLIS *et al.,* 2005). Application of a biodegradable film or coating is considered as a novel approach to protect not only meat products but also further food products against deteriorating agents (NOWZARI *et al.,* 2013). A combination of chitosan and cumin essential oils may be formulated to prepare biodegradable films with considerable protective effects. The aim of the present study is to evaluate and assess the effect of chitosan coating enriched by cumin essential oil in combine of acetic acid to be used in enhancements of the shelf life and quality of turkey fillet stored at (4±1°C).

2. MATERIALS AND METHODS

2.1. Turkey breast preparation

Fresh turkey breast samples (18 kg) were purchased from a local market in Ahvaz (Khuzestan province, South Iran). The average weight of each breast piece was set on 3 kg. The turkey breast samples were placed and sealed in an ice box with ice (refrigeration temperature) and transferred to Food and Drug Administration Laboratory at Jundishapur University within 30 minutes. Turkey breast samples were filleted manually and carefully washed with cold water. The weight of each fillet was set on 110±5 g. The prepared fillets were used for the selected experiments.

2.2. Cumin seeds

Cumin seeds' essential oil (*Cuminum cyminum* L.) and the required chemicals and reagents for GC-MS analysis (gas chromatography - mass spectrometry) were provided from Barij Essence Company in Iran.

2.3. Preparation of the coating film and treatment of the fillets

A chitosan solution was prepared with 2% (W/V) chitosan (Sigma Chemical Co, medium molecular weight, viscosity 200-800 cP) in 1% v/v acetic acid. 20 g of chitosan solution was mixed well with 900 mL of distilled water and the obtained mixture was stirred for 10 min, afterward 10 mL of glacial acetic acid was added to the mixture and stirred at room temperature by achieving a smooth solution. The solution was reached and diluted up to 1000 mL by the addition of distilled water. Glycerol was added as a plasticizer to the achieved solution with the concentration of 0.75 mL. g^{-1} and was stirred for 10 min (NOWZARI *et al.*, 2013; OJAGH *et al.*, 2010). Thereafter the cumin essential oil (CEO), (mixed with Tween 80 (Aldrich Chemical Co., Steinheim, Germany), was added to the final prepared solution (BAZARGANI GLILANI *et al.*, 2015; OJAGH *et al.*, 2010) to comfort distribution and complete incorporation of cumin seeds' oil in the final solution. The final coating solution consisting of 2% chitosan, 1% acetic acid, 0.75 % glycerol and 0.2 % Twen 80 as well as cumin seeds' essential oil 1% was homogenized under aseptic conditions for 1 min. The fillet samples were divided in 3 separated groups. Samples of the first group were left untreated (Control, Sterile distilled water), and two other groups were treated by the following solution: chitosan 2% - CEO 1% and acetic acid 1%. Each sample was immersed for 30 min in the solution (YUAN *et al.*, 2016). Then the prepared meat samples were removed from the solution and allowed to drain for 30 min before packaging (coating) (KANATT *et al.*, 2013). After that, all of the fillet samples were individually packed in sterile LDPE containers; all of the containers were kept in a refrigerator at the temperature of 4±1°C. Fillet samples were experimented on days 0, 3, 6, 9, 12 and 15 after packaging and storage, and analyzed for chemical and microbial tests as well as sensory alterations analysis. Each experiment was done in triplicate.

2.4. Microbial analysis

10 g of each sample was mixed with 90 mL of sterile saline (0.85 % NaCl) solution in a sterile stomacher bag and was stomached continuously for 1 min. Other decimal dilutions were prepared from the achieved uniform solution or dilution of stomacher and cultivated in an appropriate microbial medium regarding the type of the microbial test. The Total viable count (TVC) was determined by pour plate medium approach with the use of plate

count agar (PCA) (Merck, Germany). The inoculated plates were incubated at 37 °C for 48 h for total viable count, and at 10 °C for 7 days for psychrophilic count. The achieved results were expressed as log 10cfu. g^{-1} of samples (NOWZARI *et al.*, 2013).

2.5. pH value determination

For determination of pH value, 5 g of turkey breast samples (of each treatment) were homogenized for 1 min with 45 mL of distilled water. The pH value was measured using a standardized portable pH meter (TOA, Kobe, Japan; TAHER*I et al*., 2013).

2.6. Determination of peroxide value (PV)

Peroxide value (PV) was determined in the lipid extract according to the method described previously by (AOAC, 2000). The achieved results were expressed as milli-equivalents peroxide value per each kg of lipid (meq O2/kg lipid).

2.7. Determination of Total Volatile Basic Nitrogen (TVB-N)

Total volatile basic-nitrogen (TVB-N) values were detected by the direct distillation approach according to (GOUDLAS and KONTOINAS, 2005) method. The micro diffusion method was determined by distillation after the addition of MgO to the homogenized turkey breast samples. The TVB-N value (mg nitrogen. 100 g^{-1} breast sample) was determined regarding the consumed volume of sulphuric acid reagent.

2.8. Sensory evaluation and analysis

Sensory analyses were performed by an instructed taste panel consisting of five experienced judges, according to the guidelines presented in Table 1 (OCTAVIAN and OCTAVIAN, 2010). Three different categories were ranked in the prepared questioners: 3 scores for excellent, 2 scores for acceptable, and 1 for unacceptable rates. The assessed and studied parameters in sensory assessment were detected as the following: appearance, odor, color, consistency and elasticity.

Table 1. Sensorial attributes and quality of refrigerated turkey breast.

Attribute	Excellent	Acceptable	Unacceptable
Appearance	Without slime present on surface	Slime present in some part of the surface	Slime present on the entire surface
Muscular elasticity	Fast return	Slow return	No return
Odor	Characteristic	Off odors (slight sulphurous or ammoniacal)	Foreign (rancid, acid, putrid)
Color	Pink	Dark pink	Pale pink

2.9. Statistical analysis

SPSS software version 22 was applied for data analysis in the present study. All of the selected experiments for each sample were performed in triplicate. Nonparametric statistics were used to analyze the achieved data. The analysis of Variance (ANOVA) test

was applied to detect the significant difference among the obtained data in the confidence level of 0.05. Duncan's multiple range tests were applied to compare the achieved means in the confidence level of 0.05.

3. RESULTS AND DISCUSSION

3.1. Microbial analysis

It has been well known that through the refrigeration storage time of poultry meat, an extensive range of bacterial species may be characterized (VASILATOS and SAVVAIDIS, 2013). Changes in the value of total viable counts (TVC) in turkey breast fillet during the refrigerated storage are presented in (Fig. 1). The initial TVC (log10 cfu. g^{-1}) of the control, acetic acid and chitosan-cumin treatment were detected 4.77, 4.62, and 3.90 (log10 cfu. g^{-1}), respectively. According to the recommended and standard limits (7 log10 cfu. g^{-1}) for fresh meat (RAEISI *et al.*, 2015), the samples have shown acceptable quality. These achieved results were in solid agreement of those from BAZARGANI-GILANI et al. (2015) and LATOU et al. (2014) for fresh chicken meat, and RAEISI et al. (2015) in term of fish fillet. All of the studied samples expressed an increased TVC value with enhancements in storage time ($p<0.05$). In 6 days after storage, the obtained mean of TVC of control samples was detected 6.54, which was close to the maximum allowed limit of TVC (7 log10 cfu. g^{-1}) for raw meats, indicating the shelf life confined 5 - 6 days. This phenomenon (6 days shelf life) may be attributed to the longer acidic environment started after the bleeding of slaughtered animals (SHALTOUT *et al.*, 2014). For untreated samples (control), the TVC presented a value rather than the acceptable healthy limit in 9 days after storage time (8.76 log10 cfu. g^{-1}). In contrast, the TVC values for the treated samples with Acetic acid (1%) and Chitosan (2%) + Cumin (1%) was determined lower than the proposed standard value by the end of day 15^{th} of storage period. Reduction in microbial count by floating of the samples in the prepared solution mixed of chitosan, cumin and acetic acid, have been reported previously for chicken meat by (BIN JASASS, 2008), turkey breast by (VASILATOS and SAVVAIDIS, 2013) and shrimp by (YUAN *et al.*, 2016). In the present study, the Chitosan + Cumin 1% treatment was the most effective formulation against TVC.

Gram-negative psychotrophic bacterial species (PTC) are detected as the major group of microorganisms leading to spoilage of aerobically stored fresh meats at chilled temperatures (NOWZARI *et al.*, 2013; OJAGH *et al.*, 2010). In the current study, the initial PTC (day 0) in the control sample was detected 3.55 (log10 cfu. g^{-1}), it was determined 4.04 and 3.194 (log10 cfu. g^{-1}), in meat samples coated by AA and Ch + C, respectively. Furthermore, the growth pattern on TVC and PTC expressed an increasing rate through storage period (Fig. 2). For all of the treatments, storage time had significant ($p < 0.05$) effects on the PTC value (log10 cfu. g^{-1}), On day 6^{th} of storage time, the mean value of PTC of the control samples increased up to 7.57 and spoilage started to appear as a slight foul smell. A significant reduction ($p<0.05$) of PTC value was detected in the samples treated by AA compared to the control ones. The effectiveness of acetic acid against microorganisms may be attributed to a decrease in pH and metabolic inhibition by the undissociated acid molecules as detected and reported by BIN JASASS (2008). In control samples, the PTC was detected rather than the acceptable limit on day 6^{th} of storage time (7.57 log10 cfu. g^{-1}). In contrast, the TVC values for the treated samples with chitosan + cumin (5.78 log10 cfu. g^{-1}) remained lower than the proposed standard value by the end of day 15^{th} of storage period. The antimicrobial activity of cumin essential oil might be attributed to the phenolic compounds (BAZARGANI-GILANI *et al.*, 2015; RAEISI et al.,

2015; ALLAHGHADRI *et al.*, 2010). Chitosan has been reported to be effective as an antimicrobial agent (SHAHIDI *et al.*, 1999; FAN *et al.*, 2009; KANATT *et al.*, 2013). Chitosan may act on the cells of the microorganisms and pathogens, therefore by alterations in the permeability of the cytoplasmatic membranes, may lead to the leakage of intracellular electrolytes and protein compounds out, as a result, it may lead to the death of the cells (YUAN *et al.*, 2016; BAZARGANI-GILANI *et al.*, 2015). The mechanism of action of chitosan appears to be associated with the disruption of the lipopolysaccharide layer of the outer membrane of gram-negative bacteria (NOWZARI *et al.*, 2013; PEREDA *et al.*, 2011), as well as its function as a barrier against oxygen penetration (OJAGH *et al.*, 2010; JEON *et al.*, 2002).

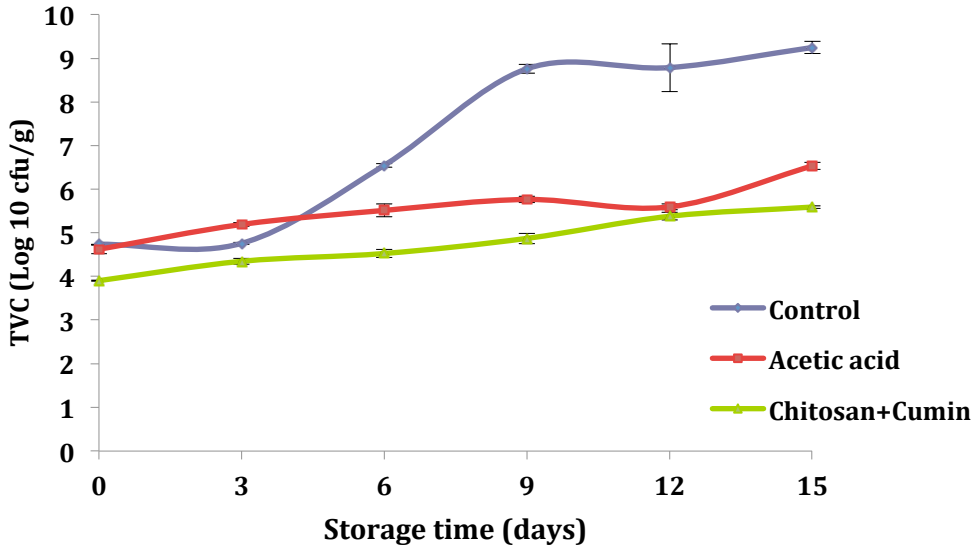

Figure 1. Changes in total viable count (TVC) of turkey breast samples during refrigerated storage.

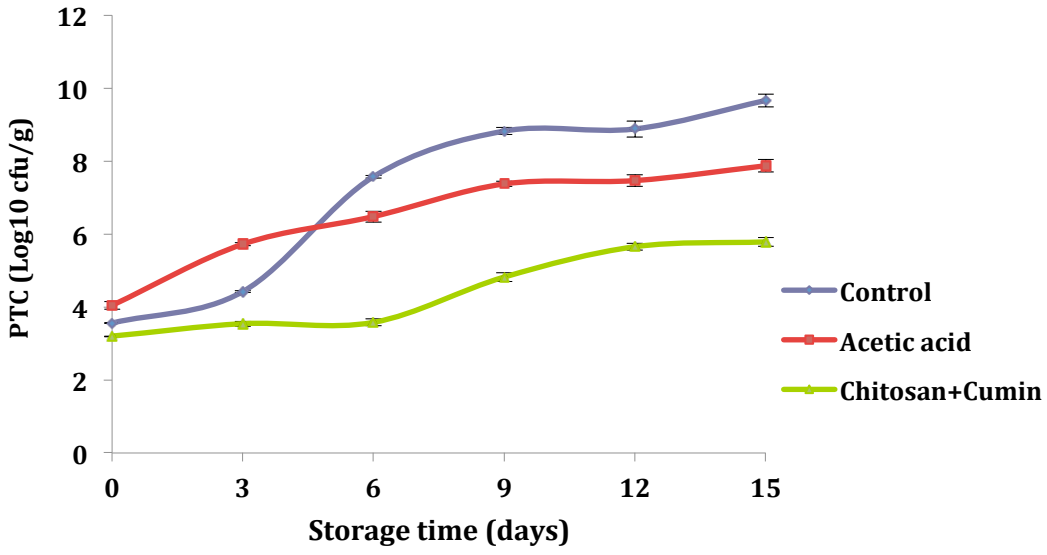

Figure 2. Changes in psychrotrophic counts (PTC) of turkey breast samples during refrigerated storage.

3.2. pH value

The pH and its alteration during storage time (0, 3, 6, 9, 12 and 15 storage days) for turkey breast in the control and two other treatments (AA and Ch+C) have been shown in (Fig. 3). An increase in pH from 5.86 to 7.07, 5.32 to 5.87, and 5.14 to 5.20 in the Control, samples treated by AA 1%, and Ch 2 % + C 1% was observed respectively, during 15 days storage time. For all of the treatments, storage time showed a significant ($p < 0.05$) effect on the pH values.. The initial pH value of the control sample was significantly ($p < 0.05$) higher than those from all of the treated samples. In all of the turkey breast samples, the values of pH showed a decrease by the day 6th of storage time, and then increased significantly. Decrease of pH may be attributed to increasing of solubility of CO_2 at storage time, affecting growth of aerobic microflora (TAHERI *et al.*, 2013), while an increase in pH of the control sample may be due to an increase in volatile compound contents (e.g. ammonia and trimethylamine), produced by either endogenous or microbial enzymes through storage time (FAN *et al.*, 2009; BAZARGANI–GILANI *et al.*, 2015). No significant difference was observed between the pH values of treatment groups (AA and Ch+C) through 15 days of storage time ($p>0.05$), with exceptions in samples stored for 3 and 15 days ($p< 0.05$). Samples treated by acetic acid, chitosan and cumin essential oils expressed a gradual increase throughout storage period, probably due to the presence of the acidified antimicrobial agents (BAZARGANI–GILANI *et al.*, 2015) and phenolic compounds (IBRAHIM and EL-SHERIF, 2008). The achieved results of the present study are in solid agreement of those for chicken breast (containing pomegranate juice and chitosan and essential oil) (BAZARGANI–GILANI *et al.*, 2015), beef meat (containing organic acid) (SHALTOUT *et al.*, 2014) and marinated chicken thigh (sodium lactate and lactic acid) (SMAOUI *et al.*, 2012).

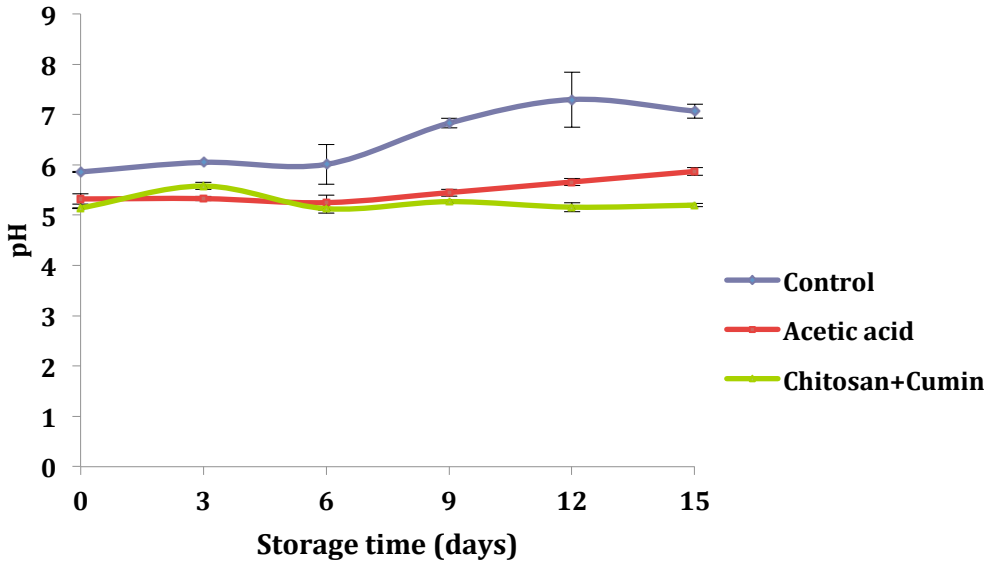

Figure 3. Changes in pH values of turkey breast samples during refrigerated storage.

3.3. Total volatile basic nitrogen (TVB-N)

Total volatile basic nitrogen (TVB-N) mainly composed of ammonia and primary, secondary and tertiary amines, is extensively used as an indicator for meat deterioration determination. An increase in this parameter may be attributed to the activity of bacterial species and endogenous enzymes (FAN *et al.*, 2009; KYRANA *et al.*, 1997; NOWZARI *et al.*, 2013; DUAN *et al.*, 2010). The TVB-N values for turkey breast samples through storage period have been presented in (Fig.4) as well.

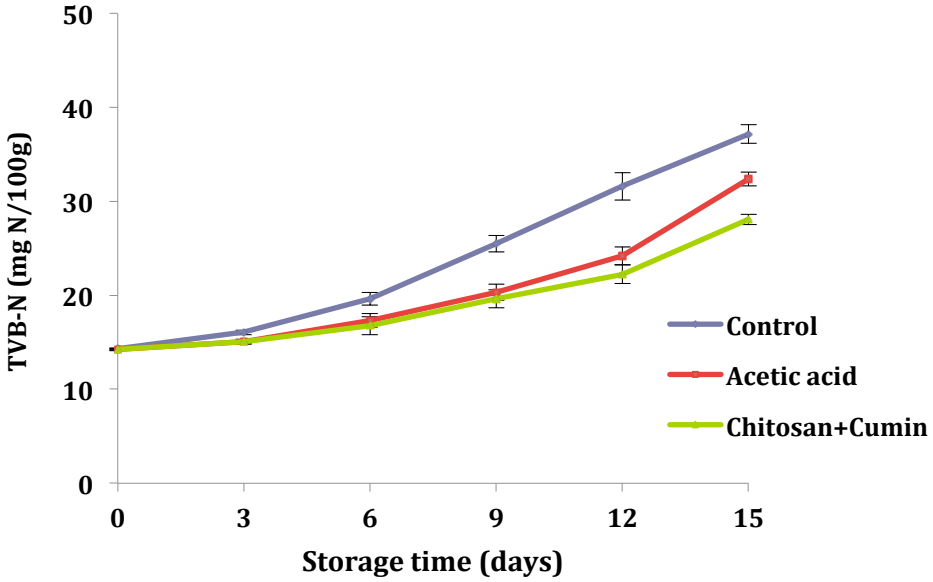

Figure 4. Changes in TVB-N values of turkey breast samples during refrigerated storage.

An increase in TVB-N value was observed from 14.30 to 37.16, 14.23 to 32.40, and 14.23 to 28.06 mg N. 100 g^{-1}, in Control, samples treated by AA 1%, and Ch+C 1%, respectively, through storage time for 15 days. According to (BALAMATSIA *et al.*, 2006), the value of 28-29 mg N. 100 g^{-1} is proposed as the highest acceptable level in poultry meat products. In the present study, the TVB-N values were detected higher than the acceptable limit by 12 and 15 days of storage time for the untreated samples (control) and the treated ones by acetic acid (1%), respectively. However, TVB-N values in treated samples by chitosan + cumin remained lower than the limit of acceptable index throughout the entire storage time. Higher microbial counts resulted in a significant increase in the basic nitrogen fraction for the untreated samples compared to chitosan treated samples (NOWZARI *et al.*, 2013; MOHAN *et al.*, 2012). The TVB-N level presented enhancements gradually along with the time of storage for the control and both of the treated samples ($p<0.05$). By 6 days after storage, the TVB-N value of the control samples increased significantly compared to the treated samples, ($p<0.05$). At the end of the storage time, the TVB-N value of the control sample was detected significantly rather than the studied treatments ($p<0.05$). These achieved results are in line with those of previous studies that reported, the TVB-N value of fish and chicken meats treated by acetic acid, chitosan, and cumin essential oil showed reductions significantly ($p<0.05$) (RAEISI *et al.*, 2015; SMAOUI *et al.*, 2012). An increase rate in TVB-N value of turkey breast treated by chitosan coating was also

inhibited compared to the control, that is in agreement with the achieved results of (Yuan *et al.*, 2016) and (OJAGH *et al.*, 2010). In addition, an increase in TVB-N value of turkey breast treated by chitosan + cumin coating was significantly lower than the samples treated by acetic acid by 15 days after storage period, presenting the synergism effect of chitosan coating on TVB-N value once used in combination with cumin seeds' essential oils.

3.4. Peroxide value (PV) Determination

Lipid oxidation value was detected regarding the PV formation (primary oxidation compounds). The peroxide value of the studied samples indicates the concentrations of peroxide and hydroperoxide compounds produced during early stage lipid oxidation process. The peroxide value is commonly determined for a sample, and a sharp increase indicates the end of the shelf-life for the studied samples (TAHERI *et al.*, 2013). Alterations in PV values of the control sample and both treatments (AA and Ch + C) during 15 days of storage time at the temperature of 4±1°C have been presented in (Fig. 5).

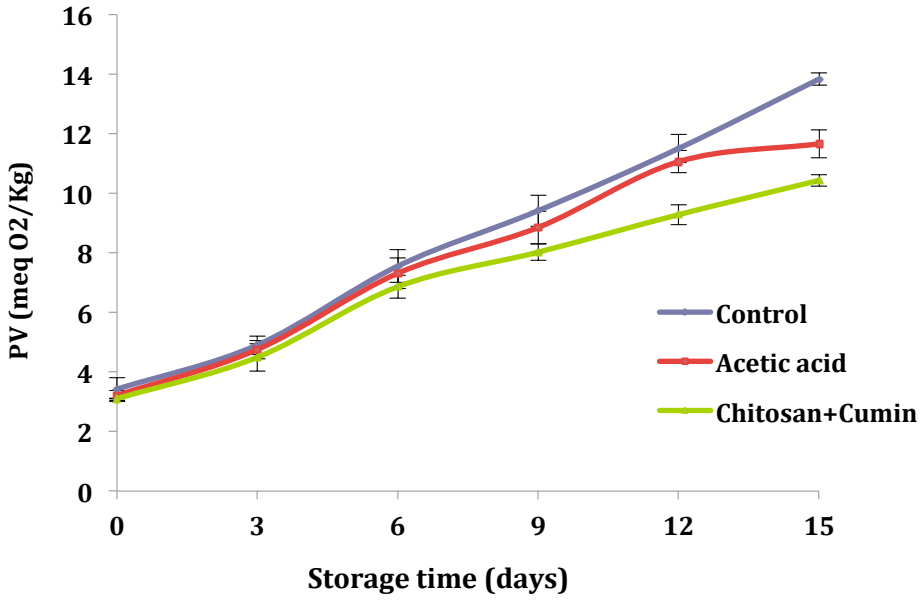

Figure 5. Changes in PV values of turkey breast samples during refrigerated storage.

Initial PV values of control, samples treated by acetic acid, and chitosan + cumin were determined as the following: 3.41, 3.21, and 2.10 meq O_2. Kg^{-1} followed by enhancements up to 13.83, 11.66, and 10.33, respectively. All of the samples expressed an increased PV value in turkey breast fillets once the frozen storage time increased ($p<0.05$). In control samples, PV values were detected higher than other samples in the current study during the storage time. The differences among detected peroxide values of the treated and untreated samples (control) may be associated with different bioactivity properties of the materials with natural origins. Plant phenols and flavonoids are known to inhibit lipid peroxidation by quenching lipid peroxy radicals and reduce and/or chelate iron ions in lipoxygenase enzymes, and as a result of it, may prevent the initiation of lipid peroxidation reactions (ALLAHGHADRI *et al.*, 2010). The antioxidant property of cumin

seeds' essential oil may be associated to phenolic and γ-terpinene compounds as well as monoterpenes (CHEN *et al.*, 2014; RAEISI *et al.*, 2015). According to the achieved results, it is concluded that cumin seeds' essential oils may have a significant effect on lipid oxidation retardation. Similar results were reported by further scientists (RAEISI *et al.*, 2015; ALLAHGHADRI *et al.*, 2010). The results of the present study indicate that chitosan coating is effective in retarding the production of PV in turkey breast fillets stored by refrigeration. JEON et al. (2002) demonstrated that chitosan may be considered as a potential natural antioxidant for stabilizing shelf life enhancements in food products containing lipid. These results are in solid agreement with those of (HU *et al.*, 2002), who reported that chitosan loaded by cinnamon essential oils was effective against lipid oxidation in pork meats stored at 4±1°C. The achieved results of the present research confirmed the obtained results by (BAZARGANI-GILANI *et al.*, 2015), who reported that chitosan coating was effective in retarding of lipid oxidation reactions in chicken breast fillets stored at 4±1°C. Moreover (NOWZARI *et al.*, 2013) reported, that chitosan coating is effective in retarding of POV in trout fillets stored at 4±1°C.

3.5. Sensory evaluation

The sensory qualities of turkey breast samples were assessed in terms of appearance, color, odor, meat consistency and elasticity, with the use of a three-point hedonic scale (1 representing unacceptable and 3 indicating excellent). The turkey breast samples were considered acceptable for customers by 2, suggested by (OCTAVIAN and OCTAVIAN, 2010). The obtained results of the sensory evaluation of turkey breast samples have been shown in (Table 2).

Table 2. Changes in sensory attributes score of turkey breast samples stored at 4±°C.

Sensory attributes	Treatment	Storage period (days)					
		0	3	6	9	12	15
Appearance	Control	3.0±0.00^{aA}	3.0±0.00^{aA}	2.6±0.54^{bAB}	1.2±0.44^{bB}	1.0±0.00^{cB}	1.0±0.00^{bB}
	AA	3.0±0.00^{aA}	3.0±0.00^{aA}	3.0±0.00^{aA}	2.6±0.54^{aAB}	2.0±0.70^{bB}	1.8±0.44^{aB}
	Ch+C	3.0±0.00^{aA}	3.0±0.00^{aA}	3.0±0.00^{aA}	2.8±0.44^{aAB}	2.4±0.54^{aB}	2.0±0.00^{aC}
Meat elasticity	Control	3.0±0.00^{aA}	2.8±0.44^{aA}	2.8±0.44^{aA}	1.8±0.44^{bB}	1.0±0.00^{cC}	1.0±0.00^{cC}
	AA	3.0±0.00^{aA}	3.0±0.00^{aA}	3.0±0.00^{aA}	2.6±0.54^{aB}	1.8±0.83^{bC}	1.6±0.54^{bC}
	Ch+C	3.0±0.00^{aA}	3.0±0.00^{aA}	3±0.00^{aA}	2.8±0.44^{aAB}	2.4±0.54^{aB}	2.0±0.00^{aC}
Odor	Control	3.0±0.00^{aA}	2.6±0.54^{bB}	2.0±0.00^{bC}	1.6±0.54^{bD}	1.0±0.00^{cE}	1.0±0.00^{bE}
	AA	3.0±0.00^{aA}	3.0±0.00^{aA}	2.6±0.54^{abB}	2.2±0.44^{abC}	1.6±0.54^{bD}	1.6±0.54^{abD}
	Ch+C	3.0±0.00^{aA}	3.0±0.00^{aA}	3.0±0.00^{aA}	2.8±0.44^{aAB}	2.4±0.54^{aB}	2.0±0.00^{aC}
Color	Control	3.0±0.00^{aA}	2.8±0.44^{aA}	2.8±0.44^{aA}	1.6±0.54^{cB}	1.0±0.00^{bC}	1.0±0.00^{bC}
	AA	3.0±0.00^{aA}	3.0±0.00^{aA}	2.8±0.44^{aAB}	2.4±0.54^{bBC}	2.2±0.44^{aC}	1.4±0.54^{bD}
	Ch+C	3.0±0.00^{aA}	3.0±0.00^{aA}	3.0±0.00^{aA}	3.0±0.00^{aA}	2.2±0.44^{aB}	2.0±0.00^{aB}

Means in column with different small letters indicate significant differences ($p<0.05$) among treatments, and means in row with different capital letters indicate significant differences ($p<0.05$) as result of refrigerated storage time.

At the beginning of the evaluations, the appearance, odor, color, and consistency of breast fillets were fresh. As expected, progressive quality deteriorations of samples were observed, as a result of an increase in storage time ($p<0.05$). The sensory evaluation result is associated with the microbial and chemical properties. Due to a high lipid oxidation and microbial growth, the control samples (untreated) of turkey breast fillet showed deterioration, appearing as off-odor, and slimy as well as discoloration after 6 days of

storage period. In comparison, chitosan + cumin coated samples showed an acceptable sensory score up to 15 days of storage time. Thus, antioxidant and antimicrobial effects of chitosan + cumin coating may minimize the oxidative reactions, and as a result extending the products' shelf life while maintaining their quality as well (OJAGH *et al.*, 2010). The achieved results indicated that chitosan + cumin treatment led to the highest score among other treatments in all of the studied sensory properties through storage time. This phenomenon may be attributed to the unique flavor of cumin seeds' essential oil. Addition of cumin seeds' essential oil to chitosan coating enhanced the beneficial effects on color, odor, and overall acceptability of turkey breast fillets significantly ($p<0.05$) in the final days of storage periods. Considerable correlations among the microbial and chemical qualities as well as sensory attributes were found by (BAZARGANI-GILANI *et al.*, 2015; KANATT *et al.*, 2013; SHALTOUT *et al.*, 2014; VASILATOS and SAVVAIDIS, 2013; RAEISI *et al.*, 2015; OJAGH *et al.*, 2010) where were in solid agreement of the achieved results of the current study.

4. CONCLUSIONS

Fresh meats and their products are very susceptible to deterioration by microbial growth and oxidative reactions. The shelf life of refrigerated turkey meat is normally short due to the chemical and microbial activities in it, leading to quality loss and spoilage. The achieved results of microbial (TVC and PTC), physicochemical (pH, TVN-B and PV) and sensory evaluation analyses indicated that acetic acid and Ch + C (chitosan and cumin oil) coating on turkey breast fillets may lead to the maintenance of qualitative characteristics, improvement of microbial safety and extension of the shelf life of meat products through the chilled storage period. Chitosan + cumin treatment could maintain turkey breast fillet shelf life till the end of the storage period (day 15), while acetic acid treatment and the control sample had a shelf life just for 9 and 6 days, respectively. Therefore, natural preservatives such as chitosan + cumin oil combination may be used as a safe preservation approach to extend the shelf life of chilled turkey meat and its products.

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