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Effect of titanium dioxide nanoparticles and thyme essential oil on the quality of the chicken fillet

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ABSTRACT

This study aimed to assess the effect of titanium dioxide (TiO2), Thyme essential oil, and a mixture of both on the quality of chicken fillets. Fresh chicken breast fillets samples were treated with TiO_2 nanoparticles as a trial (T), Thyme oil (2%) as a trial (O) individually and in mix of both as a trial (M). All samples were examined during cold storage (4 ± 1 °C at zero, 2, 4, 6, 8, 10, 12 and 14 days from sensory, bacteriologically and chemical points of view. The results indicated a positive effect on the shelf life of treated samples as compared to untreated ones especially in trial (M). On the other hand, there was a good antibacterial activity of such treatment on APC, Psychrotrophic and coliform counts. Also, the results showed that pH, TBA and TVN values were increased but not reached to spoilage (6.4) in all Thyme oil 2% treated samples; which gave the best effectiveness followed by TiO_2 and finally the combination of both Thyme oil 2% and TiO_2.

1. INTRODUCTION

Chicken meat is a competitive source of animal proteins compared to red meat from other farm animals (USDA, 2006). Fresh chicken meat is highly susceptible to microbial spoilage due to its high levels of moisture and nutrients (Bazargani-Gilani et al., 2015). In recent years, antimicrobial packaging has attracted much attention from the food industry to the increase in consumer demand for minimally processed and preservative-free products. Use of antimicrobial substances based on nanoparticles and essential oils are of great importance and can control the microbial population and target specific microorganisms to provide higher safety and quality products (Appendini and Hotchkis , 2002). Thyme (thymus sp.) has much attention due to its high content and wide spectrum of phenolic compounds, antimicrobial and antioxidant properties, and potential for use in meat and meat products (Guttierrez et al., 2008 ; Barbosa et al., 2009 ; Gutierrez et al., 2009 ; Jayasena and Jo, 2013 ; Bensid et al., 2014). Nanotechnology is used as a novel approach in meat industries for enhancing the safety and quality of products (Pradeep et al., 2016). Also, it can be applied throughout different aspects of the food chain processing for improving food safety and quality control and increasing shelf life (Bošković et al., 2013). The metal nanomaterial that commonly used for antibacterial activity in food industry are Silver (Ag), Zinc (Zn), Magnesium (Mg), Copper (Cu) and Titanium (Ti) (Duncan, 2011). Titanium dioxide (TiO2) is an inert, nontoxic, and inexpensive material with potential activity against a wide variety of microbes due to its photo-catalytic activity. When microbiological, biochemical and sensory techniques have been used to assess freshness and quality during handling and storage. Therefore, the main target of this work was to investigate the antioxidant as well as the antibacterial effectiveness of TiO2, thyme oil and combination of both on the quality of fresh chicken fillet during cold storage.

2. MATERIAL AND METHODS

2.1. Collection of samples (chicken fillets)

A total of 1.600 g of fresh chicken breast fillets represented by 16 portions (100 ± 10 g for each), were collected from different local markets in Toukh¸ Qalubyia governorate¸ Egypt

2.2. Preservatives

Two types of preservatives include titanium dioxide nanoparticles (TiO2) (12 mM) and thyme oil (2%) was used.

2.3. Experimental applications

The samples were placed in sterile plastic bags in an ice box and transferred to the laboratory without delay under aseptic conditions. Fresh chicken breast meat samples were divided into two groups (treated and control group). Treated ones were subdivided into three subgroups (TiO2, thyme oil 2% and a combination of both), (24 of each), First subgroup; the samples were dipped in in 2% Thyme essential oil for 5 minutes with proper mixing. The second subgroup; samples were dipped in 12 mM TiO_2 nanoparticles. Third subgroups; samples were dipped in mixture of (2% Thyme essential oil + 12mM TiO_2 nanoparticles). All samples (treated and control) were stored at 4 ± 1 °C and examined every two days starting from zero (after 2 hours), 2¸ 4, 6, 8, 10, 12, till 14^{th} days for their sensory, chemical and bacteriological profile. The experiments were conducted in triplicates.

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3. RESULTS

Table (1) pH values of control and treated chicken fillet samples

Exp. Period	PH-values for different Trials			
	Control	Trial T	Trial O	Trial M
Zero day	5.71±0.02^{Ab}	5.70±0.03^{Af}	5.69±0.03^{Ad}	5.71±0.02^{Ae}
2nd day	6.57±0.30^{Aa}	5.80±0.02^{Be}	5.77±0.02^{Bcd}	5.81±0.01^{Be}
4th day	6.12±0.04^{Aab}	5.91±0.03^{Bd}	5.85±0.03^{Cc}	5.96±0.03^{Bd}
6th day	6.40±0.04^{Aa}	6.04±0.04^{BCc}	5.97±0.04^{Cb}	6.11±0.03^{Bc}
8th day	Spoiled	6.04±0.04^{ABc}	5.97±0.04^{Bb}	6.11±0.03^{Ac}
10th day	Spoiled	6.14±0.03^{Ab}	6.06±0.03^{Ab}	6.17±0.04^{Ac}
12th day	Spoiled	6.25±0.04^{Aa}	6.17±0.04^{Aa}	6.29±0.04^{Ab}
14th day	Spoiled	6.32±0.03^{Aba}	6.24±0.05^{Ba}	6.42±0.05^{Aa}

Exp. Period refer to experimental period

Table (2) TVN values of control and treated chicken fillet samples

Exp. Period	TVN values of different Trials			
	Control	Trial T	Trial O	Trial M
Zero day	2.86±0.1^{Ad}	2.78±0.08^{Ah}	2.74±0.08^{Ah}	2.81±0.09^{Ah}
2nd day	5.72±0.1^{Ac}	4.07±0.06^{BCg}	3.92±0.07^{Cg}	4.21±0.06^{Bg}
4th day	11.55±0.2^{Ab}	6.27±0.21^{Bf}	5.52±0.17^{Cf}	6.51±0.28^{Bf}
6th day	18.83±0.3^{Aa}	9.59±0.23^{Be}	8.57±0.22^{Ce}	10.18±0.37^{Be}
8th day	Spoiled	12.55±0.39^{ABd}	11.43±0.26^{Bd}	13.04±0.39^{Ad}
10th day	Spoiled	14.76±0.22^{Ac}	13.73±0.34^{Bc}	15.32±0.24^{Ac}
12th day	Spoiled	16.14±0.25^{ABb}	15.09±0.46^{Bb}	16.77±0.26^{Ab}
14th day	Spoiled	18.63±0.37^{ABa}	17.71±0.55^{Ba}	19.38±0.32^{Aa}

Exp. Period refer to experimental period

Table (3) TBA values of control and treated chicken fillet samples

Exp. Period	TBA-values for different Trials			
	Control	Trial T	Trial O	Trial M
Zero day	0.08±0.01^{Ad}	0.07±0.01^{Ae}	0.06±0.01^{Af}	0.07±0.01^{Af}
2nd day	0.29±0.03^{Ac}	0.17±0.02^{Be}	0.14±0.01^{Bef}	0.19±0.02^{Be}
4th day	0.47±0.03^{Ab}	0.28±0.04^{BCd}	0.21±0.02^{Cde}	0.35±0.03^{Bd}
6th day	0.80±0.04^{Aa}	0.37±0.04^{BCd}	0.29±0.03^{Cd}	0.45±0.03^{Bc}
8th day	Spoiled	0.50±0.05^{Ac}	0.44±0.07^{Ac}	0.55±0.05^{Ac}
10th day	Spoiled	0.63±0.04^{ABb}	0.55±0.03^{Bb}	0.70±0.04^{Ab}
12th day	Spoiled	0.75±0.03^{Aba}	0.68±0.03^{Ba}	0.81±0.03^{Aa}
14th day	Spoiled	0.83±0.04^{Aa}	0.72±0.04^{Aa}	0.90±0.04^{Aa}

Exp. Period refer to experimental period

Table (4) Reduction percentage of Aerobic Plate Count (cfu/g) in control and treated chicken fillet samples

Exp. Period	Values for different Trials		
	Trial T	Trial O	Trial M
Zero day	16.00	10.00	24.00
2nd day	11.61	50.89	49.11
4th day	47.68	68.87	74.17
6th day	70.69	84.91	85.34
8th day	82.20	93.18	92.58
10th day	93.98	96.90	95.80
12th day	96.18	98.68	97.76
14th day	97.91	99.46	97.73

Exp. Period refer to experimental period

Table (5) Reduction percentage of Coliform Count (cfu\g)in control and treated chicken fillet samples

Exp. Period	Values for different Trials		
	Trial T	Trial O	Trial M
Zero day	32.00	36.00	32.00
2nd day	4.62	35.38	9.23
4th day	25.35	47.89	49.30
6th day	78.65	84.83	81.46
8th day	92.31	96.55	92.04
10th day	96.58	96.96	95.26
12th day	98.04	98.88	97.48
14th day	98.87	99.53	98.69

Exp. Period refer to experimental period

Table (6) Reduction percentage of Psychrotrophic Count (cfu/g) in control and treated chicken fillet samples

Exp. Period	Values for different Trials		
	Trial T	Trial O	Trial M
Zero day	34.78	52.17	56.52
2nd day	4.93	75.35	71.83
4th day	81.65	84.18	81.65
6th day	89.77	90.70	86.51
8th day	94.59	97.57	92.97
10th day	97.52	98.18	96.53
12th day	99.35	99.19	98.62
14th day	99.41	99.78	98.83

Exp. Period refer to experimental period

3.1. Chemical indices

Table (1) revealed that the initial mean pH value of control and Thyme oil 2% , Titanium dioxide 12 mM, and the Mix (Thyme oil 2% - TiO_2) were 5.69±0.03, 5.70± 0.03 and 5.71± 0.02 respectively at zero day (after two hours). While at 14th day of cold storage the pH value were 6.24 ± 0.05, 6.32± 0.03 and 6.42± 0.05 in thyme oil 2% , TiO_2 12 mM, Mix (Thyme oil 2% - TiO_2) respectively, where control samples were spoiled (Table, 1). TVN values of control, and in treated samples with Thyme oil 2% , Titanium dioxide 12 mM, and their Mix(Thyme oil 2% - TiO_2 were 2.74± 0.08 ,2.78± 0.08 and 2.81± 0.09 mg % at zero day, respectively. While at 14th day of cold storage TVN value were 18.63± 0.37 and 19.38± 0.32 in Thyme oil 2% , Titanium dioxide 12 mM, Mix(Thyme oil 2% - TiO_2), respectively where control samples were spoiled (Table, 2). TBA values of control , and in treated samples with Thyme oil 2% , Titanium dioxide 12 mM, Mix (Thyme oil 2% - TiO_2) were 0.06± 0.01 ,0.07± 0.01 and 0.07± 0.01 at zero day (after two hours), respectively. At 14th day of cold storage TBA value were 0.72 ± 0.04 mg/Kg ,0.83± 0.04 and 0.90± 0.04 in Thyme oil 2% , Titanium dioxide 12 mM, Mix (Thyme oil 2% - TiO_2), respectively where control samples were spoiled (Table 3).

3.2. Sensory Examination

It is obvious from results obtained in table (2) that, the sensory characteristics of different treated chicken fillet samples were enhanced in compared to untreated ones (control) at all time of storage. Shelf life of samples were extended in the three trials as following trial(O) (Thyme oil 2%) then trial(T) (TiO_2) followed by trial (M) (mix of both)

3.3. Bacteriological Examination

The results achieved in table (4) noticed that the initial mean count of total aerobes in control group , was 1.25×10^7 ± 2.5×10^6. Such count was slightly decreased to 1.25×10^7 ± 5×10^5, 1.05×10^7 ± 5×10^5 and 1.55×10^7 ± 5×10^5 after treatment with Thyme oil 2% , TiO_2 (12 m M) and Mix (Thyme oil 2%, TiO_2 (12 m M) respectively, with reduction percentage of 10.00%, 16.00% and 24.00, respectively. Finally at 14th day of refrigeration storage at 4 °C the samples of untreated control group its mean count of total aerobes, was 5.51×10^8 ± 6.1×10^7 such count was slightly decreased to 3×10^6 ± 1×10^6 , 1.15×10^7 ± 3.5×10^6 and 1.25×10^7 ± 5×10^5 after treatment with Thyme oil 2%, TiO_2 (12 m M) and Mix (Thyme oil 2%, TiO_2 (12 m M), respectively, with reduction percentage of 99.46, 97.91 and 97.73%, respectively. The results achieved in table (5) cleared that the mean total coliform count in control group was 1.25×10^7 ± 2.5×10^6. Such count was slightly decreased to 1.7×10^7 ± 6×10^6, 1.65×10^7 ± 5.5×10^6 and 5.25×10^7 ± 4.45×10^7 after treatment with Thyme oil 2%, TiO_2 (12 m M) and Mix (Thyme oil 2%, TiO_2 (12 m M), respectively, with reduction percentage of 36, 32 and 32% respectively. Finally at 14th day of refrigeration storage at 4 °C, mean total Coliform count of control group samples was 5.33×10^8 5.3×10^7 such count was slightly decreased to 2. 5×10^6 ± 5×10^5, 6×10^6 ± 2×10^6 and 7×10^6 ± 2×10^6 after treatment with Thyme oil 2%, TiO_2 (12 m M) and Mix (Thyme oil 2%, TiO_2 (12 m M) respectively with reduction percentage of 99.53, 98.87 and 98.69% respectively. The results achieved in table (6) revealed that the mean total psychrotrophic count in control group, was 1.15×10^7 ± 1.5×10^7 such count was slightly decreased to 1.75×10^7 5.5×10^6, 1.5×10^7 5.5×10^6 and 1.8×10^7 ±5×10^6 after treatment with Thyme oil 2%, TiO_2 (12 m M) and Mix (Thyme oil 2%, TiO_2 (12 m M) respectively with reduction

percentage of 52.17, 34.78 and 56.52% respectively. Finally at 14th day of refrigeration storage at 4 °C, Mean total psychrotrophic count of control group was $6.81\times10^8 \pm 3.9\times10^7$ such count was slightly decreased to $1.5\times10^6 \pm 5\times10^5$, $4\times10^6 \pm 1\times10^6$ and $8\times10^6 \pm 1\times10^6$ after treatment with Thyme oil 2% , TiO_2 (12 m M) and Mix (Thyme oil 2%, TiO_2 (12 m M) ,respectively, with reduction percentage of 99.78, 99.41 and 98.83% respectively.

4. DISCUSSION

The obtained results indicated that the best acceptable quality was attained at thyme oil-treated samples, then TiO_2 treated sample while slight improvement in acceptability of mixture samples as compared with control samples. Natural products and naturally derived compounds from plants may have applications in controlling pathogens in foods (Davidson, 1997 and Bowles and Juneja, 1998).Thyme EOs have gained greater acceptance among food technologists due to their better sensory evaluation and antimicrobial properties (Fischer and Phillips, 2006). The major active compound of thyme is thymol, which exerted its antimicrobial action through binding to membrane proteins by hydrophobic bonding and hydrogen bonding, and then changing the permeability of the membranes (Burt, 2004). These results agree with those obtained by Sasse et al. (2009) who reported that spices as thyme contain antioxidant components that improve both color and flavor stability in meat. Also, Sallem-Amany et al. (2010) indicated that sensory properties of meat samples during cold storage (4°C) were enhanced by treatment meat by thyme oil as compared to the untreated (control) samples. However, Shaltout et al. (2017) whose results were that meat samples containing 2% thyme oil demonstrated the highest enhancement of sensory attributes. Accordingly, the changes in microbial count in the fresh chicken fillet samples during storage especially aerobic bacterial count , coliform count and psychrotrophic count were decreased with addition of thyme essential oil than other treated groups.

5. CONCULOSION

In conclusion, thyme essential oil 2% maintained the sensory qualities of fresh chilled chicken fillet meat sample, due to have amounts of phenolic compounds exhibiting potent antioxidant , antibacterial effects enabling to increase quality and shelf life. Thyme essential oil 2% had been shown to cause significant decrease in pH, TVN, and TBA values compared to control sample. Thus, one can suggest that addition of this essential oil to meat as natural preservative could improve the overall quality and serve consumer needs.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest for current data

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