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Evaluation of the effect of corn starch film composed of Ag-TiO_2 nanocomposites and *Satureja khuzestanica* essential oil on the shelf-life of chicken fillet

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ABSTRACT

Nowadays it seems necessary to replace synthetic plastics with biodegradable films in food packaging due to their major threats to human health and the environment. In this study corn starch film composed of Ag-TiO_2 nanocomposites and *Satureja khuzestanica* essential oil (SEO) were prepared and the antimicrobial, morphological, physical, and mechanical characteristics in chicken fillet packaging were assessed. The morphology of the films was investigated by scanning electron microscopy (SEM). The combination of energy-dispersive X-ray spectroscopy (EDX) with SEM analyzed the near-surface elements. The plain film showed higher WVP (2.82×10^{-7} g/m.h.Pa) than other films and the nano/essence film had the lowest moisture content% (21.6%). For determining the film's antimicrobial activity, chicken fillets were inoculated with *Escherichia coli*, *Salmonella* Typhimurium, and *Staphylococcus aureus* (separately with four prepared films). Microbial counting of the fillets was performed at three intervals (14 and 7th day) and the results showed a significant difference in reducing the number of microorganisms in nano/essence and essence films compared to the control group (chicken fillets packed in plastic bags) and plain film (at a rate of 1.5-2 log CFU/g). The rate of reduction of S. aureus was higher compared to *S.* Typhimurium and *E. coli* in the packing groups respectively. Sensory properties were also evaluated at three- intervals. The bio-polymer film incorporated with SEO and Ag-TiO_2 nanocomposites can be used for packaging foods and is able to delay microbial and physical spoilage in foodstuffs.

1. Introduction

Chicken meat is a healthy source of minerals vitamins high-quality protein and fats rich in polyunsaturated fatty acids (PUFA) and omega (n)-3 fatty acids and is a cheap source of protein available (1,2). The Food and Agriculture Organization (FAO) forecasts that meat production will increase by 1.8 million tons per year by 2025 which is mainly related to pork and poultry (2). However, poultry production is the fastest-growing and most flexible sector among meat products (1). Due to the special composition of this type of meat (for example the content of protein and high humidity) as well as the high pH growth rate of spoilage and pathogenic microorganisms is easy to indicate the reason for considering chicken meat as a food with high perishability (3,4). Reduction in production imposes a heavy responsibility on poultry meat producers the results of which are the efforts and research of the food industry to gain access to new technologies and methods for increasing the shelf-life safety and quality of poultry meat products (3). Biodegradable packaging is a new perspective to increase shelf life that guarantees efficient and effective food safety vulnerable to microbial contamination (5). In active packaging technology, bioactive compounds are added to systems that enhance quality and increase the shelf life of food products such as meat (6). Antimicrobial packaging incorporated with essential oils in recent decades as an alternative technology has been proposed for food preservation (7-9). The direct addition of essential oils to the texture and composition of the food has two major drawbacks: one is the high cost and the other is the change in the

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organoleptic and sensory properties of the food due to their strong natural aroma (5, 10). For this reason, incorporating these extracts into biodegradable compounds has been suggested to overcome these defects and increase food shelf-life, especially for fresh fish and chicken fillets which have already been packed with starch-based films incorporated with *Satureja khuzestanica* essential oil (SEO) and Ag-TiO_2 nanocomposites (11,12). The properties of starch such as being biodegradable and obtained from a biological source (e.g., corn) place it in a unique position for food packaging (13). Corn starch films are characterized by increased permeability to water and weak mechanical properties than traditional plastic material (14). Through the interaction with the polymeric chain, Ag-TiO_2 nanocomposite and SEO incorporated into the starch film are effective in improving the antimicrobial mechanical and physical characteristics of the film (14). The *Satureja* genus belongs to the *Lamiaceae* family which has about 30 species that are distributed in subtropical parts of Africa Europe North America and the Middle East. *S. khuzestanica* is one of the native species of Iran which by having compounds alpha-Terpinene Carvacrol and Thymol the antimicrobial properties of its essential oil have been determined on *Escherichia coli*, *Salmonella typhimurium* and *Staphylococcus aureus* (15). Food-borne pathogens are inactivated through the loading of EOs and NPs into the corn starch matrix (16, 17). Titanium dioxide is one of the metal oxides that has been used in recent years in the nanoworld, especially in food packaging, and also it is used in purification disinfection decolorization decontamination killing of cancer cells, and preparation of protective coatings against UV light. Titanium dioxide can absorb UV light and due to its photocatalytic properties can create an antibacterial coating on surfaces and food packaging (18). To improve the photocatalytic properties of TiO_2 it is chemically and non-chemically doped with metal and non-metallic ions (19, 20). The composition of TiO_2 with Ag results in more favorable photocatalytic effects of TiO_2 to debilitate bacteria. Ag disrupts cell function by attaching to the bacterial cell wall and leads to generating reactive oxygen species and finally cell death (14). In previous studies, various plant extracts and nanocomposites have been used to produce films based on carboxy methyl cellulose, chitosan, Cassava starch, and types of gelatins to make food packaging including types of meat (14). In this study, Ag-TiO_2 nanocomposite along with SEO was utilized to produce corn starch films for the first time and investigate their synergistic effects and antimicrobial activity against *S. aureus*, *S.* Typhimurium and *E. coli*. Psychrophilic bacteria and total bacteria counts were determined in chicken fillets. Finally, possible effects on the sensory properties (color, odor, texture, and overall acceptance) of fresh chicken fillets were studied.

2. Materials and methods

2.1. Chemicals and materials

$AgNO_3$ (99% pure) and TiO_2 NPs (P25 Evonik), Tween 80 reagents and other chemicals were prepared from Merck Co; and Sigma-Aldrich Co. Baird-Parker Agar (BPA), Plate Count Agar, Tryptone Bile x-Glucuronide medium (TBX), and Xylose Lysine Deoxycholate agar (XLD) culture medium were provided by Merck Co. and *E. coli* strain ATCC 25922 *S. aureus* strain ATCC 25923 and *S.* Typhimurium strain ATCC 14028 were purchased from the Iranian Research Organization for Science and Technology (IROST).

2.2. Film preparation with CS/SEO/Ag–TiO_2 nanocomposite

2.1.1.Simple cornstarch film

The preparation method was according to the approach by Sallak et al. (14). First 50 g of cornstarch granules was dissolved in 150 ml of deionized water. Then 4 ml of glycerol was mixed with the solution and stirred at 80 ° C for 30 minutes (for no evaporation the barrel that contained the mixture was covered with foil while heating). After cooling the mixture to room temperature, it was poured into the model (11×11 cm^2) and located in an oven at 50–60 °C for 12 h (the glycerol to CS ratio was 80%).

2.1.2.The film incorporated with Ag-TiO_2 nanocomposites

Fifty grams of cornstarch granules were dissolved in deionized water (150 ml). Then 4 ml of glycerol was mixed with the above solution followed by stirring at 80 ° C for 30 minutes (we used foil to cover the barrel containing the mixture to prevent evaporation while heating). Then Ag-TiO_2 nanocomposite was mixed with the mixture gently and stirred at 80 °C for 30 min followed by cooling at room temperature and pouring into the model (11×11 cm^2) and placing in the oven at 50–60 °C for 12 h (the glycerol to CS and NP to CS ratio was 80% and 3% respectively) (14).

2.1.3.The film incorporated with extracted SEO

Firstly 50 g of cornstarch granules were dissolved in deionized water (150 ml). Then 4 ml of glycerol was mixed with this solution and stirred at 80 ° C for 30 minutes (we used foil to cover the barrel containing the mixture to prevent evaporation while heating). After cooling the mixture to 45°C it was gently added to 10 g SEO emulsion (0.15 g Tween 80 + 50 g water +1 g SEO) followed by pouring into the model (11×11 cm^2) and placing in the oven at 50–60 °C for 12 h (the glycerol to CS and EO to CS ratio was 80% and 4% respectively) (14).

2.1.4.The film incorporated with Ag-TiO_2 nanocomposites and SEO (nano/essence film)

Fifty grams of cornstarch granules were dissolved in deionized water (150 ml). Then 4 ml of glycerol was mixed with this solution and stirred at 80 ° C for 30 minutes (we used foil to cover the barrel containing the mixture to prevent evaporation while heating). Then Ag-TiO_2 nanocomposite was mixed with the mixture gradually followed by stirring at 80 °C for 30 min cooling at 45 °C adding 10 g emulsion of SEO (0.15 g Tween80+50 g water+1 g SEO) pouring into the model (11×11 cm^2) and placing in the oven at 50–60 °C for 12 h. (the glycerol to CS EO to CS and NP to CS ratio was 80%, 4%, and 3% respectively) (14).

2.3. Measurement of the films' thickness

Five areas of the desired film were selected randomly to measure the thickness of the film using an IP 65 digital micrometer with a resolution of 0.001 mm (Mitutoyo Manufacturing Japan). The mean obtained values were used for calculating the film's mechanical features and water vapor permeability (21).

2.4. Assessment of the moisture content of the films

The moisture content of the films was measured by weighing each film before and after their placement in an oven (Model UNB 400 Germany) at a temperature of 160 °C for 12 h to reach a constant weight. Pieces of 1 × 3 cm^2 were prepared from each of the films and the test was repeated three times and the moisture content of the films was calculated as follows (22):

$$The\ moisture\ content\ (\%)\ = \frac{Wi - Wt}{Wi}$$

Where, Wi=initial weight, Wt=secondary weight.

2.5. Measurement of the films' Water vapor permeability

The WVP of the films was measured according to ASTM E 96 standard (ASTM 1995). According to this standard vials (15 mm in diameter and 45 mm in height) with pierced lids of 4 mm were selected. From each of the 4 types of prepared films, pieces were cut in a circle. The calcium sulfate (3 g; 0% relative humidity) was poured into vials and the vials were sealed with cut films and located in a desiccator that contained potassium sulfate (97% relative humidity) at 25° C. The vials were weighed for 7 days using a digital scale with a precision of 0.0001g. The water vapor transmission rate was calculated based on the following equitation (23):

$$WVTR = \frac{Wi - Wt}{T \times A}$$

Where, Wt= the vial primary weight (g), Wi= the vial secondary weight (g), A=the film cross-section (m), and T=time (h).

The WVP was determined as follows:

$$WVP = \frac{WVTR \times x}{P(R2 - R1)}$$

Where, X=the film thickness (m), R1= vial relative humidity (0%), P=the water vapor pressure at 25 °C (3169 Pa), R2= the desiccator relative humidity (97%).

2.6. Scanning electron microscope (SEM) and energy-dispersive x-ray spectroscopy

Electron microscopy measurements were performed using a scanning electron microscope (FEI ESEM QUANTA 200 USA). The specimens were cut into small sections (0.5×0.5 cm^2) and were located on the gold-covered holder in the sputter coater. The samples were scanned by SEM at 10 kV (24). NPs structure chemically was analyzed by energy dispersive X-ray method (EDAX. EDS Silicon Drift, 2017).

2.7. The mechanical tests

The films' mechanical features (Strength Tensile Elongation at break Elasticity of Modulus) were performed using SANTAM machine (ENG.DESIN, CO.LTD) according to ASTM standard by D 882_10 method for all 4 types of films. For mechanical properties assessments, the specimens were prepared as 25 x 80 mm^2 strips. The samples were placed in a desiccator that contained a saturated solution of magnesium nitrate (humidity: 50% ± 5%) for 24 hours before the tests. The speed of movement of the upper jaw was 5 mm min^{-1} and the initial space between the two jaws was 50 mm (25).

2.8. Confirmation of the antibacterial effect of the films with chicken fillet

The antimicrobial effectiveness of simple corn starch film (plain film) nanofilm essence film and nano/essence film was examined in chicken comparable to a model food system against *S.* Typhimurium (ATCC 14028) *E. coli* strain (ATCC 25922) *S. aureus* strain (ATCC 25923) psychrophilic bacteria and total bacteria count (TBC). To inoculate the first three bacteria firstly 10 g pieces of chicken fillet were prepared and immersed in pre-boiled water for 5 seconds to sterilize them. Then chicken fillets were submersed in microbial suspension (10^6 CFU / mL) for 20 to 30 minutes (21). All 4 types of films were sterilized by exposing them to UV light for 30 minutes before contacting the inoculated chicken fillets with the films. After that minced chicken inoculated with evaluated organisms was wrapped separately with the chosen films (11× 11 cm^2) and kept at 4 °C. All specimens were examined for *S.* Typhimurium *E. coli* strain *S. aureus* strain psychrophilic bacteria and TBC at different time intervals (days 1^{st}, 4^{th} and 7^{th}). For counting the films were first separated from the chicken fillets and were subjected to homogenization for 2-3 min in sterile peptone water (10 mL; 0.1 % w/v). Homogenates (0.1 ml) were spread-plated on plate count agar for TBC and Psychrophilic bacteria XLD agar for *S.* Typhimurium BPA for *S. aureus* and (1 ml) on TBX for *E. coli*, respectively. Plates were subjected to incubation (6.5° C / 10 days) (psychrophilic bacteria) at 30° C for 72 h (TBC), 37° C for 24 h (*S. typhimurium*), 37° C for 24 and 48 h (*S. aureus*) and 44° C for 18 -24 h (*E. coli*). The results were presented as log CFU/g of chicken. The tests were assessed in duplicate and repeated two times. Occulted Chicken fillets packed in plastic bags were considered as the control group (n=240).

2.9. Sensorial attributes

According to Saber Ibrahim et al. (26), three experienced test panels (Food Hygiene Department Science and Research Branch) the specimens were evaluated for the odor color texture and General acceptance features, and the mean was obtained as overall sensory score as follows: 5=very good 4=good 3=accepted 2=dislike to 1=very dislike. Three measurements were performed for each specimen.

2.10. Statistical analysis

Data and information were analyzed in SPSS (V. 27) software. The significance level was considered five percent ($p < 0.05$) in all evaluations.

3. Results and discussion

3.1. Thickness and Moisture content of films

The means of films' thickness are shown in Table 1 and also according to this table there was a significant decrease in the moisture content of films following the simultaneous loading of Ag-TiO_2 nanocomposite and essential oil in the nano/essence film (21.6%) compared to with plain film (33.6%) in line with the findings of Hasheminya et al. (11). After loading the nanoparticles or essential oil separately the moisture content increased in nanofilm (36.8%) and essence film (38.4%) compared with plain film (33.6%) consistent with the findings of Ojagh et al. (22), Meena et al. (27), Shojaee-Aliabadi et al. (28), and Sabounchi et al. (29). In general, titanium alone is highly hydrophilic and since we used *Satureja khuzestanica* extraction in the preparation of the nanocomposite we have hydrophilic groups made near the nanocomposite also emulsifiers were used when adding essential oils to the films all of which can lead to increase in the moisture content in essence film and the nanofilm separately. Interaction between plasticizer film matrix and fillers such as essential oils and nanocomposites reduces water access to hydroxyl groups and results in less hygroscopic matrix formation (22, 30).

Table 1. The thickness moisture level and Water vapor permeability of the films were affected by adding Ag–TiO_2 nanocomposite and *Satureja khuzestanica* essential oil.

Film sample	Means of Thickness (mm)	Moisture content (%)	WVP[α] ($\times10^{-7}$ g.m/m^{2}Pa.h)
Control	0.183	33.6 2± 0.50*	2.82 ± 0.81*
Nanofilm	0.263	36.81 ± 1.10*	2.64 ± 0.16*
Essence film	0.238	38.4 1± 0.32*	2.76 ±0.74*
Nano/essence film	0.402	21.90 ± 0.41*	2.41 ± 0.07*

[α]: Water vapor permeability "*" indicates a significant difference (p<0.05).

3.2. The films' WVP

Table 1 shows the effects of loading Ag-TiO_2 nanocomposite and SEO to 4 types of film treatments. The plain film showed higher WVP (2.82×10^{-7} g/m. h. Pa) than other films and was significantly reduced by the loading of Ag-TiO_2 nanocomposites. Besides the hydrophobic properties of the nanocomposite, the interaction between the film matrix and the nanocomposite also affects this reduction (31). Shahabi-Ghahfarrokhi et al. (32) reported similar results and explained that special hydrogen bonds between the film matrix and the nanocomposite led to a stronger structure and decrease the permeability of water molecules between the film matrix molecules. In general, the structure of nanocomposites including the presence of large spaces and free cavities can affect WVP (32). The addition of essential oil was associated with a significant decrease in WVP in essence film (2.76×10^{-7} g/m. h. Pa) and nano/essence film (2.41×10^{-7} g/m. h. Pa) compared to the plain film which was in line with the findings of Arafat et al. (33) and Jahed et al. (34). The presence of monoterpene hydrocarbons in SEO causes the hydrophobicity of the film and the release of the hydrophobic stage of the essential oil is able to limit the transfer of water vapor through interference with the hydrophilic phase and lead to changes in the flexibility factor (35). Adding essential oil can change the hydrophilic stage to the hydrophobic stage and influence the WVP (36, 37).

3.3. SEM and EDX tests

SEM images were taken from all four film treatments and the images with the magnification of 1, 2, 5, 10, 20 and 100 µm showed that the nanoparticles (size: nearly 30–60 nm) and the essential oil emulsion were evenly distributed in the films (Fig. 1). The EDX test was performed only for films containing nanocomposite (nanofilm and nano/essential film) (Fig. 2). SEM images of the four types of film treatments in Fig.1 showed that the plain film had a perfectly uniform structure and surface. The nanofilm showed the uniform distribution of the nanocomposite in the matrix and the essence film showed a uniform structure without pores. This uniform structure without pores indicates a stable emulsion system during the film drying process (37). According to the findings of these images, the addition of SEO had no negative influence on the film matrix, and the film incorporated with SEO had a softer surface than the plain film due to the stability of the emulsion system (38). The EDX test is a method commonly used in conjunction with SEM to evaluate components near the film surface in different situations and provides a good map of the samples. This test was only done for nano and nano/essence films to show the composition and the level of Ag-TiO_2 nanocomposites in films (Fig. 2). According to studies EDX images show both qualitatively and quantitatively the components (nanocomposite) of the film and how they are distributed (39).

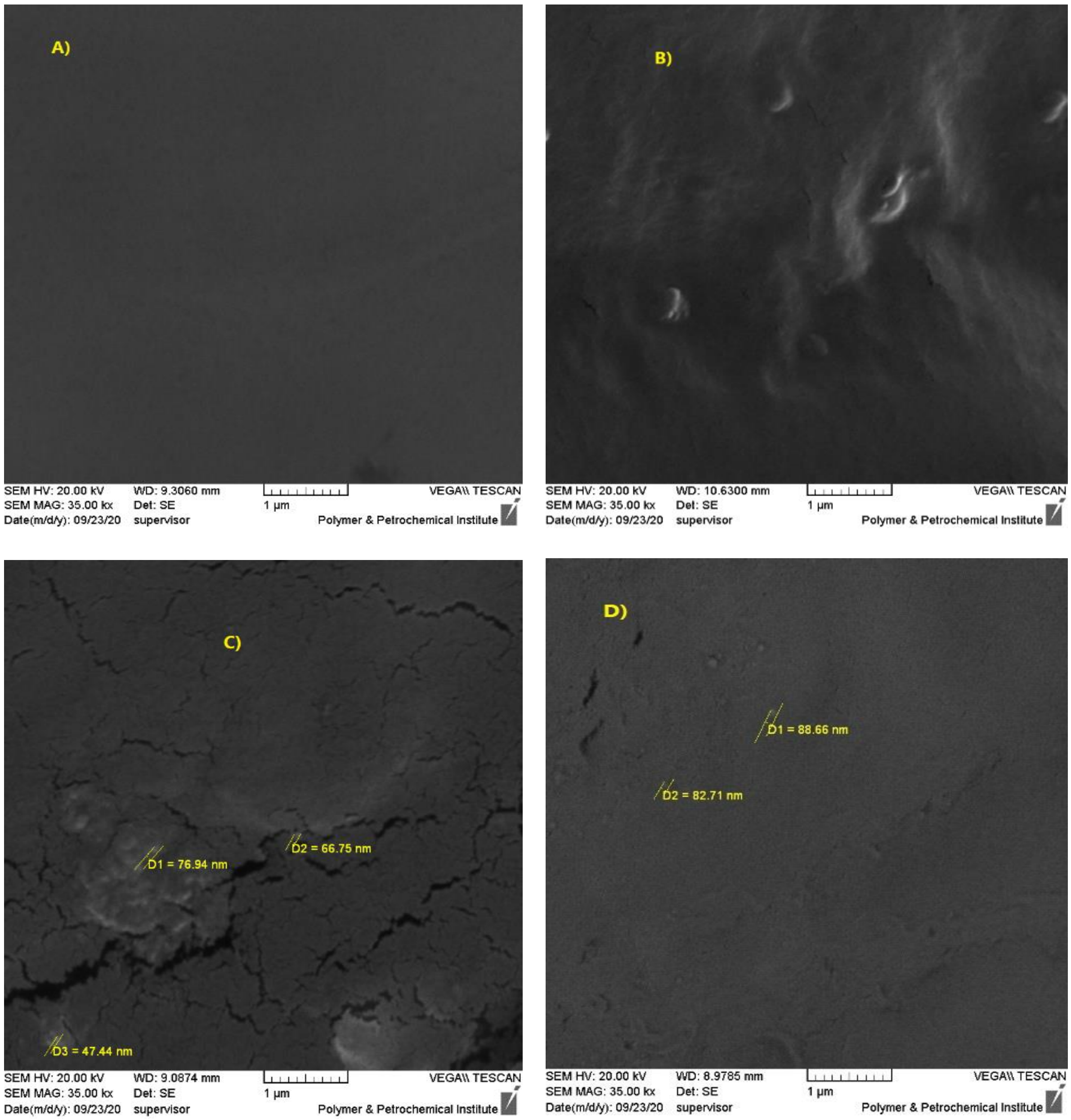

Fig. 1. Scanning electron microscopy (SEM) images of the films incorporated with extracted *Satureja khuzestanica* essential oil and Ag–TiO_2 nanocomposites (A): control (B): essence film (C): nanofilm and (D): nano/essence film.

3.4. The mechanical tests

Based on the results shown in Fig. 3 all mechanical properties were reduced in all treatments compared to plain film. In terms of elongation at the break the highest decrease was related to nanofilm (56.7%) compared to plain film (73%). In strength tensile and elastic modulus properties the highest decrease was related to nano/essence film compared to plain film. In general, the addition of SEO and Ag-TiO_2 nanocomposite can replace some of the stronger polymers with weaker polymers resulting from the interaction of SEO or nanocomposite molecules and change the mechanical properties. Similar results in some studies have shown that the addition of EOs reduces tensile strength and improves elongation at break (22, 27, 33). In addition, Tongnuanchan et al. (37) assessed the impact of adding citrus essential oil on a film made of fish skin gelatin and reported that the addition of the EO reduces the gelatin molecules interaction and leads to reduce hardness and fragility and improves film elasticity. Shojaee-Aliabadi et al. (22) declared that incorporating *Satureja Hortensis* essential oil into the film made from carrageenan reduced tensile strength and improved elongation at break. Hasheminya et al. (11) studied the characterization of biocomposite films of kefiran carboxymethyl cellulose and SEO and reported that increasing the essential oil level increased significantly the strength tensile and reduced elongation at break. These results were in line with those of Ojagh et al. (29), Jahed et al. (34), Hasanin et al. (40), and Ni et al. (41). Mathew et al. (42) evaluated the characterization and antibacterial properties of poly (vinyl alcohol): montmorillonite: boiled rice water (starch) blend film reinforced with Ag nanoparticles and reported that the nanocomposite increased the tensile strength because of intermolecular interactions between starch Montmorillonite (Mt) AgNPs and polyvinyl alcohol. Similarly, the elongation at break was reduced and the incorporation of rigid nanoparticles might have fixed the polymer and caused decreasing its plasticity of it (43, 44). In general, these mechanical properties are related to the microstructure of the film composition the interactions of the film components the nature of the components the preparation conditions, and the component ratios of the film components (39).

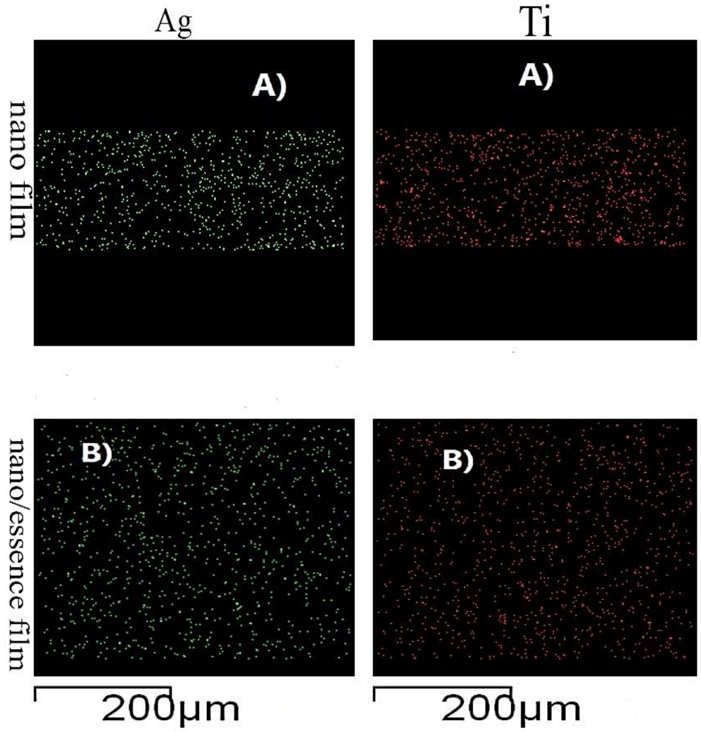

Fig. 2. (A) EDX of nanofilm: maps indicating the Ti (red) and Ag (green) spatial extent. (B) EDX of nano/essence film: maps indicating the Ti (red) and Ag (green) spatial extent.

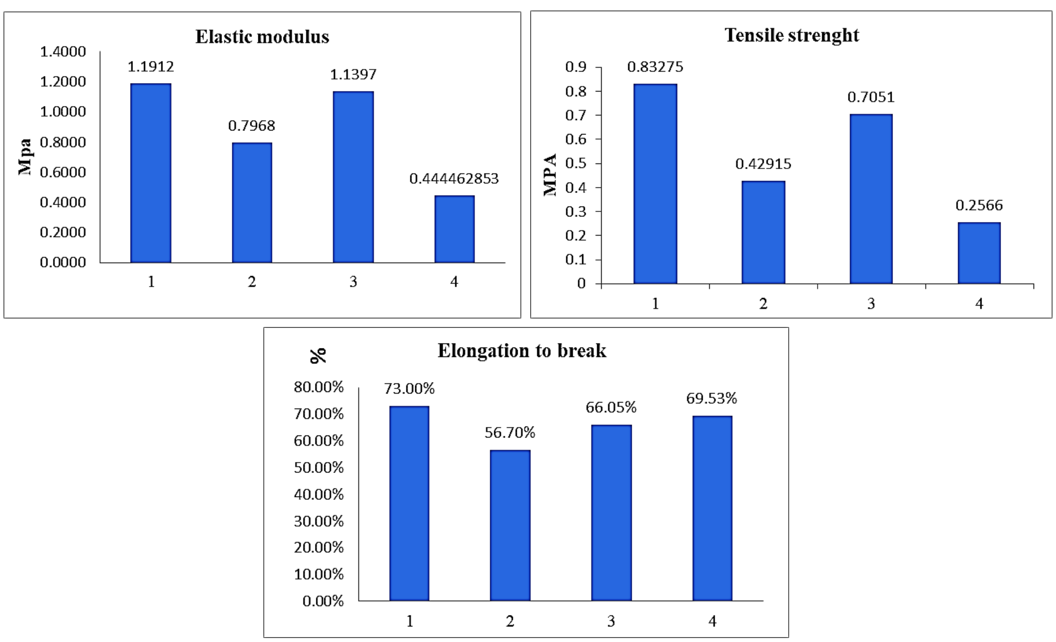

Fig. 3. Mechanical features of films incorporated with Ag–TiO_2 nanocomposite and *Satureja khuzestanica* essential oil 1: control, 2: nanofilm, 3: essence film, 4: nano/essence film.

3.5. Antibacterial effectiveness of the films with chicken fillet

According to the results shown in Fig. 4 in all test microorganisms (*S.* Typhimurium, *E. coli*, *S. aureus*). Psychrophilic bacteria and Total Bacteria Count regardless of storage time a significant difference was observed in reducing the number of microorganisms in nano/essence and essence films compared to the control group and plain film (at a rate of 1.5-2 log CFU/g). The reduction in the number of test microorganisms in the plain film compared to the control group (plastic bags) is due to the hydrophilicity of the starch film which reduced the water activity (aw) in the chicken fillet (45). A comparison between the plain film and the control group on days 1st, 4th, and 7th revealed a significant increase in the number of the studied microorganisms with increasing storage time.

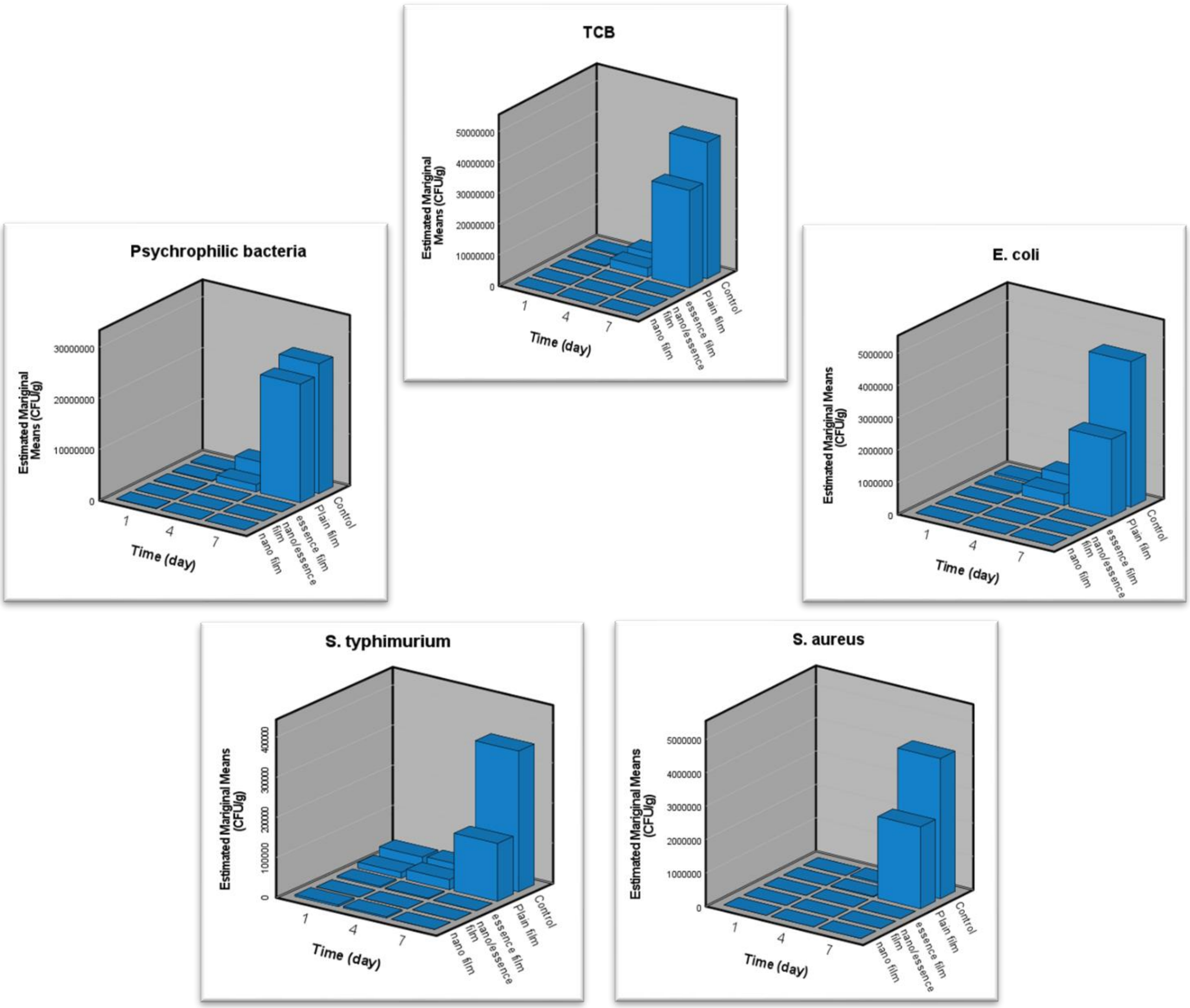

Fig. 4. Graphs of estimated marginal means by time and group for TBC, Psychrophilic bacteria, *E. coli*, *S.* Typhimurium, and *S. aureus*. *Control: Occulted chicken fillets packed in plastic bags.

In other packaging groups (the nano/essence and essence films) although a decrease in the number of microorganisms was observed with increasing the storage time this reduction was not significant. On the other hand, these three packaging groups (nano/essence and essence films) were compared to determine the effectiveness of SEO and Ag-TiO_2 nanocomposite to reduce the number of studied microorganisms with increasing storage time, and results indicated that differences were not meaningful. The maximum mortality reached against *S. aureus S.* Typhimurium and *E. coli* foodborne pathogens were respectively 1.3 1 and 1.5 log reductions after 7-day contact for nano/essence and essence films. Films were more effective against Gram-positive bacteria compared to Gram-negative bacteria consistent with Souza et al. (46). In a study conducted by Souza et al. to evaluate chicken fillets packed with bio nanocomposite with ginger essential oil it was found that the total number of coliforms and mesophile aerophiles decreased by 1.2-2.6 CFU/g in comparison with unpacked chicken fillet group (46). EOs often have antimicrobial effects against Gram (+) and (–) bacteria due to their active ingredients. Although the mechanism of EOs´ function has not been fully elucidated there are different hypotheses about their antimicrobial properties: Phenolic compounds in EOs (especially carvacrol in SEO) can impair cell wall function and lead to leakage of essential compounds inside the bacterial cell. This mechanism depends on the ability of phenolic compounds to penetrate bacterial cell cytoplasmic membrane damage interference with the intracellular energy production system (ATP) and interference with the proton transport system (47). Gram (+) bacteria such as *S. aureus* are more sensitive to EOs than gram (–) bacteria such as *E. coli* due to the presence of an outer layer that surrounds the cell wall and limits the release of hydrophobic compounds into the lipopolysaccharide membrane (22, 47). Carvacrol in *Satureja khuzestanica* EO destroys the outer layer of gram (–) bacteria and kills bacterial cells by changing the permeability of the cytoplasmic membrane to ATP (47). On the other hand, the release of nanoparticles such as Ag^{+} and TiO_2 from packaging films can perforate the cell wall and react with vital intracellular compounds which eventually leads to cell death (12). Three hypotheses have been proposed for the antimicrobial activity of nanocomposites (11):

a) Accumulation of nanoparticles in the cell wall and change its permeability
b) Production of reactive oxygen groups that cause structural damage to bacterial cells.
c) Inactivation of intracellular enzymes for ATP production

The results of our study are consistent with other research conducted in this field (11, 22, 28, 33).

3.6. Sensorial attributes

According to the results shown in Fig. 5, the scores given for sensorial properties (odor color texture and overall acceptance) decreased on days 1^{st}, $4^{th,}$ and 7^{th} for all of the packaging groups. It should also be noted that in the last days especially on the seventh day the control group and the plain film group had lower scores and a significant difference with the samples with nano/essence and essence films which indicates the positive effect of this type of coating on shelf life and the sensory properties of chicken fillet samples which were kept at refrigerated temperatures. On day 1 the higher

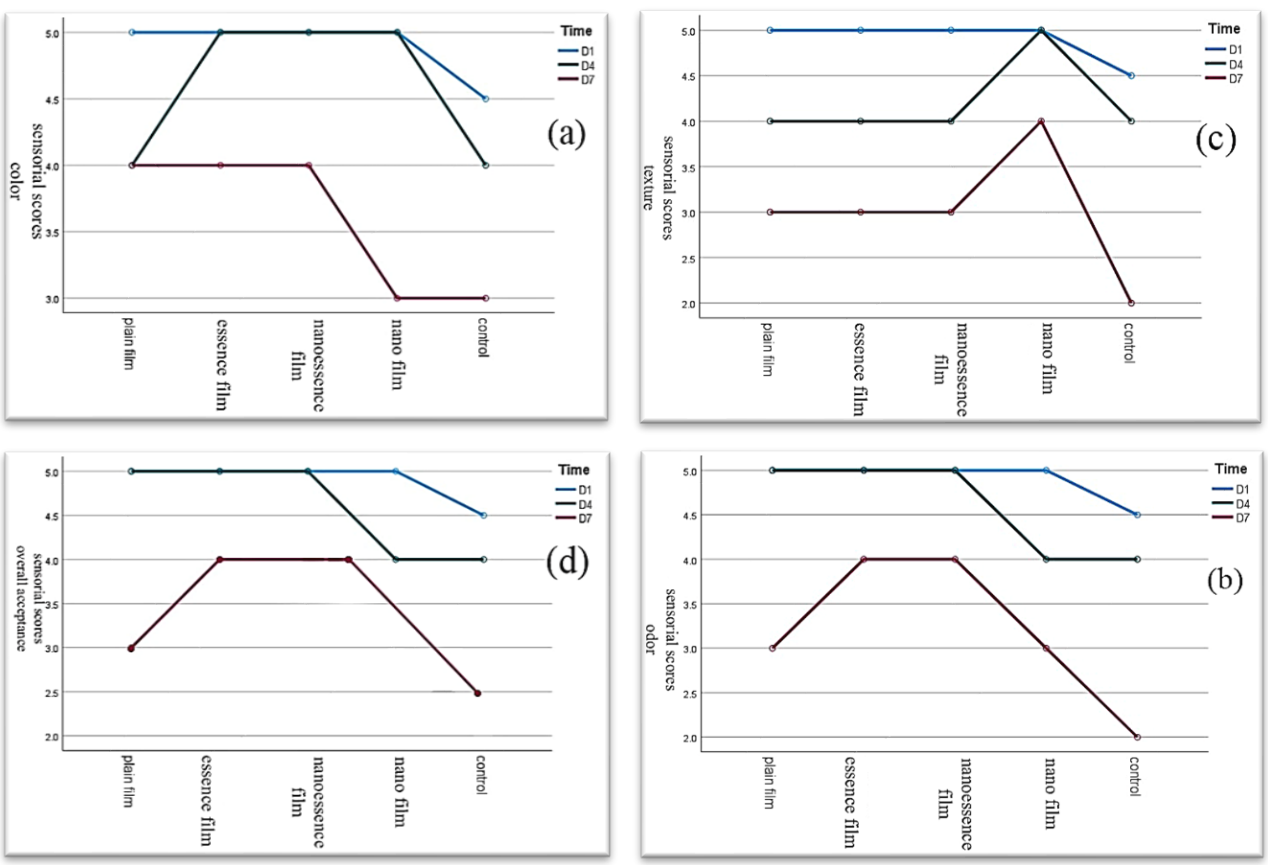

Fig. 5. Graphs of estimated marginal means by time and group for sensorial scores; a) color, b) odor, c) texture, d) overall acceptance. *Control: occulated chicken fillets packed in plastic bags.

score of the control samples and the plain film samples compared to days 4 and 7 was due to the slight effect of the film on the quality of the new samples but over time sensorial properties were better preserved for samples with nano/essence and essence films. The highest scores were recorded for the sensory characteristics of chicken fillets on the first and fourth days after packaging for nano/essence and essence films. Our results were consistent with the results of Mohammadi and Khani (52) study which examined the impact of *Heracleum persicum* essential oil on sensory properties and shelf-life of broiler chicken breast during refrigerated storage. Oxidation of myoglobin in chicken fillet samples leads to a decrease in redness and an increase in meat yellowness which by creating an undesirable color in the fillets will reduce the sensory evaluation score (color factor). On the other hand, by releasing Ag-TiO_2 nanocomposite from nano and nano/essential films which were dark brown the color of chicken fillets became unfavorable in the last days of storage especially on the seventh day thus reducing the color factor score in the chicken fillet. Higher sensory scores of chicken fillets packed with nano/essence and essence films compared to plain film and control group were due to the effect of the mentioned essential oil and nanocomposite on the activity of microorganisms and thus reducing the degradation and denaturation of proteins and texture of chicken, therefore, these results have affected the overall acceptance score of the product (13, 52- 55).

4. Conclusion

We produced novel corn starch films by incorporating SEO and Ag-TiO_2 nanocomposite. loading NPs and SEO greatly influenced the mechanical physical and antibacterial features of corn starch films. Our results indicated that the moisture content of films decreased significantly following the simultaneous loading of SEO and Ag-TiO_2 nanocomposite in the nano/essence film compared with plain film. The plain film showed higher WVP than other films and was significantly reduced by the loading of Ag-TiO_2 nanocomposites. SEM images showed that the nanocomposite and the essential oil emulsion were evenly distributed in the films. The EDX test was only done for nano and nano/essence films to show the amount and composition of Ag-TiO_2 nanocomposites in the films. All mechanical properties were reduced in all treatments compared to plain film. In terms of elongation at the break the highest decrease was related to nanofilm in strength tensile and elastic modulus properties the highest decrease was related to nano/essence film compared to plain film. According to the results regardless of storage time, a significant difference was observed in reducing the number of TBC *E. coli S.* Typhimurium *S. aureus* and Psychrophilic bacteria in nano/essence and essence films compared to the control group and plain film. The scores given for sensorial properties (odor color texture and overall acceptance) of chicken fillets decreased during days 1, 4, and 7 for all packaging groups. Overall, the corn starch film-based Ag-TiO_2 nanocomposite and SEO had the potential for antimicrobial packaging material inhibiting the growth of food-borne pathogens and preserving sensorial properties of food during storage.

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