Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Evaluation of film rheology and coating of nanocomposites (polylactic acid and chitosan) during shelf life in Seven grain Toast

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ABSTRACT

Nowadays, In today's world, the issue of food packaging to improve the quality of food during its shelf life. In this study, the use of a film and a nanocomposite coating based on polylactic acid and chitosan containing zinc oxide nanoparticles was investigated to reduce microbial contamination and increase the shelf life of seven-grain bread. Zinc oxide nanoparticles were added to the polylactic acid and chitosan nanocomposite at three levels: 1%, 3%, and 5%, and the quality properties of the bread, physical and chemical parameters of the film, as well as its electron microscopy (SEM) characteristics were evaluated. The results showed that the films containing polylactic acid and chitosan had an irregular and dense structure, and with the addition of zinc oxide nanoparticles, the structure became more regular and cohesive. Additionally, the water vapor permeability (WVP) of the film and nanocomposite coating increased significantly at the 3% level of zinc oxide nanoparticles, leading to a significant increase in water vapor permeability ($P<0.05$). The results obtained from the texture analyzer showed that with the increase of nanoparticle concentration, the tensile strength of the film and nanocomposite coating were significantly lower than the control treatment ($P<0.05$). The changes in length up to the breaking point did not show a statistically significant difference ($P>0.05$). The effect of the nanocomposite film based on polylactic acid and chitosan containing zinc oxide nanoparticles on the microbial properties of the seven-grain test bread during the shelf-life period had an inhibitory effect on fungal growth, and this inhibition increased significantly with the increase of zinc oxide nanoparticle concentration ($P<0.05$). Finally, it can be concluded that the shelf life of the seven-grain test bread in the nanocomposite packaging based on polylactic acid and chitosan containing zinc oxide nanoparticles will have a considerable increase compared to the control treatment.

ARTICLE INFO

Article History:

Received: 2022/11/27
Accepted: 2023/7/20

Keywords:

Polylactic acid,
zinc oxide,
chitosan,
seven grain toasts,
nanoparticles,
nanocomposites

DOI: 10.22034/FSCT.20.139.61

DOR: 20.1001.1.20088787.1402.20.139.4.8

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1. Introduction

In today's world, wheat is known as a basic and important food item, which is politically as important as oil. Today, about 60% of the world's fields are devoted to grain cultivation, of which 34% is devoted to wheat and rye, 9-11% to barley and oats, and the rest to rice and corn [1]. Bread, as the oldest and most important food in the household food basket, has a special place [2]. With the increase in population and decrease in food resources, keeping this product plays an important role in reducing its food loss [3]. In general, active packaging includes the interaction between food, packaging material and gaseous atmosphere inside the package, which, in addition to having packaging conditions, increases the safety and shelf life of food without changing its quality [4]. They are also able to penetrate the food surface through the release of antimicrobial substances from the polymer matrix and prevent the growth of harmful microorganisms [5]. Today, the use of nanocomposites in the food packaging industry due to their small size (1-100 nanometers) leads to an increase in surface tension and a decrease in the amount of the required film in the packaging, an increase in the barrier properties against penetration.O_2 ،CO_2 AndUV, moisture, volatile compounds, food identification and removal of undesirable flavors are used [6]. Polylactic acid belongs to the family of aliphatic polyesters with high strength and their raw materials are produced from renewable resources such as potatoes and corn; introduced [7]. This biodegradable polymer is easily molded in standard plastic devices [8]. Because PLA is more fragile, it can be improved by using suitable softeners, combining it with other polymers, optimizing crystallization conditions, and using suitable additives [9]. chitosan (CHBy forming a strong bond between carboxyl and amine groups, they are able to provide a suitable combination for food packaging. Therefore, the researchers conducted a study on the bread containing sodium propionate, calcium acetate and potassium sorbate in order to prevent the growth of microorganisms and the positive effects of shelf life. [10]. In another research that contains packagingPLA and polycarbonate was done to show that the barrier characteristics in this mixture compared toPLA It has an increasing trend on food [11]. During a study conducted on montmorillonite nanoparticles in starch packaging, it was shown that the mentioned arrangement in active packaging increases the mechanical and structural properties of the product [12]. In the review, the researchers admitted that copper and silver nanoparticles in the preparation of food packaging film have a greater effect on the shelf life of the product than copper nanoparticles [13].Mihály Cozma et al. stated in a study that adding vitamin C to bread and packaging nanocomposites of silver, zinc oxide and polyethylene increased the shelf life of bread in the packaging of nano particles of zinc oxide [14]. In numerous studies conducted by researchers on cellulose acetate, methyl cellulose, polyethylene, etc., on the shelf life of bread; showed that cellulose acetate methyl cellulose films with cloves and organic essential oils and the combination of silver polyethylene and titanium dioxide increase the storage time of bread compared to conventional packaging [7,15,16]. Because bread products without packaging remain fresh for a few hours after baking, which is due to the reduction in the quality of stale bread and the growth of microorganisms. Therefore, new packaging methods with the aim of increasing the shelf life of bread and reducing the growth of microorganisms can

be of great importance in the bread industry. Therefore, the use of nanoparticles in food packaging improves the shelf life of bread and the quality of bread [17]. In a research, researchers of nano zinc oxide/high density polyethylene composite layers (HDPE) were prepared through the melt mixture and hot compression molding process and investigated the mechanical properties, antibacterial and plasticizing behavior of the composites and reached the results that the absorption in the ultraviolet region of the layersHDPE After adding modified ZnO nanoparticles to the matrixHDPE Increased. It also improves the tensile strength and increases the length of the layersHDPE By combining nanoparticlesZnO modified by 0.5% by weight compared to the original nano composite filmsZnO/HDPE became. The antibacterial results of this study indicated that the filmsHDPE with ZnO nanoparticlesmodified had a favorable effect on the antibacterial properties of Staphylococcus aureus [18]. Researchers in a research on bread packaging containing nanocomposite layers and multi-walled carbon nanotubes (MWCNT) /LDPE They achieved these results by increasing the amount of carbon nanotubes, the change inhibition properties and permeability of oxygen and water in the nanocomposite decreased and delayed the hardening of the bread. On the other hand, the antibacterial properties of multi-walled carbon nanotubes and low oxygen levels reduced the growth rate of mold [19]. During the reports that the researchers on the packaging of chitosan and carboxymethyl cellulose film withZnO they did; They observed that the above compounds prevented microbial growth in the final product. They also showed that the addition of oleic acid to the mixture of chitosan and carboxymethyl cellulose improved the mechanical and microbial properties [3].Pantaniet al. (2013) acknowledged in a research that nanocomposite filmsPLA It has attracted the attention of the food industry with its multi-purpose properties as packaging biomaterials. Today, modern nanocomposite filmsPLA-ZnO by meltingPLA with rod nanoparticlesZnO 5/0-3 production percentage and to obtain better dispersion and limit molecular weight lossPLA, morphological, molecular, thermal-mechanical properties and water vapor transfer to filmsPLA-ZnO according toPLAwas investigated. according toDSC AndXRDIt was observed that the produced films were essentially amorphous and the resulting changes in permeation propertiesPLA It strongly depends on temperature and nanofiller loading. It was also observed that nanoparticlesZnO Well in the polyester matrix, it increases the twisting of the diffusion path of penetrating molecules. Nanocomposites are active against Gram-positive and Gram-negative bacteria, and in this study, its antibacterial activity was shown after 7 days. The researchers also acknowledged that considering the multi-purpose properties of nanocompositesPLA-ZnOFilms produced by extrusion can be introduced to society as a desirable alternative as environmentally friendly packaging materials [20]. In this study, with the aim of investigating films and coatings containing polylactic acid and chitosan containing nanoparticles of zinc oxide based on the percentages of 1, 3 and 5% on seven-grain bread, it can be introduced as a suitable alternative for bread packaging.

2- Materials and methods

In this research, raw materials such as polylactic acid (PLA) from companyNature Workllc chitosan (CH) from companySigma Aldrich, glycerol (emulsion fire) from the companyMerck, Nano

ParticlesZno with a size of less than 25 nm from the companySigma Aldrich And other chemicals were purchased with laboratory purity percentage.

1-2- Preparation of film and coating

In order to prepare a film with a ratio of 1:1 chitosan (CH(and polylactic acid)PLA) was dissolved at the rate of 0.2 grams in 50 ml of acidic water (0.5% acetic acid) and after adjusting the interest at 6.8pH=; powderZno NPs It was dissolved with different amounts of 1, 3 and 5% in 50 ml of water and after being placed in an ultrasonic bath, 0.2 grams of polylactic acid was added and mixed with a stirrer for one hour. Next, emulsion is added to the resulting solution and stirred after 15 minutes in order to increase the flexibility and softening of the film. At the end, 50 ml of each solution was dried in Petri dishes with a diameter of 9 cm at a temperature of 25 degrees Celsius and a relative humidity of 0% for 72 hours. In order to prepare the coating, the preparation was done in the same way as the film preparation method. Then the prepared suspensions were sterilized by autoclave at 121 degrees Celsius for 20 minutes. Then, 50 ml of each suspension was smeared with a sterile brush on the surface of the bread slices and dried for one hour under the air conditioner.

2-2- water vapor permeability (WVP)

Water vapor permeability test through the modified gravimetric cup method of American National Standard noASTM E96-05 It was done in order to determine the degree of permeability in the films. In this test, the cups were filled with water and air was placed about 1.5 cm between the surface of the film and the water. The films cut to the size of the opening of the cup were kept on the cup with the help of play dough, and after measuring the initial weight of the cups, they were placed in a desiccator, and after every 2 hours, the samples were weighed according to the obtained weight chart. came against time [23], in order to determine (WVTR) used. It should be noted that the slope of the linear part of this graph shows the value of the steady state water vapor penetration between the films per unit of time.g/h) (WVTR) is based on grams per square meter per day. Regression, which is calculated through the following formula, in such a way that the range of coefficients is 0.99% or higher.WVP(film by multiplying)WVTR) is calculated in the average thickness of the film and dividing it by the water vapor pressure on the surface of the film, which in this formula P: saturation vapor pressure of water in pascals at 25 degrees Celsius, zeroRH1: ‘RH2: 97; t: is the thickness of the layer [14].

$$WVP=\frac{WVTR \times t}{P(RH2-RH1)} \quad (1):$$

2-3- Permeability to oxygen

In the test to measure the permeability of the films byMoconOxtran 2/21 It was done using penetration softwareWinPermTM Through the standard methodASTM D3985-05 Oxygen permeability was measured. In this section, aluminum coatings at a temperature of 25 degrees Celsius, atmospheric pressure and relative humidity of 50%RH) were placed on a diffusion cell with 21% oxygen gas in the open space of 5 cm2. Test at a temperature of 25 degrees Celsius, atmospheric pressure and relative humidity of 50%.RH) was done with 21% oxygen gas as test gas. It should be noted that the oxygen transferred through the films using a gas carrier (N2/H2) was passed to the calorimetric sensors and the external carrier was measured once every 1 hour in order to reach the steady state of oxygen transfer and its permeability coefficient.cc-μm/(m2 day atm) was calculated

based on the oxygen transfer rate in steady state, taking into account the film thickness [21].

2-4- Electron microscopeWHICH)

In the examination of coated microstructures by scanning electron microscope in order to determine the effect of nanoparticles on microstructures using the methodWHICHAtA Quanta 200, the samples were examined under low vacuum and at a distance of 10-12 mm. Then, in order to check the turbidity of the amount of light passing through the layers (40 x 10) mm from the UV-VIS spectrometer; The turbidity of the layers was checked and its amount was calculated through the following formula [22].

(2): A_{600}/t = cloudy

5-2- Tensile strength test

Tensile strength test is expressed in MPa unit. It measures the force required to tear a part of the sample. The maximum force that causes the object to break, divided by the cross-sectional area of the sample, indicates the tensile strength of the film (film resistance). where F is the force in Newtons and A is the area of the part of the film that is tested (thickness x width in square millimeters).

(3): $$E=\frac{\sigma}{\varepsilon}$$

2-6- Elongation test up to breaking point

Elongation test up to breaking point, the unit of which is percentage, which is the displacement ratio to the initial length of the sample. The maximum length change to the initial length examines the flexibility of the film (how many percent of the length can be stretched but not torn). where L is displacement (mm) and L_0The initial length (mm) of elongation at the breaking point is in the form of a relative percentage, which is a measure of the flexibility of films [21].

(4): $$\varepsilon=\frac{\Delta l}{L0}\times 100$$

2. 7. Young's modulus test

Young's modulus is equal to the slope in the linear region of the stress-strain curve (the ratio of tensile stress to tensile strain) and indicates the degree of hardness of the films, and based on this, the mechanical properties of each fracture are determined [5].

8-2- Moisture content and water activity (aw) of coated bread slices

The moisture content of coated bread slices with different formulas was investigated at 120°C after drying in three replicates [23].

2-9- Determining the degree of stiffness

In the bread hardness test according to the standardAACC 74-09 Coated bread using penetration test and texture tester Instran was done. Then the bread in the same size with dimensions of 5 x 5 cm was placed on the holding plate and the probe was compressed by 4 mm at a speed of 30 mm per minute, which was the maximum compression applied to the texture of the bread (hardness of the bread) in 3 repetitions [24].

2-10- Preparation of mushroom suspensions

Aspergillus niger suspension was purchased from Iran Scientific and Industrial Research Institute and according to the methodBalaguer et al. (2013) prepared and its spores were counted, as well as the concentration of the fungal suspensioncfu/ml 10^6 was set [15].

2-11- Determining the antifungal properties of active films in seven-grain toast

Haft Gholeh toast bread slices were purchased from Se Nan industrial bulk and semi-bulky bread production factory, whose chemical ingredients include (wheat flour, barley flour, rye flour, rolled oats, sunflower seeds, sesame, flax seeds, black seeds, water, canola oil, sugar, wheat gluten, yeast and salt) in this test, bread slices were cultured with Aspergillus niger suspension inside the incubator at three points in the amount of 5 microlitercfu/ml 10^6In the following, the same number of breads without mushroom culture will be stored in a place to be evaluated after a suitable time. Mushroom culture and uncultured samples were packed in polythene bags and kept for 2 months.

2-12- Determining the antifungal properties of active coatings in seven-grain toast

After preparing coated bread slices, the desired treatment was kept in polyethylene bags for 15 days at 25 degrees and to count the number of yeasts and molds using the methodOtani (2014) their number was counted. In this way, 10 grams of bread is added inside the flask containing 90 ml of physiological serum and under sterile conditions withrpm260 It was mixed for 5 minutes. The material was diluted and placed inside a Petri dish containing culture mediumDg18 Cultured data and petri dishes were placed in an incubator at 25 degrees Celsius for 5 days. Then the number of mold and yeast based on a logarithmic scale (log cfu/g) was shown [16].

2-13. Statistical analysis

In this research, the results obtained in the form of a completely random design in 3 repetitions using the softwareSPSS ،ANOVA ; It was done through Tukey's multi-range test at a probability level of 5%. Charts related to data using 2016 softwareExcel were drawn

3. Results and Discussion

1-3- water vapor permeability (WVP)

Generally, water vapor permeability is used with the aim of checking the transfer of moisture inside the film, so the effect of heat exchange between the food and the surrounding air has a positive effect on the shelf life and quality of the food [25]. The results of permeability of polylactic acid-chitosan-zinc oxide nanoparticles films on the surface (1, 3 and 5%) are shown in Table 1. These results showed that with the passage of water vapor through the film, which depends on the dissolution and diffusion of water molecules in the polymer network. The combination of polylactic acid and chitosan with additionZnO NPs ،WVPIn the composite layers, it decreased significantly and with increasing amountZnO NPs This reduction was more significant. Also, the results of the analysis of variance of this study showed that the variables of Moore's study on the treatments have a significant difference at the probability level of 5% ($p>0.05$). During the reports conducted by the researchers, they stated that nanoparticles, due to their fine structure,

can easily be placed in the empty space of the film's porous matrix and fill it, therefore, it causes the loss of moisture, and when nanoparticles are present in the polymer, water molecules are relatively It takes a more complicated path to the pure composition of the polymer [26]. They also admitted that the film containedZnO It is able to hold more water molecules in the packaging system, for this reason, the useful life of food storage is increased, and these results were consistent with the results of this study. In the study, the researchers reached this conclusion by uniformly distributing the nanoparticles in the compounds and creating a link between the nanostructure and the biopolymer, causing a dense network and reducing water vapor permeability [27].

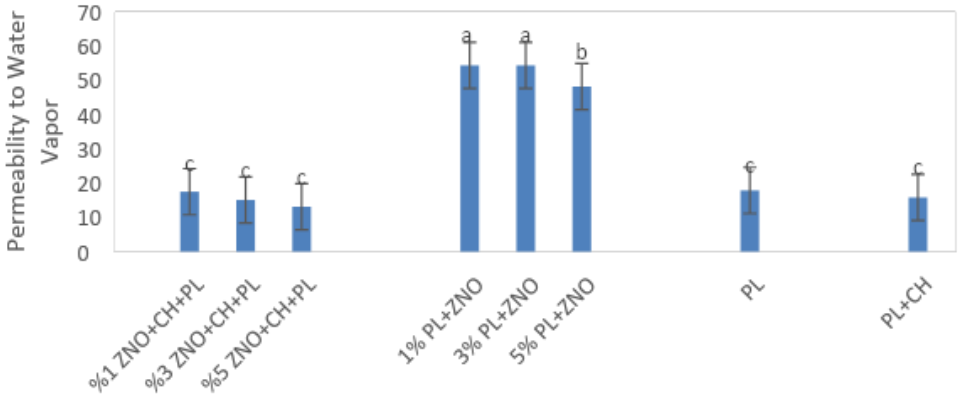

Figure 1. The effect of studied variables at different levels (1, 3, 5%) on water vapor permeability.

2

-3- The blurring of movies

According to table 1, the results of this investigation showed that the film containing polylactic acid and chitosan had the lowest turbidity (3.19), which after addingZnO NPs The turbidity of polylactic acid and chitosan containing filmZnO NPs 5% It reached the highest amount (5.15). Also, the results of analysis of variance of this study stated that the film containing polylactic acid and chitosan has a significant difference on the degree of turbidity of the films (p>0.05).

Table 1 - Turbidity and water vapor permeability in the film.

Type film	Clumsy (mm^{-1} nm 600)
PLA+CH	0.19^{d} ± 1.97
PLA+CH+ZnO NPs 1%	^{c} 0.79± 2.38
PLA+CH+ZnO NPs 3%	^{b} 0.67± 2.60
PLA+CH+ZnO NPs 5%	^{a} 0.68± 3.48
PLA	^{c} 0.69± 2.06
PLA+ZnO NPs 1%	^{c} 0.37± 2.25
PLA+ZnO NPs 3%	^{b} 0.78± 2.51
PLA+ZnO NPs 5%	^{a} 0.80± 3.42

Different letters in each column are due to the existence of significant differences at the 5% level in the films.

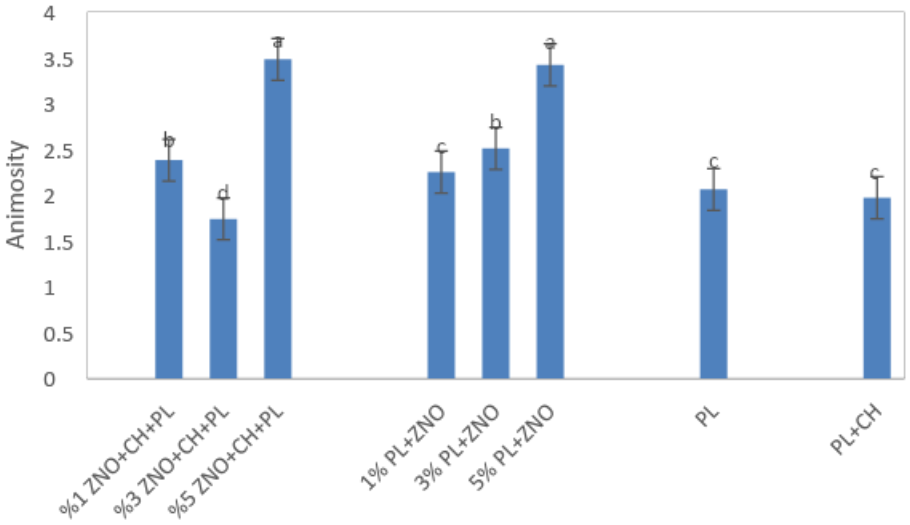

Figure 2. The effect of studied variables at different levels (1, 3, 5%) on turbidity.

3-3- Permeability to oxygen

The results obtained from oxygen permeability, moisture impermeability, oxygen impermeability is one of the important characteristics of food packaging polymers, because the presence of oxygen is a factor that helps the growth of microorganisms in reactions such as oxidation and rancidity. Because the average permeability to oxygen for the filmPLA AndCH containZnO NPs 3%, the lowest amount (1.15) and for polylactic acid (PLA) and chitosan (CH) was the highest value (2.29). AddZnO NPs 3% caused a decrease in permeability to oxygen, which is related to the homogeneous distribution of zinc oxide particles with the lowest concentration according to Table No. 2. In the research, the researchers reported that increasing the amount of clay nanoparticles in the polymer networks, the oxygen permeability of the films decreases significantly [28,29].

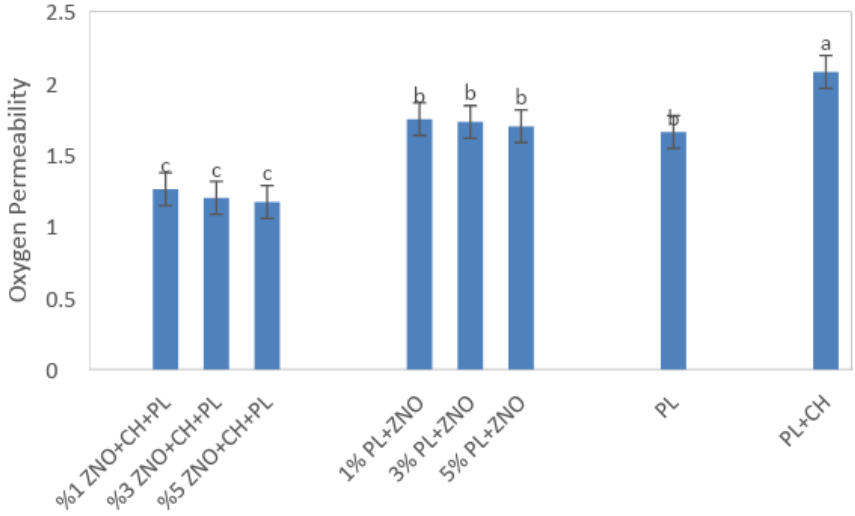

Figure 2. The effect of the studied variables at different levels (1, 3, 5%) on oxygen permeability.

4-3- Microstructure of films

Since the polylactic acid film and chitosan are compatible with each other due to their

structural similarity, they are able to establish a strong ionic bond (the amine group of chitosan with the carboxyl group of polylactic acid). Therefore, afterAddition of ZnO NPsThe structure of the films remains compressed, which in this case addZnO NPs 3% of the film structure was regular. The results of this review with the resultsGasariegoAnd Colleagues (2009) were consistent in this study and showed that with the increase in the amount of nanoparticles (nanoclay), the electron microscope images are compressed and distributed in the polymer matrix, therefore, the increase in the amount of nanoparticles (nanoclay) did not destroy their structure [30].].

Table 2 - Oxygen permeability in films.

Film	Oxygen permeability
PLA+CH	[a]0.12± 2.08
PLA+CH+ZnO NPs 1%	[c]0.09± 1.26
PLA+CH+ZnO NPs 3%	[c] 0.21±1.2
PLA+CH+ZnO NPs 5%	[c] 0.06± 1.17
PLA	[b]0.17± 1.66
PLA+ZnO NPs 1%	[b] 0.02± 1.75
PLA+ZnO NPs 3%	[b]0.21± 1.73
PLA+ZnO NPs 5%	[b] 0.04± 1.7

The different letters in each column are due to the existence of a significant difference at the 5% level in the films.

5-3- Mechanical characteristics

The investigated mechanical properties include the tensile strength test, elongation to breaking point test, Young's modulus test, which depends on the intermolecular forces of the polymer chain, the ratio of film compositions, additives in the films, and environmental conditions. The tensile strength values of films containing zinc oxide are significant (p>0.05). It was more than the polymer film of polylactic acid and chitosan and pure polylactic acid. This reduction is due to the absence of a strong chemical bond between the nanoparticles and the polymer texture or the unfavorable distribution of the nanoparticles inside the polymer matrix. In the comparison of length increase at the breaking point, all groups in (p>0.05). It was checked that these groups were not significant with each other. The results showed that the maximum increase in length to the breaking point was related to the polylactic acid containing filmZnO NPs 1% with a value of 13.4 and the lowest value related to pure polylactic acid film with a value of 9.3 is shown in Table 3. The results of the researchers showed that the concentration of zinc nanooxide on the films increases from zero to 5%, and they also reported that the weight percentage of the combined nanoparticles increases.ZnO-CMC increases, the tensile strength of the treatment also increases. Therefore, it can be said that with the uniform distribution of nanoparticles in the structure of the polymer and the creation of the connecting surface of the molecules, the formation of ionic bonds between the particles of the nanoparticles and the constituent compounds of the polymer increases [10].

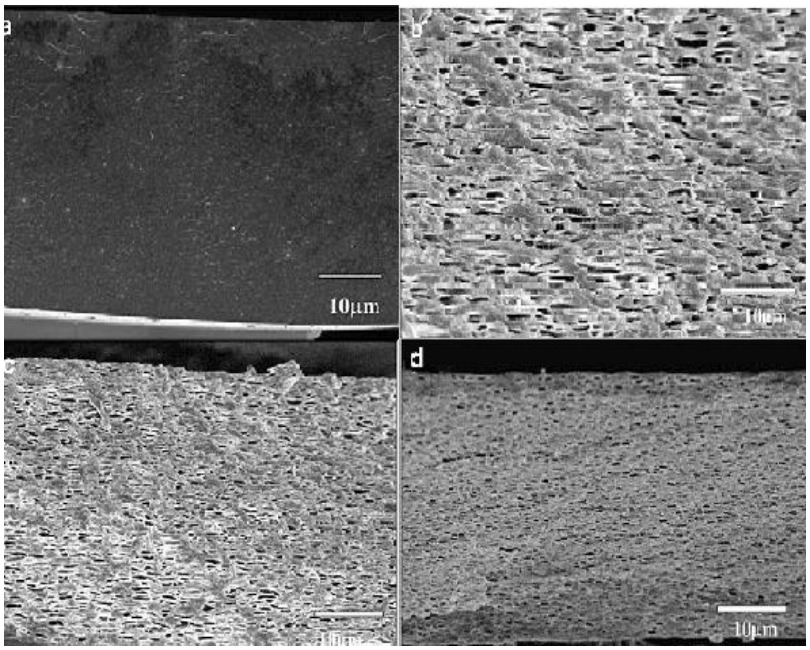

Figure 1. Electron microscope images a) Polylactic acid-chitosan b) Polylactic acid-chitosan-zinc oxide 1% c) Polylactic acid-chitosan-zinc oxide 3% d) Polylactic acid-chitosan-zinc oxide 5%.

Table 3 - Comparison of mechanical properties of films.

Samples (weight percent)	E(MPa)	$_b$(MPa) d	b ^{a}(%)e
PLA+CH	^{a} 210±3100	^{a} 3± 40	^{b} 1.8± 0.77
PLA+CH+ZnO NPs 1%	^{c} 320± 2566	^{a} 5± 355	^{c} 1.4± 0.73
PLA+CH+ZnO NPs 3%	^{b} 98± 2680	^{b} 3± 31.6	^{a} 1.2± 0.84
PLA+CH+ZnO NPs 5%	^{c}0130± 2446	^{b} 3± 33.3	^{b} 1.7± 0.76
PLA	^{c}0180 ± 2501	^{c} 3± 29	^{a} 1.2± 0.83
PLA+ZnO NPs 1%	^{b} 298± 2697	^{a} 5± 37	^{c} 3.1± 0.72
PLA+ZnO NPs 3%	^{b} 140± 2762	^{a} 3± 35	^{b} 1.3± 0.78
PLA+ZnO NPs 5%	^{b}999± 2721	^{b} 3± 34	^{b} 1.4± 0.79

The different letters in each column are due to the existence of a significant difference at the 5% level in the films.

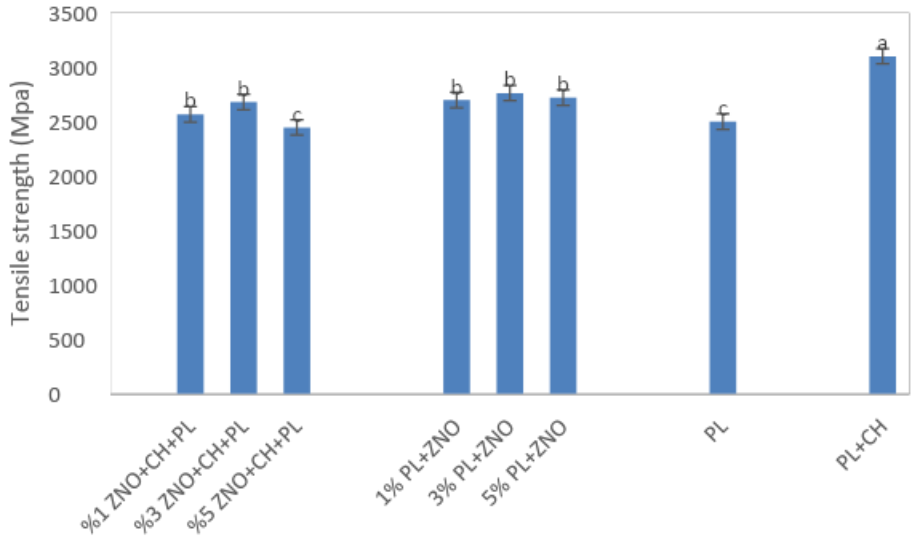

Figure 3- Comparison of the effect of zinc oxide at levels (1, 3 and 5%) on the tensile strength of films.

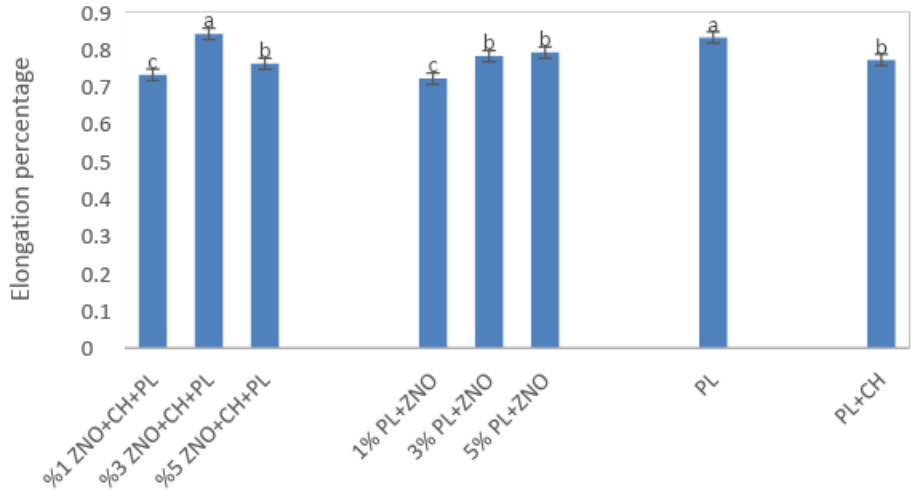

Figure 4- Comparison of the effect of zinc oxide at levels (1, 3 and 5%) on the elongation of films.

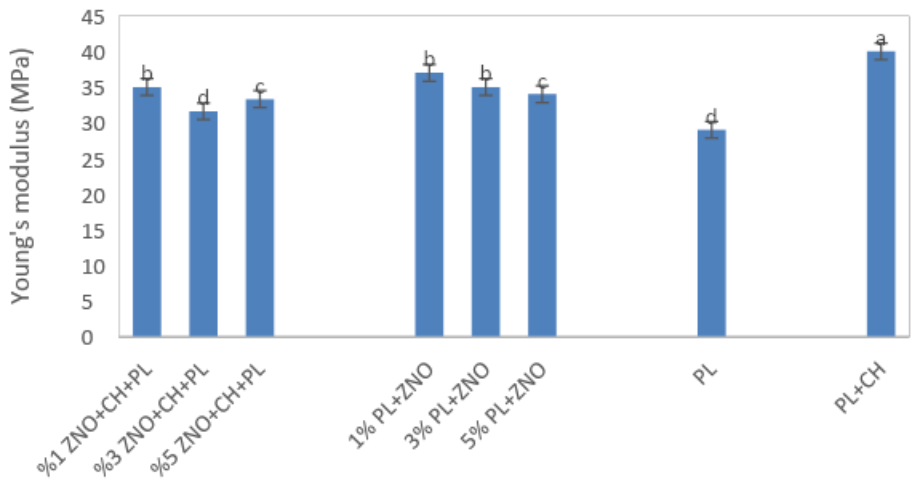

Figure 5- Comparison of the effect of zinc oxide at levels (1, 3 and 5%) on the Young Modulus of films.

6-3- Moisture content andwellSliced samples of seven-grain toast

Moisture content andwellSliced samples of Haft Gholeh toast with active coating during 15 days of storage at 25 degrees Celsius showed that the moisture content of the treatments decreased, and this decrease was more evident in the control sample, which can be the reason for the decrease in moisture content in the sliced samples of Haft toast. He attributed the grain to the retrogradation of amylopectin and the existence of crosslinks between gluten and starch. In this study, it was observed that addnZnO NPs ‹WVPIn all movies, it reduces its amount. Because these films prevent the movement of water vapor from the core of the bread to the crust, it has a positive effect on the storage and shelf life of the product [31]. Some researchers reported that zinc nanooxide on the properties of biocomposite films (fish gelatin films) has a significant decrease in their moisture content and attributed the reason to the hydroxyl groups present in gelatin. By adding zinc nanooxide in the biopolymer matrix, it reduces the hydroxyl groups of water molecules, which were consistent with the results of this study. They also stated that by increasing the amount of nano clay or nanoIt's not$_2$ The moisture content and water solubility of the film matrix decreases, and this phenomenon was attributed to the formation of strong hydrogen bonds between the soybean protein matrix and nanoparticles [32].

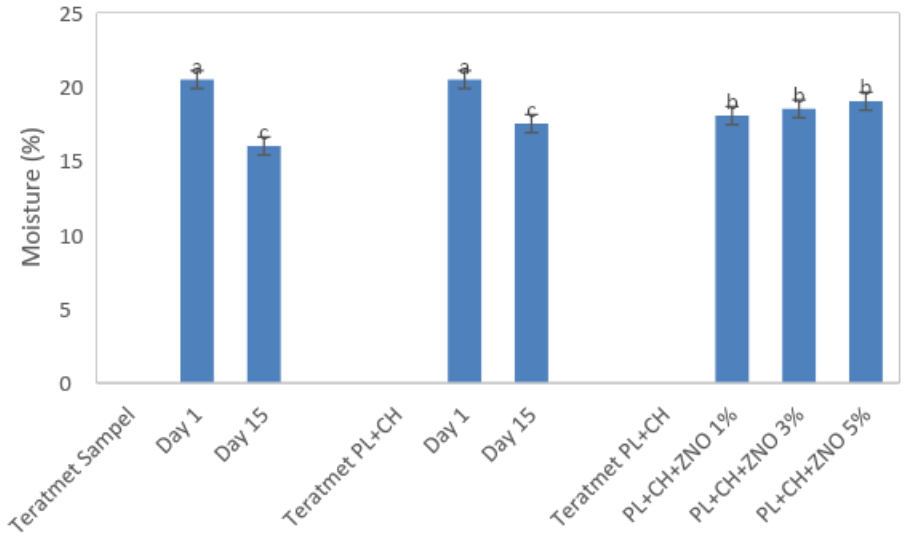

Figure 6- Moisture percentage of seven-grain toast during 15 days of storage at 25 degrees Celsius.

3-7- Bread texture stiffness

Staleness has a direct effect on the preservation of bread. The firmness of the texture was evaluated after storage for 15 days at 25°C and showed that the firmness of coated breadsZnO NPs It was less than other slices of bread tested. The presence of water plays an important role in the hardness of bread. Retrogradation of starch causes the removal of sufficient water and the reduction of the formation of hydrogen bonds between starch molecules and starch and gluten molecules, which results in texture stiffness. In a research, the researchers stated that since the nanoparticles in the pores of the polyethylene films increase the resistance of the films against moisture, therefore, with the increase in the concentration of the clay nanoparticles, the hardness of the bread texture, which is an indication of staleness, decreased. This reduction is related to the ability of polyethylene clay nanocomposites to increase the moisture inside the bread packages [33].

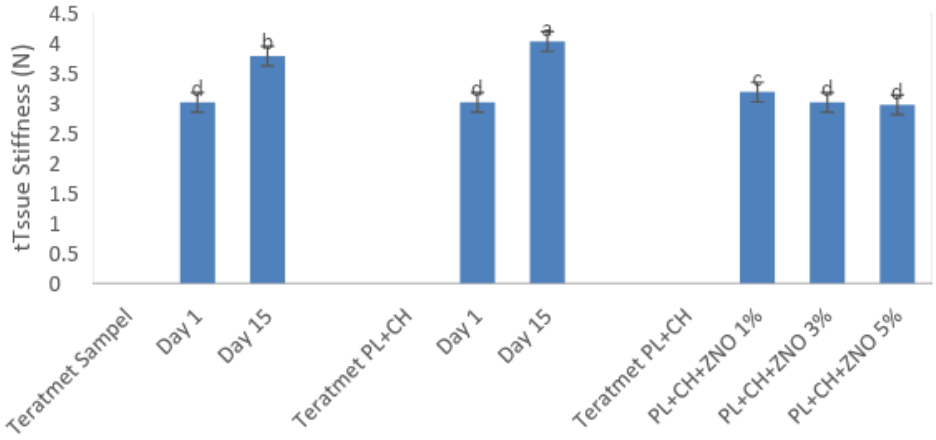

Figure 7 - Hardness of the texture of seven-grain toast during 15 days of storage at 25 degrees Celsius.

8-3- Cultivation with Aspergillus niger fungus

Slices of bread cultured with Aspergillus niger fungus were kept at 25 degrees for 15 days. Fungal growth was observed in the control breads (without coating) after three days, but in coated breads after 15 days, only in the non-coated samples.ZnO NPs Fungal growth was observed in samples withZnO After 20 days, a small amount of fungal growth was seen. A comparison has been made between them as shown in Table 4. The reason for this is the creation of an ionic bond between zinc ion and the surface of the microorganism cell, which reduces the cytoplasmic content and inactivates the respiratory enzymes. Zinc ions penetrate into the polymer and create an antimicrobial coating. During storage, the number of mushrooms increases, but this number in coated bread withZnO NPs It was less than others. Whatever the percentageZnO NPs The higher the number of fungi, the less number was observed. Researchers reported that clay nanoparticles in polymer films reduce the permeability of the package and prevent the release of water vapor, and this phenomenon prevents the growth of molds inside the package [32-34].

Table 4 - Investigation of fungal growth results in different slices of seven-grain toast with different films at 25 ° C.

Package type	Growth delay	Intensity of fungal growth				The number of mold and yeast (log CFu/g)		
		Day 7	Day 15	Day 25	Day 30	Day 7	Day 15	Day 25
Control	It is 0.3± 2	+	++	+++	+++	c03/0 ± 5.1	b 0.03± 6.32	a 0.04± 7.18
pLA-CH	d 1.3± 6	+	++	+++	+++	c08/0 ± 1.7	b 0.03± 3.93	a 0.04± 6.78
pLA-CH-ZnO 1%	c 1.3± 14	-	-	+	++	c0/0 ± N.D	c 0.0± N.D	a 0.04± 2.09
pLA-CH-ZnO 3%	b 2.2± 24	-	-	-	+	a0/0 ± N.D	a 0.0± N.D	a 0.0± N.D
pLA-CH-ZnO 5%	a 3.1± 28	-	-	-	+	a0/0 ± N.D	a 0.0± N.D	a 0.0± N.D
pLA	b 2.2± 6	+	++	+++	+++	c03/0 ± 1.2	b 0.05± 4.1	a 0.04± 6.61
pLA-CH-ZnO 1%	c 2.2± 14	-	-	+	++	c0/0 ± N.D	c 0.0± N.D	a 0.04± 2.89
pLA-ZnO 3%	b 1.3 ± 21	-	-	-	+	a0/0 ± N.D	a 0.0± N.D	a 0.0± N.D
pLA-ZnO 5%	a 1.3± 28	-	-	-	+	a0/0 ± N.D	a 0.0± N.D	a 0.0± N.D

No fungal growth, + fungal growth less than 25% of the surface, ++ fungal growth between 25 and 50% of the plate surface, +++ fungal growth more than 50%.

4 - Conclusion

Important factors that cause the loss of nutritional value of bread are microbial spoilage and chemical and physical changes. There are many ways to increase the shelf life of bread, such as modified atmosphere packaging (MAP), antimicrobial additives, radiation.UV, gamma radiation, freezing, adding sugar or pentosan and... recently nanoparticles in order to increase mechanical action in food packaging such as flexibility, moisture stability, temperature stability, reduction in gas penetration, resistance toUV And antimicrobial properties are used. Physicochemical, mechanical and antifungal properties of films containingPLA AndCH Contains nanoparticlesZnO NPs It

was investigated with percentages of 1, 3 and 5%. The obtained mechanical properties showed that when the percentage of zinc oxide in the respective films increased from 1 to 5%, the tensile strength and elongation changes of these films decreased (P<0.05). But it increased Young's modulus. In the study of permeability to water vaporWVPContains videosPLA AndCH Containing 1 and 3% of zinc oxide nanoparticles show more permeability (around 20%) than films without zinc oxide (P<0.05), and no change was observed for higher percentages of zinc oxide. The effect of reducing oxygen permeability in films withZnO NPs 3% was an impressive increase

ZnO NPs Had no effect. Examining the effect of films containingZnO NPs On fungal growth, it showed that in all three cases, the inhibitory effect was observed and the percentage increaseZnO NPs increasing its inhibitory effect on fungal growth significantly (P<0.05). follows The hardness of the breads of the control group is higher than the breads with coating and filmsCH AndPLA containZnO NPs Was. Also, maintaining moisture in coated breads and nanoparticle filmsZnO was more Microbial tests show reduced microbial growth from films and coatings containingZnO NPs It has been the best case inZnO NPs 5% is shown. As the amount increasesZnO NPs FilmsPLA-CH-ZnO NPs It has higher mechanical, physical and microbial properties and the shelf life of packaged bread increases.

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مقاله علمی_پژوهشی

ارزیابی ویژگی‌های رئولوژی پوشش نانوکامپوزیت (پلی لاکتیک اسید و کیتوزان) طی زمان ماندگاری در نان تست هفت غله

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۱/۶/۹

تاریخ پذیرش: ۱۴۰۲/۴/۲۹

کلمات کلیدی:

پلی لاکتیک اسید،

اکسید روی ،

کیتوزان،

نان هفت غله،

نانوذرات،

نانوکامپوزیت.

DOI: 10.22034/FSCT.20.139.61

DOR:20.1001.1.20088787.1402.20.139.4.8

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چکیده

امروزه مبحث بسته بندی مواد غذایی به منظور ارتقا کیفیت مواد غذایی طی زمان نگهداری از اهمیت ویژه‌ای برخوردار است. در این پژوهش، استفاده از فیلم و روکش نانوکامپوزیت بر پایه پلی لاکتیک اسید و کیتوزان حاوی نانو ذرات اکسید روی، به منظور کاهش آلودگی میکروبی و افزایش ماندگاری نان هفت غله مورد بررسی قرار گرفت. نانوذرات اکسید روی در سه سطح ۱، ۳ و ۵ درصد به نانوکامپوزیت پلی لاکتیک اسید و کیتوزان افزوده شد و خواص کیفی نان، پارامترهای فیزیکی و شیمیایی فیلم، همچنین ویژگی‌های میکروسکوپ الکترونیکی (SEM) آن مورد ارزیابی قرار گرفت و نتایج نشان داد، فیلم های حاوی پلی لاکتیک اسید و کیتوزان، دارای ساختار نامنظم و فشرده هستند و با افزودن نانوذرات اکسید روی، ساختار منظم و منسجم‌تر گردید بعلاوه نفوذپذیری بخار آب (WVP) فیلم و روکش نانوکامپوزیت در فیلم های دارای نانو ذرات اکسید روی در سطح ۳ درصد، سبب افزایش نفوذ پذیری به بخار آب در سطح معنی دار شد ($P<0.05$). نتایج حاصل از دستگاه بافت سنجی نشان داد، با افزایش غلظت نانو ذرات، استحکام کششی فیلم و روکش نانوکامپوزیت به طور معنی داری کمتر از تیمار شاهد بود ($P<0.05$). تغییرات طول تا نقطه شکست، از نقطه نظر آماری اختلاف معنی‌داری را نشان نداد ($P>0.05$). تاثیر فیلم نانوکامپوزیت بر پایه پلی لاکتیک اسید و کیتوزان حاوی نانوذرات اکسید روی برخصوصیات میکروبی نان تست در طی زمان ماندگاری، دارای اثر مهارکنندگی بر رشد قارچ بود بعلاوه این مهارکنندگی با افزایش غلظت نانو ذرات اکسید روی، به طور معنی داری افزایش می یابد ($P<0.05$). در نهایت می‌توان نتیجه گرفت، مدت زمان ماندگاری نان تست هفت غله برش داده شده در بسته‌بندی نانوکامپوزیت بر پایه پلی لاکتیک اسید و کیتوزان، حاوی نانوذرات اکسید روی، در مقایسه با تیمار شاهد افزایش قابل توجهی خواهد داشت.