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Investigating the effect of edible coating of chitosan and gum Arabic containing natamycin on the microbial, chemical and sensory properties of raw pistachios

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ABSTRACT

This study was done to investigate the effect of edible coating of chitosan and gum Arabic containing natamycin on the microbial, chemical and sensory properties of raw pistachios during 28 days of storage in the refrigerator (4±1 C° and 90-95% relative humidity). Samples were designed in five groups include control (C), coated with chitosan (Ch), coated with gum Arabic (Ga), coated with chitosan and natamycin (Ch+Na), coated with gum Arabic and natamycin (Ga+ Na) and coated with chitosan, gum Arabic and natamycin (Ch+Ga+Na). Then preparation and characterization tests (Fourier transform infrared spectrum, X-ray diffraction, thermal gravimetric analysis and scanning electron microscopy), microbial (total count, Aspergillus growth and mold and yeast count), chemical (weight loss and moisture) and sensory tests were done. The results of microbial tests showed that the samples coated with chitosan/gum Arabic/natamycin were significantly more effective in inhibiting the growth of microorganisms compared to other treatments, as total count, mold and yeast and Aspergillus growth were reached from 3.47 log cfu/g to 4.61 log cfu/g, 2.22 log cfu/g to 1.04 log cfu/g, and from 20% to 12% respectively at the beginning and at end of the study period. Also, coating with chitosan/gum Arabic/natamycin had a positive effect on the chemical properties, especially preventing weight loss, as it increased from 12.5% on day 0 to 77.3% on the final day, while in control group it increased from 4.08 to 7.03. Coating with chitosan/gum Arabic/natamycin not only did not adversely affect the appearance of pistachios, but also improved the sensory characteristics in all parameters except taste. In general, the results showed that the coating of chitosan and gum Arabic, especially when it contains natamycin, can be considered as an effective food coating in maintaining and improving the quality of food, especially nuts.

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1-Introduction

Pistachios due to their content of nutrients such as beneficial fatty acids, high levels of potassium, c- Tocopherol and its unique taste are famous worldwide and are always a popular product (1). However, the tender nature of fresh pistachios makes them perishable and this affects the shelf life of this product after harvest. Mold growth, aflatoxin contamination, discoloration, tissue destruction and reaction Oxidative effects are among the challenges of pistachio storage (2). To overcome these issues and increase the shelf life of pistachios, researchers have investigated various storage techniques, including the use of edible coatings (3).

Food coatings, which are generally protein or polysaccharide in nature, are thin layers of materials that act as a barrier and prevent the transfer of moisture, oxygen, and soluble substances in food. They play an important role in maintaining the quality and increasing the shelf life of various food products. When combined with ingredients with antioxidant and antimicrobial properties, edible coatings offer additional benefits (3).

Chitosan is a polysaccharide that has been noted for its unique properties and nutritional effects and has been approved as a food additive by the US Food and Drug Administration. Chitosan is widely used in edible coatings due to its antioxidant, antimicrobial and non-toxic properties and favorable characteristics in film formation (6, 5, 4).

Arabic gum is a biopolymer composed of galactose, rhamnose, arabinose and glucuronic acid, which is widely used in the food industry and other sectors due to its emulsifying, strengthening and adhesive properties (6). One of the main uses of gum arabic is in making edible coating. When gum arabic is mixed with liquids, it creates a thin protective film on the surface of the food. This coating provides protection against oxidation, mold and drying of foods and increases their shelf life (9, 8, 7).

Natamycin, sometimes also known as pimaricin, is a polyene macrolide antibiotic that is naturally produced by some bacteria and is specifically used to inhibit molds and yeasts (9,10). Coatings containing natamycin are commonly applied to the surface of cheeses, breads, and some meat products, which extend the product's shelf life by creating a protective antifungal barrier. Also, since natamycin has only superficial effects and is broken down in the human digestive system, it is considered as a safe additive in this sense (11).

According to the mentioned materials, the present study was conducted with the aim of investigating the effect of edible coating of chitosan and gum arabic containing natamycin on the microbial, chemical and sensory characteristics of raw pistachios.

2- Materials and work methods

2-1-preparation of edible coating

To prepare chitosan solution, chitosan powder (0.5%), acetic acid (0.5 ml) and distilled water (100 ml) were mixed using a magnetic stirrer and heated to 60 degrees Celsius. Gum arabic solution (2.5%) containing glycerol was prepared by mixing acacia powder with water and was stirred using a magnetic stirrer at room temperature (20±2°C) for 1 hour. Finally, after cooling the mixture to 30 degrees Celsius, natamycin (0.15%) was added to the mixture of chitosan and gum arabic with the help of a magnetic stirrer (12).

Fresh and healthy pistachios without any mechanical damage were washed with tap water and then excess moisture was removed from its surface. Fresh pistachios were immersed in the prepared coating solutions at 20°C for 5 minutes, and finally the pistachio surface was allowed to dry. The pistachios were packed in a zip cap and placed in the refrigerator (4°C ± 1 and relative humidity 90-95%) and the tests

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were performed on days 28, 21, 14, 7, and 0 of storage (13).

2-2- Characterization tests

2-2-1-Fourier transform infrared spectrum measurement (FTIR) [1]

profiles FTIR The resulting nanoparticles using a spectrometer Bruker, VERTEX 70, Germany)) in range cm^{-1} 4000-400 was determined (14).

2-2-2- X-ray diffraction measurement[2] (XRD)

Using an X-ray diffraction spectrometer Panalytical, Xpert Pro MPD, Nederland)) Crystal structure of samples was determined (14).

2-2-3- thermal gravimetric analysis[3](TGA)

With thermo analyzer and thermogravimetric system under conditions N2 Thermo Scientific, Niton xl2, USA)) Thermal degradation processes of nanoparticles It was measured up to 400 degrees Celsius (14).

2-2-4-scanning electron microscope analysis

Morphology of synthesized nanoparticles using field emission scanning electron microscope(FE-SEM) Made in Japan (Hitachi, S-4160, Japan) was determined)14،١٥(.

2-3-Microbial tests

2-3-1-General count of microorganisms

10 grams of each sample was prepared with 90 ml of homogenous peptone water and successive dilutions. To count the microbial load, 0.1 ml of each dilution was poured into nutrient agar medium and the surface culture method was used. Petri dishes were incubated at 37°C for 48 hours)13(.

2-3-2- counting mold and yeast

Transfer 1 gram of each sample to a mixer that contains 9 ml of peptone water to prepare serial dilutions in dextrose agar culture medium. and after inoculation, the petri dishes were incubated for one week at 30°C.)16(.

2-3-3-Assessment of Aspergillus growth

10 pistachios from each treatment were placed in pre-sterilized petri dishes containing moist filter paper and kept in a greenhouse at 30 degrees Celsius for 5-7 days and finally after incubation, the number of infected pistachios in each plate was counted and the growth rate of Aspergillus was reported as a percentage.)16(.

2-4-Chemical tests

2-4-1-Determining the amount of weight loss

The samples were weighed during the storage period and the weight loss was calculated from the following equation)17(:

100x initial weight / secondary weight - initial weight = percentage of weight loss

2-4-2- Determination of humidity

To determine the moisture content of pistachios, about 3 to 5 grams of the sample was ground and dried in an oven at a temperature of 103 ± 2 degrees Celsius for 3 hours until the difference between the two weights becomes insignificant. Now the amount of evaporated moisture was calculated and the amount of moisture was expressed as a percentage)18(.

5-2-sensory characteristics

The samples were evaluated by 12 trained panelists. The participants were asked about the different qualitative characteristics (color, texture, taste, aroma, and overall acceptance) of fresh pistachios, using a scale of 1 to 9 as follows: color from very dark brown (1) to very yellow-red with minimal brown spots (9), texture from very soft (1) to very hard (9), pistachio aroma from strong odorlessness (1) to very fresh aroma (9), and pistachio taste from very bad

1- Fourier Transform Infrared Spectroscopy

2- X-Ray Diffraction

3- Thermal Gravimetric Analysis

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taste (1) to very fresh taste (9). Overall acceptance was also evaluated using a hedonic scale from very unfavorable (1) to very favorable (9).)19(.

6-2-Statistical analysis

To compare the trend of microbial and chemical changes during the study period in each group, linear procedure model test for repeated data and Bonferroni's post hoc test were used. To compare between groups at any time, parametric one-way analysis of variance and Tukey's post hoc test were used. The non-parametric Friedman test was used to compare the changes in sensory variables during the study period in each group. Kruskal-Wallis non-parametric test was used to compare between groups at any time. The results were expressed based on the mean and standard deviation. Data analysis using software SPSS Version 25 was done. A significance level of less than 5% was considered.

3-Results

1-3-Results of characterization tests

3-1-1-Fourier transform infrared spectrum measurement

Figure 1a) image FTIR analysis of coating Chitosan/gum arabic/natamycin shows Peaks observed at cm wavelengths^{-1} 785, 1410 and 1641 correspond to the synthesized three-component sample, respectively, related to the vibrations of (C-O), (C-N) and (N-H) chitosan structure. Also, the peak located in cm^{-1}2892 related to stretching vibrations (C-H) of chitosan structure has been prepared. In addition, the peak is wide and wide in cm^{-1}3440 corresponds to the (OH) and (NH) stretching vibrations. Peaks in cm^{-1}605 and cm^{-1}900 to cm^{-1}1200 are related to the structure of gum arabic. In the three-component structure, bonds at cm points^{-1} 1079 to cm^{-1} 1152 is known to be related to the structure of natamycin ether. Plus the peak in the wave length cm^{-1} 2940 related to transplant C-H The structure of natamycin is

3-1-2- Thermal gravimetric analysis

The results of this analysis in Figure 1b) presentation has been The initial weight loss (approximately 11.07%), observed in the temperature range below 105°C, can be attributed to the removal of water absorbed by the structure and the removal of impurities. The secondary weight loss that occurred at temperatures higher than 105 degrees is the result of the breakdown of the gum arabic structure, as well as the breakdown of chitosan and natamycin, which accounts for approximately 65.12% of the weight of the structure.

3-1-3- X-ray diffraction measurement

pattern XRD Three-component coating, consisting of chitosan, gum arabic and synthesized natamycin, in Figure 1c) badge given In the picture XRD, chitosan crystal planes (020) and (110) are found, which correspond to peaks at angles of 11.41◦ and 20.74◦. On the other hand, the peak identified at 18.6 ◦ angle indicates the presence of gum arabic in this three-component arrangement. By further examining the X-ray diffraction pattern test, different peaks at angles of 16.9, 18.86, 19.8, 20.26, 20.9, 21.56, 23.29 and 24.57 have been shown, which are clearly related to natamycin. The presence of peaks of all three compounds indicates the tricomponent combination of chitosan/gum arabic/natamycin.

3-1-4 Scanning electron microscope analysis

Image of chitosan structure obtained from FE-SEM particle for direct object can be in Figure 2 (a) observed Obviously, chitosan showed spherical particles with stable morphology. In addition, the particles have shown an almost lumpy structure due to their high tendency to aggregate. Figure 2(b) The picture of MThe link to the scanning electron microscope shows the structure of the edible coating composed of chitosan/gum arabic/natamycin. As can be seen, chitosan particles are scattered throughout the gum arabic structure. This experimental analysis confirms the presence of both chitosan and gum arabic in the overall structure of the composite. On the other hand, no crystals of natamycin can

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be seen on the surface of the structure, which indicates that natamycin is placed in a three-component structure.

2-3- Microbial test results

3-2-1-General count of microorganisms

in Table 1 changes Total bacterial counts in different treatments are presented. The general trend of the number of bacteria in the samples was increasing during the study. A significant difference was observed between the control group and all the treatment groups on all days of the study, except day zero (0.05).>*P*), so chitosan and pure Arabic gum also showed an antimicrobial effect, and with the addition of natamycin, this effect was stronger (especially on days 21 and 28 of storage). Initial amount of total bacteria count on day zero of control treatment log cfu/g It was 3/11 that on the 28th day of keeping this amount log cfu/g It reached 6.81 and showed the highest amount. The lowest amount of total bacteria on the last day of storage related to the treatment Chitosan/gum arabic/natamycin (log cfu/g 61/4) was.

3-2-2- counting mold and yeast

In Table 1, the results Changes of mold and yeast counts in different raw pistachio treatments are presented. No significant difference was observed between the treatments on the zero day of maintenance (0.05<*P*). On the seventh day of storage, the lowest number was related to pistachios treated with chitosan/gum arabic/natamycin (log cfu/g 2.01) which had a significant difference compared to all treatments (0.05>*P*). The number of mold and yeast showed a significant difference between the chitosan/gum arabic/natamycin group and the other groups in all days of storage except day zero. Also, a significant difference was observed between chitosan group and chitosan containing natamycin and also between gum arabic group and gum arabic containing natamycin on all days of the study except day zero.

3-2-3- Aspergillus growth

according to Diagram 1 The growth trend of Aspergillus on the zero day of keeping the control group was 20% and on the last day this value reached 100%. On the final day of the control treatment, the highest percentage (100) and cover treatment Chitosan/gum arabic/natamycin The lowest percentage (12) had Aspergillus growth. During storage, the percentage of mold development in the samples of chitosan/natamycin and gum arabic/natamycin was between 25 and 37%, which was lower than the control group, and in all three groups containing natamycin, a decrease in the growth percentage of Aspergillus was observed from the 14th day onwards, while in the groups without natamycin, this trend was always increasing.

3-3- Results of chemical tests

3-3-1-The amount of weight loss

Changes in Table 2 Weight loss in different treatments of raw pistachio samples is presented. The amount of weight loss of raw pistachio samples, except for chitosan/gum arabic/natamycin samples, increased in other treatments during storage (0.05>*P*). In all the days of maintenance except day zero, a significant difference in terms of weight loss between the control group and other treatments was observed, and this difference is more prominent in the last days of maintenance. On the last day of storage, the highest rate of weight loss was observed in the control sample (7.03%) and the lowest rate of weight loss was observed in the samples coated with chitosan/gum arabic/natamycin (3.77%) and gum arabic/natamycin (4.21%).

3-3-2-The amount of humidity

in Table 2 changes The amount of moisture in different treatments of raw pistachio samples is presented. In examining the changes, it can be seen that there was no significant difference between the different treatments on day zero (0.05).<*P*) and with the passage of time, an increasing trend was observed in the treatments. On the seventh day of storage, the lowest amount of moisture was observed in the treatment coated with chitosan/gum arabic/natamycin

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(5.41%), which had a significant difference compared to other treatments, and this significant difference was maintained until the end of the study (0.05).>*P*). It should be noted that significant differences were observed between the control group and other treatments on all days of storage except day zero.

3-4-sensory characteristics

The results related to the investigation of sensory characteristics Taste, aroma, color, texture and acceptance overall In chart 2, it is possible observation Investigating the interaction effect of storage time and type of coating on the sensory changes in raw pistachios treated during storage showed that in the assessment of color, texture and overall acceptance on the last day, the highest score was for the samples coated with chitosan/gum arabic/natamycin, while this treatment received the lowest score in the evaluation of taste compared to other coated samples (0.05).>*P*). It was also found that the control samples had the highest taste score at the beginning of the storage period, but with the passage of time on the 14th, 21st and 28th days of storage, the taste score of this group decreased and had a significant difference with other treatments (0.05).>*P*). It also showed the results of the perfume review The score related to this sensory attribute was decreasing in all treatments, and the control treatment had the highest score at the beginning of the study and the lowest score at the end of the study. On the last day, with a significant difference, the highest score was for the samples covered with chitosan containing natamycin (0.05).>*P*) and after that, the highest score was for samples coated with chitosan and samples coated with chitosan/gum arabic/natamycin, which received the same score (0.05<*P*).

4-Discussion

4-1- Characterization tests

test FTIR In order to investigate the synthesis of the composite and analyze the chemical compounds of the bonds created in the chitosan/gum arabic/natamycin edible coating, it was done. Hamodin et al. (2023) in the chitosan structure, peaks at wavelengths of cm^{-1} 898، cm^{-1} 1373، cm^{-1} 1423، cm^{-1} 1589 and cm^{-1} 1645 observed that respectively related links (C-O) ، (CH_2) ، (CH_3), (N-H), (N-RED_3) were In addition, in the mentioned research, the peaks in cm^{-1} 2921 and cm^{-1} 3451 respectively related to the group CH and OH have been (20).It is placed et al. (2017) composition of gum arabic in the cm wavelength range^{-1}800 to cm^{-1}1200 with links C-O، C-C، C-O-C، C-O-H and C-H identified that corresponds to the wavelength related to the structure of gum arabic reported in this study. In addition, it was found that the peaks in the range of cm^{-1}1436 to cm^{-1} 1627 with bond tensile vibration COO Carboxyl groups are related (21). Spectrum FTIR Related to natamycin, links at cm points^{-1} 1006 and cm^{-1} 1267 showed that it was related to the ether structure in natamycin. Also peaks in cm^{-1} 1572 and cm^{-1} 17160 have been exhibited, which are attributed to the amino groups and stereonatamycin, respectively (22). As a result, it can be clearly seen the presence of common organic peaks in all three structures, leading to the overlapping of specific peaks and their removal, as well as increasing or decreasing the intensity of the peaks in the graph. FTIR The sample is composite.

Thermal integrity of chitosan/gum arabic/natamycin structure through test implementation TGA was investigated. In general, the exam TGA, examines the weight changes of a structure while the sample is subjected to controlled temperatureslow down Mousapour et al. (2023), showed that by increasing the temperature to 150 °C, 7% of the chitosan structure was destroyed as a result of the removal of physical water. In addition, a significant amount of the structure (63%) was destroyed during a secondary removal up to 600 degrees, which can be related to the destruction of the chitosan structure

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(23).Daoub et al. (2018) A comprehensive review on the composition of gum arabic by analytical analysis TGA they did Their research showed a two-stage path during the thermal degradation process, the first stage was due to the loss of physical water and the second stage was due to the destruction of the polysaccharide structure (24).

X-ray diffraction test (XRD) plays a significant role in observing the structural properties of materials as well as the crystalline properties of compounds. That et al. (2023) in a study, using the X-ray diffraction pattern results, proved the presence of two peaks at ◦10 and ◦20 angles for chitosan structure (25).Chikungunya et al. (2019) investigated the structure of gum arabic using X-ray diffraction pattern analysis and reported the existence of different peaks. By examining this analysis, the presence of peaks at angles of 7.7◦ and 18.5◦ was confirmed, which indicated the amorphous nature of gum arabic (26). By comparative analysis of previous studies and the results of this research,It can be concluded that the diffraction pattern of this study has a peakrecognizable features associated with all three structures in the compositeBe that as clear evidence of success synthesisIt works like a composite do

test FE-SEMIt was used to analyze the morphology of the prepared composite. The results of the study conducted by Oh et al. (2019) showed that chitosan particles have a spherical structure and are arranged together in a three-dimensional matrix structure (27). In another study, scanning electron microscopy provided an image of gum arabic with an irregular structure and a diverse range of sizes.depicted the particles of matter (28). By comparing the analysis results FE-SEM Previous studies with microscopic images of this research, it was found that the images FE-SEM Chitosan/gum arabic/natamycin oral coating shows the presence of chitosan particles dispersed in gum arabic structures. The aforementioned natamycin is placed as a layer of the active agent group in the composite structure is

2-4-Microbial evaluation

According to the results, the chitosan/gum arabic/natamycin oral coating samples showed the lowest overall bacteria count and this trend continued with slight changes until the end of the storage time. It seems that the edible coating of chitosan and Arabic gum has a high power against microorganisms. In research Jiang et al. (2013) investigated the effect of gum arabic-natamycin coating on the microbial properties of shiitake mushrooms during 16 days of storage and the results showed that the number of psychrophilic and mesophilic bacteria in gum arabic-natamycin samples was significantly lower than gum arabic and control samples (10). Similarly to the results of the present study, Molamohammadi et al. (2019) investigated the effect of chitosan coating containing salicylic acid as an antimicrobial compound on the shelf life of fresh pistachios inside the shell during 28 days of storage. In their results, it was stated that the population of total bacteria increased gradually and significantly during the storage period in all treatments. The control treatment showed the highest increase and the chitosan-salicylic acid coating effectively and also to a lesser extent the chitosan coating treatment were effective in reducing the microbial amount (29).

Molds are the main contaminant of nuts, especially pistachios, and they are considered a threat to human health due to the production of mycotoxins (30). Among the factors affecting the growth of mold and yeast are the increase in relative humidity and the presence of oxygen in the storage environment (31). In the present study, the population of mold and yeast in the control group had the highest number of fungi due to the lack of cover and barrier against oxygen and moisture. But the covers had a significant effect on the amount of mold

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and yeast, so that In a study byKong et al. (2008) titled the antimicrobial activity of chitosan microspheres in a solid dispersion system. It was found that in the presence of chitosan, the amount of positive charge due to the presence of amine groups increased and caused the formation of stronger electrostatic bonds. This causes strong reactions between chitosan and the cell wall of microorganisms and as a result increases its antimicrobial effect (32) In the present study, in the chitosan/gum arabic/natamycin coating samples, the percentage of mold development decreased, which can be related to the antimicrobial activity of natamycin and the coating.hazing et al. (2020) evaluated the effect of edible chitosan coatings (1, 1.5 and 2%) on fungi in different storage periods of pistachio nuts. According to the findings, the highest number of Aspergillus molds was observed in the control sample, while the lowest was observed in the samples treated with 2% chitosan (33). Natamycin in very small amounts has a broad inhibitory activity on a wide range of yeasts and molds and prevents the production of mycotoxins (34).Jiang et al. (2013) investigated the effect of gum arabic coating enriched with natamycin on the physicochemical and microbial properties of shiitake mushrooms during storage and stated that gum arabic coating containing natamycin led to a decrease in the number of mold and yeast in this mushroom (10).

3-4-Chemical evaluation

The parameter of weight loss and its effect on product quality is of great importance, because weight loss leads to economic loss. The basic mechanism of weight loss of fresh products through the skin is caused by differences in vapor pressure in different places (35). Edible coating acts as a semi-permeable barrier against oxygen, carbon dioxide, moisture and solvent movement, and ultimately reduces respiration and weight loss (36). In the present study, the highest weight loss was observed in the control sample, and chitosan/gum arabic/natamycin treatment showed the lowest weight loss. In one studyJiang et al. (2012) investigated the effect of natamycin-enriched gum arabic coating on the physicochemical properties of shiitake mushrooms during storage and stated that the coating maintained the firmness of the tissue and prevented the weight loss of the product (10). Gum arabic forms a semi-impermeable layer, although it allows certain small molecules to pass through, but by preventing the movement of oxygen, carbon dioxide and moisture, it reduces the respiration and transpiration of the product surface, and ultimately the amount of weight loss. decreases (37). In a similar study Shaker et al. (2019) evaluated the effect of gum arabic edible coatings containing thyme on the quality of fresh pistachios inside the shell. They stated that the use of gum arabic coating led to a decrease in the weight loss of fresh fruits (38). In another study Maqsoodlou et al. (2013) in investigating the effect of edible chitosan coating on pistachio brain characteristics and stated that the weight change percentage of samples without chitosan coating was always higher than coated samples (7,39).

Humidity is one of the important factors affecting the quality of brains Its content varies depending on the time of harvest, storage, and climatic conditions (40). The rate of moisture transfer between food and the surrounding atmosphere is reduced by completely covering the food with a film or edible coating (41). In this study, the results of measuring the moisture content of raw pistachios show that the chitosan/gum arabic/natamycin coating, like a barrier, prevents the transfer of moisture to the pistachio tissue, and its moisture content remains within the range of 5%, while in the control samples Due to the lack of barrier against moisture transfer, at the end of the storage period, the moisture content has reached about 8%. Maqsoodlou et al. (2013) who investigated the activity of chitosan

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coating and its effect on moisture absorption of pistachio nuts, stated that chitosan prevented the absorption of pistachio moisture, but the concentration of chitosan did not have a significant effect in this field (39). hazing et al. (2020) evaluated the effect of edible chitosan coatings (1, 1.5 and 2%) on some physicochemical properties and fungal growth during pistachio kernel storage. Although the moisture trend in all samples (coated and uncoated) increases slightly with storage time, there is a significant difference between the samples.The control and coated samples were observed. While the highest amount of moisture was observed in the uncoated pistachio and the coated treatments in different concentrations had a significant effect in reducing the undesirable moisture of the pistachio (33).

4-4- Sensory evaluation

Investigating the effect of the type of coating on sensory parameters during storage in raw pistachios showed that the edible coatings used not only did not adversely affect the appearance quality of pistachios, but in some cases improved the texture and sensory characteristics. The coating of chitosan/gum arabic/natamycin acts as a protector by placing it on the product and prevents unwanted reactions and changes in the texture and color of the product. Use coverAlthough edibles reduce the transparency of the product at first, with the passage of storage time, due to preventing the spread of chemical and microbial spoilage reactions and the loss of product moisture, compared to uncoated samples, it prevents many changes (33,43). It should be noted that pistachio texture refers to its crispness and fragility when chewing, which is significantly affected by pistachio moisture content. If moisture is absorbed from the surrounding environment, the pistachio kernels will have a soft and sticky texture, which is undesirable from the consumer's point of view (41).Shakerardekani et al. (2019) evaluated the effect of gum arabic coating containing thyme on the quality of fresh pistachios. They stated that the coating treatments showed positive effects on the sensory properties of color, texture and overall acceptance. They also stated that due to the barrier effect of the coating against the infiltration of moisture into the pistachio tissue, its moisture remains constant and as a result, the pistachio tissue maintains its crispness and fragility, which was consistent with the results of the present study (17).

5-Conclusion final

The results obtained from this research showed that coating raw pistachios with chitosan/gum arabic/natamycin had a positive effect on maintaining and improving microbial (bacterial and fungal), chemical and sensory characteristics and increased the shelf life and food safety of pistachios. These results show that the coating of chitosan and gum arabic, especially with natamycin, can be used as an effective factor in maintaining and improving the quality of food, especially brains.

6- Thanksgiving

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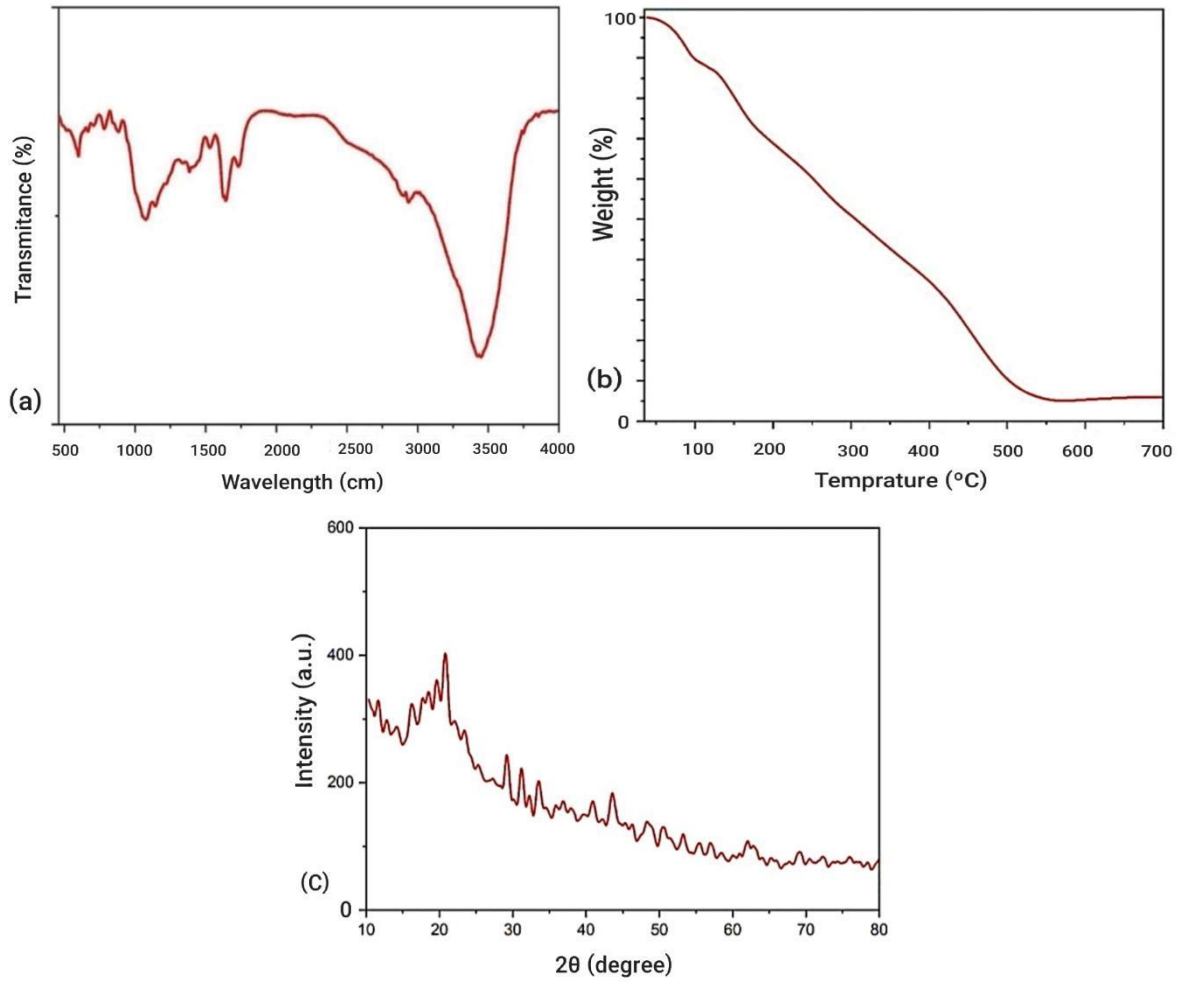

Figure 1. FTIR spectrum image (a), thermal gravimetric test results (b) and XRD (c) of chitosan/gum Arabic/natamycin edible coating

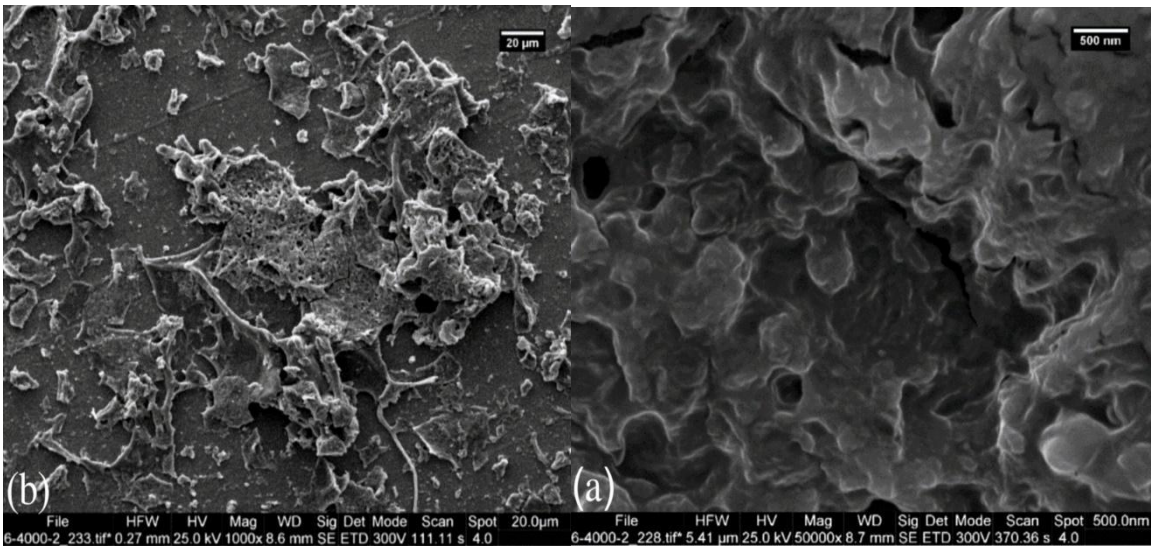

Figure 2. FE-SEM image of chitosan (a) and chitosan/gum Arabic/natamycin edible coating (b)

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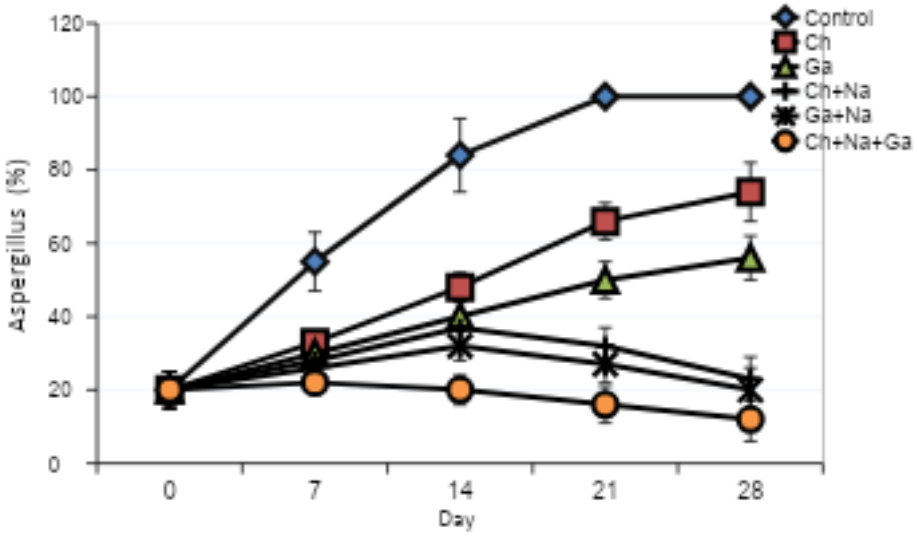
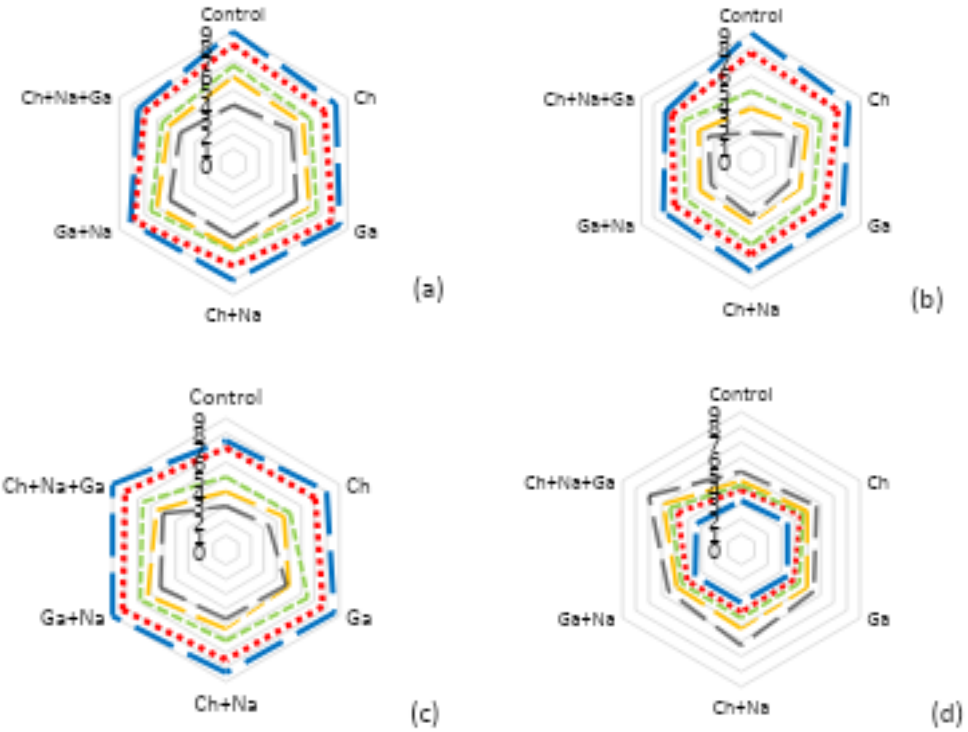


Figure 1. Changes in the growth percentage of aspergillus mold in treated raw pistachios during storage



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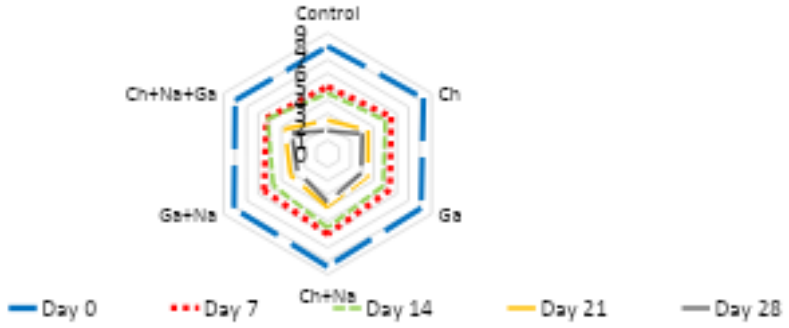

Figure 2. Sensory changes in taste (a), aroma (b), color (c), texture (d) and overall acceptance (e) in treated raw pistachios during storage

Table 1. The results of total counting of bacteria, mold and yeast in raw pistachios treated during storage. Non-similar upper and lower case English letters indicate significant differences between different days of keeping in the same treatment and different treatments in the same day, respectively (P<0.05).

counting Total bacteria	**day**				
	Zero	**7**	**14**	**21**	**28**
C	^{Aa}06/0 ± 11/3	^{Not}05/0 ± 37/4	^{That}09/0 ± 09/5	^{And}18/0 ± 89/5	^{Yes}**13/0 ± 81/6**
Ch	^{Aa}04/0 ± 13/3	^{Bb}07/0 ± 03/4	^{Cb}13/0 ± 51/4	^{Db}09/0 ± 99/4	^{Eb}**06/0 ± 83/5**
Here	^{Aa}03/0 ± 10/3	^{Bb}11/0 ± 87/3	^{Cb}16/0 ± 32/4	^{Dc}08/0 ± 68/4	^{Ec}**15/0 ± 26/5**
Ch+Na	^{Aa}02/0 ± 12/3	^{Bb}10/0 ± 00/4	^{Cb}11/0 ± 44/4	^{Dc}06/0 ± 76/4	^{Ec}**08/0 ± 39/5**
For + My	^{Aa}07/0 ± 15/3	^{Bb}09/0 ± 92/3	^{Cb}05/0 ± 25/4	^{Dd}06/0 ± 43/4	^{Ed}**11/0 ± 88/4**
Ch+Ga+Na	^{Aa}06/0 ± 14/3	^{Be}13/0 ± 61/3	^{This}10/0 ± 01/4	^{Dc}04/0 ± 27/4	^{Ec}**04/0 ± 61/4**
counting mold and yeast					
C	^{Aa}03/0 ± 21/2	^{Bc}05/0 ± 56/3	^{This}06/0 ± 15/4	^{Df}09/0 ± 99/4	^{Eh}**07/0 ± 68/5**
Ch	^{Aa}01/0 ± 25/2	^{Bd}02/0 ± 11/3	^{Cd}06/0 ± 66/3	^{Of}02/0 ± 97/3	^{Ed}**04/0 ± 24/4**
Here	^{Aa}02/0 ± 26/2	^{Bc}01/0 ± 06/3	^{Cd}02/0 ± 62/3	^{Dd}03/0 ± 89/3	^{Ed}**05/0 ± 20/4**
Ch+Na	^{That}05/0 ± 23/2	^{Cb}03/0 ± 30/2	^{Cc}02/0 ± 21/2	^{Bc}04/0 ± 14/2	^{And}**06/0 ± 03/2**
For + My	^{And}04/0 ± 24/2	^{Eb}02/0 ± 33/2	^{Cb}02/0 ± 15/2	^{Bb}01/0 ± 00/2	^{Ab}**04/0 ± 89/1**
Ch+Ga+Na	^{Yes}02/0 ± 22/2	^{And}04/0 ± 01/2	^{That}05/0 ± 66/1	^{Not}02/0 ± 19/1	^{Aa}**03/0 ± 04/1**

counting Total bacteria	day				
	Zero	**7**	**14**	**21**	28
C	^{Aa}06/0 ± 11/3	^{Not}05/0 ± 37/4	^{That}09/0 ± 09/5	^{And}18/0 ± 89/5	^{Yes}13/0 ± 81/6
Ch	^{Aa}04/0 ± 13/3	^{Bb}07/0 ± 03/4	^{Cb}13/0 ± 51/4	^{Db}09/0 ± 99/4	^{Eb}06/0 ± 83/5
Here	^{Aa}03/0 ± 10/3	^{Bb}11/0 ± 87/3	^{Cb}16/0 ± 32/4	^{Dc}08/0 ± 68/4	^{Ec}15/0 ± 26/5
Ch+Na	^{Aa}02/0 ± 12/3	^{Bb}10/0 ± 00/4	^{Cb}11/0 ± 44/4	^{Dc}06/0 ± 76/4	^{Ec}08/0 ± 39/5
For + My	^{Aa}07/0 ± 15/3	^{Bb}09/0 ± 92/3	^{Cb}05/0 ± 25/4	^{Dd}06/0 ± 43/4	^{Ed}11/0 ± 88/4

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Ch+Ga+Na	Aa06/0 ± 14/3	Be13/0 ± 61/3	This10/0 ± 01/4	Dc04/0 ± 27/4	Ec04/0 ± 61/4
counting mold and yeast					
C	Aa03/0 ± 21/2	Be05/0 ± 56/3	This06/0 ± 15/4	Df09/0 ± 99/4	Eh07/0 ± 68/5
Ch	Aa01/0 ± 25/2	Bd02/0 ± 11/3	Cd06/0 ± 66/3	Of02/0 ± 97/3	Ed04/0 ± 24/4
Here	Aa02/0 ± 26/2	Bc01/0 ± 06/3	Cd02/0 ± 62/3	Dd03/0 ± 89/3	Ed05/0 ± 20/4
Ch+Na	That05/0 ± 23/2	Cb03/0 ± 30/2	Cc02/0 ± 21/2	Bc04/0 ± 14/2	And06/0 ± 03/2
For + My	And04/0 ± 24/2	Eb02/0 ± 33/2	Cb02/0 ± 15/2	Bb01/0 ± 00/2	Ab04/0 ± 89/1
Ch+Ga+Na	Yes02/0 ± 22/2	And04/0 ± 01/2	That05/0 ± 66/1	Not02/0 ± 19/1	Aa03/0 ± 04/1

Table 2. Average changes in weight loss and moisture content in treated raw pistachios during storage. Non-similar upper and lower case English letters indicate significant differences between different days of keeping in the same treatment and different treatments in the same day, respectively (P<0.05).

counting Total bacteria	**day**				
	Zero	**7**	**14**	**21**	**28**
C	Aa06/0 ± 11/3	Not05/0 ± 37/4	That09/0 ± 09/5	And18/0 ± 89/5	**Yes13/0 ± 81/6**
Ch	Aa04/0 ± 13/3	Bb07/0 ± 03/4	Cb13/0 ± 51/4	Db09/0 ± 99/4	**Eb06/0 ± 83/5**
Here	Aa03/0 ± 10/3	Bb11/0 ± 87/3	Cb16/0 ± 32/4	Dc08/0 ± 68/4	**Ec15/0 ± 26/5**
Ch+Na	Aa02/0 ± 12/3	Bb10/0 ± 00/4	Cb11/0 ± 44/4	Dc06/0 ± 76/4	**Ec08/0 ± 39/5**
For + My	Aa07/0 ± 15/3	Bb09/0 ± 92/3	Cb05/0 ± 25/4	Dd06/0 ± 43/4	**Ed11/0 ± 88/4**
Ch+Ga+Na	Aa06/0 ± 14/3	Be13/0 ± 61/3	This10/0 ± 01/4	Dc04/0 ± 27/4	**Ec04/0 ± 61/4**
counting mold and yeast					
C	Aa03/0 ± 21/2	Be05/0 ± 56/3	This06/0 ± 15/4	Df09/0 ± 99/4	**Eh07/0 ± 68/5**
Ch	Aa01/0 ± 25/2	Bd02/0 ± 11/3	Cd06/0 ± 66/3	Of02/0 ± 97/3	**Ed04/0 ± 24/4**
Here	Aa02/0 ± 26/2	Bc01/0 ± 06/3	Cd02/0 ± 62/3	Dd03/0 ± 89/3	**Ed05/0 ± 20/4**
Ch+Na	That05/0 ± 23/2	Cb03/0 ± 30/2	Cc02/0 ± 21/2	Bc04/0 ± 14/2	**And06/0 ± 03/2**
For + My	And04/0 ± 24/2	Eb02/0 ± 33/2	Cb02/0 ± 15/2	Bb01/0 ± 00/2	**Ab04/0 ± 89/1**
Ch+Ga+Na	Yes02/0 ± 22/2	And04/0 ± 01/2	That05/0 ± 66/1	Not02/0 ± 19/1	**Aa03/0 ± 04/1**

weight loss	**day**				
	Zero	7	14	21	**28**
C	Aa03/0 ± 08/4	Be03/0 ± 01/5	Cd02/0 ± 99/5	Df04/0 ± 61/6	**If01/0 ± 03/7**
Ch	Aa04/0 ± 01/4	Ad02/0 ± 41/4	Bc00/0 ± 62/4	This01/0 ± 88/4	**Of03/0 ± 98/4**
Here	Aa01/0 ± 91/3	Bb04/0 ± 93/3	That03/0 ± 01/4	Dc01/0 ± 21/4	**Ec02/0 ± 32/4**
Ch+Na	Aa03/0 ± 96/3	Not01/0 ± 84/3	That02/0 ± 99/3	Dd03/0 ± 44/4	**Ed00/0 ± 69/4**
For + My	Aa02/0 ± 90/3	Bb01/0 ± 95/3	That02/0 ± 00/4	Db02/0 ± 16/4	**Eb01/0 ± 21/4**
Ch+Ga+Na	Aa01/0 ± 12/4	Bc00/0 ± 10/4	Cb01/0 ± 08/4	And01/0 ± 95/3	**Yes02/0 ± 77/3**

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humidity					
C	Aa07/0 ± 38/5	Be03/0 ± 14/6	Cd02/0 ± 97/6	Of04/0 ± 93/7	**Eh01/0 ± 81/8**
Ch	Aa02/0 ± 42/5	Bd03/0 ± 67/5	Cc01/0 ± 15/6	Dd04/0 ± 52/6	**Ed04/0 ± 78/6**
Here	Aa06/0 ± 36/5	Bb02/0 ± 54/5	Cb01/0 ± 91/5	Db03/0 ± 12/6	**Eb04/0 ± 32/6**
Ch+Na	Aa05/0 ± 39/5	Bc04/0 ± 62/5	Cc03/0 ± 11/6	Dc05/0 ± 41/6	**Ec03/0 ± 69/6**
For + My	Aa06/0 ± 37/5	Bb02/0 ± 52/5	Cb01/0 ± 90/5	Db03/0 ± 13/6	**Eb04/0 ± 35/6**
Ch+Ga+Na	Aa05/0 ± 40/5	Aa05/0 ± 41/5	Not05/0 ± 53/5	That05/0 ± 65/5	**And05/0 ± 77/5**

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چکیده

این مطالعه با هدف بررسی تأثیر پوشش خوراکی کیتوزان و صمغ عربی حاوی ناتامایسین بر ویژگی‌های میکروبی، شیمیایی و حسی پسته خام طی ۲۸ روز نگهداری در یخچال (۱±۴ درجه سانتی‌گراد و رطوبت نسبی ۹۵-۹۰ درصد) انجام شد. نمونه‌ها در پنج گروه شامل کنترل (C)، پوشش داده شده با کیتوزان (Ch)، پوشش داده شده با صمغ عربی (Ga)، پوشش داده شده با کیتوزان و ناتامایسین (Ch+Na)، پوشش داده شده با صمغ عربی و ناتامایسین (Ga+Na) و پوشش داده شده با کیتوزان و صمغ عربی و ناتامایسین (Ch+Ga+Na) تهیه و آزمون‌های مشخصه‌یابی (طیف مادون‌قرمز تبدیل فوریه، پراش اشعه ایکس، آنالیز وزن‌سنجی حرارتی و میکروسکوپ الکترونی روبشی)، میکروبی (شمارش کلی میکروارگانیسم‌ها، رشد آسپرژیلوس و شمارش کپک و مخمر)، شیمیایی (افت وزن و رطوبت) و حسی انجام شد. نتایج آزمون‌های میکروبی نشان داد نمونه‌های پوشش داده شده با کیتوزان/صمغ عربی/ناتامایسین در مقایسه با سایر تیمارها بطور معناداری در مهار رشد موثر عمل کرده است ($P<0/05$) بطوریکه در ابتدا و انتهای دوره شمارش باکتری‌ها از ۳/۴۷ log cfu/g به ۴/۶۱ log cfu/g، کپک و مخمر از ۲/۲۲ log cfu/g به ۱/۰۴ log cfu/g و درصد توسعه آسپرژیلوس از ۲۰ به ۱۲ درصد رسید. همچنین پوشش‌دهی با کیتوزان/صمغ عربی/ناتامایسین تأثیر مثبتی بر ویژگی های شیمیایی به‌ویژه ممانعت از افت وزن داشت بطوریکه از ۵/۱۲ درصد در روز صفر به ۳/۷۷ درصد در روز پایانی رسید درحالیکه این میزان برای تیمار کنترل در روز صفر و ۲۸ به ترتیب ۴/۰۸ و ۷/۰۳ درصد بود. پوشش‌دهی با کیتوزان/صمغ عربی/ناتامایسین نه تنها بر کیفیت ظاهری پسته‌ها تأثیر نامطلوب نگذاشته، بلکه در تمامی پارامترها به استثنای طعم موجب بهبود مشخصات حسی شده است. بطور کلی نتایج نشان داد که پوشش کیتوزان و صمغ عربی، بویژه زمانی که حاوی ناتامایسین باشد می‌تواند به عنوان پوشش خوراکی موثر در حفظ و ارتقاء کیفیت مواد غذایی به‌ویژه خشکبار مورد توجه قرار گیرد.

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