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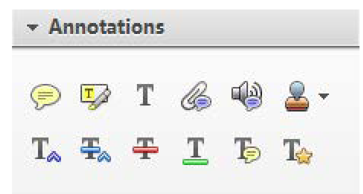

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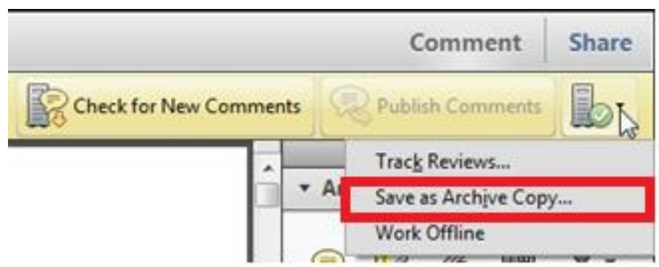

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Effects of the combination of gamma irradiation and Ag nanoparticles polyethylene films on the quality of fresh bottom mushroom (*Agaricus bisporus* L.)

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Abstract

This study was conducted to examine the combined method of gamma irradiation doses (0, 1, and 2 kGy) and Ag nanoparticles polyethylene films on the quality of fresh bottom mushroom during storage. For this purpose, physical and chemical properties such as pH, color, weight loss, as well as texture parameters test of the mushroom samples were measured and microbial test for Ag nanoparticles polyethylene films were also performed during 21 days of storage at 4 °C. It was observed that the samples irradiated with a dose of 2 kGy and placed in Ag nanoparticles polyethylene films had the lowest reduction in pH (14.33%) and L^* (lightness; 6.0%), while weight loss, b^* and browning index had the fewest changes with the amount of 9.47, 5.58, and 13.84, respectively. Also, a^*, for the control sample and Ag nanoparticles polyethylene films after 21 days of storage increased up to 8.39 and 7.17%, respectively, compared to the initial samples. Also, the greatest changes in the firmness and elasticity for the treatment, respectively was 5.22 and 3.24% compared to the initial samples. Finally, it has been indicated that Ag nanoparticles polyethylene films could prevent the accumulation of microbial load. The results thus demonstrate that the combined use of gamma irradiation and Ag nanoparticles polyethylene films is an effective approach to maintain the quality of fresh bottom mushroom during storage.

Practical applications

Irradiating food causes changes in flavor, color, nutrients, taste, and other qualitative properties and such merits could extend the shelf life of the food products for preservation aims. Also, use of nanoparticles polyethylene films could help to better preservation of the mushrooms. Such combinations (nanoparticles films with gamma rays) could be of interest for the industry in packaging process and consequently export for long time consumption.

1 | INTRODUCTION

Bottom mushroom (*Agaricus bisporus*) is one of the most commonly used type of mushroom worldwide and makes about 40% of the world mushroom production (Guan, Fan, & Yan, 2013). Storage duration of fresh mushrooms is very short and is customer-friendly until it does not change the quality and freshness (Oliveira, Sousa-Gallagher, Mahajan, & Teixeira, 2012a). Mushrooms quality attributes include browning, softening (Yurttas, Moreira, & Castell-Perez, 2014), cap widening, and losses in weight (Kim, Ko, Lee, Park, & Hanna, 2006).

Many ways to keep the freshness and quality of fresh mushrooms during storage have been reported, such as electron irradiation (Mami, Peyvast, Ziaie, Ghasemnezhad, & Salmanpour, 2014), packaging with different films (Taghizadeh, Gowen, Ward, & O'Donnell, 2010), packaging with cinnamon oil (Echegoyen & Nerín, 2015), packaging with modified atmosphere (Kim et al., 2006), washed with hydroxide peroxide (Sapers, Miller, Choi, & Cooke, 1999), and ozone (Yuk, Yoo, Yoon,

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Marshall, & Oh, 2007). These ways are very efficient to protect mushroom texture and quality of this product (Gilman, Jacxsens, De-Meulenaer, & Devlieghere, 2015).

Irradiating food causes changes in flavor, color, nutrients, taste, and other qualitative properties (Oliveira et al., 2012a). The use of gamma irradiation has long history in different types of food such as citrus (Mahrouz et al., 2002; Oufedjikh, Mahrouz, Amiot, & Lacroix, 2000; Oufedjikh, Mahrouz, Lacroix, Amiot, & Taccini, 1998), Spices (Khatun et al., 2017), and vegetables (Majeed et al., 2017). Also gamma irradiation because of high penetration power is commonly used in food packaging that of course it is considered as a method for cold sterilization (Madera-Santana, Meléndrez, González-García, Quintana-Owen, & Pillai, 2016). The level of changes caused by the ray in different foods in the aroma, color, and taste depends on the food material, irradiation dose, and ray source (Oliveira, Sousa-Gallagher, Mahajan, & Teixeira, 2012b).

In a study conducted by Han et al. (2015) for increasing shelf-life of the wild mushroom, poly (lactic acid [PLA]) packaging films were used and the results demonstrated that the shelf-life has increased up to 18 days and this kind of film showed antimicrobial activity. Furthermore, Qin et al. (2015) conducted a study on the effect of antibacterial film of PLA/poly (ε-caprolactone) (PCL) on the physicochemical and microbial properties of bottom mushroom. The results showed that packaging bottom mushroom with PLA polymer films maintained the color and sensory and physical properties and prevented water vapor loss from the mushroom after 12 days of storage and microbial load aggregation. Gantner et al. (in press) conducted a study on the effect of type of packaging films and modified atmosphere on the shelf-life of white mushroom. According to the results, after 14-day storage, a polymer film in combination with modified atmosphere maintained the color, weight loss, texture, and shelf-life. Donglu et al. (2016) conducted a study on the effect of polyethylene (PE) film on mushroom shelf-life and concluded that this type of film maintained the mushroom shelf-life and quality and played a significant role in commercialization of the product.

Mushroom is one of the most popular foods, but its customer satisfaction is for healthy and white, nonshrink, and nonbrown warheads. In contrast, this product is highly corrupted and its qualitative changes decrease in a short time. This product is dramatically produced around the world (Xu et al., 2017). Irradiation is a process confirmed by global health organizations and exist irradiation companies for agricultural and food products in all countries and irradiation of a high volume of the product is very cost effective (Ekezie, Cheng, & Sun, 2018). Furthermore, the polyethylene coating is a polymer coating of silver nanoparticles that have very low cost in high production volume. The silver nanoparticles contained in the coatings in combination with irritation of products eliminate the use of chemicals and have little disadvantage over other methods of storage. The cost of deterioration of high volume of the product as well as the cost of treatment caused by the introduction of various chemicals into the human body is far more than packaging with this type of coating and is very cost effective in a large volume.

Some studies have been conducted on the mushroom by just gamma irradiation method (Charlesby, 2016; Choi, Park, Choi, Kim, & Chun, 2015; Marra et al., 2016; Schmid, Held, Hammann, Schlemmer, & Noller, 2015; Severino et al., 2015). But, regarding the knowledge of the paper authors, so far no study has been reported on the combination of gamma irradiation and Ag nanoparticles polyethylene films. The aim of this study is to evaluate the effect of different doses of gamma irradiation in combination with Ag nanoparticles polyethylene films on the physical and chemical properties and texture of fresh bottom mushroom and microbial properties of Ag nanoparticles polyethylene films. Therefore, the idea behind of the research is quit novel and original.

2 | MATERIALS AND METHODS

2.1 | Samples preparation and irradiation

The samples of fresh mushrooms were harvested from the farms in 2016 with uniform size, same color, and no injuries. Specifications of gamma source were gamma cell (GC) 220, Nordin, dose rate 3.05 Gary, 18 kkori Source power, 0 (control), 1 and 2 kGy irradiation dose (Fernandes et al., 2016). Then, they were stored at 4 °C, and the experiments were performed.

2.2 | Fabricating and producing the films

Medium-density polyethylene film (1.2 kg/m^3) was prepared. Ag nanoparticles with a size of 35 nm were also purchased. To combine nanoparticles with a polymer film, extrusion process took place in the extruder. The temperature in different areas of extruder, from feeding chamber to output was 125, 145, 155, 170, 185, 195, and 200 °C, respectively. The extruder chamber pressure was 12.5 bar and melt temperature was about 200 °C.

To ensure the proper path and conditions, polyethylene film and Ag nanoparticles (0.5 and 1 wt %) were well mixed and fed through a funnel into the extruder. The materials were mixed together by creating shear force and pressure. The mixture was exited from the extruder, and the created granules was then exited from the chamber, after being heated it was passed as a thin film over a cooling roller and subsequently threw in a cold water pool (Emamifar, Kadivar, Shahedi, & Soleimanian-Zad, 2010).

The treatments of Ag nanoparticles polyethylene films and irradiation were as follow:

- Nonirradiated samples in paper bags ©
- Nonirradiated samples in polyethylene films without Ag nanoparticles (PE + C)
- 1 kGy irradiated sample in polyethylene films without Ag nanoparticles (PE + 1i)
- 2 kGy irradiated sample in polyethylene films without Ag nanoparticles (PE + 2i)
- Nonirradiated samples in Ag nanoparticles polyethylene films (PE + Ag + C)

- 1 kGy irradiated samples in Ag nanoparticles polyethylene films (PE + Ag + 1i)
- 2 kGy irradiated samples in Ag nanoparticles polyethylene films (PE + Ag + 2i)

2.3 | pH measurement

After separating the waste over the mushroom cap, 20 fresh mushrooms per treatment were cut into small pieces, mixed well by a blender and passed through a clean fabric. Finally, pH level of the solution was measured by a pH meter (PH-2211, Hana, Italy) (Aday, Caner, & Rahvalı, 2011).

2.4 | Measuring color of samples

The color of samples was measured using a portable colorimeter (Konica Minolta, CR400, Japan). To calibrate the colorimeter the standard white plate (CR-A43) was used and the parameters L^* (lightness), a^* (red–green), and b^* (yellow–blue) were recorded. Browning index (*BI*) was calculated using the following equations (Abbasi & Azari, 2009):

$$BI=\frac{[100(x-0.31)]}{0.17} \quad (1)$$

$$x=\frac{(a^*+1.75L^*)}{(5.645L^*+a^*-3.012b^*)} \quad (2)$$

2.5 | Weight loss

The mushroom weight for each treatment was recorded at the beginning and end of the experiments. Before the experiment, all the treatments were labeled and the sample weight loss percentage was recorded (Koutsimanis, Harte, & Almenar, 2015).

2.6 | Texture analysis of the samples

Twenty mushrooms were used and Texture Test (TPA) was performed on mushroom cap using Instron (STM-Santam20, Iran) under the conditions as follow: test speed of 2 mm/s, pretest speed of 10 mm/s, and 30% strain. Then, force-time diagram was calculated using the software installed on the apparatus and the firmness and elasticity of the mushroom samples were calculated using the software (Wong et al., 2017).

2.7 | Microbial test

To perform microbial tests, *Escherichia coli* bacteria ATCC 25922 and *Staphylococcus aureus* ATCC 29523, respectively, were used as negative-gram and positive-gram bacterial microorganisms. For cultivation of the microorganisms, Violet Red Bile Dextrose Agar (VRBDA) medium was used for the bacteria *E. coli* cultivation and Mannitol Salt Agar (MSA) medium was used for the bacteria *S. aureus* cultivation. Both sterile nutrients agar were kept until reaching the desired number for performing microbial tests for 24 hr at 37 °C.

Polymer film was cut as a small circle with a diameter of 5 cm, disinfected with alcohol at 70 °C, and 15 ml of the bacteria *E. coli* and *S. aureus* was added to the Falcon. The Falcon containing the film and microorganisms was kept for 24 hr at 37 °C. To count the number of colonies, dilution was done at 10^{-6} and 10^{-7}. Then, using micrometer sampler, 0.1 ml of microbial suspension was taken and sprayed over VRBDA for the bacteria *E. coli* cultivation and over MSA for the bacteria *S. aureus* cultivation in the medium, and kept for 24 hr at 37 °C. After 24 hr, the number of colonies was counted and multiplied by the dilution determined (Restrepo-Flórez, Bassi, & Thompson, 2014).

TABLE 1 Effect of different treatments on pH value during storage

	Storage time (Week)			
	0 Week	1 Week	2 Week	3 Week
C	6.21 ± 0.06	5.64 ± 0.07	5.39 ± 0.01	4.09 ± 0.02
PE + C	6.21 ± 0.06	5.87 ± 0.05	5.60 ± 0.04	4.21 ± 0.05
PE + 1i	6.21 ± 0.06	6.13 ± 0.06	6.13 ± 0.01	6.13 ± 0.04
PE + 2i	6.21 ± 0.06	6.09 ± 0.03	5.82 ± 0.03	4.81 ± 0.06
PE + Ag + C	6.21 ± 0.06	6.01 ± 0.04	5.71 ± 0.07	4.60 ± 0.02
PE + Ag + 1i	6.21 ± 0.06	6.14 ± 0.02	5.97 ± 0.05	5.10 ± 0.03
PE + Ag + 2i	6.21 ± 0.06	6.17 ± 0.05	6.02 ± 0.04	5.32 ± 0.03
Overall	6.21 ± 0.06A	6.10 ± 0.08B	5.73 ± 0.12C	4.86 ± 0.07D

Data are means ± *SD* of three replicates.
A–D means in the same row with different letters are significantly different ($p \leq .05$; mean separation was performed by Tukey test).

2.8 | Data analysis

In this study, experiments were conducted at three stages and statistical analysis was performed using software SAS 9.1.3. Additionally, 2-way ANOVA method was used to examine the effect of different treatments on the mushroom quality and the differences between means were examined using Tukey model at the significance level of .05.

3 | RESULTS AND DISCUSSION

Table 1 shows the pH value in each treatment during storage that was 6.21 at the beginning of the experiment. pH values for all treatments significantly reduced by increasing the storage duration. The results are consistent with the study of Aday (2016) who reported pH value reduced by increasing the storage duration. pH values influenced by irradiation dose and Ag nanoparticles were measured during three weeks of storage. The highest pH value among all treatments belongs to the sample irradiated in Ag nanoparticles polyethylene films that O_2/CO_2 value due to reduced respiratory rate compared with the samples of nonirradiated inside the paper bag and the samples irradiated with the dose of 1 kGy of polyethylene films without Ag nanoparticles (PE + 1i) is in the balance. It seems that the production of organic acids by microorganisms has reduced the pH value in the mushroom (Oliveira et al., 2012b).

Color Index is one of the important parameters for the consumer. When the mushrooms are harvested white, they began to slowly

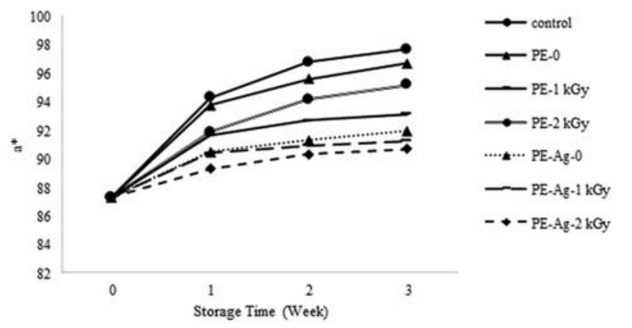

FIGURE 1 Effect of different treatments on a^* value during storage

change color and become dark gradually (Cao et al., 2010). According to the results, during storage, no significant difference was observed between different treatments in the values of a^*, but the treatments irradiated with the dose of 2 kGy in Ag nanoparticles polyethylene films after the storage time were less red and compared to the control treatment in the paper bag were significantly different and less discolored (Figure 1). In all treatments, L^* value reduced and b^* value increased and browning index remained almost stable after two weeks of the storage (Tables 2–4). The study results are consistent with the findings of Caner and Aday (2009) where strawberry samples become dark over time.

Based on the results, a significant difference was observed between the treatments in the packages. Most of changes in the index b^* in the control treatments were observed after the storage period. Conversely, by increasing the irradiation dose, the index b^* value increased and lightness reduced. Yellowing value increased by increasing the irradiation dose because the mushroom lost its volatiles during storage and browning index after the harvest is linearly related to storage time (Anthon & Barrett, 2003). Also, for the samples placed in Ag nanoparticles polyethylene films, Ag nanoparticles prevent the mold growth on the film as well as the color change and increase browning index and b^*. Jo, Son, Shin, and Byun (2003) in their research showed that by increasing the irradiation dose and the placement of the samples at refrigerator temperature, the value of the index b^* will increase in comparison to the control.

The amount of weight loss in all treatments is shown in Table 5. The mushroom quality reduced over time due to the loss of intracellular water (Khan & Gibbons, 2014). Based on the results, a significant increase was observed for all treatments during storage. The results of statistical analysis showed that no significant difference was found between the samples irradiated with the dose 2 kGy in polyethylene bags with and without Ag nanoparticles and at the end of the storage period, the value of weight loss was 1.5 and .9%, respectively. The highest value of weight loss of 3.02, 1.9, 1.7, and 1.1% were respectively for the control sample, the sample nonirradiated in polyethylene films, the sample irradiated with doses of 1 and 2 kGy in polyethylene film, nonirradiated samples in polyethylene film with Ag nanoparticles. The reason for this phenomenon is that the intracellular water of the mushroom samples reduces by increasing the storage time and becomes dried. Also, due to the respiration of the biological activity, the moisture content reduces (Burton, 1989). Because the cells are in fresh mushrooms, fresh samples have also higher density (Zhou, Lv, He, He, & Shi, 2011).

Texture analysis (TPA) shows important indices for the samples. Texture is the most important parameter that is related to the mechanical and structural properties of food (Abbott & Harker, 2004). During storage, texture parameters, including firmness and elasticity of the mushroom, reduced by increasing adhesion. According to the literature, the firmness is associated with the cell turgor pressure, cell size, cell wall resistance, and intercellular adhesion (Aday, Buyukcan & Caner, 2013).

Figure 2 shows the changes in firmness in the treatments. In general, for the samples irradiated in Ag nanoparticles polyethylene films, the mushroom firmness reduced in comparison with other treatments. The control samples without irradiation in polyethylene bags without Ag nanoparticles had less firmness during storage. Samples of PE-Ag-2 kGy, PE-Ag-1 kGy, PE-2 kGy, and PE-Ag samples have highest firmness at the end of study as 700 ± 23, 510 ± 31, 460 ± 39, and 401 ± 28, respectively. Reduced turgor pressure on the walls of cells, weight, and

TABLE 2 Effect of different treatments on L^* value during storage

Treatment	Storage time (Week) 0 Week	1 Week	2 Week	3 Week
C	73.5 ± 2.29	57.9 ± 2.12	54.1 ± 0.91	45.2 ± 0.78
PE + C	73.5 ± 2.29	69.5 ± 1.19	69.2 ± 1.02	64.4 ± 1.43
PE + 1i	73.5 ± 2.29	70.2 ± 1.27	69.3 ± 1.31	65.3 ± 1.08
PE + 2i	73.5 ± 2.29	71.6 ± 2.02	70.7 ± 1.67	66.5 ± 1.31
PE + Ag + C	73.5 ± 2.29	71.4 ± 0.97	70.4 ± 2.03	65.8 ± 0.82
PE + Ag + 1i	73.5 ± 2.29	72.3 ± 1.37	71.6 ± 1.09	68.3 ± 2.05
PE + Ag + 2i	73.5 ± 2.29	72.7 ± 1.76	72.0 ± 1.15	68.5 ± 2.12
Overall	73.5 ± 2.29 A	70.72 ± 0.83A	68.12 ± 1.52B	57.85 ± 0.93C

Data are means ± *SD* of three replicates.
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TABLE 3 Effect of different treatments on b^* value during storage

Treatment	Storage time (Week)			
	0 Week	1 Week	2 Week	3 Week
C	34.67 ± 1.52	42.59 ± 1.05	57.63 ± 0.08	76.80 ± 0.07
PE + C	34.67 ± 1.52	39.13 ± 1.12	42.94 ± 0.15	55.19 ± 0.09
PE + 1i	34.67 ± 1.52	41.30 ± 0.84	43.08 ± 0.73	50.78 ± 0.1
PE + 2i	34.67 ± 1.52	41.10 ± 0.67	42.46 ± 0.57	46.67 ± 0.52
PE + Ag + C	34.67 ± 1.52	38.49 ± 1.23	38.83 ± 1.09	41.28 ± 0.49
PE + Ag + 1i	34.67 ± 1.52	36.03 ± 1.50	36.15 ± 1.12	37.79 ± 0.63
PE + Ag + 2i	34.67 ± 1.52	34.89 ± 0.83	35.46 ± 0.37	36.72 ± 0.08
Overall	34.67 ± 1.52A	38.07 ± 0.79A	39.79 ± 0.91B	51.37 ± 0.14B

Data are means ± *SD* of three replicates.
A, B means in the same column with different letters are significantly different ($p \le .05$; mean separation was performed by Tukey test).

TABLE 4 Effect of different treatments on *BI* value during storage

Treatment	Storage time (Week)			
	0 Week	1 Week	2 Week	3 Week
C	14.62 ± 0.25	17.62 ± 0.31	20.12 ± 0.17	19.54 ± 047
PE + C	14.62 ± 0.25	16.62 ± 0.52	18.19 ± 0.22	18.79 ± 0.43
PE + 1i	14.62 ± 0.25	16.18 ± 0.43	17.49 ± 0.91	18.30 ± 0.08
PE + 2i	14.62 ± 0.25	15.31 ± 0.09	16.17 ± 1.03	17.42 ± 0.43
PE + Ag + C	14.62 ± 0.25	15.57 ± 0.12	16.49 ± 0.52	17.73 ± 0.71
PE + Ag + 1i	14.62 ± 0.25	14.82 ± 0.34	15.73 ± 0.72	16.98 ± 0.51
PE + Ag + 2i	14.62 ± 0.25	14.71 ± 0.67	15.40 ± 0.63	16.97 ± 0.49
Overall	14.62 ± 0.25 A	15.34 ± 0.31B	17.22 ± 0.36B	17.52 ± 0.23C

Data are means ± *SD* of three replicates.
A–C means in the same row with different letters are significantly different ($p \le .05$; mean separation was performed by Tukey test).

TABLE 5 Effect of different treatments on weight loss value during storage

Treatment	Storage time (Week)			
	0 Week	1 Week	2 Week	3 Week
C	0.05 ± 0.05	0.21 ± 0.09	0.35 ± 0.12	0.49 ± 0.19
PE + C	0.02 ± 0.04	0.17 ± 0.09	0.27 ± 0.15	0.38 ± 0.18
PE + 1i	0.03 ± 0.08	0.19 ± 0.07	0.25 ± 0.09	0.31 ± 0.20
PE + 2i	0.03 ± 0.05	0.18 ± 0.08	0.23 ± 0.08	0.30 ± 0.21
PE + Ag + C	0.02 ± 0.02	0.16 ± 0.06	0.20 ± 0.13	0.29 ± 0.09
PE + Ag + 1i	0.04 ± 0.03	0.20 ± 0.03	0.29 ± 0.15	0.44 ± 0.17
PE + Ag + 2i	0.04 ± 0.09	0.21 ± 0.01	0.31 ± 0.18	0.42 ± 0.26
Overall	0.03 ± 0.05A	0.18 ± 0.13B	0.23 ± 0.5B	0.37 ± 0.07C

Data are means ± *SD* of three replicates.
A–C means in the same row with different letters are significantly different ($p \le .05$; mean separation was performed by Tukey test).

volume of the texture (Jaworska & Bernaś, 2010) was more for the irradiated samples in Ag nanoparticles polyethylene films.

Elasticity is recovery after removal of the force of the matter that was more in the samples irradiated in Ag nanoparticles polyethylene

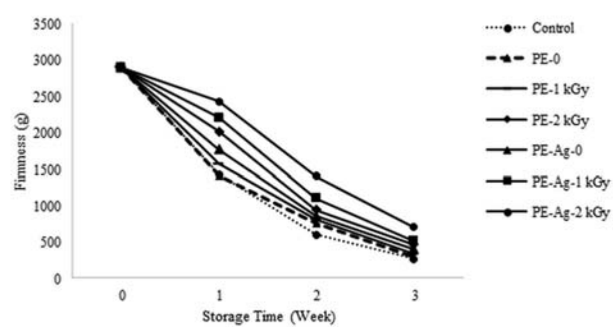

FIGURE 2 Effect of different treatments on firmness value during storage

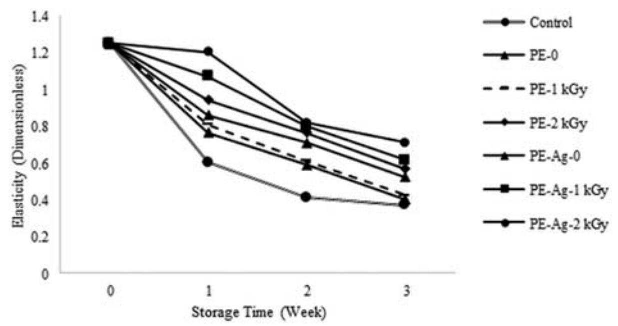

FIGURE 3 Effect of different treatments on elasticity value during storage

TABLE 6 Results of observed colonies on films

Films	Logarithm the number of *Escherichia coli* × 10^8	Logarithm the number of *Staphylococcus aureus* × 10^7
PE	2.3 ± 0.07	3.1 ± 0.34
PE + Ag	0.7 ± 0.12	1.2 ± 0.52

films during storage. The amount of elasticity is associated with the elasticity of food (Aday & Caner, 2010). The amount of elasticity in the control and irradiated sample has reduced during storage time F3 (Figure 3). The control and nonirradiated sample in polyethylene film without Ag nanoparticles has less elasticity than the other sample. Samples of PE-Ag-2 kGy, PE-Ag-1 kGy, PE-2 kGy, and PE-Ag samples have highest elasticity at the end of study as 0.71 ± 0.0138, 0.615 ± 0.0197, 0.568 ± 0.037, and 0.523 ± 0.029, respectively. The difference is related to food moisture, minerals and cell water causing turgor pressure that cell water is also influenced by irradiation dose and nanoparticles (Jaworska & Bernaś, 2010).

Based on the initial number of bacteria, microbial load in Ag nano-T6 particles polyethylene films is given in Table 6.

Ag nanoparticles reduce the number of colonies of bacteria *S. aureus* compared with polyethylene film without Ag nanoparticles, but the bacteria *E. coli* are stronger bacteria (Table 6). Li, Xing, Jiang, Ding, and Li (2009) showed that Ag and ZnO nanoparticles have antibacterial properties and the bacteria *E. coli* compared to the bacteria *S. aureus* are stronger against antibacterial properties that this is due to the differences in the bacterial negative-gram and positive-gram structure and/or dependent on the bacteria sensitivity to hydrogen peroxide generated from the surface of Ag and ZnO nanoparticles. Conversely, Ag nanoparticles are an effective way to reduce the microbial load of negative-gram bacteria such as *E. coli*.The latter results of this study are consistent with the report of Emamifar et al. (2010).

4 | CONCLUSION

In this study, combined method of gamma irradiation and Ag nanoparticles polyethylene films, in order to maintain the quality of fresh bottom mushroom, was examined. The results of this study show that the sample irradiated with a dose of 2 kGy in Ag nanoparticles polyethylene films makes more proper conditions to maintain the mushroom. The experimental results and measured parameters such as pH, weight, color, and textural indices have better values with gamma irradiation and Ag nanoparticles polyethylene films in these indices. Also, Ag nanoparticles polyethylene films have antibacterial properties and compared with conventional films, reduce the accumulation of microbes and microorganisms. Finally, the results of this study show that the physical and chemical properties of food irradiated in Ag nanoparticles polyethylene films are maintained and the fresh bottom mushroom quality are satisfactorily maintained during storage.

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