



Article Gelatin-Based Film Integrated with Copper Sulfide Nanoparticles for Active Packaging Applications

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Abstract: Gelatin-based multifunctional composite films were prepared by reinforcing various amounts of copper sulfide nanoparticles (CuSNP, 0.0, 0.5, 1.0, and 2.0 wt %), and the effect of CuSNP on the film was evaluated by analyzing its physical and antibacterial properties. CuSNP makes a compatible film with gelatin. The inclusion of CuSNP significantly enhanced the UV blocking, mechanical strength, and water vapor barrier properties of the gelatin film. The inclusion of CuSNP of 1.0 wt % or less did not affect the transparency of the gelatin film. When 2.0 wt % of CuSNP was mixed, the hydrophilicity of the gelatin film did not change noticeably, but its thermal properties slightly increased. Moreover, the gelatin/CuSNP composite film presented effective antibacterial activity against *E. coli* and some activity against *L. monocytogenes*. Gelatin/CuSNP composite films with better functional and physical properties can be used for food packaging or biomedical applications.

Keywords: gelatin; CuSNP; multifunctional film; UV-barrier property; mechanical property; antimicrobial activity

1. Introduction

With the essential packaging functions of protection, containment, communication, and utility, food packaging plays a vital role in reducing food waste by ensuring food safety, maintaining quality, and extending shelf life [1–4]. Commodity plastics (polyethylene, polypropylene and polystyrene) are widely used as food packaging materials, and these plastic packaging materials cause enormous environmental pollution due to their non-biodegradability and improper waste management after use [5]. Therefore, the need to use biopolymer-based biodegradable packaging materials has emerged to reduce the plastic waste problem and replace plastic packaging materials. Various biopolymers, such as chitosan, cellulose, agar, carrageenan, and gelatin, are utilized for this purpose owing to their excellent film-producing ability, bio-degradability, and biocompatibility [6–9]. Gelatin, a protein-based natural biopolymer, is an edible biodegradable material blended with functional ingredients to create efficient packaging films [10,11]. Gelatin is the denatured and hydrolyzed product of collagen. Gelatin is frequently applied in the food industry due to its excellent gelling and thickening properties. Gelatins are prone to degrade under irradiation as they produce free radicals from the tyrosine and phenylalanine moiety [12]. Prolyl-hydroxyproline and glycine are the major degradation products of gelatin. The gelatin-based film is commonly used in food packaging and has an adequate gas barrier and mechanical properties [13,14]. For added value utilization of biopolymer-based films, they are usually reinforced with functional fillers to enhance their physicochemical properties with additional features, such as antibacterial, antioxidant, and UV-blocking properties [15–27]. Among these functional materials, various nanomaterials attract attention because they have a solid reinforcing effect in improving physical properties and antibacterial properties.

In particular, to manufacture gelatin-based functional composite films, various filler materials, such as zinc oxide nanoparticles (ZnONP), silver nanoparticles (AgNP), copper



Citation: Roy, S.; Rhim, J.-W. Gelatin-Based Film Integrated with Copper Sulfide Nanoparticles for Active Packaging Applications. *Appl. Sci.* 2021, *11*, 6307. https://doi.org/ 10.3390/app11146307

Academic Editor: Adina Magdalena Musuc

Received: 2 June 2021 Accepted: 7 July 2021 Published: 8 July 2021

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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). nanoparticles (CuNP), titanium dioxide (TiO₂), nanochitin, melanin nanoparticles (MNP), montmorillonite (MMT), graphene oxide, nanoclay, corn oil, and curcumin, have been used [28–31]. Numerous studies have shown that the addition of nanofillers improved the physical (mechanical, thermal, and barrier) and functional properties of biopolymer films [32–36]. To this end, various metal or metal-oxide nanomaterials have been widely applied to provide additional functionality to the polymer film. However, few studies on the use of metal sulfide nanoparticles, such as copper sulfide nanoparticles (CuSNP), have been performed. CuSNPs are attracting substantial consideration today owing to their low toxicity, ability to absorb infrared radiation, and potential application in the biomedical field [33,35–38]. CuSNP was also recently used to make active packing films made of agar, carrageenan, alginate, and pullulan [38–41]. Their results showed that the incorporation of CuSNPs significantly increased the antibacterial, UV shielding, water vapor barrier, and tensile strength of these films.

Moreover, CuSNP and polyurethane have recently been used to make a light-induced shape-memory polymer, which can be applied for medical device and packaging applications [42]. CuSNP has various functional properties that are less toxic than other metal nanoparticles, making it a promising candidate as a functional nanofiller to produce active food packaging films. Therefore, we studied the effect of CuSNP as a protein gelatin-based film. The combination of gelatin and CuSNP can make excellent functional films given the excellent film properties of gelatin and the excellent properties (physical and functional) of CuSNP. So far, there have been no studies on the preparation of gelatin-based functional nanocomposite films integrated with CuSNP.

The main aim of the current work was to use gelatin as a polymer matrix and CuSNP as a reinforcing agent to create a multifunctional packaging film that controlled microbial protection and improved the physical properties of active packaging applications.

2. Materials and Methods

2.1. Materials

Gelatin (Type A, 200 Bloom) and corn starch were purchased from Gel Tec Co. Ltd. (Seoul, Korea). Glycerol, copper acetate, and thiourea were obtained from Daejung Chemicals & Metals Co., Ltd. (Siheung, Korea). CuSNP was prepared according to the method reported previously [40]. The corn starch stabilized CuSNP was fabricated with copper acetate and thiourea [40]. The structure of the CuSNP was detected using field emission transmission electron microscopy (JEM-2100F, JEOL, Ltd., Tokyo, Japan).

2.2. Fabrication of Gelatin/CuSNP Nanocomposite Films

The films were fabricated by a solution casting process [43]. First, CuSNP suspensions were prepared by adding various quantities of CuSNP (0.0, 0.5, 1.0, and 2.0 wt % by weight of polymer) to 150 mL DI water with strong agitation for 1 h, and then sonicated for 20 min and shear mixed for 10 min at 5000 rpm. Subsequently, as a plasticizer, 1.2 g of glycerol (30% by weight of polymer) and then 4 g of gelatin were gradually mixed at 80 °C for 20 min with continuous stirring at 500 rpm to prepare the film-forming solutions, cast on a Teflon film-coated glass plate and dried. The films were conditioned (25 °C and 50% relative humidity (RH)) for 48 h before further testing. All film specimens were fabricated in triplicate and designated Gelatin, Gel/CuS^{0.5}, Gel/CuS^{1.0}, and Gel/CuS^{2.0}, respectively, according to the content of CuSNP (Table 1).

Table 1. Composition of gelatin/CuSNP nanocomposite films.

Gelatin (g)	Glycerol (g)	CuSNP (mg)
4	1.2	0
4	1.2	20
4	1.2	40
4	1.2	80
	Gelatin (g) 4 4 4 4 4	Gelatin (g) Glycerol (g) 4 1.2 4 1.2 4 1.2 4 1.2 4 1.2 4 1.2 4 1.2

2.3. Film Characterization and Properties

2.3.1. Optical Properties

The surface color of the film sample was estimated using a Chroma meter (Konica Minolta, Tokyo CR-400, Japan) to measure Hunter color (*L*, *a*, *b* and ΔE) values [44].

The film's light absorbance (UV–visible and near IR, 200–1100 nm) for the UV-barrier property and transparency of the film transmittance at 280 (T_{280}) and 660 nm (T_{660}) were taken using a UV-vis spectrophotometer (Mecasys Optizen POP Series UV/Vis, Seoul, Korea) [44].

2.3.2. Surface Morphology and FTIR

The morphological examination of the prepared films' surface was performed using FESEM (FE-SEM, S-4800, Hitachi Co., Ltd., Matsuda, Japan) [44]. The films' FTIR spectra were recorded in an attenuated total reflectance-FTIR spectrophotometer (TENSOR 37 Spectrophotometer, Billerica, MA, USA), and all spectra were measured with 32 scans and 4 cm⁻¹ resolution. [43].

2.3.3. Thickness, Mechanical Properties, and Thermal Stability

The film thickness was measured using a QuantuMike IP 65 digital micrometer (Japan). For mechanical properties, an Instron Universal Testing Machine (Model 5565, Instron Engineering Corporation, Canton, MA, USA) was used (ASTM method D 882-88) [40].

Thermogravimetric analysis (TGA) was performed in the temperature range of 30–600 °C with a Hi-Res TGA 2950, TA Instrument thermogravimetric analyzer (New Castle, DE, USA) [44].

2.3.4. Water Vapor Permeability (WVP) and Water Contact Angle (WCA)

The WVP was measured according to the ASTM E96-95 standard method. In the WVP cup, distilled water (18 mL) was added, and then the test film (7.5×7.5 cm) was fixed on the top of the cup and sealed to prevent vapor leakage. The cup was kept in a humidity chamber ($25 \,^{\circ}$ C and 50% RH), and the alteration in the weight of the cup was determined. The WVP (g·m/m²·Pa·s) was calculated as per our earlier report [44].

The films' wettability was measured using a WCA analyzer (Phoneix 150, Surface Electro Optics Co., Ltd., Kunpo, Korea) by depositing a drop of water onto the film surface [39].

2.3.5. Antibacterial Activity

The nanocomposite films' antibacterial properties were tested using the colony count method [40]. The bacterial strain was grown overnight at 37 °C. The inoculum was diluted and shifted to 50 mL of culture broth with ~100 mg of films and incubated at 37 °C for 12 h at 110 rpm agitation. At different intervals, samples were removed and plated on agar plates after correct dilution to compute viable cell counts. Broth without film and with the control gelatin film was also checked for comparison.

2.3.6. Statistical Analysis

Analysis of variance (ANOVA) was applied to compare the mean differences between the samples, and the significance was determined (p < 0.05) by Duncan's multiple range test using a statistical analysis system using SPSS Inc. (Chicago, IL, USA).

3. Results and Discussion

3.1. Morphology of CuSNP

Due to the low stability of CuSNPs in aqueous media, corn starch was used as a stabilizing agent to prevent the aggregation of these particles and increase their dispersibility in aqueous solutions. The morphology of the CuSNP was observed using FETEM, as shown in Figure 1, and the particle size was analyzed using ImageJ. CuSNP nanoparticles had



Figure 1. TEM image of CuSNP.

3.2. Properties of the Nanocomposite Films

3.2.1. Optical Properties

The appearance of the neat gelatin and its nanocomposite films is shown in Figure 2a. The neat gelatin film is colorless and has high transparency, but the gelatin film with CuSNP added has a green color depending on the concentration of the nanofiller. The color properties of the films are presented in Table 2. When CuSNP was included in the gelatin film, the *L*- and *a*-values of the film were reduced, and the *b*-value increased, demonstrating that the brightness of the film was reduced, and the greenness and yellowness of the film improved. The total color difference (ΔE) also increased noticeably compared to the control film, mainly due to the green color of CuSNP. A similar color alteration was detected for the agar-based film to which CuSNP was added [40].



Figure 2. Appearance (a) and UV-vis transmittance spectra (b) of Gel/CuSNP films.

an irregular shape and size ranging from 2 to 10 nm with an average of 6.2 ± 1.7 nm, consistent with the previously described data of guar gum stabilized CuSNP [34].

Films	L	а	b	ΔE	T ₂₈₀ (%)	T ₆₆₀ (%)
Gelatin	91.1 ± 0.1 ^d	-0.7 ± 0.1 a	$6.6\pm0.2~^{a}$	2.3 ± 0.3 ^a	18.2 ± 0.1 ^d	89.5 ± 0.3 ^d
Gel/CuS ^{0.5}	83.7 ± 1.0 ^c	-1.3 ± 0.2 ^b	9.5 ± 0.6 ^b	10.0 ± 1.1 ^b	$11.0\pm0.9~^{\rm c}$	78.1 ± 0.5 ^c
Gel/CuS ^{1.0}	66.5 ± 3.0 ^b	-2.1 ± 0.3 c	$18.2\pm1.6~^{\rm c}$	$29.2\pm3.4~^{\rm c}$	3.9 ± 0.8 ^b	$61.3\pm1.8~^{\rm b}$
Gel/CuS ^{2.0}	55.7 ± 4.0 ^a	-1.35 ± 0.3 ^b	$19.1\pm0.7~^{ m c}$	39.3 ± 4.0 ^d	1.0 ± 0.1 a	39.5 ± 2.1 ^a

Table 2. Optical properties of gelatin/CuSNP films.

The matching superscript letters in each column indicate that they are not significantly dissimilar (p > 0.05) from Duncan's multiple range tests.

The UV-visible light transmittance spectra of the films are shown in Figure 2b. The control gelatin film presented high UV and visible light transmittance. In contrast, the transmittance of gelatin/CuSNP composite films reduced reliance on the CuSNP content due to the obstruction of the light passageway via light opaque nanoparticles. An increase in the UV blocking properties of gelatin/CuSNP films was primarily due to CuSNP's UV absorption capacity [40]. The UV-barrier and transparency properties of the film are also provided in Table 2. The control gelatin film was extremely transparent with some UV blocking properties with 89.5% of T_{660} and 18.2% of T_{280} . The control film's UV protection properties were due to the UV absorption ability of the aromatic amino acids of gelatin, such as tyrosine and phenylalanine [7]. The addition of CuSNP significantly reduced the T_{660} and T_{280} of the film depending on CuSNP concentration. As the concentration of CuSNP increased, the reduction in the transmittance for visible and ultraviolet light was different; namely, the T₆₆₀ decreased linearly with increasing CuSNP concentration (C) such that $T_{660} = -25.371C + 89.3$ (R² = 0.9929), while the T_{280} decreased exponentially such that $T_{280} = 19.535e^{-1.494C}$ (R² = 0.9901). In other words, the clarity of the film decreased linearly, while the UV-light blocking property of the film decreased exponentially with CuSNP concentration. These results imply that the UV-blocking phenomena of the film improved significantly with less sacrificing visibility of the film. At 2 wt % of CuSNP added gelatin film, ultraviolet rays were almost completely blocked. However, the transparency of the film was still high enough to see through the film with a T_{660} of 39.5%, which is a useful property in UV-barrier packaging applications. A similar conclusion of CuSNP on the optical properties of agar and alginate-based films has recently been described [40,44].

3.2.2. Morphology and FTIR

Figure 3 shows the FESEM surface and cross-section micrographs of gelatin-based films. The control gelatin film was integral and smooth, deprived of cracks or defects. The nanocomposite film with a low content of CuSNP formed a well-dispersed and homogeneous film without any aggregation. However, when a high amount of CuSNP (1.0 and 2.0 wt %) was added, the film showed an accumulation of nanoparticles. The cross-section image also showed good compatibility of nanofillers in the polymer matrix. The neat gelatin film has a relatively soft morphology, but with the addition of nanofillers, it became somewhat rough. Previously, an analogous accumulation of particles at higher CuSNP content was reported for agar/CuSNP and carrageenan/CuSNP nanocomposite film [40,41].



Figure 3. FESEM micrographs (surface and cross-section) of Gel/CuSNP films.

The FTIR spectra of the gelatin and gelatin/CuSNP films are presented in Figure 4a,b. Due to the absence of characteristic peaks in the range of 2000–2700 cm⁻¹, a break was added. The peak detected in all films at 3283 cm⁻¹ was due to the O-H stretching vibration of gelatin [45]. The peak around 2934 cm⁻¹ was owing to the C-H stretching vibrations of alkane groups in the gelatin polymer chain. The peaks at 1625 and 1542 cm⁻¹ were attributed to the carbonyl stretching amide I and the N-H stretching of amide-II of gelatin [46]. The peaks at 1451 and 1239 cm⁻¹ corresponded to the C-N and N-H stretching of gelatin, respectively [27]. A peak at 1030 cm⁻¹ was ascribed to the -OH group of glycerol. The gelatin/CuSNP composite film's peaks are similar to the gelatin film, apart from a slight variation in the peak magnitude. Overall, the addition of CuSNP did not alter the chemical structure of the film matrix. The slight changes in peak magnitude (3283, 1625, 1239, and 1030 cm⁻¹) were mainly owing to the weak interactions between CuSNP and gelatin, such as Van der Waals force [19].

3.2.3. Mechanical Properties

The thickness of the neat gelatin film was $51.8 \pm 0.9 \,\mu$ m, which slightly decreased when 0.5 wt % of CuSNP was added. It increased somewhat with a higher amount of CuSNP (1.0 and 2.0 wt %) (Table 3); however, the change was not statistically significantly (p > 0.05).



Figure 4. Structure of gelatin (a) and FTIR spectra (b) of Gel/CuSNP films.

Table 3. Mechanical properties, hydrophobicity, and water vapor permeability of control and gelatin/CuSNP films.

Films	Thickness (µm)	TS (MPa)	EB (%)	EM (GPa)	WCA (Deg.)	WVP (× 10 ^{−9} g·m/m ² ·Pa·s)
Gelatin Gel/CuS ^{0.5} Gel/CuS ^{1.0} Gel/CuS ^{2.0}	$51.8 \pm 0.9 \ ^{ab}$ $49.8 \pm 0.3 \ ^{a}$ $55.6 \pm 4.3 \ ^{b}$ $56.5 \pm 3.4 \ ^{b}$	$\begin{array}{c} 45.0 \pm 2.7 \ ^{a} \\ 58.1 \pm 2.4 \ ^{b} \\ 65.1 \pm 2.4 \ ^{c} \\ 63.4 \pm 3.8 \ ^{c} \end{array}$	$\begin{array}{c} 8.6 \pm 1.7 \ ^{\rm b} \\ 6.0 \pm 0.1 \ ^{\rm a} \\ 7.2 \pm 0.4 \ ^{\rm ab} \\ 6.7 \pm 0.2 \ ^{\rm a} \end{array}$	$\begin{array}{c} 1.5 \pm 0.04 \ ^{a} \\ 2.3 \pm 0.04 \ ^{b} \\ 2.3 \pm 0.12 \ ^{b} \\ 2.2 \pm 0.05 \ ^{b} \end{array}$	63.4 ± 0.8 ^a 63.2 ± 0.5 ^a 61.1 ± 1.4 ^a 61.4 ± 1.8 ^a	$\begin{array}{c} 2.26 \pm 0.37 \ ^{\rm b} \\ 1.98 \pm 0.03 \ ^{\rm ab} \\ 1.84 \pm 0.09 \ ^{\rm ab} \\ 1.64 \pm 0.14 \ ^{\rm a} \end{array}$

The matching superscript letters in each column indicate that they are not significantly dissimilar (p > 0.05) from Duncan's multiple range tests.

On the other hand, the addition of CuSNP significantly influenced the mechanical properties of the gelatin film (Table 3). The tensile strength (TS) of gelatin film was 45.0 ± 2.7 MPa, similar to the earlier reported data [40,41]. The TS of the gelatin film significantly increased to 58.1 ± 2.4 MPa when 0.5 wt % of CuSNP was included and further improved to 65.1 ± 2.4 MPa at 1.0 wt % of CuSNP, then slightly declined to 63.4 ± 3.8 MPa at 2.0 wt % of CuSNP. The reduced TS of the 2 wt % CuSNP-added film compared to the 1 wt % of CuSNP-added film was due to the accumulation of particles at the high content as perceived in the surface microstructure (Figure 3). Similar to the TS, the elastic modulus (EM) (stiffness) of the gelatin film was also noticeably increased, adding CuSNP.

On the contrary, the elongation at break (EB) (flexibility) of the gelatin film was reduced significantly (p < 0.05) by adding CuSNP; however, there was no significant difference in flexibility between the gelatin/CuSNP composite films. The improved strength and reduced flexibility of gelatin films by blending CuSNP are most likely owing to the increased molecular interaction between the nanofiller and polymer matrix at the interface, strengthening the nanocomposite and reducing the mobility of polymer chains. A similar result of CuSNP has been detected in other films, such as agar/CuSNP and carrageenan/CuSNP nanocomposite films [24]. Meanwhile, the mechanical properties of gelatin-based films seem to vary depending on the class of nanoparticles added. For example, the gelatin film's strength increased when a low concentration of TiO₂ was added [19,20], but the physical strength decreased when ZnONP and AgNP were added [17].

3.2.4. Thermostability

Thermogravimetric analysis (TGA) of the gelatin and gelatin/CuSNP films and its derivative (DTG) is shown in Figure 5. The first weight loss occurred at ~60–120 °C owing to the disappearance of physisorbed moisture. The subsequent decomposition appeared around 200 °C and touched a maximum of about 250 °C due to the degradation of glycerol. The third decomposition was due to the thermal degradation of the gelatin matrix, observed at 310 °C in the neat gelatin film and 310 and 323 °C in the Gel/CuS^{0.5} and gelatin/CuSNP^{2.0} films, respectively. The addition of a lower concentration of nanoparticles (0.5 wt %) did not change the gelatin degradation temperature. However, the addition of a high content of CuSNP (2.0 wt %) slightly increased the decomposition temperature of gelatin, which may be due to the good crosslinking interactivity of CuSNP with gelatin [47].



Figure 5. TGA and DTG thermograms of Gel/CuSNP films (in a nitrogen atmosphere and a heating rate of 5 °C/min).

In contrast to this result, it was reported that the thermal properties of the agarbased film were not significantly changed by the inclusion of CuSNP [40]. Conversely, the thermal stability of the gelatin film has been reported to be substantially increased by the addition of ZnONP and AgNP [17,19]. The final residues at 600 °C of the gelatin, gelatin/CuSNP^{0.5}, and gelatin/CuSNP^{2.0} nanocomposite films were 26.2, 28.3, and 29.9%, and the increase was presumably due to the content of heat-stable nanoparticles. The relatively high residual content of gelatin-based films is likely due to the non-flammable raw materials and impurities of the polymer [40].

3.2.5. WVP and WCA

The WVP and surface wettability (hydrophilicity or hydrophobicity) of the gelatin films are presented in Table 3. The WVP of the neat gelatin film was $(2.26 \pm 0.37) \times 10^{-9}$ g·m/m²·Pa·s and was significantly decreased by adding CuSNP depending on the CuSNP concentra-

tion, which decreaseed to $(1.64 \pm 0.14) \times 10^{-9} \text{ g·m/m}^2 \cdot \text{Pa·s}$ (reduction of 27%) when 2 wt % of CuSNP was added. The improved water vapor barrier (or reduced WVP) of the gelatin/CuSNP films was most likely due to forming a tortuous path for water vapor dissemination by the homogeneously dispersed nanoparticles in the polymer [40]. A similar result was found in the agar film incorporated with a low concentration of CuSNP [40]. Meanwhile, it was reported that the effect of WVP on the gelatin-based film varied depending on the nanoparticles used. For example, AgNP and TiO₂ increased, but ZnONP reduced the water vapor barrier property of gelatin film [17,19,24]. This difference seems to be due to the difference in the wettability of these nanoparticles.

The WCA of the neat gelatin film was $63.4 \pm 3.5^{\circ}$, representing that it has a wettable surface [48]. Though the change was not statistically substantial (p > 0.05), the addition of CuSNP slightly reduced the WCA of the gelatin film. Previously, it has been reported that the addition of CuSNP, AgNP, and ZnONP increases the surface hydrophobicity of agar and gelatin films [19,20]. The wettability of the composite films can be influenced by the type and compatibility of nanofillers and biopolymers.

3.3. Antimicrobial Activity

The gelatin/CuSNP nanocomposite films' antimicrobial activity is shown in Figure 6. As anticipated, the gelatin film had no antibacterial action. Conversely, the CuSNPintegrated nanocomposite film drastically decreased the cell viability of E. coli but did not significantly affect the growth of *L. monocytogenes*. The antimicrobial effect of CuSNP varied with concentration. A low concentration (0.5 wt %) of CuSNP was not sufficient to inhibit microbial growth. However, at a high concentration (2.0 wt %), it exhibited solid antibacterial activity enough to entirely impede the growth of *E. coli* after 9 h of contact. These results clearly showed that the gelatin/CuSNP film showed more vigorous antibacterial activity against Gram-negative compared with Gram-positive bacteria, presumably owing to the bacterial cell wall structure, which consists of a thick cell wall composed of several layers of peptidoglycans. In addition, CuSNP has a lower antimicrobial activity than CuNP due to the sulfidation process, but CuSNP is more advantageous because it has much less cytotoxicity than CuNP [40,49,50]. Similar antimicrobial activity behavior has been reported for the agar films integrated with CuSNP [40]. The antimicrobial action of CuSNP has yet to be discovered. However, copper ions are assumed to be released in contact with water and interact with negatively charged membrane proteins, destroying the cell wall and causing cell death [51]. Another probable cause is the interaction between bacteria and nanoparticles that activate reactive oxygen species in the cell, causing oxidative harm to the antioxidant defenses and damaging the cell membrane, thus directing cell death [51].



Figure 6. Antimicrobial activity of Gel/CuSNP films against (a) E. coli and (b) L. monocytogenes.

4. Conclusions

Gelatin-based functional films incorporated with CuSNP were prepared for active food packaging use. The inclusion of CuSNP improved the mechanical properties of the gelatin film by more than 40% and amplified the water vapor barrier properties by more than 25%. Moreover, the addition of CuSNP improved the UV-shielding effect of the gelatin film by 90% or more. CuSNP was well dispersed between gelatin polymers to make a composite film with high compatibility with gelatin. However, FTIR results displayed that the addition of CuSNP did not modify the chemical structure of the gelatin film. The thermal stability of the film was slightly improved, which may have been due to the crosslinking interaction between CuSNP and gelatin. The gelatin/CuSNP films also presented potent antimicrobial activity against foodborne pathogenic bacteria, *E. coli*, and some action against *L. monocytogenes*. The functional gelatin/CuSNP films with antibacterial and UV-blocking properties are expected to be useful in active food packaging applications.

Author Contributions: Conceptualization, investigation, data curation, and writing—original draft preparation, S.R.; resources, review and editing, project administration, and supervision, J.-W.R. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2019R1A2C2084221).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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