

Development of Chitosan-TiO₂ Nanocomposite for Packaging Film and its Ability to Inactive Staphylococcus Aureus

by Dhena Ria Barleany

Submission date: 04-Apr-2023 06:51PM (UTC+0700)

Submission ID: 2055565988

File name: OJC_Vol35_No3_p_1132-1137.pdf (1.04M)

Word count: 3348

Character count: 18294



Development of Chitosan-TiO₂ Nanocomposite for Packaging Film and its Ability to Inactivate *Staphylococcus aureus*

INDAR KUSTININGSIH^{1,3*}, ASEP RIDWAN², DEVI ABRIYANI¹, MUHAMMAD SYAIRAZY¹,
TEGUH KURNIAWAN¹ and DHENA RIA BARLEANY¹

¹¹
¹Chemical Engineering Department, University of Sultan Ageng Tirtayasa, Serang, 42118, Indonesia.

³⁶
²Industrial Engineering Department, University of Sultan Ageng Tirtayasa, Serang, 42118, Indonesia.

¹⁵
³Indonesia Center of Excellence for Food Security (I-CEFORY) University of Sultan Ageng Tirtayasa, 42118, Indonesia.

*Corresponding author E-mail: indar.kustiningsih@untirta.ac.id

<http://dx.doi.org/10.13005/ojc/350329>

(Received: March 14, 2019; Accepted: May 14, 2019)

ABSTRACT

The aim of present study is to synthesize chitosan-TiO₂ nanocomposite for packaging and its ability to inactivate *Staphylococcus aureus*. TiO₂ Degussa P25 were dispersed in chitosan matrix in order to produce film-forming solution. The samples were characterized by SEM, FTIR, tensile strength, antibacterial and biodegradable test. The tensile strength test results showed that CS-0.1Ti was the best nanocomposite compared to other variations of TiO₂ addition. Whereas for the test of *S. aureus* bacteria showed that no more *S. aureus* bacteria were found in chitosan-TiO₂ nanocomposite after incubation for 24 hours. It indicated more effective use of nanocomposites by adding TiO₂ compared to without adding TiO₂. For biodegradation analysis, the addition of TiO₂ slows the nanocomposites degradation process, which is indicated by the less mass loss that occurs in CS-0.5 Ti nanocomposite.

Keywords: TiO₂, Biocomposite, Biodegradation, Chitosan(CS), *Staphylococcus aureus*, Food Packaging.

INTRODUCTION

Plastic is widely used as food packaging due to elastic, lightweight, not easily broken, transparent, waterproof and easy to carry. However, plastics made from petroleum has led to serious ecological problems due to their non biodegradability^{1,2}. In the recent years there has been an increasing interest in developing biodegradable plastics from renewable resources.

One of renewable plastic is bioplastic

¹⁴
because the compounds inside are derived from plants like cellulose, lignin, starch and animal like casein, protein, lipid and chitosan³. Chitosan represents biodegradable^{4,5} and biocompatible cationic polysaccharide with premium film forming ability, mechanical strength, flexibility and also a non toxic^{4,6}. Unfortunately, bioplastic from chitosan has a disadvantage that is its lower mechanical properties compared to fossil based plastic. ³⁰ modification in the form of nanocomposite can be a good solution to improve the mechanical properties of chitosan-based bioplastic⁸.



The synthesis of nanocomposite was carried out by incorporating nanofillers such as silica, clay, and titanium dioxide (CS) chitosan which made it possible not only to improve mechanical and barrier properties but also to provide other functions in food packaging applications^{9,10}. TiO₂ is a photocatalyst and has been widely utilized in many applications such as hydrogen generation, water purification, and decomposition of pollutants air purification and also in medical applications self cleaning and self-disinfecting materials¹¹⁻¹⁵. TiO₂ nanoparticle has been used as an effective antibacterial agent because its widespread availability, broad-spectrum antibiosis and low cost. It has excellent physico-chemical properties, physical and chemical stability, good dispersing properties, strong oxidizing power, fast electron transfer rate and good biocompatibility^{16,17}.

The migration of the active compounds into the food stuff is the major disadvantage of antimicrobial package. This is especially undesirable, when the general trend is to limit the presence of additives in processed food. Therefore, chitosan and TiO₂ are ideal candidates for food packaging due to nontoxicity. Furthermore there are few reports on the synergistic effect between TiO₂ nanoparticles and chitosan regarding its biodegradability and antibacterial activity especially on *Staphylococcus aureus*. The aim of this study was to prepare chitosan-TiO₂ nanocomposite and to characterize these films for their structure, morphology, mechanical properties and antibacterial activity.

METHODS AND MATERIALS

Synthesis of Chitosan-TiO₂ nanocomposite

1 g of chitosan (DD 85-89% Biochitosan) was added to 1% (v/v) 10 mL glacial acetic acid. The mixture was stirring using an overhead stirrer for 3 h at room temperature. Then, the solution was homogenized for 30 minutes. Furthermore, TiO₂ nanoparticles were added with variations in the composition (0 g, 0.1 g, 0.2 g, 0.5 g, and 1 g). The solution was stirred using an overhead stirrer for 4 h at room temperature and then the solution was homogenized for 1 hour. The solution was poured into a glass plate and dried at a temperature of 80°C. After obtaining bioplastic, SEM characterization, FTIR analysis, mechanical strength test, antibacterial activity test and biodegradable plastic analysis were carried out.

Biodegradability analysis

Biodegradation analysis was carried out by the method of sample burial in a mixture of soil and compost. The simplest quantitative method to determine the biodegradation of a polymer is by measuring mass loss. Mass loss measurement was done by weighing the polymer mass before and after the biodegradation process for a certain time interval. In this study, six plastic samples were used with dimensions of 4 x 4 cm and weighed regularly 1 week for 2 months.

Antimicrobial activity

Staphylococcus aureus was first rejuvenated then the NA media and nanocomposite with predetermined variations were sterilized. Serial dilution of *Staphylococcus aureus* was performed by using of 10³ and 10⁴ dissolution. After that, the media and bacteria were poured on the petri dish. The process was followed by incubation for 24 h in a dark room with UV irradiation. After the incubation, the number of bacterial colonies were calculated by CFU method (colony forming units).

RESULTS AND DISCUSSION

Fourier-transform infrared spectroscopy (FTIR) analysis

FTIR is a useful technique for the detection of chemical bonds in the materials. The FTIR spectra of chitosan and chitosan-TiO₂ nanocomposites are shown in Fig. 1. It shows the similarity of the resulting spectrum.

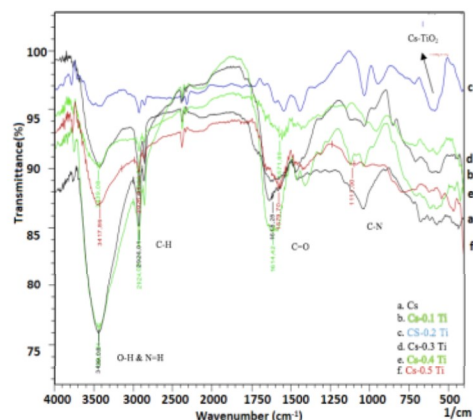


Fig. 1. FTIR pattern of chitosan bioplastic and chitosan-TiO₂ nanocomposites

Figure 1 shows the similarity of the resulting spectrum. This similarity shows that most functional groups owned by CS are also owned by CS-TiO₂ bioplastics. If two ingredients are mixed (CS and TiO₂) a physical mixture can be formed and even chemical interactions can occur which are characterized by characteristic changes at the peak of the spectrum of bioplastic analysis results on FTIR. Compared to pure chitosan (CS), hydroxyl bonds, amino and amide groups experience changes in the CS-Ti spectrum. It indicated there are interaction between CS and TiO₂⁴. The interaction of CS and TiO₂ is characterized by the formation of CS-TiO₂ bonds in the wavelength range of 450-950 cm⁻¹.

Figure 1 shows that CS spectrum had OH and NH functional groups which absorption peaks at wavelengths 3419.79 cm⁻¹, CH groups at wavelengths 2924.09 cm⁻¹, groups C=O at wavelengths 1616.35 cm⁻¹, CO group at wavelength 1257.59 cm⁻¹, and CN group at wavelength 1039.63 cm⁻¹. While the CS-Ti spectrum was a combination of the peaks of chitosan and TiO₂ groups. It indicated that there was a cross-linking process between chitosan and TiO₂. The OH functional group overlaps with NH at a wavelength of 3439.08 cm⁻¹, the R-NH-R group at a wavelength of 1600.92 cm⁻¹, the deformation group OH at a wavelength of 1442.75 cm⁻¹, the deformation group CS-TiO₂ at a wavelength of 947.05 cm⁻¹.

Scanning electron microscopy (SEM) Characterization

In an attempt to study microstructural changes in the CS-Ti nanocomposites, SEM was conducted to visualize the surface topography for different samples. The SEM images of chitosan bioplastic (CS), nanocomposite chitosan-0.1 g TiO₂ (CS-0.1Ti), chitosan-0.2 g TiO₂ (CS-0.2 Ti), chitosan-0.3 g TiO₂ (CS-0.3 Ti), chitosan-0.5 g TiO₂ (CS-0.4 Ti) and chitosan-0.5 g TiO₂ (CS-0.5 Ti) can be seen at Fig. 2. Addition of TiO₂ on bioplastic strongly influenced the morphology of the CS-Ti nanocomposites as evidenced in Figure 2.

Figure 2(a) shows bioplastics without the addition of TiO₂ have homogeneous, smooth and clean morphology without granules. It is different to the SEM images of CS-Ti nanocomposites. Fig. 2(b-e) indicated that the addition of TiO₂ created morphology of bioplastic had an irregular granule distribution which shows the distribution of TiO₂ in the matrix. SEM images of nanocomposites CS-Ti shows irregular shapes of TiO₂ distribution in the matrix.

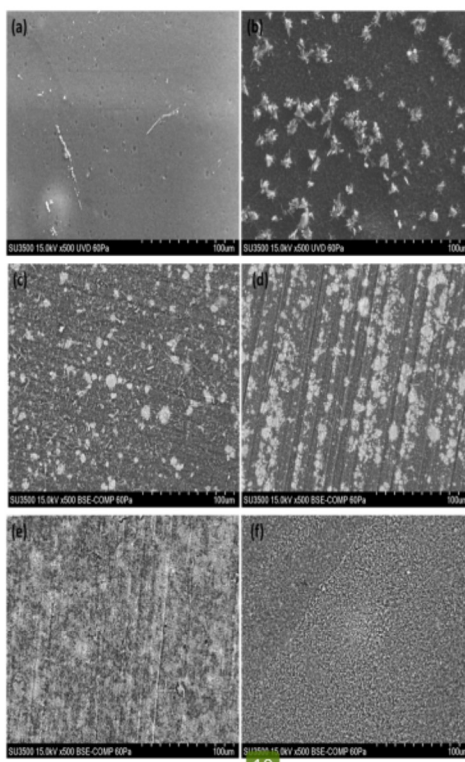


Fig. 2. SEM images of (a) CS (b) CS-0.1 Ti (c) CS-0.2 Ti (d) CS-0.3 Ti (e) CS-0.4 Ti (f) CS-0.5 Ti

In Fig. 2(b) to Fig. 2(f) show that the surface of the nanocomposite had a homogeneous, less smooth surface, granules and looks less than perfect. The irregularity of the nanocomposite surface was due to the addition of TiO₂ in the chitosan matrix. It indicated that the distribution of granules in the matrix increases with the addition of TiO₂. It can be seen in Fig. 2(f) that CS-0.5Ti had denser granule distribution than the other nanocomposites with different TiO₂ compositions. A study reported that the homogeneous dispersion in matrix polymers is one of the most important factors in creates a good composite performance¹⁸.

Tensile Strength and Elongation

The effect of TiO₂ addition on nanocomposites to the value of tensile strength (TS) and elongation (E) can be seen at Table 1.

Table 1 shows the addition of TiO₂ on nanocomposites lead to the decreasing value of TS

and E. The results showed the highest TS and E at the addition of 0.1 g TiO₂ (CS-0.1 Ti). This decrease was due to the presence of granules in the matrix which caused the matrix to be less homogeneous, whereas to get a large TS, a homogeneous molecular structure was needed. The higher the addition of TiO₂ caused the composition of chitosan which is originally homogeneous to change its molecular structure to become irregular.

²⁸
Table 1: The effect of TiO₂ addition on nanocomposites to the value of tensile strength and elongation

No	Mixture Tensile	Strength (MPa)	Error of TS	Elongation (%)	Error of elongation
1	CS	63.86	±0.001	4.66	±0.0001
2	CS-0.1Ti	12.35	±0.001	2	±0.0001
3	CS-0.2Ti	10.21	±0.001	1.66	±0.0001
4	CS-0.3Ti	7.85	±0.001	0.59	±0.0001
5	CS-0.4Ti	4.97	±0.001	0.57	±0.0001
6	CS-0.5Ti	0.24	±0.001	0.12	±0.0001

Biodegradable analysis

Samples (4 x 4 cm) were tested for biodegradation by measuring their weight every week. A decrease in mass from nanocomposites can be seen in Table 2 and Figure 3.

³¹
Table 2. Biodegradable analysis of CS-Ti nanocomposites

Sample	Initial mass (g)	Final mass (g)	Mass. loss (%)
CS	0.05	0.02	60
CS-0.1 Ti	0.1	0.05	50
CS-0.2 Ti	0.1	0.05	50
CS-0.3 Ti	0.14	0.09	35.71
CS-0.4 Ti	0.15	0.10	33.33
CS-0.5 Ti	0.17	0.12	29.41

Table 2 shows the decreasing mass of bioplastics and loss of mass after 2 months of hoarding process. Visually, the results of nanocomposites hoarded have changed, hoarded samples are brownish and appear to shrink even appear to be torn for sample without the addition of TiO₂. This is clearly different from the initial conditions of bioplastics that are still smooth clear for pure and white chitosan when TiO₂ is added. The level of plastic biodegradation can be seen from the percentage mass loss of bioplastic material after being hoarded for a certain period.

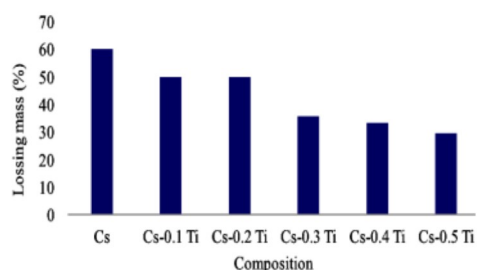


Fig. 3. Biodegradable analysis of CS-Ti nanocomposites

Figure 3 shows the addition of TiO₂ affected the degradation process even though there was still a process of reduced mass. The decrease in mass tends to be long and slightly in line with the increasing number of TiO₂ compositions added. This results in a smaller percentage of mass loss and shows that cs-Ti nanocomposites took a long time to be completely degraded. It is due to the anti bacterial properties of CS-Ti which causes the decomposition process of the nanocomposites to be inhibited¹⁹.

Antimicrobial activity of CS-Ti nanocomposites

In a series of experiments, the antibacterial activities of chitosan and Ti-CS nanocomposites were assessed using the *S. aureus* microbiological test system as described earlier. The results of this work can be seen at Table 3.

Table 3: Antimicrobial activity of CS-Ti nanocomposites

Sample	UV Radiation	Survival Ratio (%)	Without UV Radiation	
	CFU (mL ⁻¹)		CFU (mL ⁻¹)	Survival Ratio (%)
Control	2.9 x 10 ⁵	100	2.9 x 10 ⁵	100
CS	2 x 10 ⁴	6.90	2 x 10 ⁴	3.45
TiO ₂	0	0	0	0
CS-0.1Ti	0	0	0	0
CS-0.2Ti	0	0	0	0
CS-0.3Ti	0	0	0	0
CS-0.4Ti	0	0	0	0
CS-0.5Ti	0	0	0	0

Table 3 shows the ability of CS bioplastic to inhibit bacterial but it could not reduce *S. aureus* bacteria to zero. One of the antimicrobial properties of CS is a positively charged amino group that interacts with a negatively charged microbial cell membrane, which causes the destruction of proteins and intracellular constituents of microorganisms. CS has been shown to be more effective against Gram-negative bacteria than Gram-positive bacteria¹⁸.

Table 3 shows the presence of TiO₂ in Ti-CS composite increasing the ability to kill bacteria to zero. The survival of *S. aureus* bacteria was significantly impaired due to the addition of TiO₂ nanoparticles. CFU calculations performed after 24 h of incubation under UV irradiation or without UV irradiation have shown similar results, namely successfully killing all *S. aureus* bacteria added. This study have in common results with the previous experiments conducted by other researchers^{18, 20}.

The illuminated TiO₂ capable of killing bacteria entirely is because CS-Ti positively charged interacts with membranes of charged lipid bacteria negatively affecting cell permeability, blocking cell growth and survival thus causing bacteria death. Biological organisms are killed by various reactive species such as hydroxyl radicals, hydrogen peroxide, or superoxide which are produced in the photocatalytic process of TiO₂ nanoparticles. When a TiO₂ nanoparticle is irradiated with UV it will experience the generation of electrons in the conduction band and form a hole (h⁺) in the valence band. Interaction of holes with water molecules will produce hydroxyl radicals •OH. Radical •OH is an oxidizing agent from organic compounds. From this photocatalysis process, reactive radical species •OH and •O₂ can be released which are strong oxidative substances to degrade organic compounds from the composition of bacterial cell walls²¹. When there was no UV irradiation but TiO₂ addition is carried out, it shows that TiO₂ nanoparticles can kill bacteria

entirely, but it is not clear how the mechanism is. It can be assumed that the mechanism that occurs is the same as Ag which both have antibacterial activity because Ag has a positive charge that can interact with a negative charge on bacteria. So that without UV irradiation, TiO₂ can also act as an antibacterial.

CONCLUSION

Bioplastics can be synthesized with a mixture of chitosan and TiO₂ with the interaction between chitosan and TiO₂ nanoparticles as seen in the FTIR test results. The surface morphology of chitosan-TiO₂ nanocomposites showed the distribution of granules which indicate that 25 nm TiO₂ nanoparticles were scattered in the matrix. Tensile strength and elongation decrease with the addition of TiO₂ nanoparticles, CS-0.1Ti was the best result compared to other variations of TiO₂ addition. CS-Ti nanocomposites has been proven to effectively kill *Staphylococcus aureus* bacteria entirely with or without UV irradiation. Bioplastics with the addition of TiO₂ could inhibited biodegradable process.

ACKNOWLEDGEMENT

The authors would like to thank to the Islamic Development Bank for financial assistance under IDB-UNTIRTA Research Grant project No. 593/UN43.9/PL/2018

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

- Gautam, R.B. and Kumar, S., Development in nano-particle embedded biodegradable polymers for packing and storage of fruits and vegetables. *Journal of food Research and Technology*, **2015**, 3(2), 43-61.
- Goudarzi, V., Shahabi-Ghahfarrokhi, I., Photo-producible and photo-degradable starch/TiO₂ bionanocomposite as a food packaging material: Development and characterization. *International Journal of Biological Macromolecules*, **2018**, 106, 661-669.
- Avérous, L., Biodegradable Multiphase Systems Based on Plasticized Starch: a review. *Journal of Macromolecular Science-Part C Polymer Reviews*, **2004**, C4(3), 231-274.
- Haldorai, Y and Shim J-J. Novel Chitosan-TiO₂ Nanohybrid: Preparation, Characterization, Antibacterial, and Photocatalytic Properties. *Polymer Composites*, **2014**, 35(2), 327-333.
- Mazin C., Thanshif, A., Anandapadmanabhan, Ashfaq, Mujeeb, A., dan Lobo, A. G. Study on the Effect of Nano TiO₂ on Mechanical Properties of Chitosan. *IOSR Journal of Mechanical and Civil Engineering*, **2015**, 12 (3 Ver. I), 48-54.
- Ostafinska, A., Mikesová, J., Krejčíková, S., Nevořalová, M., Sturcová, A., Zhigunov, A., Micháľková, D., Slouf, M. Thermoplastic starch composites with TiO₂ particles: Preparation, morphology, rheology and mechanical properties. *International Journal of Biological Macromolecules*, **2017**, 101, 273-282.

7. Mallakpour, S. and Madani, M. Effect of Functionalized TiO₂ on Mechanical, Thermal and Swelling Properties of Chitosan-Based Nanocomposite Films. *Polymer-Plastics Technology and Engineering.*, **2015**, *54*(10), 1035-1042.
8. Othman, S. H. Bio-nanocomposite Materials for Food Packaging Applications: Types of Biopolymer and Nano-sized Filler. *Agriculture and Agricultural Science Procedia.*, **2014**, *2*, 296 – 303.
9. Azeredo, H.M.C.D., Nanocomposites for Food Packaging Applications. *Food Research International.*, **2009**, *42*, 1240-1253.
10. Azeredo, H.M.C.D., Mattoso, L.H.C. and McHugh, T.H., Nanocomposites in Food Packaging – A Review, in "Advances in Diverse Industrial Applications of Nanocomposites". In: Reddy, B. (Ed.), InTech. Available from: <http://www.intechopen.com/books/advances-in-diverse-industrial-applications-of-nanocomposites/nanocomposites-in-food-packaging-a-review>.
11. Kustiningsih I, Slamet, Purwanto WW, Synthesis of Titania Nanotubes and Titania Nanowires by Combination Sonication hydrothermal Treatment and their Photocatalytic Activity for Hydrogen Production. *International Journal of Technology.*, **2014**, *5*, 133-141.
12. Ismail, S., Lockman, Z., Kian, T.W., Formation and photoelectrochemical properties of TiO₂ nanotubes arrays in fluowrinatedorganic electrolyte, *Journal of Mechanical Engineering and Science.*, **2017**, *11*, 3129-3136.
13. Kustiningsih, I., Sutinah, Stefitizky, M., Slamet, Purwanto, W.W., Optimization of TiO₂ nanowires synthesis using hydrothermal method for hydrogen production. *Journal of Mechanical Engineering and sciences.*, **2018**, *12*(3), 3876-3887.
14. Alexander, F., AlMheiri, M., Dahal, P., Abed, J., Rajput, N.S., Aubry, C., Viegas, J., Jouiad, M., Water splitting TiO₂ composite material based on black silicon as an efficient photocatalyst. *Solar Energy Materials and Solar Celss.*, **2018**, *180*, 236-242.
15. Sikander, U., Sufian, S., KuShaari, K., Chong, F.K., Effects of catalytic bed position oh hydrogen production by methane decomposition. *Journal of Mechanical Engineering and Science.*, **2018**, *12*, 3313-3320.
16. Li, B., Zhang, Y., Yang, Y., Qiu, W., Wang, X., Liu, B., Wang, Y., Sun, G., Synthesis, characterization, and antibacterial activity of chitosan/TiO₂ nanocomposite against *Xanthomonas oryzae* pv. *oryza*. *Carbohydrate Polymers.*, **2016**, *152*, 825-831.
17. Li, Y., Zhang, W., Niu, J. F., & Chen, Y. S. Mechanism of photogenerated reactive oxygen species and correlation with the antibacterial properties of engineered metal-oxide nanoparticles. *ACS Nano.*, **2012**, *6*, 5164–5173.
18. Visurraga, J. D., Meléndrez, M. F., García, A., Paulraj, M. & Cárdenas, G. Semitransparent Chitosan-TiO₂ Nanotubes Composite Film for Food Package Applications. *Journal of Applied Polymer Science.*, **2010**, *116*, 3503-3515.
19. Matsunaga, T., Tomoda, R., Nakajima, T., Wake, H. Photo-electrochemical Sterilization of Microbial Cells By Semiconductor Powders. *FEMS Mikrobiol Lett.*, **1985**, *29*(1-2), 211-214.
20. Tsuang, Y.H., Sun, J.S., Huang, Y.C., Lu, C.H., Chang, W.H.S. and Wang, C.C. Studies of Photokilling of Bacteria Using Titanium Dioxide Nanoparticles. *Artif Organs.*, **2008**, *32*(2).
21. Gumiero, M., Donatella P., Andrea P., Alessandro S., Lucilla L., Giuseppe C. and Rosanna T. Effect of TiO₂ Photocatalytic Activity in a HDPE-based Food Packaging on the Structural and Microbiological Stability of a Short-ripened Cheese. *Food Chemistry.*, **2013**, *138*(2-3), 1633.

Development of Chitosan-TiO₂ Nanocomposite for Packaging Film and its Ability to Inactive Staphylococcus Aureus

ORIGINALITY REPORT

20%

SIMILARITY INDEX

10%

INTERNET SOURCES

16%

PUBLICATIONS

4%

STUDENT PAPERS

PRIMARY SOURCES

- | | | |
|---|--|----|
| 1 | Submitted to Chulalongkorn University
Student Paper | 1% |
| 2 | www.mdpi.com
Internet Source | 1% |
| 3 | eprints.undip.ac.id
Internet Source | 1% |
| 4 | James S. Paik. "Antimicrobial activity of UV-irradiated nylon film for packaging applications", Packaging Technology and Science, 07/1998
Publication | 1% |
| 5 | flas.kps.ku.ac.th
Internet Source | 1% |
| 6 | Bin Li, Yang Zhang, Yingzi Yang, Wen Qiu, Xiaoxuan Wang, Baoping Liu, Yanli Wang, Guochang Sun. "Synthesis, characterization, and antibacterial activity of chitosan/TiO ₂ nanocomposite against Xanthomonas oryzae pv. oryzae", Carbohydrate Polymers, 2016
Publication | 1% |

7 M. Ratova, A. Mills. "Antibacterial titania-based photocatalytic extruded plastic films", Journal of Photochemistry and Photobiology A: Chemistry, 2015

Publication

1 %

8 Mohsen Zolfi, Faramarz Khodaiyan, Mohammad Mousavi, Maryam Hashemi. "Development and characterization of the kefiran-whey protein isolate-TiO₂ nanocomposite films", International Journal of Biological Macromolecules, 2014

Publication

1 %

9 Arief Setyanto, Kusrini Kusrini, Gardyas Bidari Adninda, Renindya Kartikakirana et al. "Ecological Impact Assessment Framework for areas affected by Natural Disasters", International Conference on Content-based Multimedia Indexing, 2022

Publication

1 %

10 Industrial Lubrication and Tribology, Volume 62, Issue 5 (2010-08-21)

Publication

1 %

11 Iskari Ngadiarti, Fahrul Nurkolis, Matthew Nathaniel Handoko, Fachruddin Perdana et al. "Anti-aging potential of cookies from sea grapes in mice fed on cholesterol- and fat-enriched diet: in vitro with in vivo study", Heliyon, 2022

1 %

12

www.tandfonline.com

Internet Source

1 %

13

Chairul Amni, Ismet, Sri Aprilia, Mariana. "Addition of Serbitol in Biodegradable Plastic Cateristics from Janeng", Journal of Physics: Conference Series, 2019

Publication

1 %

14

M H S Ginting, R Hasibuan, M Lubis, D S Tanjung, N Iqbal. "Effect of Hydrochloric Acid Concentration as Chitosan Solvent on Mechanical Properties of Bioplastics from Durian Seed Starch (*Durio Zibethinus*) with Filler Chitosan and Plasticizer Sorbitol", IOP Conference Series: Materials Science and Engineering, 2017

Publication

1 %

15

orbi.uliege.be

Internet Source

1 %

16

pubs.rsc.org

Internet Source

1 %

17

A. Ostafińska, J. Mikešová, S. Krejčíková, M. Nevoralová, A. Šturcová, A. Zhigunov, D. Michálková, M. Šlouf. "Thermoplastic starch composites with TiO₂ particles: Preparation, morphology, rheology and mechanical

<1 %

properties", International Journal of Biological Macromolecules, 2017

Publication

18

Indar Kustiningsih, Cecep Saripudin, Siti Suwansih, Denni Kartika Sari, Jayanudin, Slamet. " Photocatalytic Degradation of Organic Waste in Visible light using TiO Nanotubes Array ", IOP Conference Series: Materials Science and Engineering, 2020

Publication

<1 %

19

J. Theron, J. A. Walker, T. E. Cloete. "Nanotechnology and Water Treatment: Applications and Emerging Opportunities", Critical Reviews in Microbiology, 2008

Publication

<1 %

20

Clothilde Le Guen, Candice Dussouillez, Antoine Kichler, Delphine Chan-Seng. "Insertion of hydrophobic spacers on dodecalysines as potential transfection enhancers", European Polymer Journal, 2021

Publication

<1 %

21

Tahani M. Almutairi, Nadjat Rezki, Mohamed Reda Aouad, Mohamed Hagar et al. "Exploring the Antiparasitic Activity of -1,3,4-Thiadiazoles against -Infected Mice", Molecules

Internet Source

<1 %

22

cyberleninka.org

<1 %

23

S. Sajeesh, C. Vauthier, C. Gueutin, G. Ponchel, Chandra P. Sharma. "Thiol functionalized polymethacrylic acid-based hydrogel microparticles for oral insulin delivery", Acta Biomaterialia, 2010

Publication

<1 %

24

Yage Xing, Xuanlin Li, Xunlian Guo, Wenxiu Li, Jianwen Chen, Qian Liu, Qinglian Xu, Qin Wang, Hua Yang, Yuru Shui, Xiufang Bi. "Effects of Different TiO₂ Nanoparticles Concentrations on the Physical and Antibacterial Activities of Chitosan-Based Coating Film", Nanomaterials, 2020

Publication

<1 %

25

[dokumen.pub](#)

Internet Source

<1 %

26

[link.springer.com](#)

Internet Source

<1 %

27

Ebise Getacho Bacha. "Response Surface Methodology Modeling, Experimental Validation, and Optimization of Acid Hydrolysis Process Parameters for Nanocellulose Extraction", South African Journal of Chemical Engineering, 2022

Publication

<1 %

- 28 Nasim Fathi, Hadi Almasi, Mir Khalil Pirouzifard. "Sesame protein isolate based bionanocomposite films incorporated with TiO₂ nanoparticles: Study on morphological, physical and photocatalytic properties", *Polymer Testing*, 2019
Publication <1 %
-
- 29 jmes.ump.edu.my
Internet Source <1 %
-
- 30 scholarworks.wmich.edu
Internet Source <1 %
-
- 31 www.ideals.illinois.edu
Internet Source <1 %
-
- 32 "Nanoclay Reinforced Polymer Composites", Springer Science and Business Media LLC, 2016
Publication <1 %
-
- 33 Ahmed A. Tayel, Noha M. Sorour, Ashraf F. El-Baz, Wael F. El-Tras. "Nanometals appraisal in food preservation and food-related activities", Elsevier BV, 2017
Publication <1 %
-
- 34 Glenn Magerman, Zuzanna Studnicka, Jan Van Hove. "Distance and Border Effects in International Trade: A Comparison of Estimation Methods", *Economics: The Open-Access, Open-Assessment E-Journal*, 2016 <1 %

35

Lei Wang, Xiaodong Liu, Peng Qi, Jun Sun, Shengling Jiang, Hongfei Li, Xiaoyu Gu, Sheng Zhang. "Enhancing the thermostability, UV shielding and antimicrobial activity of transparent chitosan film by carbon quantum dots containing N/P", Carbohydrate Polymers, 2022

Publication

<1 %

36

D E Intari, W Fathonah, B Saputro. "Performance of asphalt concrete mixture (AC-WC) using asphalt added with the waste of rice husk ash", IOP Conference Series: Materials Science and Engineering, 2019

Publication

<1 %

37

Othman, Siti Hajar. "Bio-nanocomposite Materials for Food Packaging Applications: Types of Biopolymer and Nano-sized Filler", Agriculture and Agricultural Science Procedia, 2014.

Publication

<1 %

Exclude quotes On

Exclude matches Off

Exclude bibliography On

Development of Chitosan-TiO₂ Nanocomposite for Packaging Film and its Ability to Inactive Staphylococcus Aureus

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6
