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BIODEGRADABILITY OF NANOCOMPOSITE MADE FROM PVA, ZnO NANOPARTICLES AND STEARIC ACID

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ABSTRACT

Nanocomposite film has been developed from PVA polymer added with ZnO nanoparticle and stearic acid to enhance its performance. Preparation of nanocomposite film was using the optimum film formulation with ZnO nanoparticle and Stearic acid composition 3.4% ($^{w}/_{w}$ PVA) and 6.6% ($^{w}/_{w}$ PVA), respectively. The biodegradability of the resulting film was evaluate using soil burial test and statistically analyze using t-test. The result show that the rate degradation of optimum nanocomposite film (1.3785 %/day) was not significantly difference ($p>0.05$) compare with control (1.4885 %/day).

Keywords: Nanocomposite, PVA, ZnO nanoparticles, stearic acid, biodegradable

INTRODUCTION

Packaging play an important role for obtaining food products with attractive appearance as well as to protect products during storage and distribution. Plastic packaging, that widely used at this time, is contributor to the problem of instability in environmental ecosystems, because it is non-biodegradable. Based on data from the Ministry of Environment, each individual produces around 0.8 kilograms of garbage per day (15% in the form of plastic waste) (Gusmayanti, 2010). Nanocomposite film appear as one of the environmentally friendly packaging alternatives and expected to reduce the amount of use of non-biodegradable packaging.

One of many biopolymers that has been studied intensively as nanocomposite packaging is PVA (polyvinyl alcohol) because it can form films well, water soluble, easy to process, non-toxic, biocompatible and biodegradable (Chandrakala et al, 2012). On contrary, PVA has poor barrier properties against water vapor, so it needs to be combined with fillers that can improve the characteristics of produced film. An alternative of nano-sized fillers that potentially improve the barrier properties of PVA film is ZnO nanoparticles (ZnO NPs). ZnO NPs have large surface area to volume ratio and antimicrobial properties, so it can used as active packaging (Esmailzadeh et al, 2016), increase surface reactivity, thermal, mechanical, stable to heat and recognized as safe by FDA (Sharon et al, 2010).

Another alternative to overcome the low retention of PVA to moisture is by adding fatty acids. Stearic acid (SA) is chosen because of its abundant availability, affordable price, and does not easily interact chemically with other elements. There have been many studies that have developed film making with the addition of fatty acids including corn starch (Jimenez et al, 2011) , soybean protein concentrates (Caba et al, 2012), starch (Nobrega et al, 2012; Schmidt et al, 2013), cassava starch (Chiumarelli et al, 2014), soybean protein isolates (Wang et al, 2014), Lepidium perfoliatum seed gum (Seyedi et al, 2015).

This study aims to prepare the optimum formulation of PVA-based nanocomposite films with the addition of ZnO nanoparticles and stearic fatty acids as well as evaluate to biodegradability using soil burial test.

MATERIALS AND METHODS

Tools and Materials

The equipment that are used including hot plate stirrer, Memmert oven and dessicator, digital ultraturax IKA T-25, Pyrex glassware, teflon, petri dish, digital scales and other supporting tools.

The main materials used in this study were 17K type commercial PVA (polyvinyl alcohol), inorganic zinc oxide (ZnO) nanoparticle, and stearic acid, aquades, and other chemical such as KCl was laboratory grade.

Methods

Preparation of Nanocomposite Film

Nanocomposite films was prepared using casting solvent method according to Chandrakala et al. (2013) with slight modification. A 5 grams of polyvinyl alcohol was dissolved in 95 ml of aquades and homogenized using hot plate stirrer at 120^{o}C for 30 minutes. Subsequently, the PVA solution was mixed with 3.4% ($^{w}/_{w}$ PVA) ZnO NPs and 6.6% ($^{w}/_{w}$ PVA) stearic acid, and tween 80 which had been melted first at the temperature of 70-80oC. Then, the completed solution was poured into teflon crucible and dried in a vacuum oven at 40-45^{o}C for 3 hours. The dried film was packed with aluminum foil and stored on the desiccator (RH 75%, saturated $KCl_{(aq)}$) prior to analysis.

Biodegradibility Analysis (Azahari, 2012)

A nanocomposite films was buried in soil with a depth of 3 cm from the ground. The soil is placed in a pot and stored outdoors to get the actual conditions in the environment. Calculation of degradation is determined every time interval (7 days) for 42 days.

Statistic Analysis

The statistical analysis used in this study is t-test performed by SPSS version 22.0 software to compare the differences between control and nanocomposite film.

RESULTS AND DISCUSSION

Biodegradable plastic is plastic used as a conventional one, but will be broken down by the activity of microorganisms become water and carbon dioxide after being used up and disposed of into the environment. Biodegradable plastics are polymers that can change into biomass, H2O, CO2 and or CH4 through stages of depolymerization and mineralization. Depolymerization occurs because of extracellular enzymes work (consisting of endo and ekso enzymes). Endo enzymes break the internal bonds in the main polymer chain randomly, and the enzyme ekso breaks the monomer units in the main chain in sequence. The parts of the oligomer formed are transferred into the cell to be mineralized. The mineralization process formes CO2, CH4, N2, water, salts, minerals and biomass. The definition of biodegradable polymers and the final products formed can vary depending on polymers, organisms, and the environment (Anonymous, 2005).

To determine the biodegradability of bioplastics made, soil burial test is carried out with the aim to determine the rate of degradation samples with some variations so that it would be predictable how long the samples would decompose by microorganisms in the soil. This method is done by burying the sample in the soil controlled by physical and chemical properties then calculating the residual weight fraction of the sample in each time unit (gram / 7 days).

Tests is carried out on two samples, which are the optimum sample with 4 replications and controls. Sample mass reduction was weighed every seven days for 42 days. The sample was weighed every after removed from the soil to weigh it in a dry state. The average results are then plotted weight residue (%) againts time (days) of nanocomposite films. The results as shown in Figure 1.

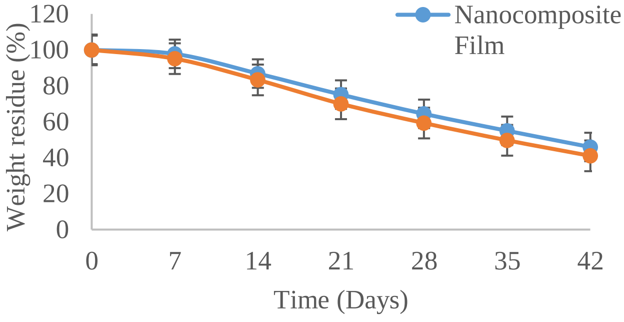

Figure 1. Biodegrability of PVA nanocomposite films, ZnO nanoparticles and stearic acid

Table 1. Rate of degradation of sample

Sample	Rate of degradation	t_{50} (50% weight residue)
Control	1.4885 %/day	35 day
Nanocomposite film	1.3785 %/day	39 day

Based on Figure 2, it can be seen that degradation of control films is faster than nanocomposite films, although the degradation value is not different at last day. The rate of degradation of the control film was -1.4885 %/day and 1.3785 %/day for the nanocomposite film. The control film need less day to gain 50% weight residue, while the nanocomposite was 4 days longer to half-part decomposed. However, this result was not significantly different ($p>0.05$).

Day 1

Day 42

Day 1

Day 42

Figure 2. Biodegrability of nanocomposite films

Degradation occurs in two stages in the grave test in the soil: (a) water diffusion into film samples which results in swelling of the film that allows microorganisms to live in the film, (b) enzymatic degradation and other secretions causing severe decrease and damage to film samples. PVA have hydrophilic properties so that its solubility can also be another factor that causes decreasing in film weight (Guohua et al, 2006). Moreover, the addition of ZnO nanoparticles is not influence the biodegradability of nanocomposite film. This result might be the same as the addition of nano SiO2 in PVA / starch-based films, which did not prove any significant effect on the film biodegradation. In addition, nano SiO2 makes miscibility and compatibility increase and form a solid matrix structure, which in time will reduce the speed of infiltration of microorganisms. With increasing degradation time, the compactness of the film will be destroyed (Tang et al, 2008). On contrary, Hejri et al. (2013) reported that the addition of TiO_2 in the starch/PVA film formed many big cavities in the film surface observed by SEM. After the soil burial degradation, it was expected these holes become bigger and damage the structure of the films.

CONCLUSION

The PVA-based nanocomposite was prepared using optimum formula with the addition of 3.4% ($^{w}/_{w}$ PVA) ZnO nanoparticles and 6.6% ($^{w}/_{w}$ PVA) stearic acid. The rate of degradation of nanocomposite and control film were -1.3785 %/day and-1.4885 %/day, respectively. This results was not significantly different ($p>0.05$).

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