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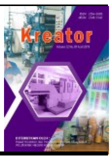

Study of the Optical Properties of Bioplastic-Lead as an Alternative Packaging Material for X-ray Radiation Protection

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ABSTRAK

Penelitian ini bertujuan untuk mengkarakterisasi sifat optik kemasan bioplastik berbasis campuran pati singkong dan timbal asetat sebagai bahan alternatif untuk proteksi radiasi sinar-X. Metode eksperimen digunakan dengan memvariasikan komposisi campuran pati singkong dan timbal asetat dalam rasio 100:0, 70:30, 65:35, 60:40, 55:45, 50:50, dan 45:55. Karakterisasi optik dilakukan menggunakan spektrofotometri UV-Vis untuk mengukur absorbansi, reflektansi, dan transmitansi sampel. Hasil menunjukkan bahwa sampel dengan konsentrasi timbal asetat yang lebih tinggi memiliki absorbansi yang lebih besar, terutama pada rentang UV, serta transmitansi yang lebih rendah di seluruh spektrum. Sampel dengan rasio 45:55 dan 50:50 (pati singkong:timbal asetat) menunjukkan potensi terbaik sebagai pelindung radiasi karena absorbansi tinggi dan transparansi rendah. Penelitian ini memberikan pemahaman komprehensif tentang sifat optik campuran pati singkong dan timbal asetat, memungkinkan optimisasi komposisi untuk aplikasi spesifik dalam proteksi radiasi sinar-X.

ABSTRACT

This research aims to characterize the optical properties of bioplastic packaging based on a mixture of cassava starch and lead acetate as an alternative material for X-ray radiation protection. The experimental method was used by varying the composition of a mixture of cassava starch and lead acetate in ratios of 100:0, 70:30, 65:35, 60:40, 55:45, 50:50, and 45:55. Optical characterization was carried out using UV-Vis spectrophotometry to measure the absorbance, reflectance and transmittance of the sample. The results show that samples with higher lead acetate concentrations have greater absorbance, especially in the UV range, as well as lower transmittance throughout the spectrum. Samples with ratios of 45:55 and 50:50 (cassava starch:lead acetate) showed the best potential as radiation shielding due to high absorbance and low transparency. This research provides a comprehensive understanding of the optical properties of a mixture of cassava starch and lead acetate, enabling composition optimization for specific applications in X-ray radiation protection.

1. INTRODUCTION

In the healthcare industry, radiation is used as a complementary tool for medical diagnostics among other applications. Radiation also has side effects, one of which can cause genetic changes, in addition to its beneficial effects. (A.F. Septiano et al, 2020). X-ray radiation can damage molecular structures, cause discoloration, chemical changes, and DNA damage in biological samples. This damage occurs when the resulting X-rays experience photoelectric absorption below 30 keV. At this energy level, it produces photons or photoelectrons, which produce excess heat during the process. As a result, high-energy X-rays cause greater damage than low-energy X-rays. (P.D. Quinn et al, 2021).

The dose limit value for the environment according to the International Atomic Energy Agency (IAEA) is no more than 1 μSv/hour at a distance of 1 m from the radiation source. The dose

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distribution in the environment around the X-ray source is influenced by the thickness of the protective material, with the recommended standard for workers being 10 μSv/hour, while for the surrounding environment it is 0.5 μSv/hour. This equivalent dose value is obtained from the variation in exposure factors provided by the X-ray tube. (A.F. Septiano et al, 2023).

Radiation exposure dose and effective dose have the same units as the absorbed dose. The radiation exposure dose or equivalent dose limit value for general users is different from that recommended for radiation workers. In this study, the standard equivalent dose limit value for general users on the skin was 50 mSv/year, which is 5.707 μSv/hour. (M. Bonczyk et al, 2022). Because the interaction of radiation with humans can change cell structure, causing dangers from the mildest to the most fatal for workers or patients. Therefore, to maximize the use of radiation and avoid radiation threats, a radiation shielding system is needed (A.F. Septiano et al, 2021).

Shielding is an important component in nuclear and radiation experiments. Radiation shielding protects people and the environment from radiation exposure when used in medical, research, and industrial fields (K.V. Sathish et al, 2021). Due to its strength and high capacity to prevent ionizing radiation from passing through all materials, lead (Pb) and its derivatives have been used for many years as ideal materials for shielding applications. Scientists also suggest materials such as polymers, alloys, concrete, glass, and stone for reliable protection from ionizing radiation. (M.I. Sayyed et al, 2022). Due to its high density, atomic number, and high photon absorption, Pb has been used as a cost-effective shielding material for X-rays and gamma rays. (S.A. Hashemi et al, 2022).

Plastics have changed the daily life of humans and greatly affect all aspects of life. (S. Nigam et al, 2021). Bioplastic packaging derived from biomass can replace petrochemical plastics because they are biodegradable, renewable, and have many resources. (G. Chen et al, 2022). Due to changes in their biological properties, the molecular chains of bioplastics can decompose into smaller particles. (N.H. Yusoff et al, 2021). Petrochemical plastics can be replaced with less hazardous biodegradable plastics. Two types of bioplastics are made from corn and cassava starch. (Y. Zoungranan et al, 2020). Chitosan, cassava starch, or PVA can be used to increase the thickness and tensile strength of biodegradable plastics. (S.N. Ayyubi et al, 2022).

The combination of cassava starch and lead acetate in bioplastic packaging materials can be an alternative choice as a radiation shield. According to a study conducted (Septiano et al, 2023), by combining cassava starch and lead acetate in a ratio of 45:55, the data showed an effective radiation absorption rate of 49.4%. Based on the morphological structure of the SEM image, the grouping of lead content tends to be even for a balanced mixture content.

UV-Vis spectrophotometry is a popular analytical technique that can be used to measure the concentration of chemicals with high accuracy. (A.F. Septiano et al, 2023). Ultraviolet-visible (UV-Vis) spectroscopy is a technique that analyzes the absorption of UV-Vis energy by molecules, producing a characteristic spectrum for qualitative and quantitative analysis of substances. (Z. Chen, 2024). UV-Vis spectroscopy measures the absorption of light, indicating the transparency of the material; higher absorbance correlates with lower transparency, while lower absorbance indicates greater transparency in the analyzed sample. (J.M. Aldabib & M.F. Edbeib, 2020).

2. METHOD

The method used in this study is an experimental method. The tools and materials used in this study are 1 set of Shimadzu brand UV-Vis Spectrophotometry units type 2600, measuring cups, spatulas, scales, ovens, cassava starch and lead acetate. The flow of this study began with the preparation of samples by mixing cassava starch and lead acetate. A mixture of cassava starch and lead acetate with variations in composition in percent 100: 0, 70: 30, 65: 35, 60: 40, 55: 45, 50: 50, and 45: 55. In the mixing process, a temperature of 70 - 80ºC is used to minimize the formation of air bubbles in the molding process and drying the sample requires strict supervision to eliminate the air bubbles that are created. Then the sample is ground until a powder is obtained which is used as a UV-Vis test sample. Then the absorbance, reflectance and transmittance measurements are carried out using UV-Vis Spectrophotometry.

3. RESULT AND DISCUSSION

Result

We have succeeded in making bioplastic packaging made from cassava starch and lead. We varied the concentration of lead acetate and found that with a higher concentration of lead acetate produced the strongest bioplastic (optimum composition 45:55). The results are as shown in Figure

1. The sample shown shows transparent physical properties. Physically, there are also bubbles in the sample indicating an oxidation reaction. Regarding the recycling of micro-/nano-(bio)plastic composites, most research has focused on the recovery of the fiber phase, with the polymer phase being fully recycled into fuel. Considering the worldwide policy shift towards sustainability and circularity of materials, a closed-loop approach to composite recycling will become increasingly important. As is well known, (bio)plastic composites have significant uses in various everyday life manufacturing, automotive components, devices for energy recovery, etc., and their use is constantly increasing, including in emergencies for proper management and collection at end-of-life.

Figure 1. Bioplastic-Lead Sample (45:55)

UV-Vis Spectroscopy is an analytical technique that measures the amount of UV or visible light wavelengths absorbed or transmitted through a sample compared to a reference sample or blank sample. This property is influenced by the composition of the sample, potentially providing information about what is in the sample and at what concentration. In this study we used UV-Vis Spectroscopy to identify the absorbance (Figure 2), reflectance (Figure 3) and transmittance (Figure 4) values.

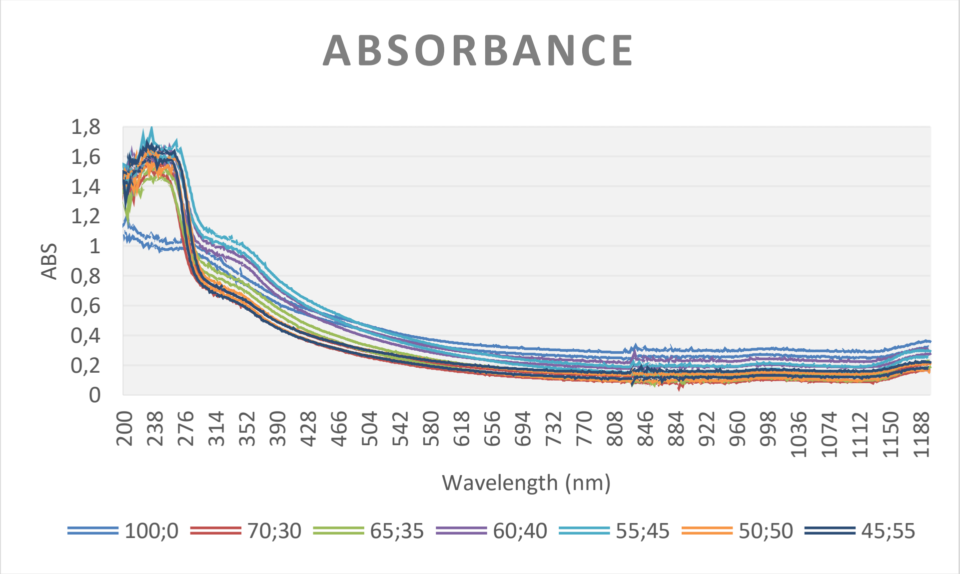

Figure 2. Graph of Absorbance Sample

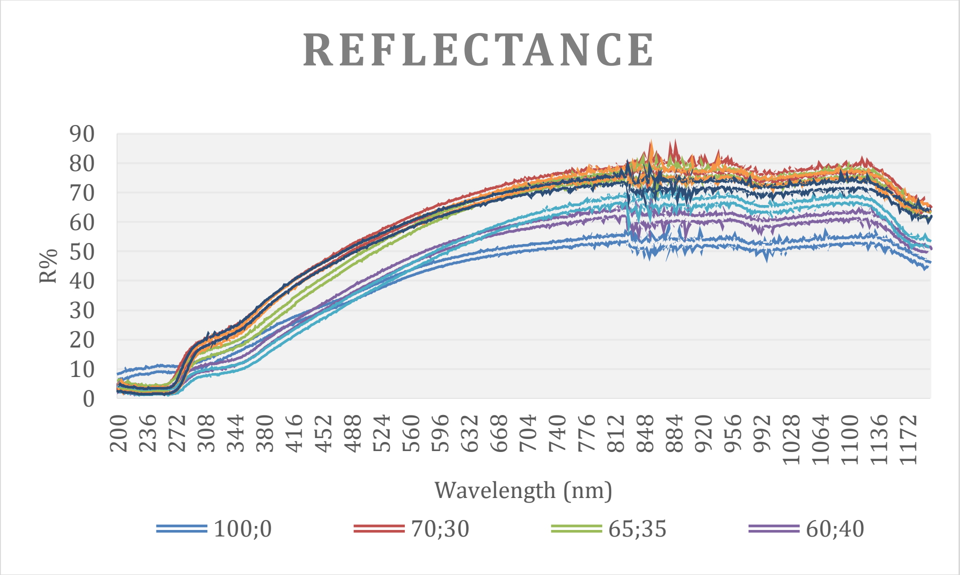

Figure 3. Graph of Reflectance Sample

Reflectance describes how much light is reflected from a surface or optical element. Reflectance is equal to the ratio of reflected power and incident power when light is shot onto a surface. Transmittance describes how much light is transmitted from a surface or optical element. Transmission is equal to the ratio of the transmitted power and the incident power when light is shot onto a surface.

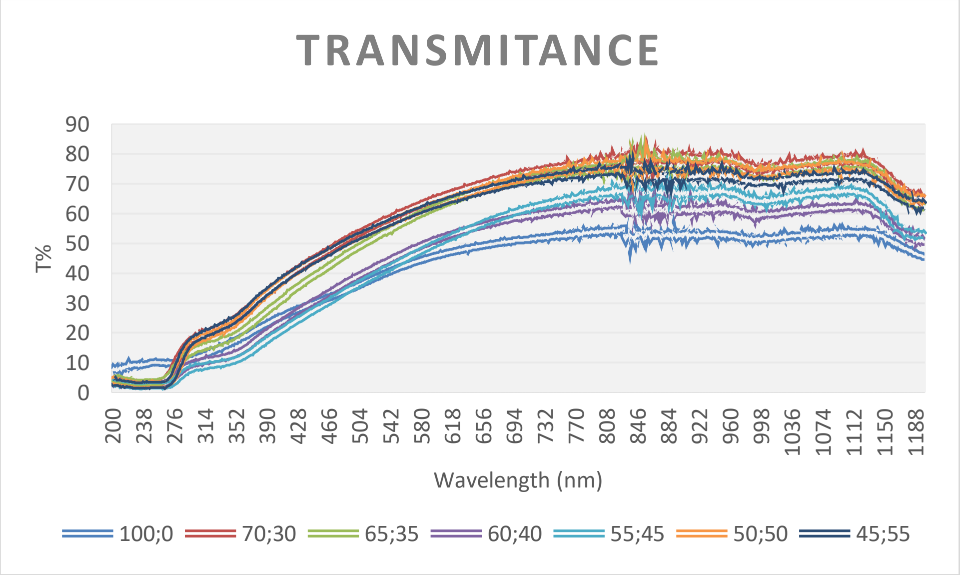

Figure 4. Graph of Transmitance Sample

Discussion

The results of UV-Vis spectrophotometry testing on the mixture of cassava starch and lead acetate show interesting optical characteristics. Absorbance analysis from Figure 2 reveals that samples with higher lead acetate concentrations (45:55, 50:50, 55:45) have greater light absorption capabilities, especially in the UV range (200-400 nm). This absorbance pattern indicates the effectiveness of the material in absorbing UV radiation and possibly low-energy X-rays. As the wavelength increases, the absorbance decreases, indicating increased transparency in the visible light spectrum.

The reflectance data in Figure 3 provides additional information about the optical properties of the samples. Samples with higher cassava starch compositions (100:0, 70:30) show greater reflectance, especially at wavelengths above 500 nm. This indicates that these samples are more likely to reflect visible light. Conversely, samples with higher lead acetate concentrations have lower reflectance, indicating a better ability to absorb or transmit light.

Based on Figure 4, transmittance analysis provides a direct picture of the transparency of the samples. It can be seen that the transmittance is very low in the UV range for all samples, confirming their good UV absorption ability. As the wavelength increases, the transmittance increases, especially for samples with higher cassava starch concentrations. Sample 100:0 (pure cassava starch) shows the highest transmittance in the visible spectrum, reaching more than 80% above 500 nm. In contrast, samples with higher lead acetate concentrations (45:55, 50:50) have much lower transmittance, less than 20% across the spectrum.

The correlation between absorbance, reflectance, and transmittance data with sample transparency shows a clear trade-off between radiation protection ability and optical transparency. Samples with higher lead acetate concentrations have high absorbance and low transmittance, indicating good potential as radiation shielding, but at the cost of decreasing transparency. In contrast, samples with higher cassava starch concentrations have better transparency but lower radiation protection ability.

It is important to note that the transparency of the samples varies significantly depending on the wavelength. All samples showed very low transparency in the UV range, which is beneficial for protection against UV radiation. In the visible spectrum, especially above 500 nm, the difference in transparency between samples became more pronounced. The 100:0 and 70:30 samples showed quite high transparency in visible light, while the samples with higher lead acetate concentrations remained relatively opaque.

The implications of these results for X-ray radiation protection applications are promising. The samples with higher lead acetate concentrations (45:55, 50:50) showed the best potential as radiation shields due to their high absorbance and low transparency. These characteristics allow the material to effectively absorb UV radiation and possibly low energy X-rays. However, it should be considered that these samples will also block most of the visible light, which may be undesirable in some applications that require visibility.

These UV-Vis spectrophotometric data provide a comprehensive understanding of the optical properties of cassava starch and lead acetate mixtures. The transparency of the samples can be controlled by adjusting the composition of the mixture, allowing optimization for specific applications in radiation protection. The selection of the optimal composition will depend on the specific needs of the application, balancing the desired level of radiation protection and the required level of transparency. For applications requiring maximum radiation protection, samples with a higher concentration of lead acetate will be more suitable, although at the expense of reducing optical transparency. Conversely, for applications requiring a balance between radiation protection and transparency, intermediate compositions such as 60:40 or 55:45 may be a more optimal choice.

4. CONCLUSION

This study reveals the significant potential of cassava starch and lead acetate mixture as an alternative material for X-ray radiation protection. Optical characterization using UV-Vis spectrophotometry showed that samples with higher concentrations of lead acetate (45:55, 50:50) had better radiation absorption ability, especially in the UV range and possibly low energy X-rays. There is a trade-off between radiation protection ability and optical transparency, where increasing radiation protection ability is followed by decreasing transparency. The composition of the mixture can be optimized to balance the level of radiation protection and transparency according to the needs of specific applications. These findings open up opportunities for further development of cassava starch and lead acetate-based bioplastics as environmentally friendly and biodegradable radiation protection materials, with potential practical applications in the health and radiation safety industries.

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