Analit: Analytical and Environmental Chemistry
Volume 10, No. 02, Ocotber 2025 - May 2026

TAGUCHI EXPERIMENTAL STUDY: THE EFFECT OF BAY LEAF EXTRACT WEIGHT PERCENTAGE AND SAMPLE SIZE ON THE CHARACTERISTICS OF POLYVINYL ALCOHOL FILMS

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Submitted	Revised	Accepted	Published	
04.11.2025	10.12.2025	26.01.2026	11.02.2026	

PISSN 2540-8224
EISSN 2540-8267

Publisher:
Department of Chemistry, FMIPA, University of Lampung

ABSTRAK

Penelitian ini bertujuan untuk menentukan parameter optimum penambahan ekstrak daun salam (DS) ke dalam matriks polivinil alkohol (PVA) sehingga membentuk polimer baru, PVA/DS. Metoda eksperimental Taguchi digunakan untuk memperoleh sifat anti-UV dan karakteristik mekanik yang optimal pada PVA/DS. Faktor yang dikaji meliputi konsentrasi DS serta ukuran sampel. Rancangan percobaan disusun menggunakan matrik ortogonal L16. Hasil analisis *Signal to Noise Ratio* menunjukkan bahwa faktor konsentrasi DS merupakan variabel yang paling dominan terhadap respon anti-UV serta perpanjangan putus. Sedangkan untuk performansi kekuatan tarik kedua faktor tidak signifikan, walaupun faktor luas penampang lebih dominan dibandingkan konsentrasi DS. Penambahan konsentrasi DS terhadap respon anti-UV mampu menghalangi 100% sinar UV. Sedangkan untuk kekuatan tarik terjadi peningkatan sebesar 50,98% serta perpanjangan putus naik sebesar 14,71%. Dengan demikian film PVA/DS1 (1% DS) merupakan film dengan kondisi optimum yang dapat menjawab performansi, sehingga film ini merupakan alternatif pengganti plastik konvensional yang tidak mudah terurai.

Kata kunci: Analisis Varians, Indonesian Bay Leaf, Metoda Taguchi, Polivinil Alkohol

ABSTRACT

This study aims to determine the optimal parameters for incorporating bay leaf extract (DS) into a polyvinyl alcohol (PVA) matrix to form a new polymer, PVA/DS. The Taguchi method was employed to achieve optimal anti-UV and mechanical properties of PVA/DS. The factors studied included DS concentration and sample size. The experimental design was arranged using an L16 orthogonal matrix. The results of the Signal-to-Noise Ratio analysis showed that the DS concentration was the dominant variable in the anti-UV and elongation at break. Meanwhile, for tensile strength performance, neither factor was significant, although the cross-sectional area factor was more dominant than the DS concentration. The addition of DS concentration to the anti-UV response was able to block 100% of

https://doi.org/10.23960/analit.v10i02.231

UV rays. Meanwhile, for tensile strength, there was a 50.98% increase, and elongation at break increased by 14.71%. Thus, the PVA/DS1 film serves as an alternative to conventional plastics under optimal conditions.

Keywords: Analysis of Variance, Indonesian Bay Leaf, Taguchi Method, Polyvinyl Alcohol.

INTRODUCTION

The increased use of synthetic polymer materials derived from fossil petroleum has led to significant environmental problems, particularly related to the accumulation of plastic waste in terrestrial and aquatic ecosystems (Agarwal, 2020; Olalla et al., 2021). Therefore, the development of environmentally friendly polymers based on natural materials has become a primary focus of recent studies. One of the materials that was potentially used was polyvinyl alcohol (PVA) because of its biodegradable nature, transparency, and good film-forming ability (Liu et al., 2022), However, pure PVA had weaknesses such as being unable to resist UV light, having relatively low mechanical properties, and high water permeability, so modification was needed to improve its performance (Chen et al., 2020; Ghazi, 2022).

Several studies have demonstrated that incorporating plant extracts rich in bioactive compounds, such as polyphenols, flavonoids, and tannins, can interact with the hydroxyl groups of PVA via hydrogen bonding, thereby strengthening and stabilizing the PVA structure (Abral et al., 2022). The crosslinking mechanism of the -OH bonds acted as a natural reinforcing and antioxidant agent, improving the mechanical, thermal, and functional properties of the PVA polymer matrix (Koopmann et al., 2020; Wu et al., 2023). However, the results obtained often varied because they were influenced by the extract concentration and the sample size during film preparation, which had not been systematically optimized (Annu et al., 2021; Peña-Ortiz et al., 2023). Previous authors' studies confirmed that the incorporation of Indonesian bay leaf/Daun salam extract (DS) into PVA and also starch from durian seeds could increase tensile strength, reduce the water vapor transmission rate, and improve the UV-blocking ability of the formed polymer (Sunarsono, Abral, Mahardika, et al., 2025; Sunarsono, Abral, Pratoto, et al., 2025). The DS acts as a natural additive, enhancing the functional properties of the PVA matrix. Its primary role is to introduce bioactive compounds with antioxidant and UV-absorbing capabilities. These compounds interact with the polymer chains, improving the film's resistance to UV degradation and potentially contributing to enhanced mechanical and thermal stability through secondary bonding or hydrogen interactions with PVA molecules. Based on a previous study, the optimum threshold concentration was 1% wt (Sunarsono, Abral, Mahardika, et al., 2025; Sunarsono, Abral, Pratoto, et al., 2025). Based on this premise, this study employed the Taguchi experimental method to determine the optimal parameters for incorporating DS into the PVA polymer matrix. Through the orthogonal array design, this method enabled the identification of the relative influence of each factor on the observed response using Signal-to-Noise Ratio (S/N ratio) analysis and analysis of variance (ANOVA). The novelty of this study lies in the application of the Taguchi method to determine the optimal formulation parameters for incorporating DS into PVA-based polymer. To the best of our knowledge, no prior research has systematically investigated the effect of DS addition on the physicochemical and functional properties of PVA films using a statistical optimization approach, such as Taguchi design. This research aimed to provide a scientific basis for the formulation of biodegradable materials with enhanced anti-UV performance and mechanical properties (Baranwal et al., 2022; Saha et al., 2020)., as well as to expand the potential applications of biopolymers as an environmentally friendly food packaging material (Zainal & Eka Pratiwi, n.d.).

Taguchi Experimental Design and Analysis of Variance (ANOVA)

Data processing was carried out using the Minitab software. The performance/responses measured in this study were three, namely: UV-blocking ability (anti-UV), which used two factors—DS concentration (%) and sample thickness (t, mm); and tensile strength and elongation at break, which used two factors DS concentration (%) and cross-sectional area (A, mm^2), as shown in Table 1. Both factors had four levels; therefore, the orthogonal array used was L16 (4^2), corresponding to 16 experimental combinations (runs), as shown in Table 2. Each combination was repeated three times to obtain an estimate of variability. In the Signal-to-Noise (S/N) ratio analysis, the optimization criterion for the anti-UV performance was "the smaller is better". This approach was chosen because the smaller the UV transmission through the film, the better the film quality in protecting against UV exposure. Meanwhile, for mechanical properties (tensile strength) and elongation at break, the criterion "the larger is better" was applied, as an increase in these properties indicates an improvement in the characteristics of the PVA polymer.

The analysis of quality parameters was carried out using ANOVA and linear regression tests (Handayani et al., 2025). The ANOVA test was used to determine the significance of the differences in the mean results obtained from the Taguchi experimental design and to identify whether variations in product quality were caused by the specific factors being tested. Meanwhile, the linear regression test was used to understand the relationship between the significant factors and the measured responses.

Table 1. Factors in the Experiment

Factor	Level			
	1	2	3	4
DS (%)	0	0.05	0.5	1
Thickness/t (mm)	0.30	0.54	0.44	0.40
Cross-sectional area/A mm^2)	0.71	0.90	0.86	0.77

Table 2. *Orthogonal Array*

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DS (%)	0	0	0	0	0.05	0.05	0.05	0.05	0.5	0.5	0.5	0.5	1	1	1	1
t (mm)	0.30	0.54	0.44	0.40	0.30	0.54	0.44	0.40	0.30	0.54	0.44	0.40	0.30	0.54	0.44	0.40
A (mm^2)	0.71	0.90	0.86	0.77	0.71	0.90	0.86	0.77	0.71	0.90	0.86	0.77	0.71	0.90	0.86	0.77

METHOD

Sample Preparation

ANOVA (analysis of variance) was used to determine the significance of the film qualities for each of the three samples. The differences were examined using Duncan's multiple-range test for significance at $p < 0.05$.

1. Materials

   Polyvinyl alcohol with a molecular weight of 89,000–98,000 and 99+% purity (Sigma Aldrich, catalog number 341584) was purchased through PT Mutiara Labsains Padang. Fresh bay leaves were collected from the biomass laboratory garden of Andalas University, Padang. Ethanol and distilled water were supplied by PT Kisbiokim Medika Padang.

2. Pure Polyvinyl alcohol (PVA) Film

   Ten grams of PVA powder were dissolved in 100 ml of distilled water and stirred using a magnetic stirrer at a speed of 650 rpm for 2 h at a temperature of 70°C. The solution was then subjected to ultrasonication for 5 minutes at 600 W. The resulting solution was poured and cast into a Petri dish, then placed in an oven at 50°C for 20 h to dry (Xiao et al., 2020).

3. Film PVA/DS

   Ethanol (100 ml) was mixed with bay leaf extract at concentrations of 0 g, 0.05 g. 0.5 g. and 1 g, with the sample codes PVA/DS, PVA/DS0.05, PVA/DS0.5, and PVA/DS1, respectively. The obtained mixture was stirred using a magnetic stirrer at 500 rpm for 30 min at 25°C. The mixture was then centrifuged to remove any undissolved material. Next, 10 g of PVA was dissolved in 100 mL of distilled water and stirred on a magnetic stirrer at 500 rpm for 2 hours at 70°C. The ethanol solution containing bay leaf extract (after centrifugation) was then slowly added to the PVA solution. Subsequently, sonication was

https://doi.org/10.23960/analit.v10i02.231

performed for 5 minutes at 600 W. The resulting solution was poured and cast into Petri dishes, then placed in an oven at 50°C for 20 hours to dry.

Characterization

1. Anti-UV

   The transparency of the film (a rectangular shape 10 × 25 mm) was determined in the wavelength 200–800 nm range using a UV-Vis spectrophotometer (Shimadzu) according to ASTM D 1003-00. Three measurements were taken to calculate the average value.

2. Tensile Test

   ASTM D638 was used as the standard for measuring tensile strength. Before testing, each sample was dried in a desiccator for 48 hours at a temperature of 25°C and a relative humidity of 50 ± 5%. The thickness and width of the samples were measured with an accuracy of 0.01 mm using a dial micrometer. Tensile strength and elongation at break tests were conducted at room temperature (75 ± 5% relative humidity) using a 95T Com-Ten testing machine. A constant crosshead speed of 5 mm/min was applied during the tensile test. Three tensile tests were performed for each sample.

RESULTS AND DISCUSSION

Obtained Performance/Responses

The anti-UV properties of PVA and PVA/DS films in the wavelength range below 400 nm are presented in Table 3. The film with a 1% DS addition (PVA/DS1) blocked 100% of UV light, whereas PVA blocked only 16%. The highest tensile strength was observed in the film with 1% bay leaf extract (PVA/DS1) at 75.65 MPa, while the highest elongation at break was recorded for PVA/DS0.5 at 304.43%, as shown in Table 3. In contrast, the film without DS (PVA) exhibited a tensile strength of only 50.13 MPa and elongation at break of 265.40%.

Table 3. Tensile Strength, Elongation at Break, and Anti-UV of PVA/DS Films (*)

Sample's code	DS (%)	*Tensile Strength* (MPa) [SD]	*Elongation at Break* (%) [SD]	*Anti-UV at 400 nm* (%) [SD]
PVA	0	50.13 [4.41]	265.40 [20.46]	16.0
PVA/DS0.05	0.05	54.35 [25.02]	220.80 [16.87]	58.0
PVA/DS0.5	0.5	57.64 [10.10]	304.43 [26.85]	97.5
PVA/DS1	1	75.67 [15.37]	281.94 [24.47]	100.0

[SD]: Standard Deviation.
(*)Based on previous studies (Sunarsono, Abral, Pratoto, et al., 2025).

Anti-UV film PVA/DS

The S/N ratio values obtained from the data processing were presented in Table 4 and mapped as Main Effects Plot (MEP) in Figure 1. Meanwhile, the results of the ANOVA and linear regression tests of the S/N ratio are shown in Tables 5 and 6.

Table 4. Signal-to-Noise Ratio anti-UV

Level	DS (%)	Sample's thickness
1	-33.376	-11.303
2	-32.608	-11.304
3	-5.418	-10.209
4	33.885	-9.699
Delta	72.261	1.605
Rank	1	2

Table 5. ANOVA Results for anti-UV

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
DS (%)	3	13046.6	13046.6	4348.86	2437.80	0.000
t (mm)	3	7.8	7.8	2.60	1.46	0.290
Residual Error	9	16.1	16.1	1.78		
Sum	15	13070.5				

Table 6. Regression Test Results for anti-UV

Term	Coef.	SE Coef.	T	P
Constant	-10.6290	0.3339	-31.832	0.000
Concentration 0	-27.7469	0.5783	-47.976	0.000
Concentration 0.05	-21.9787	0.5783	-38.003	0.000
Concentration 0.5	5.2113	0.5783	9.011	0.000
Cross-Se 0.71	-0.6744	0.5783	-1.166	0.274
Cross-Se 0.90	-0.6754	0.5783	-1.168	0.273
Cross-Se 0.86	0.4202	0.5783	0.727	0.486
S	R-Sq.		R-Sq. (adj.)	
1.3356	99.88%		99.80%	

Based on the S/N ratio results, the DS concentration was the most influential factor compared to the sample thickness. In the case of UV resistance, the percentage of DS plays a more significant role than the film thickness. This can be explained by the fact that the bioactive compounds present in DS—such as flavonoids, polyphenols, and other antioxidant molecules—have the ability to absorb and block ultraviolet radiation. These compounds interact with the PVA matrix, enhancing its UV-shielding capability through chemical absorption and free-radical scavenging mechanisms. Although film thickness can influence light transmission to some extent, its effect is primarily physical and less substantial compared to the chemical contribution of the extract. This is evident from the factor influence (delta) values shown in Table 4, where a value of 72.261 is compared to the sample thickness of 1.605. Furthermore, the Main Effects Plot (in Figure 1) showed a significant change in the S/N ratio as the DS concentration increased, while the sample thickness exhibited only a small change. The optimal factor combination was achieved at a DS concentration of 1% with a sample thickness of 0.3 mm, resulting in the most effective UV-blocking ability. Although the thickness factor was found to be statistically insignificant in influencing the overall UV resistance of the PVA/DS films, the Taguchi analysis revealed that a thickness of 0.3 mm produced the most optimal results.

The ANOVA results, presented in Table 5, showed that the DS concentration factor had a P-value of 0.000, indicating that this factor had a significant effect on the anti-UV capability. The calculated F-value for this factor was 2437.80, indicating that its influence was highly significant in determining the anti-UV characteristics. Meanwhile, the sample thickness factor had a P-value of 0.290, which was greater than 0.05, indicating that this factor did not significantly affect the anti-UV properties. The F-value for this factor was 1.46, which is much lower than that of the DS concentration, indicating that its effect on anti-UV characteristics was relatively small. Based on the linear regression test in Table 6, the model showed an R-Sq of 99.88% and an Adjusted R-Sq of 99.80%, indicating that the model explained the variation in anti-UV properties very well. With the very high R-Sq value. the model indicated that DS concentration had a greater influence on UV resistance than sample thickness.

Tensile Strength film PVA/DS

The S/N ratio values obtained from the data processing were presented in Table 7 and mapped in Figure 2. Meanwhile, the results of the ANOVA and linear regression tests of the S/N ratio were shown in Table 8 and Table 9.

Table 7. Signal-to-Noise Ratio Tensile Strength

Level	DS (%)	*Cross Sectional Area*/A (mm^2)
1	33.98	33.63
2	34.11	36.92
3	34.60	34.95
4	36.75	33.83
Delta	2.77	3.29
Rank	2	1

https://doi.org/10.23960/analit.v10i02.231

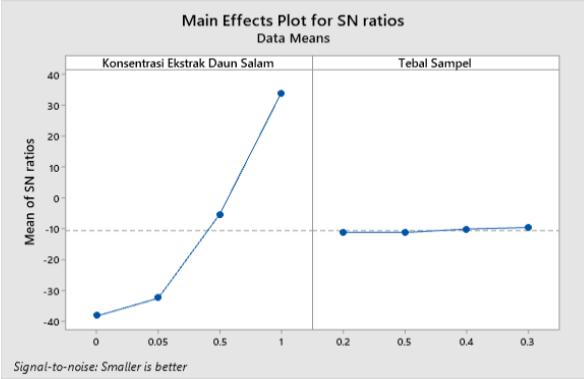

Figure 1. Main Effects Plot for anti-UV

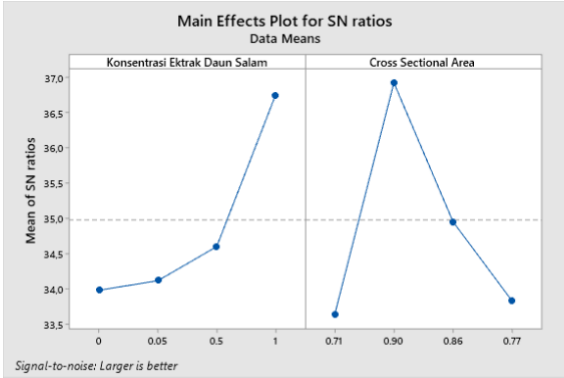

Figure 2. Main Effects Plot for Tensile Strength

Table 8. ANOVA Results for Tensile Strength

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
DS (%)	3	18.41	24.44	8.148	2.83	0.116
A (mm^2)	3	31.05	31.05	10.351	3.60	0.074
Residual Error	7	20.13	20.13	2.876		
Total	13	69.60				

Table 9. Regression Test Results for Tensile Strength

Term	Coef.	SE Coef.	T	P
Constant	34.5534	0.4896	70.580	0.000
Concentration 0	-1.1905	0.8480	-1.404	0.203
Concentration 0.05	-1.0553	0.8480	-1.245	0.253
Concentration 0.5	0.0456	0.7741	0.059	0.955
Cross Se 0.71	-0.9188	0.7741	-1.187	0.274
Cross Se 0.90	2.3708	0.7741	3.063	0.018
Cross Se 0.86	0.3977	0.7741	0.514	0.623
S	R-Sq.		R-Sq. (Adj.)	
1.6959	71.07%		46.28%	

The S/N ratio calculation results for tensile strength (Table 7) showed that the cross-sectional area had a greater influence compared to the DS concentration. This finding may be attributed to variations in sample preparation, particularly inconsistencies in film thickness or uniformity during casting and drying. Since tensile strength is calculated by dividing the applied force by the cross-sectional area, even slight differences in sample dimensions can significantly impact the resulting values. This was evident from the factor influence (delta) value of the cross-sectional area, which was 3.29, higher than the DS concentration value of 2.77. As shown in Figure 2, the Main Effects Plot also indicated that the optimal combination was 1% DS concentration and a cross-sectional area of 0.90 m^2. The ANOVA results, presented in Table 8 showed that the P-value for the DS concentration factor was 0.116, and for the cross-sectional area factor it was 0.074. Both values were greater than 0.05, indicating that neither factor had a significant effect on tensile strength. However, the F-value for the cross-sectional area (A) was 3.60, higher than the F-value for the DS concentration of 2.83, indicating that the cross-sectional area had a greater influence. Based on the linear regression test results (Table 9), the model had an R-Sq of 71.07% and an Adjusted R-Sq of 46.28%, indicating that the model was fairly good at explaining the variation, even though some factors were not significant.

Elongation at Break of PVA/DS Films

The S/N ratio values obtained from the data processing were presented in Table 10 and mapped in Figure 3. Meanwhile, the results of the ANOVA and linear regression tests of the S/N ratio are shown in Tables 11 and 12.

Table 10. Signal-to-Noise Ratio of Elongation at Break

Level	DS (%)	*Cross Sectional Area*/A (mm^2)
1	48.46	48.93
2	46.86	47.64
3	49.30	48.83
4	49.09	48.95
Delta	2.43	1.31
Rank	1	2

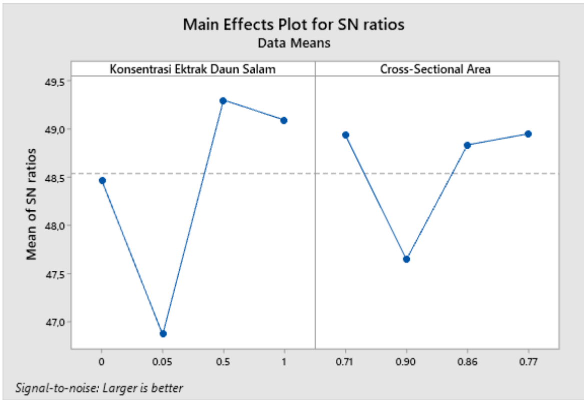

Figure 3. Main Effects Plot for Elongation at Break

Table 11. ANOVA Results for Elongation at Break

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
DS (%)	3	11.962	11.731	3.9104	9.30	0.008
A (mm^2)	3	4.287	4.287	1.4291	3.40	0.083
Residual Error	7	2.943	2.943	0.4204		
Total	13	19.192				

Tabel 12. Regression Test Results for Elongation at Break

Term	Coef.	SE Coef.	T	P
Constant	48.3868	0.1872	258.508	0.000
Concentration 0	-0.0087	0.3242	-0.027	0.979
Concentration 0.05	-1.6057	0.3242	-4.953	0.002
Concentration 0.5	0.9113	0.2960	3.079	0.018
Cross-Se 0.71	0.5464	0.2960	1.846	0.107
Cross-Se 0.90	-0.7450	0.2960	-2.517	0.040
Cross-Se 0.86	0.4449	0.2960	1.503	0.176
S	R-Sq.		R-Sq. (Adj.)	
0.6484	84.67%		71.52%	

The S/N ratio calculation results for elongation at break (Table 10) showed that DS concentration had a greater influence compared to the cross-sectional area. This was seen from the factor influence (delta) value of DS concentration, which was 2.43, higher than the cross-sectional area value of 1.31. As shown in Figure 3, the Main Effects Plot also indicated that the optimal combination was 0.05% DS concentration and a cross-sectional area of 0.71 mm^2. The ANOVA results presented in Table 11 showed that the DS concentration factor had a P-value = 0.008, indicating that this factor had a significant effect on the response. The cross-sectional area factor had a P-value of 0.083, which is greater than 0.05, indicating that it was not significant. The F-value for DS concentration was 9.30, much higher than the F-value for the cross-sectional area at 3.40, indicating a dominant influence on elongation at break. Based on the linear regression test results (Table 12), the model had an R-Sq of 84.67% and an Adjusted R-Sq of 71.52%, showing that the tested variables had a strong relationship with this parameter.

CONCLUSION

The results from the Taguchi experimental design on the performance/responses showed that the DS concentration factor was highly significant for the anti-UV response, with a factor influence (delta) value of 72.261 compared to the sample thickness of 1.605. Similarly, for elongation at break, the delta value of DS concentration was 2.43, higher than the cross-sectional area at 1.31. Meanwhile, for tensile strength performance, neither factor was significant; however, the cross-sectional area was more dominant than the DS concentration, with a delta value of 3.29 for cross-sectional area compared to 2.77 for DS concentration. The insignificance of the tensile strength response could have been caused by several reasons, including high data variation/spread and a limited sample size, which affected the tensile test results. High data variation could have occurred due to instability in the testing process, measurement errors, or operator errors during the tensile test. Additionally, a limited sample size could have reduced the accuracy of statistical analysis, making the effect of certain factors undetectable. Likewise, the regression model showed high predictability for anti-UV response but was less reliable for other responses. The addition of DS concentration to the anti-UV response blocked 100% of UV light, compared to PVA, which blocked only 16.00%. Meanwhile, tensile strength increased by 50.98%, with PVA/DS1 reaching 75.67 MPa compared to 50.12 MPa for PVA. Elongation at break increased by 14.71% in PVA/DS0.5 (304.43%) compared to PVA (265.40%). Then, PVA/DS1 (1% DS) was identified as the optimum film that met the performance requirements, making it a potential alternative to conventional plastics that are not easily degradable.

ACKNOWLEDGMENTS

The authors expressed their gratitude to the DBR program – National Research and Innovation Agency (BRIN), the Nano Science & Technology Laboratory – Andalas University, and the Vitka Batam Foundation for the assistance they provided.

BIBLIOGRAPHY

Abral, H., Ikhsan, M., Rahmadiawan, D., Handayani, D., Sandrawati, N., Sugiarti, E., & Muslimin, A. N. (2022). Anti-UV, antibacterial, strong, and high thermal resistant polyvinyl alcohol/Uncaria gambir extract biocomposite film. *Journal of Materials Research and Technology*, *17*, 2193–2202. https://doi.org/10.1016/j.jmrt.2022.01.120

Agarwal, S. (2020). Biodegradable Polymers: Present Opportunities and Challenges in Providing a Microplastic-Free Environment. *Macromolecular Chemistry and Physics*, *221*(6). https://doi.org/10.1002/macp.202000017

Annu, Ali, A., & Ahmed, S. (2021). Eco-friendly natural extract loaded antioxidative chitosan/polyvinyl alcohol based active films for food packaging. *Heliyon*, *7*(3). https://doi.org/10.1016/j.heliyon.2021.e06550

Baranwal, J., Barse, B., Fais, A., Delogu, G. L., & Kumar, A. (2022). Biopolymer: A Sustainable Material for Food and Medical Applications. In *Polymers* (Vol. 14, Issue 5). MDPI. https://doi.org/10.3390/polym14050983

Chen, S., Liu, D., Qian, M., Xu, L., Li, Y., Sun, H., Wang, X., Zhou, H., Bao, J., & Xu, C. (2020). Preparation of cyanobacteria-enhanced poly (vinyl)alcohol-based films with resistance to blue-violet light / red light and water. *PLoS ONE*, *15*(2). https://doi.org/10.1371/journal.pone.0228814

Ghazi, S. (2022). Do the polyphenolic compounds from natural products can protect the skin from ultraviolet rays? *Results in Chemistry*, *4*. https://doi.org/10.1016/j.rechem.2022.100428

Handayani, V. A., Railis, R. M., Sunarsono, H., Azzahra, N., Iby, I. C., Abral, H., Rushdan, A. I., Salit, M. S., & Azka, M. A. (2025). Comparison of Tensile Properties Data Analyzed Using ANOVA and MANOVA Methods: Case Study Data of PVA-Gambir Blend Film. *Pertanika Journal of Science and Technology*, *33*(1), 525–530. https://doi.org/10.47836/pjst.33.1.24

Koopmann, A. K., Schuster, C., Torres-Rodríguez, J., Kain, S., Pertl-Obermeyer, H., Petutschnigg, A., & Hüsing, N. (2020). Tannin-Based Hybrid Materials and Their Applications: A Review. In *Molecules (Basel, Switzerland)* (Vol. 25, Issue 21). NLM (Medline). https://doi.org/10.3390/molecules25214910

Liu, B., Zhang, J., & Guo, H. (2022). Research Progress of Polyvinyl Alcohol Water-Resistant Film Materials. In *Membranes* (Vol. 12, Issue 3). MDPI. https://doi.org/10.3390/membranes12030347

Olalla, A. L., Sara, L. I., & Ricardo, B. (2021). Assessment of toxicity and biodegradability of poly(Vinyl alcohol)-based materials in marine water. *Polymers*, *13*(21). https://doi.org/10.3390/polym13213742

Peña-Ortiz, M., Serrano, L., Romero, A. A., & García, A. (2023). Bay Leaves Extracts as Active Additive for Food Protective Coatings. *Foods*, *12*(20). https://doi.org/10.3390/foods12203741

Saha, T., Hoque, M. E., & Mahbub, T. (2020). Biopolymers for Sustainable Packaging in Food, Cosmetics, and Pharmaceuticals. In *Advanced Processing, Properties, and Applications of Starch and Other Bio-based Polymers* (pp. 197–214). Elsevier. https://doi.org/10.1016/B978-0-12-819661-8.00013-5

Sunarsono, H., Abral, H., Mahardika, M., Muhammad Railis, R., Sapuan, S., Adlan Azka, M., & Rizky Arrafi, M. (2025). *Enhancing mechanical properties of durian (Durio ziberthinus murr.) seed starch biopolymer filled with Indonesian bay leaf (Syzygium polyanthum) extract*. https://doi.org/10.1016/j.biombioe.2025.108159

Sunarsono, H., Abral, H., Pratoto, A., Gulo, E. F., Arrafi, M. R., Sibarani, E. I., Railis, R. M., Mahardika, M., Rushdan, A. I., Wahit, M. U., Handayani, D., Sandrawati, N., Rahmadiawan, D., Sugiarti, E., Muslimin, A. N., & Shi, S.-C. (2025). Indonesian Bay Leaf (Syzygium polyanthum Wight) Extract as a Natural Additive for UV and Red Light-Blocking Polyvinyl Alcohol Films with Enhanced Mechanical Properties. *Case Studies in Chemical and Environmental Engineering*, 101237. https://doi.org/10.1016/j.cscee.2025.101237

Wu, H., Liao, D., Chen, X., Du, G., Li, T., Essawy, H., Pizzi, A., & Zhou, X. (2023). Functionalized Natural Tannins For Preparation of a novel non-isocyanate polyure adhesive. *Polymer Testing*, *117*. https://doi.org/10.1016/j.polymertesting.2022.107853

Xiao, D., Jiang, M., Zhang, X., Niu, N., Li, J., Liu, S., Chen, Z., & Li, S. (2020). Seeking Answers from Tradition: Facile Preparation of Durable Adhesive Hydrogel Using Natural Quercetin. *IScience*, *23*(8). https://doi.org/10.1016/j.isci.2020.101342

Zainal, A., & Eka Pratiwi, D. (N.D.). Synthesis And Characterization Of Smart Packaging Film Labels Using Purple Sweet Potato Anthocyanin As Chicken Meat Quality Indicator. *Analytical: Analytical And Environmental Chemistry*, *10*(01). Https://Doi.Org/10.23960/Analit.V10i01.225