Pertanika J. Sci. & Technol. 33 (1): 525 - 530 (2025)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Short Communication

Comparison of Tensile Properties Data Analyzed Using ANOVA and MANOVA Methods: Case Study Data of PVA-Gambir Blend Film

Vitri Aprilla Handayani[1], Razan Muhammad Railis[2], Hery Sunarsono[2], Nabila Azzahra[1], Ilham Chayri Iby[3,4], Hairul Abral[3,4]*, Ahmad Ilyas Rushdan[5], Mohd Sapuan Salit[6] and Muhammad Adlan Azka[6]

[1]*Department of Mathematics, Technology Information Faculty, Batam Institute of Technology, Batam, 29425, Indonesia*
[2]*Department of Engineering Management, Industrial Technology Faculty, Batam Institute of Technology, Batam, 29425, Indonesia*
[3]*Department of Mechanical Engineering, Faculty of Engineering, Andalas University, Padang, 25163, Indonesia*
[4]*Laboratory of Nanoscience and Technology, Department of Mechanical Engineering, Andalas University, Padang, 25163, Indonesia*
[5]*Centre for Advanced Composite Materials (CACM), Universiti Teknologi Malaysia, 81310, UTM Johor Bahru, Johor, Malaysia*
[6]*Advanced Engineering Materials and Composites Research Centre, Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*

ABSTRACT

In our previous research, the Analysis of Variance (ANOVA) method was applied to analyze data on the tensile properties of pure PVA films and blend films mixing PVA (10%), BA (0.5%), and UG (1%). The results using ANOVA analysis are not significant for treatments in samples. This study compares data from Multivariate Analysis of Variance (MANOVA) and ANOVA methods. The accuracy level of both methods is $\alpha = 5\%$ (0.05). The result showed that the tensile properties of samples using MANOVA display a significant data effect. Therefore, we recommended MANOVA because the tests were performed simultaneously.

Keywords: ANOVA, MANOVA, multivariate analysis, PVA film, tensile properties

ARTICLE INFO

Article history:
Received: 16 May 2024
Accepted: 24 October 2024
Published: 27 January 2025

DOI: https://doi.org/10.47836/pjst.33.1.24

E-mail addresses:
vitri@iteba.ac.id (Vitri Aprilla Handayani)
razan@iteba.ac.id (Razan Muhammad Railis)
hery@iteba.ac.id (Hery Sunarsono)
nabila@gmail.com (Nabila Azzahra)
ilhamiby0306@gmail.com (Ilham Chayri Iby)
abral@eng.unand.ac.id (Hairul Abral)
ahmadilyas@utm.my (Ahmad Ilyas Rushdan)
sapuan@upm.edu.my (Mohd Sapuan Salit)
adlanazka24@gmail.com (Muhammad Adlan Azka)
* Corresponding author

INTRODUCTION

Polyvinyl alcohol (PVA) is a synthetic polymer with good biodegradability in the natural environment (Alonso-Lopez et al., 2021; Hashim et al., 2021). This material

ISSN: 0128-7680
e-ISSN: 2231-8526

can overcome the problem of natural environmental degradation due to its properties when disposed of in nature. However, PVA has limitations in terms of physical and chemical properties, so to overcome the limitations, the ratio of PVA (10%), BA (0.5%), and UG (1%) was chosen when developing polymer blend film because of the distinct properties each component brings and the desired characteristics of the final film. Previous research has shown that incorporating Gambir at certain concentrations improves the physical and chemical characteristics of polyvinyl alcohol (PVA), especially regarding its ability to block UV rays (Abral et al., 2022). The results show that Gambir has promising uses for food packaging. However, PVA/UG blends have some drawbacks. The limitations of these blend films for food packaging come from their highly hydrophilic (water-attracting) nature. It is recommended that substances that decrease the hydrophilic properties of the blend films be added to address these limitations. Research has shown that boric acid has the potential to reduce issues caused by the hydrophilic nature of these materials (Mahdi & Habeeb, 2023). As a result, composite film materials show improved physical and mechanical characteristics (Rahmadiawan et al., 2022).

Tensile properties describe the ability of materials to hold deformation force until they break. Tensile properties were primarily measured at the tensile test, in which the force was applied slowly at the tip of the sample while the other tip was fixed (Zheng et al., 2020).

This research has a range of applications across various industries, particularly where biodegradable, functional, and active packaging materials are needed, i.e., food or pharmaceutical packaging (Sunarsono et al., 2024). The novelty lies in the strategic use of PVA, boric acid, and Uncaria gambir to create biodegradable, mechanically robust films with sustained bioactive properties, thereby filling gaps left by earlier research.

Statistical methods, especially analysis of variance (ANOVA), have become effective analytical tools for examining significant differences between two or more data groups (Rahmadiawan et al., 2022). In the context of material tensile properties, ANOVA can be used to determine whether there are significant differences in tensile properties between different groups of materials.

The previous research was done on the same type of PVA with 1% Gambir added, using different treatment times (Rahmadiawan et al., 2022). It used ANOVA, which is a single dependent variable. Hence, this experiment used MANOVA, which extends ANOVA by allowing for the analysis of multiple dependent variables simultaneously while considering their potential interrelationships. MANOVA is a statistical method to identify the relationship between multiple dependent and one or more independent variables. Using MANOVA along with ANOVA can help determine if there are no significant differences between treatments and provide recommendations for more appropriate analyses to find treatment differences in the same sample in Khorasani et al. (2021) to find effective variables.

This research introduces a more effective alternative to ANOVA for statistically analyzing material testing data: MANOVA. It enables a more accurate and efficient evaluation of interaction effects between various materials compared to running separate ANOVA tests for each dependent variable (Huang, 2020). Additionally, MANOVA considers the correlations between the dependent variables, thereby providing more reliable results and reducing the risk of type I errors.

MATERIALS AND METHODS

Data

The data used in this study is secondary data, namely tensile properties data in previous studies (Rahmadiawan et al., 2022). The variables observed were tensile strength with additional treatment of Pure Polyvinyl Alcohol (PVA), Polyvinyl Alcohol/Boric Acid (PVA/BA), Polyvinyl Alcohol/Uncaria Gambir (PVA/UG), and Polyvinyl Alcohol Uncaria Gambir/Boric Acid (PVA/UG/BA). Samples were cut using a mold according to ASTM D638-14 type 5 tensile test standards, with five samples per variation/treatment. The thickness and width of the samples were measured using an optical microscope at 5 points. The samples were stored in a desiccator for ± 2 days until they reached RH = 50 ± 5%.

Analysis Method

ANOVA was used in the PVA-Gambir-Boric Acid Blend Film's study to determine treatment differences. ANOVA was used to assign differences in sample treatment by adding components, namely PVA, PVA/BA, PVA/UG, and PVA/UG/BA, which obtained significant results at the α level (5% = 0.05). Based on Almonroeder (2022), ANOVA compares the average between three or more groups or treatments. The primary purpose of ANOVA is to specify whether there is a significant difference between the means of the groups on one type of response or outcome variable. Whereas in the research conducted by Rahmadiawan et al. (2022), four results will be known, namely tensile strength (MPa), tensile modulus (GPa), toughness (MJ/m^3), and elongation at break (%). For this reason, this study will provide an alternative for determining differences in each treatment with four results or responses that MANOVA will see. MANOVA is a statistical method used to simultaneously compare the averages of two or more groups on two or more dependent variables. MANOVA will provide another alternative to evaluate whether there is a significant average difference between groups on all response or outcome variables simultaneously.

RESULTS AND DISCUSSION

The average difference in the sample with four treatments and four test results is made by determining the response or outcome variables and predictor variables that will be used

for the testing process to be carried out simultaneously. There are four response variables used, namely Mod Elastic (Y1), Tensile Strength (Y2), Break_Strain (Y3), and Toughness (Y4), as well as four predictor variables, namely PVA 10% (X1), PVA + BA (X2), PVA + G (X3), PVA+BA+G (X4). This research used PVA, BA, and UG to create polymer blend films due to the specific and complementary properties each material contributed to the film. It allows them to create multifunctional, eco-friendly films that meet various application requirements, especially in a critical mechanical performance field.

Table 2 contains the analysis results obtained using the MANOVA method to test the response variables and multiple predictors simultaneously through Statistical Software.

On the results of the multivariate test in Table 2, the sig. On each intercept and treatment test of 0.000 at a significance level of α (5% = 0.05). This means there are significant differences in each response and predictor variable simultaneously, and the results of the test of between-subject effects in Table 3 support this.

The results are in Table 3, where the sig value is obtained. For all observed variables, the significance level α is (5% = 0.05). It means that the addition of X1, X2, X3, and X4 components significantly impacts Y1, Y2, Y3, and Y4. The interaction mechanism between PVA, boric acid, and *Uncaria gambir* involves crosslinking through hydrogen bonding. Boric acid crosslinks the PVA chains, creating a more stable and water-resistant film, while *Uncaria gambir* contributes bioactive properties through its polyphenolic compounds. The interactions between these materials create a well-integrated polymer network with enhanced mechanical properties (Sciences, 2022).

Furthermore, a comparison was made between the results of previous studies using ANOVA and the results of tensile properties data testing using MANOVA conducted in this study, as seen in Figure 1 (Rahmadiawan et al., 2022).

Figure 1 shows a significant difference in the ANOVA and MANOVA test results. In

Table 2
Multivariate tests[a]

Effect		Sig.
Intercept	Pillai's Trace	,000
	Wilks' Lambda	,000
	Hotelling's Trace	,000
	Roy's Largest Root	,000
Treatment	Pillai's Trace	,000
	Wilks' Lambda	,000
	Hotelling's Trace	,000
	Roy's Largest Root	,000

Table 3
Tests of between-subjects effects

Source		Sig.
Corrected Model	Y1	,000
	Y2	,004
	Y3	,002
	Y4	,006
Intercept	Y1	,000
	Y2	,000
	Y3	,000
	Y4	,000
Treatment	Y1	,000
	Y2	,004
	Y3	,002
	Y4	,006

the ANOVA test, not all observed variables were significantly different. It can be seen from the sig value < α of (5% = 0.05). While testing using the MANOVA method, all observed variables significantly differ at α (5% = 0.05). This finding is in line with what was done in Khorasani et al. (2021) using the MANOVA method to find the effective variable on tensile properties.

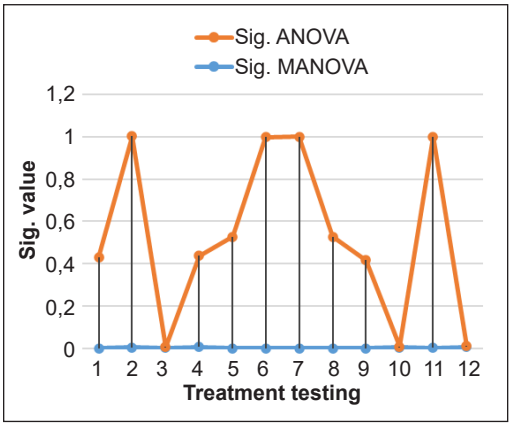

Figure 1. Comparison between ANOVA and MANOVA

Many material research studies use ANOVA to test the significance of treatments applied to the observation objects, where multiple tests are conducted simultaneously on the same sample (Abral et al., 2021). The results of this research provide a more effective alternative for performing statistical testing on material testing data other than ANOVA, namely, MANOVA.

CONCLUSION

We have compared tensile property data using ANOVA and MANOVA methods to the case study data of the blend film. Based on the comparative analysis performed, it has shown that the results using the ANOVA method were not significant for all treatments in the sample observed in the data tensile properties. The two methods' accuracy level is at the level of α = 5% (0.05). Meanwhile, the MANOVA method shows that the tensile properties of the sample have a significant effect on the tensile properties of the data. Therefore, we recommend MANOVA for testing more than one or multivariate response variables.

ACKNOWLEDGMENT

This research was funded by LPPM ITEBA 2023 and PKR UNAND through SK No. 003/SK/PKRNS/VII/2023.

REFERENCES

Abral, H., Chairani, M. K., Rizki, M. D., Mahardika, M., Handayani, D., Sugiarti, E., Muslimin, A. N., Sapuan, S. M., & Ilyas, R. A. (2021). Characterization of compressed bacterial cellulose nanopaper film after exposure to dry and humid conditions. *Journal of Materials Research and Technology*, *11*, 896–904. https://doi.org/10.1016/j.jmrt.2021.01.057

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

Almonroeder, T. G. (2022). Introduction to analysis of variance. *Advanced Statistics for Physical and Occupational Therapy*, 77–97. https://doi.org/10.4324/9781003179757-6

Alonso-Lopez, O., Lopez-Ibanez, S., & Beiras, R. (2021). Assessment of toxicity and biodegradability of Poly (vinyl alcohol)-based materials in marine water. *Polymers*, *13*, 1–9.

Hashim, A., Kadham Algidsawi, A. J., Ahmed, H., Hadi, A., & Habeeb, M. A. (2021). Synthesis of PVA/PVP/SnO_2 nanocomposites: Structural, optical, and dielectric characteristics for pressure sensors. *Nanosistemi, Nanomateriali, Nanotehnologii*, *19*(2), 353–362.

Huang, F. L. (2020). MANOVA: A procedure whose time has passed? *Gifted Child Quarterly*, *64*(1), 56–60. https://doi.org/10.1177/0016986219887200

Khorasani, M., Ghasemi, A. H., Awan, U. S., Singamneni, S., Littlefair, G., Farabi, E., Leary, M., Gibson, I., Veetil, J. K., & Rolfe, B. (2021). On the role of process parameters on meltpool temperature and tensile properties of stainless steel 316L produced by powder bed fusion. *Journal of Materials Research and Technology*, *12*, 2438–2452. https://doi.org/10.1016/j.jmrt.2021.04.043

Mahdi, S. M., & Habeeb, M. A. (2023). Low-cost piezoelectric sensors and gamma ray attenuation fabricated from novel polymeric nanocomposites. *AIMS Materials Science*, *10*(2), 288–300. https://doi.org/10.3934/MATERSCI.2023015

Rahmadiawan, D., Abral, H., Railis, R. M., Iby, I. C., Mahardika, M., Handayani, D., Natrana, K. D., Juliadmi, D., & Akbar, F. (2022). The enhanced moisture absorption and tensile strength of PVA/*Uncaria gambir* extract by boric acid as a highly moisture-resistant, anti-UV, and strong film for food packaging applications. *Journal of Composites Science*, *6*(11), Article 337. https://doi.org/10.3390/jcs6110337

Sciences, P. (2022). Fabrication and evaluation of optical characteristics of (PVA-MnO_2 – ZrO_2) nanocomposites for nanodevices. *Ukrainian Journal of Physics, 67*(10), 757-757.

Sunarsono, H., Hazimah, Rahmiati, S., Salit, M. S., Rushdan, A. I., & Azhari, F. A. (2024). Effect of various concentrations of sodium hydroxide/hot alkali treatment on the physical properties of ramie fibres. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *115*(2), 96–102. https://doi.org/10.37934/arfmts.115.2.96102

Zheng, P., Chen, R., Liu, H., Chen, J., Zhang, Z., Liu, X., & Shen, Y. (2020). On the standards and practices for miniaturized tensile test – A review. *Fusion Engineering and Design*, *161*, Article 112006. https://doi.org/10.1016/j.fusengdes.2020.112006