The Effect of Glycerol on Tensile Strength, Elongation, and Young's Modulus of Smart Edible Film from Rabbit Skin Gelatin with Purple Sweet Potato Solution

Natalia Raynalda Sihotang[1*], Jajang Gumilar[2], Andry Pratama[2]

[1]Student at the Faculty of Animal Husbandry, Department of Animal Product Technology, Universitas Padjadjaran

[2]Faculty of Animal Husbandry, Department of Animal Product Technology, Universitas Padjadjaran, Sumedang, Indonesia

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2026.1306000266

Received: 20 June 2026; Accepted: 26 June 2026; Published: 03 July 2026

ABSTRACT

Smart edible film is a biodegradable packaging material that can function not only as a physical barrier but also as an indicator of food quality. This study aimed to evaluate the effect of glycerol concentration on the tensile strength, elongation, and Young's modulus of smart edible film produced from rabbit skin gelatin with purple sweet potato solution, and to determine the optimum glycerol concentration for producing the best mechanical characteristics. The experiment used five glycerol concentrations, namely 5% (P1), 10% (P2), 15% (P3), 20% (P4), and 25% (P5), with four replications for each treatment. The observed variables were tensile strength, elongation, and Young's modulus. Data were analyzed using analysis of variance (ANOVA), followed by Duncan's multiple range test to determine differences among treatments. The results showed that glycerol concentration had a significant effect ($P < 0.05$) on the tensile strength, elongation, and Young's modulus of the smart edible film. Increasing glycerol concentration decreased tensile strength and Young's modulus, while elongation increased up to a certain level. Based on the overall mechanical characteristics, the 20% glycerol treatment (P4) was considered the most suitable treatment because it provided a balanced combination of tensile strength (0.49 MPa), elongation (73.45%), and Young's modulus (0.66 MPa). These results indicate that 20% glycerol can produce a smart edible film that is sufficiently strong, flexible, and not overly rigid, making it a potential formulation for further development as environmentally friendly active food packaging. Therefore, the formulation may support the development of biodegradable packaging materials derived from livestock by-products and natural plant pigments.

Keywords: Glycerol, Rabbit Skin Gelatin, Purple Sweet Potato, Smart Edible Film

INTRODUCTION

The increasing rabbit population in Indonesia has the potential to generate a considerable amount of skin by-products. Based on statistical data in 2024, the rabbit population in Indonesia reached 345.3 thousand head, representing a 39.15% increase compared with the previous year. In the same year, rabbit meat production also increased by 251.8 tons, equivalent to an 86.83% increase (Ditjen PKH, 2024). Rabbit slaughtering activities produce skin as a by-product in relatively significant quantities. Currently, rabbit skin utilization remains limited and is generally restricted to raw materials for handicraft industries, such as hats, bags, gloves, and other craft products. However, rabbit skin contains a high level of protein, particularly collagen. The conversion of collagen into gelatin enables its use in several products, including as a primary film-forming material for food packaging. In addition, the use of gelatin in biodegradable films supports sustainable practices through an environmentally friendly approach and may reduce dependence on non-biodegradable

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

polymers. Therefore, the utilization of rabbit skin as a gelatin source represents a potential alternative for increasing the economic value of by-products while reducing environmental pollution.

Food packaging has developed from simple packaging systems to more complex and environmentally friendly packaging materials. Packaging functions to protect products from biological, physical, and chemical damage, allowing food products to reach consumers safely. One current trend in packaging development is sustainable packaging. Edible film is one type of environmentally friendly packaging that is increasingly popular and continues to be developed. One of its innovations is smart edible film (SEF). SEF functions not only as a physical barrier but also as a packaging system with additional active compounds or intelligent properties that can help extend shelf life and provide information about food quality.

The incorporation of active compounds in SEF expands its packaging function, including the addition of color-changing pigments as food quality indicators. Synthetic pigments used in SEF production may have toxic and mutagenic potential. Therefore, natural pigments are important alternatives because they are generally safer and more readily available. Purple sweet potato (*Ipomoea batatas* var. Ayamurasaki) is one natural pigment source that is widely grown in Indonesia. Another advantage of purple sweet potato is its relatively high anthocyanin content compared with other sources such as red cabbage, blueberries, and red corn. Purple sweet potato contains approximately 134.94-240.70 mg/100 g anthocyanins and has relatively high antioxidant activity of 82.07% (Saati et al., 2024). Anthocyanins have strong antioxidant potential because of their ability to scavenge free radicals and inhibit lipid peroxidation. Their color-changing ability across a wide pH range also provides an additional advantage for use as active compounds in SEF production.

The basic materials of SEF are biopolymers, such as proteins, polysaccharides, lipids, or their combinations. Gelatin is one of the most commonly used biopolymers in SEF production because it can be obtained from various sources, has good film-forming ability, and has a relatively low melting point. Gelatin is also considered safe, inexpensive, and biodegradable. The use of gelatin in SEF offers several advantages, including good mechanical characteristics and oxygen barrier properties. Gelatin can be obtained from various sources, including rabbit skin. The amino acid composition and gelatin characteristics of rabbit skin are relatively comparable to those of porcine and bovine skin, indicating its potential as an alternative raw material for gelatin production.

Mechanical properties are important parameters in SEF characterization because packaging materials must have adequate strength to maintain their integrity during handling and storage. Parameters such as tensile strength, elongation, and Young's modulus are used to describe the ability of a film to withstand tensile force, its flexibility, and the rigidity of the material. One factor that can influence the mechanical properties of SEF is the addition of a plasticizer. A plasticizer is an organic compound that reduces polymer rigidity and improves flexibility. Glycerol is one of the most commonly used plasticizers in SEF production because it can modify mechanical characteristics such as tensile strength, elongation, and Young's modulus. Determining the appropriate glycerol concentration is important because it directly affects the mechanical characteristics of the resulting film. Therefore, this study was conducted to evaluate the effect of glycerol concentration on the tensile strength, elongation, and Young's modulus of smart edible film produced from rabbit skin gelatin with purple sweet potato solution.

METHODOLOGY

Preparation of Rabbit Skin Gelatin

Rabbit skin gelatin was prepared according to the method described by Rahmi et al., (2022) with slight modifications. The first stage was dehairing, in which rabbit skin was soaked in 7% lime solution (w/v) for 48 hours to facilitate hair removal. The dehaired skin was then washed under running water until a neutral pH was reached. The degreasing stage was carried out by heating the skin in water at 90°C for 15 minutes to remove residual fat.

After degreasing, the skin was cut into approximately 3 × 3 cm pieces and separated from the hypodermis layer. The next stage was demineralization, in which the skin was soaked in 1% HCl solution (w/v) at a skin-

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

to-solution ratio of 1:2. The container was covered with aluminium foil and left for 24 hours to remove calcium and mineral salts. The resulting demineralized material was referred to as ossein. Ossein contains collagen and several other proteins (Gumilar, Himina, et al., 2024). The ossein was washed with distilled water until a neutral pH of 6–7 was achieved. It was then packed in 200 g portions to facilitate the extraction process.

The extraction stage was performed by soaking the ossein in distilled water at a ratio of 1:2 and extracting it in a water bath at 80°C for 7 hours. The extracted solution was then filtered. The gelatin extract was dried in an oven at 50°C until completely dry. The dried gelatin was ground using a blender, packed in zip lock bags, and stored with silica gel.

Preparation of Purple Sweet Potato Solution

Purple sweet potato solution was prepared according to the method described by Dhani, (2020), using a drying temperature of 65°C. The purple sweet potatoes were thoroughly washed, peeled, and cut into small pieces. The pieces were then dried using a drying oven at 65°C for 24 hours. The dried purple sweet potato pieces were ground using a grinder to obtain purple sweet potato flour.

The purple sweet potato flour was used to prepare a 5% suspension (w/v) in distilled water. The suspension was homogenized in a water bath at 65°C for 30 minutes. After homogenization, the suspension was filtered using filter paper to separate the residue, resulting in purple sweet potato solution as a source of anthocyanins for edible film production.

Preparation of Smart Edible Film

The smart edible film was prepared according to the method described by Rahmi et al., (2022) with several modifications, including the addition of purple sweet potato solution as an anthocyanin source and the use of 6.25% gelatin (w/v). Gelatin at a concentration of 6.25% (w/v) was dissolved in 60 mL of purple sweet potato solution and homogenized in a water bath at 55°C for 30 minutes. The solution was then cooled to room temperature.

Glycerol was added according to the treatment levels, namely 5%, 10%, 15%, 20%, and 25% (v/w based on gelatin weight), and the solution was stirred until homogeneous at room temperature. A total of 50 mL of the film-forming solution was poured into a mold and dried for 48 hours. The formed film was conditioned in a desiccator for 24 hours and then stored in a zip lock bag containing silica gel to maintain its moisture condition.

Observed Variables

Tensile Strength

The tensile strength of the film was measured using a modified method based on Ma et al. (2018). The modification involved the use of a Universal Testing Machine (UTM) Instron type 3369 equipped with a 100 N load cell. Film strips measuring 30 × 70 mm were tested at a temperature of 25–28°C with a crosshead speed of 40 mm/min. Each film sample was clamped at both ends and stretched under controlled speed and distance until breakage occurred. The tensile strength value was calculated using the formula described by Mouzakitis et al., (2022):

$$\sigma max = \frac{Fmax}{A}$$

where σmax is the tensile strength (MPa), Fmax is the maximum force (N) required to break the sample, and A is the cross-sectional area (m^2), calculated by multiplying the film thickness by the film width.

Elongation

The elongation at break test was carried out simultaneously with the tensile strength test, referring to (Ma et al.,

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

2018) with modifications using a Universal Testing Machine (UTM) Instron type 3369 equipped with a 100 N load cell. Film strips measuring 30 × 70 mm were tested at a temperature of 25–28°C with a crosshead speed of 40 mm/min. Elongation at break was calculated using the following formula described by Ma et al., (2018):

$$EAB\ (\%) = \frac{\Delta L}{L0} X\ 100\%$$

where EAB is the elongation at break (%), ΔL is the increase in film length at break (mm), calculated as the difference between the final length and the initial length, and L0 is the initial length of the film sample (mm).

Young's Modulus

Young's modulus was determined from the slope of the stress–strain curve. The value was calculated using the formula described by Mouzakitis et al., (2022):

$$E = \frac{(F \times L0)}{(A \times \Delta L)}$$

where E is Young's modulus, F × L0 represents the force multiplied by the initial length, and A × ΔL represents the cross-sectional area multiplied by the increase in length.

Data Analysis and Method

This study used an experimental method with a Completely Randomized Design (CRD) consisting of five glycerol concentration treatments and four replications. The treatments were P1 = 5% glycerol, P2 = 10% glycerol, P3 = 15% glycerol, P4 = 20% glycerol, and P5 = 25% glycerol. Data on tensile strength, elongation, and Young's modulus were analyzed using analysis of variance (ANOVA). When significant differences were detected, Duncan's multiple range test was performed to compare treatment means.

RESULTS AND DISCUSSION

The addition of glycerol significantly affected the tensile strength, elongation, and Young's modulus of smart edible film produced from rabbit skin gelatin with purple sweet potato solution ($P < 0.05$). The mechanical characteristics of the film are presented in Table 1.

Treatment	Tensile Strength (MPa)	Elongation (%)	Young's Modulus (MPa)
P1	$2{,}32 \pm 0{,}19^{a}$	51.68 ± 4.91^{bc}	4.50 ± 0.36^{a}
P2	$0{,}67 \pm 0{,}18^{b}$	62.10 ± 13.64^{ab}	1.11 ± 0.34^{b}
P3	$0{,}66 \pm 0{,}17^{b}$	69.31 ± 5.03^{a}	0.96 ± 0.29^{bc}
P4	$0{,}49 \pm 0{,}11^{b}$	73.45 ± 10.94^{a}	0.66 ± 0.13^{cd}
P5	$0{,}20 \pm 0{,}04^{c}$	46.54 ± 5.65^{c}	0.43 ± 0.08^{d}

Note: Data are presented as mean ± standard deviation. Different superscript letters in the same column indicate significant differences based on Duncan's multiple range test. P1 = 5% glycerol, P2 = 10% glycerol, P3 = 15% glycerol, P4 = 20% glycerol, and P5 = 25% glycerol.

Tensile Strength

The tensile strength values of the smart edible films ranged from 0.20 to 2.32 MPa. These values were within the range reported by Gumilar et al., (2025), who found tensile strength values of 0.44±0.05 to 4.44±0.35 MPa. However, the values obtained in the present study were lower than those reported for edible films based on rabbit bone gelatin, which ranged from 3.00±0.35 to 7.34±0.30 MPa (Putri et al., 2025). Analysis of variance showed that glycerol concentration had a highly significant effect ($P<0.01$) on tensile strength, indicating that changes in glycerol concentration influenced the mechanical resistance of the film.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Duncan's multiple range test showed that P1 produced a significantly higher tensile strength value ($P<0.05$) than the other treatments. Treatments P2, P3, and P4 were not significantly different ($P>0.05$) from one another, whereas P5 showed a significantly lower tensile strength value ($P<0.05$) compared with the other treatments. The higher tensile strength in P1 may be attributed to the lower glycerol concentration of 5%, which allowed stronger interactions among gelatin polymer chains and resulted in a more compact film structure. This condition increased the ability of the film to resist tensile force (Lau & Sarbon, 2022). The decrease in tensile strength from P1 to the other treatments indicates that increasing glycerol concentration produced a clear plasticizing effect on the film matrix.

The insignificant differences among P2, P3, and P4 suggest that glycerol concentrations of 10–20% produced relatively similar plasticizing effects on tensile strength. In this range, the reduction in tensile strength was not large enough to create significant differences among treatments. However, P5 showed that the addition of 25% glycerol caused a more pronounced decrease in tensile strength. At higher concentrations, glycerol molecules may insert themselves between polymer chains, weaken intermolecular interactions, reduce matrix compactness, and increase the distance between polymer chains. Consequently, the ability of the film to withstand tensile force decreases (Gumilar et al., 2025; Swain et al., 2004).

The presence of glycerol in the polymer matrix increases chain mobility and free volume within the film structure. Glycerol may also interact with polymer molecules through physical and chemical interactions, resulting in improved flexibility and stretchability but reduced mechanical strength, cohesion, and stiffness (Chen et al., 2019). This finding is consistent with previous research reporting that the addition of plasticizers such as glycerol can reduce tensile strength (Lin et al., 2025). In smart edible film applications, tensile strength is an important parameter because it reflects the ability of the film to maintain its shape and integrity during handling. However, the best formulation should not be determined only by the highest tensile strength value, because glycerol is still required to produce a film that is not excessively rigid. Therefore, tensile strength should be evaluated together with elongation at break and Young's modulus.

Elongation

The elongation at break values of the smart edible films ranged from 46.54 to 73.45%. These values were lower than those reported for edible films based on duck feet gelatin, which ranged from 72.33 to 95.67% (Gumilar, Aulia Andiati, et al., 2024), but higher than those reported for fish skin gelatin-based films, which ranged from 30.86 to 62.86% (Li et al., 2014). Analysis of variance showed that glycerol concentration had a highly significant effect ($P<0.01$) on elongation at break, indicating that the addition of glycerol influenced the flexibility and stretchability of the film.

Duncan's multiple range test showed that P4, P3, and P2 were not significantly different ($P>0.05$) from one another, but had significantly higher elongation values ($P<0.05$) than P5. Treatment P2 was not significantly different ($P>0.05$) from P1, while P1 was also not significantly different ($P>0.05$) from P5. These results indicate that the effect of glycerol on elongation occurred gradually. The increase in glycerol concentration from P1 to P2 was not sufficient to produce a significant increase in elongation. However, P3 and P4 showed significantly higher elongation than P1, indicating that the plasticizing effect became more evident at higher glycerol concentrations.

Treatment P2 showed an intermediate response because it was not significantly different from P1, P3, and P4. This condition indicates that P2 overlapped between the lower elongation group and the higher elongation group. Mechanically, glycerol is hydrophilic and has a small molecular size, allowing it to penetrate the polymer matrix and increase polymer chain mobility (Suderman et al., 2018). Increased chain mobility makes the film more flexible and easier to stretch, resulting in higher elongation values as glycerol concentration increases up to a certain level.

However, P5 showed a lower elongation value and was not significantly different from P1, but was significantly different from P2, P3, and P4. This result indicates that the highest glycerol concentration did not provide a beneficial plasticizing effect on film elongation. A similar pattern was reported in edible films made from fish skin gelatin and bovine gelatin, where elongation increased at glycerol concentrations of 0–25% but

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

decreased at 30% glycerol (Rezaei & Motamedzadegan, 2015). Excessive glycerol may weaken interactions among polymer chains and reduce the stability of the film matrix. As a result, the film may break more easily during stretching, leading to a decrease in elongation (Kamkar et al., 2021). This suggests that there is an optimum glycerol concentration for improving the flexibility of edible films.

In smart edible film applications, elongation at break is an important parameter because it reflects the ability of the film to withstand deformation during handling. A high elongation value indicates good flexibility; however, the highest elongation value does not always represent the best overall formulation. Therefore, elongation should be evaluated together with tensile strength and Young's modulus, because a film that is too flexible but has low tensile strength may be too weak to be used as a packaging layer.

Young's Modulus

The Young's modulus values of the smart edible films ranged from 0.43 to 4.50 MPa. This range was consistent with a previous study that reported a similar decreasing trend with increasing glycerol concentration, with Young's modulus values ranging from 0.44±0.06 to 12.32±2.38 MPa (Gumilar et al., 2025). However, the values obtained in the present study were higher than those reported for duck feet gelatin-based edible films, which ranged from 0.12 to 2.90 MPa (Gumilar, Aulia Andiati, et al., 2024). Analysis of variance showed that glycerol concentration had a highly significant effect ($P<0.01$) on Young's modulus, indicating that glycerol addition influenced the stiffness of the film.

Duncan's multiple range test showed that P1 produced a significantly higher Young's modulus value ($P<0.05$) than the other treatments. Treatment P2 was not significantly different ($P>0.05$) from P3, but was significantly higher ($P<0.05$) than P4 and P5. Treatment P3 was not significantly different ($P>0.05$) from P4, but was significantly higher ($P<0.05$) than P5. Meanwhile, P4 was not significantly different ($P>0.05$) from P5. These results indicate that increasing glycerol concentration gradually reduced the stiffness of the smart edible film.

The highest Young's modulus value in P1 may be attributed to the low glycerol concentration of 5%, which allowed stronger interactions among gelatin polymer chains and produced a denser film matrix. This condition resulted in a stiffer film with a higher Young's modulus value. A previous study also reported that films with lower glycerol concentrations tend to form a more compact polymer network, resulting in higher stiffness and Young's modulus values (Lau & Sarbon, 2022). The decrease in Young's modulus from P1 to P2 indicates that increasing glycerol concentration from 5% to 10% had a clear plasticizing effect on the film matrix.

Glycerol can insert itself between gelatin polymer chains and weaken intermolecular interactions, thereby facilitating chain movement and reducing film stiffness (Piermaria et al., 2011). The insignificant differences between adjacent treatments, such as P2 and P3, P3 and P4, and P4 and P5, suggest that the reduction in stiffness occurred gradually as glycerol concentration increased. At higher concentrations, glycerol may further reduce interactions among gelatin chains, decrease matrix compactness, and increase macromolecular mobility, leading to lower Young's modulus values (Gumilar et al., 2025).

Overall, the decrease in Young's modulus indicates that the film became less rigid and more easily deformed as glycerol concentration increased. In smart edible film applications, a lower Young's modulus can be beneficial because it indicates better flexibility. However, if Young's modulus is too low and accompanied by low tensile strength, the film may become too weak to maintain its integrity during handling. Therefore, Young's modulus should be considered together with tensile strength and elongation at break when determining the best glycerol concentration for smart edible film formulation.

CONCLUSION

Glycerol concentration significantly affected the tensile strength, elongation, and Young's modulus of smart edible film produced from rabbit skin gelatin with purple sweet potato solution. Increasing glycerol concentration generally decreased tensile strength and Young's modulus, while elongation increased up to a certain level. The 20% glycerol treatment (P4) produced the most suitable mechanical characteristics because it provided a balance between tensile strength, flexibility, and stiffness. Therefore, 20% glycerol can be

considered the optimum concentration for producing smart edible film from rabbit skin gelatin with purple sweet potato solution.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided by the second author, Prof. Jajang Gumilar, for the completion of this research. The authors also thank the Faculty of Animal Husbandry, Universitas Padjadjaran, for providing facilities and technical support during the study.

REFERENCES

1. Chen, H., Wang, J., Cheng, Y., Wang, C., Liu, H., Bian, H., Pan, Y., Sun, J., & Han, W. (2019). Application of protein-based films and coatings for food packaging: A review. *Polymers*, *11*(12). https://doi.org/10.3390/polym11122039
2. Dhani, A. U. (2020). *Pembuatan Tepung Ubi Ungu Dalam Upaya Diversifikasi Pangan Pada Industri Rumah Tangga UKM Griya Ketelaqu Di Kelurahan Plalangan Kecamatan Gunungpati Kota Semarang*. *5*(1).
3. Direktorat Jenderal Peternakan dan Kesehatan Hewan, D. P. (2024). *Statistika Peternakan dan Kesehatan Hewan 2024* (Vol. 3). Direktorat Jenderal Peternakan dan Kesehatan Hewan, Kementerian Pertanian RI.
4. Gumilar, J., Aulia Andiati, H., & Wulandari, E. (2024). Physical Quality Of Edible Film From Duck Feet Gelatin Using Various Glycerol Concentrations. *International Journal of Scientific Research and Management (IJSRM)*, *12*(01), 185–164. https://doi.org/10.18535/ijsrm/v12i01.ft02
5. Gumilar, J., Himina, A. M., & Suryaningsih, L. (2024). The Effect of HCL Concentration on Gelatin Yield, Moisture, and ASH Content from Rabbit's (Lepus Nigri Collis) Skin. *International Journal of Scientific Research and Management (IJSRM)*, *12*(06), 179–184. https://doi.org/10.18535/ijsrm/v12i06.ft01
6. Gumilar, J., Putranto, W. S., Pratama, A., & Maharani, R. (2025). Utilization Of Rabbit Skin As Edible Film For Environmentally Friendly Food Packaging Using Glycerol As Plasticizer. *World Rabbit Science*, *33*(2), 139–150. https://doi.org/10.4995/wrs.2025.23032
7. Kamkar, A., Molaee-aghaee, E., Khanjari, A., Akhondzadeh-basti, A., Noudoost, B., Shariatifar, N., Alizadeh, M., & Soleimani, M. (2021). International Journal of Food Microbiology Nanocomposite active packaging based on chitosan biopolymer loaded with nano-liposomal essential oil : Its characterizations and effects on microbial , and chemical properties of refrigerated chicken breast fillet. *International Journal of Food Microbiology*, *342*(January), 109071. https://doi.org/10.1016/j.ijfoodmicro.2021.109071
8. Lau, A. Y., & Sarbon, N. M. (2022). *Effect of glycerol concentrations on the mechanical and physical properties of chicken skin gelatin-tapioca starch composite films*. *6*(August), 428–436. https://doi.org/https://doi.org/10.26656/fr.2017.6(4).546
9. Li, J., Miao, J., Wu, J., Chen, S., & Zhang, Q. (2014). Food Hydrocolloids Preparation and characterization of active gelatin-based fi lms incorporated with natural antioxidants. *Food Hydrocolloids*, *37*, 166–173. https://doi.org/10.1016/j.foodhyd.2013.10.015
10. Lin, Q., Zhou, Y., Lin, S., Cai, Y., Huang, Z., Miao, S., Lu, X., Zhou, Y., Lin, S., & Cai, Y. (2025). New insight into the glycerol plasticizer concentration effect on the properties and microstructure of soluble Tremella fuciformis polysaccharide edible films. *Journal of Future Foods*. https://doi.org/10.1016/j.jfutfo.2025.10.038
11. Ma, L., Yang, H., Ma, M., Zhang, X., & Zhang, Y. (2018). Mechanical and structural properties of rabbit skin gelatin films. *International Journal of Food Properties*, *21*(1), 1203–1218. https://doi.org/10.1080/10942912.2018.1476874
12. Mouzakitis, C., Sereti, V., Matsakidou, A., Kotsiou, K., Biliaderis, G., & Lazaridou, A. (2022). Food Hydrocolloids Physicochemical properties of zein-based edible films and coatings for extending wheat bread shelf life. *Food Hydrocolloids*, *132*(February), 107856. https://doi.org/10.1016/j.foodhyd.2022.107856
13. Piermaria, J., Bosch, A., Pinotti, A., Yantorno, O., Alejandra, M., & Graciela, A. (2011). Food

Hydrocolloids Ke fi ran fi lms plasticized with sugars and polyols : water vapor barrier and mechanical properties in relation to their microstructure analyzed by ATR / FT-IR spectroscopy. *Food Hydrocolloids*, *25*(5), 1261–1269. https://doi.org/10.1016/j.foodhyd.2010.11.024

14. Putri, S. R. P., Haryati, D., Santoso, U., Ningrum, A., Nugrahini, A., & Manikharda. (2025). Sustainable Food Technology concentration on properties and application in soybean oil packaging. 2297–2307. https://doi.org/10.1039/d5fb00316d
15. Rahmi, Q. F., Wulandari, E., & Gumilar, J. (2022). Pengaruh konsentrasi gliserol pada gelatin kulit kelinci terhadap kadar air, ketebalan film, dan laju transmisi uap air edible film. *Jurnal Teknologi Hasil Peternakan*, *3*(1), 19. https://doi.org/10.24198/jthp.v3i1.39444
16. Rezaei, M., & Motamedzadegan, A. (2015). The effect of plasticizers on mechanical properties and water vapor permeability of gelatin-based edible films containing clay nanoparticles. (December), 178–193. https://doi.org/http://dx.doi.org/10.4236/wjnse.2015.54019 The
17. Saati, E. A., Damat, & Wahyudi, A. (2024). Potensi ubi jalar ungu Analisis Kandungan Antosianin (Cetakan I). PT. Literasi Nusantara Abadi Grup.
18. Suderman, N., Isa, M. I. N., & Sarbon, N. M. (2018). The effect of plasticizers on the functional properties of biodegradable gelatin-based film: A review. In *Food Bioscience* (Vol. 24, pp. 111–119). Elsevier Ltd. https://doi.org/10.1016/j.fbio.2018.06.006
19. Swain, S. N., Biswal, S. M., Nanda, P. K., & Nayak, P. L. (2004). Biodegradable Soy-Based Plastics : Opportunities and Challenges. *Journal of Polymers and the Environment*, *12*(1). https://doi.org/https://doi.org/10.1023/B:JOOE.0000003126.14448.04