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MORALITY BEFORE KNOWLEDGE

Innovation of edible coating based on sugarcane bagasse and av ocado seeds with integrated moringa leaf fortification and QR code technology as fruit protection

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ABSTRACT

Background: Fruits are one of the leading agricultural commodities in Indonesia, with abundant availability and high consumption rates. Improper fruit storage can cause fruits to spoil quickly and increase organic waste. Sugarcane bagasse waste is one of the largest contributors to organic waste in Indonesia's agricultural sector. On the other hand, avocado seeds are often considered waste because people generally only consume the fruit flesh and discard the seeds without utilizing them. Both types of waste have the potential to be used as biodegradable and environmentally friendly edible coatings for fruits. This scientific study aims to explain the edible coating made from sugarcane bagasse and avocado seeds fortified with moringa leaves as an innovation in addressing issues in the food industry, particularly regarding the quality of fruit flesh that easily spoils due to improper packaging. **Methods:** The edible coating was produced through the extraction of sugarcane bagasse, avocado seeds, and moringa leaves, followed by homogenization for coating preparation. The edible coating can then be applied to the fruit. The writing method used in this scientific work is based on literature studies from data and information obtained through books, scientific journals, and several relevant sources. **Findings:** The results indicate that edible coating based on sugarcane bagasse waste has the potential to maintain fruit quality because it contains approximately 40-50% cellulose, which can be used as a base material for natural biopolymers in edible coating. The addition of avocado seeds acts as an antibacterial, antioxidant, starch, and lipid to form a strong, flexible, and water-resistant edible coating structure. The addition of moringa leaves acts as a fortifier for the fruit. **Conclusion:** The development of edible coatings based on sugarcane bagasse waste and avocado seeds will create an innovative fruit wrapper that preserves fruit quality and is environmentally friendly. **Novelty/Originality of this article:** Edible coatings on the market generally focus only on the wrapping layer to protect the fruit, without considering the nutritional content of the fruit, which decreases over time. Fortifying edible coatings with moringa leaves can help maintain and enhance fruit nutrients while preventing nutrient loss due to oxidation. This innovation is integrated with barcode technology to provide information about the advantages of edible coatings based on sugarcane bagasse and avocado seeds fortified with moringa leaves.

KEYWORDS: sugarcane bagasse; barcode; avocado seeds; moringa leaves; edible coating.

1. Introduction

Horticulture has the potential to become one of the agricultural commodities that can improve the welfare of farmers in Indonesia. Fruits are one of the horticultural products that are in high demand by the public, due to their nutritional content that is beneficial for health. Fruits are categorized into two types: climacteric fruits and non-climacteric fruits.

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Climacteric fruits are those that produce ethylene for fruit ripening and have a high respiration rate, causing them to ripen quickly and have a short shelf life, such as avocados, mangoes, tomatoes, papayas, kiwis, guavas, apples, and bananas. On the other hand, non-climacteric fruits are fruits that can be stored for a long time because they do not experience increased respiration and ethylene production during ripening, such as oranges, lemons, rambutans, watermelons, and strawberries (Wahyudi & Harsono, 2023). Farmers face challenges in fruit cultivation, particularly in post-harvest handling. Fruits can quickly rot and spoil during distribution, even before reaching consumers, due to inadequate post-harvest handling, improper cold storage, and suboptimal packaging. This not only impacts the economy of farmers and fruit sellers but also contributes to environmental damage from rotting, unsold fruit. Rotting fruits are the top contributor to food waste, accounting for approximately 45% of greenhouse gas emissions. Fruits discarded after production before reaching the consumer stage amount to 62.8% (Handoyo & Asri, 2023; Ihsan & Derosya, 2024).

Fruit wrapping nets or synthetic fruit nets are often used to protect fruits during distribution, but the use of fruit wrapping nets generates plastic waste, creating a new problem. Edible coating technology is one approach to solving the problem of fruit spoilage during distribution. When applied to the fruit surface, the edible coating forms a transparent layer that protects the fruit from microbial exposure, prevents wrinkling due to water loss, and slows down the fruit's respiration rate, thereby preventing rapid spoilage and extending the fruit's shelf life. Edible coatings are made from renewable materials, such as a mixture of lipids, polysaccharides, and proteins (Widyaningrum et al., 2015).

Innovations in edible coatings made from sugarcane bagasse and avocado seeds fortified with moringa leaves offer an environmentally friendly solution to maintain fruit quality and nutritional content, as well as serve as an alternative to plastic fruit nets. Generally, the main component of edible coatings is hydrocolloid, which can be sourced from starch. One abundant starch source in Indonesia is sugarcane bagasse. In 2021, sugarcane bagasse waste reached 756,582.72 tons and is expected to continue increasing as a contributor to organic waste in agriculture alongside sugarcane production processes (Huzaiva et al., 2025). In addition to starch, lipids are another component of edible coatings that can be sourced from avocado seeds. The vegetable oil content in avocado seeds is high, nearly equivalent to soybeans, reaching 15–20%. According to BPS data, avocado seed waste has increased annually, in line with the increase in avocado fruit production (Risyad et al., 2016). The utilization of avocado seeds as a component of edible coatings is one of the strategies to address the accumulation of avocado seed waste. Meanwhile, moringa leaves can enhance the quality of edible coatings due to their high nutritional content and antibacterial activity. This product is an innovation in edible coatings, where coatings made from sugarcane bagasse and avocado seeds fortified with moringa leaves offer advantages such as being natural, safe for health, non-toxic, providing additional nutritional value, and protecting against bacterial exposure. Additionally, this innovation is integrated with a QR code on the product packaging, providing information about the advantages of fruits coated with edible coating, product safety information, and the product's role in contributing to environmental conservation. Therefore, through this edible coating innovation, it is hoped that it can serve as a solution to the issue of fruit spoilage due to suboptimal post-harvest handling, thereby extending the shelf life of fruits and contributing to environmental conservation as well as the economic well-being of fruit farmers.

2. Methods

The preparation of this scientific paper consists of stages of data and information collection through literature studies, searching for relevant sources, and searching the internet. Data sources include scientific journals, books, electronic media, and other libraries related to the topic of writing. The collected data and information are then analyzed descriptively based on secondary data. This secondary data is obtained through literature review, namely by reading scientific books and examining the results of previous

studies that are closely related to the purpose and object of the writing. This analysis process aims to obtain a comprehensive picture of the issues being studied.

After processing, the data and information are analyzed by comparing various pieces of information about problems that have occurred and relating them to existing concepts and theories. This analysis aims to find key points that can strengthen the argument and generate new ideas in this scientific work. The ideas generated will be presented clearly and in detail, in accordance with the needs and issues outlined earlier, resulting in practical and scientific solutions. The aspects to be analyzed are how edible coatings made from sugarcane bagasse and avocado seeds fortified with moringa leaves can be an effective solution in protecting the structure and quality of fruit.

3. Results and Discussion

3.1 Fruit quality issues in Indonesia

Fruit is one of the most widely consumed foods in Indonesia due to its high nutritional content, including vitamins, minerals, fiber, and antioxidants, which are important for maintaining good health. Regular fruit consumption is known to help boost the immune system, maintain metabolic balance, stimulate brain function, and prevent various degenerative diseases such as diabetes, hypertension, and heart disease (Kusmiyati et al., 2022). In addition to their health benefits, fruits also offer diverse flavors and are easily accessible in various regions of Indonesia, whether through traditional markets, supermarkets, or directly from local farmers. Their abundant availability throughout the year is supported by geographical conditions and the tropical climate, making fruit an essential part of the Indonesian diet (Rai et al., 2016).

Fruit can rot over time due to natural processes that occur after harvesting. After harvesting, fruit undergoes physiological changes characterized by changes in color, texture, taste, freshness, and aroma (Fertiasari et al., 2023). Fruit spoilage can be caused by microbial activity, such as bacteria and fungi, as well as insects like fruit flies. These microorganisms attack the fruit by breaking down plant tissue, thereby accelerating the decomposition process and reducing fruit quality in terms of taste, texture, and nutritional value. Additionally, fruit flies lay eggs inside or on the surface of the fruit, and the larvae (maggots) that hatch damage the fruit tissue from the inside, worsening the decay process and shortening the fruit's shelf life (Arma et al., 2018).

Many traders in Indonesia sell fruit of poor quality, such as wilted, bruised, or even nearly rotten fruit. This condition not only reduces the nutritional value and taste of the fruit but can also harm consumers in terms of health and economics. The low quality of fruit sold can be attributed to various factors, including suboptimal post-harvest processes, improper storage, and a lack of awareness among traders about the importance of maintaining product quality. Indonesian society often stores fruit using plastic packaging. Most items are packaged using plastic because it is lightweight, durable, easy to shape, and affordable (Ihsan & Derosya, 2024). However, conventional plastic packaging often fails to provide optimal protection for fruit, allowing physical damage, moisture loss, and accelerated spoilage to occur. Additionally, the use of single-use plastic has negative environmental impacts due to plastic waste that is difficult to degrade, leading to the accumulation of plastic waste that pollutes the environment. Synthetic polymers, which are the main component of plastic, take decades or even centuries to degrade. When burned, plastic emits carbon emissions that pollute the environment (Kamsiati et al., 2017).

Proper storage of fruits is essential to maintain their quality and prevent rapid damage or decay. Appropriate fruit packaging is necessary to protect fruits from microbial activity and damaging insects. An alternative approach to prevent such damage is the use of edible coatings, which can protect fruits from microbial activity or insects and extend their shelf life by inhibiting ethylene gas transfer in post-harvest fruits. Innovations in edible coatings with nutritional fortification are essential to maintain fruit quality and enhance nutritional

value. Edible coatings are an environmentally friendly innovation, as they reduce plastic use in fruit packaging and minimize fruit waste caused by spoilage.

3.2 Innovation in edible coatings based on sugarcane bagasse and avocado seed waste

Edible coating is a transparent, edible layer that functions similarly to modified atmosphere packaging (MAP), reducing spoilage without causing anaerobic effects and without affecting the quality of the packaged fruit and food (Athmaselvi et al., 2020). The mechanism of this "coating" is to prevent the transfer of gases, water vapor, and dissolved substances, as well as protect against mechanical damage, particularly in fruits and foods (Koesmartaviani, 2015). Edible coating is one of the methods used to extend the shelf life of fruits. The main components of edible coatings consist of hydrocolloids, lipids, and other composites. Hydrocolloids that have potential as edible coating materials include polysaccharides (starch, alginate, pectin, and other modified carbohydrates) and proteins (gelatin, casein, soy protein, corn protein, and wheat gluten). Lipids that can be used include waxes, glycerol, and fatty acids. One potential source of polysaccharides is sugarcane bagasse. Sugarcane bagasse is a solid byproduct of the sugarcane processing industry that still contains high-value compounds, particularly lignocellulosic components. One of the main components in sugarcane bagasse is cellulose, a structural polysaccharide that accounts for approximately 37–45% of its composition (Heviyanti et al., 2021). The high cellulose content makes sugarcane bagasse a potential raw material for producing natural hydrocolloids. Hydrocolloids derived from cellulose are commonly used as film-forming agents in edible coatings because they have low permeability to gases such as oxygen (O_2) and carbon dioxide (CO_2). Hydrocolloids are hydrophilic, making them less effective as barriers to water vapor. To improve moisture resistance, the addition of lipid components (which are hydrophobic) to the edible coating formulation is necessary to create a composite layer with more balanced barrier properties against gases and water vapor (Ratnaduhita et al., 2025).

Avocado seeds have potential as a lipid source for edible coatings. Lipids from avocado seeds can be utilized as additional hydrophobic components in edible coatings, especially if extracted and formulated efficiently. Additionally, the antioxidant content in avocado seeds provides an extra benefit as a protector against food oxidation. Avocado seeds also contain a relatively high starch content of 23%. This makes avocado seeds a potential alternative starch source. Avocado seeds processed into starch not only help reduce environmental pollution but can also be processed into various high-value products, one of which is applied as an edible coating (Rangkuti et al., 2019). Avocado seeds are currently discarded as waste, contributing to environmental pollution. Meanwhile, avocado seeds contain a high amount of vegetable oil, nearly equivalent to soybeans, reaching 15-20%, and also contain a high starch content of 23%. Avocado seeds can be processed into various high-value products, one of which is applied as an edible coating (Risyad et al., 2016).

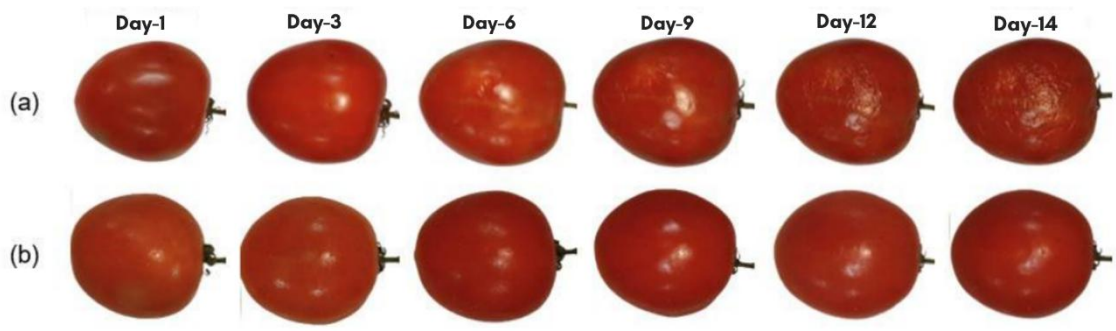

Fig. 1. Physical appearance of tomatoes during storage (a) without a protective coating; (b) with a protective coating
(Ani et al., 2024)

Edible coatings can maintain the quality and freshness of fruits and prevent wrinkling (Figure 1). The protective mechanism of edible coatings involves inhibiting the movement of ethylene gas in fruits and vegetables. Innovations in edible coatings using a combination of cellulose from sugarcane bagasse waste as a hydrocolloid component and vegetable oil from avocado seed waste as a lipid component have the potential to create an effective edible coating that inhibits oxidation, reduces gas and water vapor transmission, and extends fruit shelf life. Figure 1 shows the results of applying edible coatings to fruit.

3.3 Edible coating production process

The production process of edible coating based on sugarcane bagasse and avocado seeds requires an extraction stage to obtain cellulose from sugarcane bagasse and lipids from avocado seeds. Extraction is a process of separating components from a homogeneous mixture using a liquid solvent as a separating agent, resulting in two products: extract and raffinate. Cellulose extraction from sugarcane bagasse is carried out by drying in an oven at 80°C for 2–3 days. The dried fibers are soaked in a 15% NaOH solution for 4 hours at room temperature and rinsed several times with deionized water to remove residual alkali and residues, resulting in the cellulose extract (Charoensopa et al., 2024). Lipid extraction from avocado seeds is carried out through several stages, including crushing, grinding, drying, and sieving of the avocado seeds. Extraction is performed using n-heptane as the solvent. The mixture is heated to its boiling point, and the extraction time is calculated. Next, the oil and solvent mixture is separated through distillation to obtain the avocado seed oil extract (Risyad et al., 2016).

The addition of moringa leaf extract as fortification in edible coating products through the solid-liquid extraction process, which is the simplest technique for extracting active compounds from solid materials such as moringa leaves. In this method, moringa leaf powder is soaked in a mixture of ethanol and water in a 4:1 ratio. The active compounds in the moringa leaves dissolve in the solvent, which is then separated to obtain the moringa leaf extract. The yield of moringa leaf extract using the solvent mixture was 17.5% (Gharsallah et al., 2023). After extraction of each material—cellulose from sugarcane bagasse, lipids from avocado seeds, and moringa leaf extract—they were homogenized to form the edible coating product.

3.4 Product advantages of edible coating

The innovation of edible coating based on bagasse waste and avocado seeds fortified with moringa leaves is one of the efforts to minimize post-harvest fruit spoilage and damage, which can cause harvest losses and contribute to organic waste. The high cellulose content in sugarcane bagasse, along with the lipid and antioxidant content in avocado seeds, can be utilized as raw materials in the production of environmentally friendly edible coatings. Additionally, the high nutritional value and phytochemical compounds found in moringa leaves can serve as fortification agents in edible coatings. Fortification from moringa leaves can be applied to edible coating products to enhance and complement existing or missing nutritional content, thereby enabling edible coatings not only to slow down the spoilage process and extend fruit shelf life but also to supply nutrients that can be absorbed through the fruit's skin pores.

The Moringa oleifera Lam. plant, commonly known as moringa, is one of the plants frequently utilized in the health sector due to its diverse nutritional content. Moringa leaves contain antioxidants, anti-inflammatory compounds, hypolipidemic properties, hepatoprotective effects, antihyperglycemic properties, anticancer properties, and antihypertensive properties. Phytochemical compounds commonly found in moringa leaves include flavonoids, polyphenols, lycopene, and beta-carotene. Moringa leaves are known to contain the primary flavonoid quercetin at a concentration of 384.61 mg/100 g, with quercetin having an antioxidant strength 4 to 5 times higher than that of vitamins C and E. Other compounds found in moringa leaves include gallic acid, chlorogenic acid, ellagic acid,

proanthocyanidins, ferulic acid, kaempferol, and vanillin. Additionally, moringa leaves contain vitamin E, beta-carotene, zinc, selenium, and various minerals such as calcium, potassium, zinc, magnesium, iron, and copper (Satriyani, 2021).

Moringa leaves also contain antioxidants that play a role in neutralizing free radicals, thereby helping to prevent oxidative damage to various biomolecules and providing significant protection against oxidative stress. The antioxidant content in moringa leaves can capture DPPH free radicals with an IC50 value of 4.33 mg/mL, indicating that moringa leaves have fairly strong antioxidant activity as they can neutralize free radicals at fairly low concentrations. In addition to alkaloids and flavonoids, other antioxidant compounds found in moringa leaves include phenols, triterpenoids, tannins, saponins, and quinones (Widiastini et al., 2021).

The high bioactive and nutritional content of moringa leaves has the potential to be utilized as a fortification ingredient to enhance the nutritional value of food products. Additionally, the addition of moringa as a fortification agent has the potential to enhance pharmacological properties, such as antioxidant and anti-inflammatory effects, in edible coatings. These coatings can help protect food products like fruits from oxidative damage and microbial contamination, thereby not only extending the shelf life of fruits but also enhancing the functional value of the protective layer (Ariani et al., 2023).

This edible coating utilizes QR code-based technology. A QR code, or Quick Response code, is a black-and-white square matrix code capable of storing a large amount of information in a small space. QR codes are widely used for various purposes, including displaying locations, opening websites, downloading applications, or accessing documents (Lotfipanah, 2020). One application of QR code technology is to store information on a product so that it can be accessed quickly and easily using a smartphone. Therefore, this edible coating product is equipped with a QR code to facilitate consumers in accessing information about the product, such as its composition, advantages, and usage instructions. The presence of a QR code feature on the product packaging can streamline the dissemination of product information to consumers.

3.5 Implementation of edible coating in the agricultural and food industries

The quality of fruit after harvest is greatly influenced by management practices during and after harvest, such as fruit storage and packaging processes. The freshness level of fruit is largely determined by its moisture content and mass, so appropriate storage and packaging methods are necessary to maintain freshness and quality. One effective method for preserving fruit quality is the use of natural packaging such as edible coatings. Edible coatings are thin layers that cover the fruit surface with high selective gas permeability. This coating can slow down water evaporation and the loss of volatile chemical compounds, reduce respiration rates, and slow down changes in fruit texture (Pandya et al., 2023). Generally, edible coatings are developed from natural biopolymers such as polysaccharides, proteins, and lipids, making them safe for use in food products. Biopolymer-based packaging is an environmentally friendly technology that holds promise for food products because it can extend shelf life and maintain quality, including freshness, color, vitamin and mineral content, as well as other nutritional and sensory characteristics (Akilie, 2024).

Agricultural and horticultural products such as fruits and vegetables tend to have a short shelf life, especially climacteric fruits. Therefore, fruit management throughout the supply chain and storage poses a significant challenge for the agricultural sector and food processing industry due to their perishable nature. Post-harvest losses can be caused by various factors such as physical, chemical, mechanical, and biological factors, which often result in waste and environmental pollution. Thus, edible coatings can serve as an environmentally friendly and sustainable solution to prevent and minimize post-harvest fruit damage by extending shelf life, regulating gas exchange, and slowing down moisture loss, respiration rate, ethylene biosynthesis, enzymatic browning, decay, aroma changes, and color changes in fruits (Akilie, 2024).

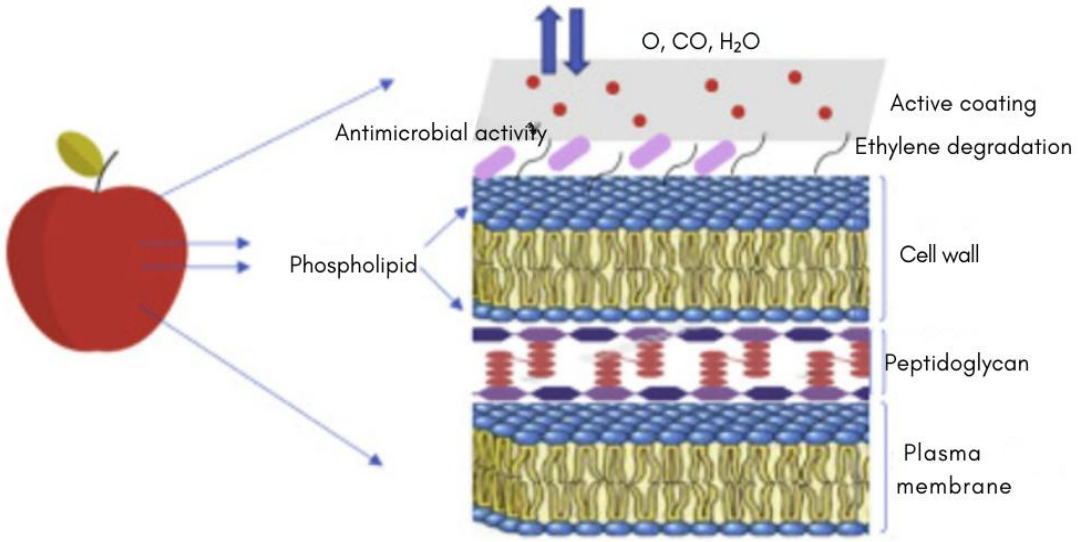

Figure 2. Gas exchange process through edible coating (Jafarzadeh et al., 2021)

Edible coating functions as a partial barrier that regulates the diffusion rate of gases such as oxygen (O_2), carbon dioxide (CO_2), and water vapor (H_2O) from and to the fruit surface. This layer is also active because it is equipped with antimicrobial compounds that can inhibit the growth of microorganisms causing damage, as well as ethylene-degrading agents that function to slow down the fruit ripening process. Thus, edible coatings not only slow down the rate of respiration and water loss from the fruit but also provide additional biological protection. Beneath the coating layer lies the fruit's natural cellular structure, including cell walls, plasma membranes, and peptidoglycans, which naturally protect the cells but still require additional external protection. The combination of the physical and functional properties of this edible coating significantly contributes to extending the shelf life and maintaining the quality of the fruit during storage and distribution (Jafarzadeh et al., 2021).

4. Conclusions

The use of plastic-based fruit net as a fruit wrapper has become a common habit in Indonesian society, given the lightweight, strong, and affordable nature of plastic. Although practical, the use of plastic in fruit packaging is not able to maintain moisture well and can accelerate the decay process. Plastic used for wrapping is often disposable and difficult to degrade. This leads to the accumulation of plastic waste that pollutes the environment. The utilization of agricultural wastes such as bagasse and avocado seeds has great potential in the development of environmentally friendly protective coatings. Bagasse, rich in cellulose can be processed into a natural hydrocolloid with the ability to form films and inhibit gas permeability. Avocado seeds contain starch and vegetable oils to serve as hydrophobic components that improve the fruit's resistance to moisture and oxidation. Meanwhile, Moringa leaves contain various bioactive compounds, such as flavonoids and strong antioxidants (quercetin), which have the potential to add nutritional value to edible coatings that can improve the pharmacological and functional properties of the protective coating. The combination of these ingredients will create a biodegradable fruit protective coating that not only helps extend the shelf life of the fruit, but also increases the nutritional value by fortification of bioactive ingredients and enhances the functionality of the edible coating through protection against oxidative damage and microbial contamination. The addition of QR code technology integration on edible coating product packaging will provide easy access to information about the composition, benefits, and how to use the product to consumers, thereby increasing the efficiency of information dissemination.

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References
Akilie, M. S. (2024). Tren kemasan edible sebagai kemasan pangan terkini dan masa depan: the tren of edible film as food packaging for the present and future. *Jurnal: Agricultural Review*, *3*(1), 49-60. https://doi.org/10.37195/arview.v3i1.792

Ani, A. E. M., Mubarok, A. Z., & Murtini, E. S. (2024). Aplikasi Edible Coating Berbasis Tepung Biji Nangka dan Alginat Terhadap Kualitas Buah Tomat. *Jurnal Teknologi Hasil Pertanian, 17*(1), 59-69. http://dx.doi.org/10.20961/jthp.v17i1.72260

Ariani, L. N., Estiasih, T., Sunarharum, W. B., & Khatib, A. (2023). Potential of moringa (Moringa oleifera) leaf powder for functional food ingredients: A review. *Czech Journal of Food Sciences*, *41*(1). http://dx.doi.org/10.17221/221/2022-CJFS

Arma, R., Sari, D. E., & Irsan, I. (2019). Identifikasi hama lalat buah (Bactrocera sp) pada tanaman cabe. *Agrominansia*, *3*(2), 109-120. https://doi.org/10.34003/272007

Athmaselvi, K. A., Sumitha, P., & Revathy, B. (2020). Development of Aloe vera Based Edible Coating for Tomato. *Jurnal Tugas Akhir Mahasiswa : Agroekotek View, 3*(3), 28–34. http://dx.doi.org/10.2478/intag-2013-0006

Charoensopa, K., Thangunpai, K., Kong, P., Enomae, T., & Ploysri, W. (2024). Extraction of Nanocellulose from the Residue of Sugarcane Bagasse Fiber for Anti-Staphylococcus aureus (S. aureus) Application. *Polymers*, *16*(11), 1612. https://www.mdpi.com/2073-4360/16/11/1612#

Fertiasari, R., Arditian, S., Yuliani, S., Nurhafiza, N., & Aryasari, P. (2023). Perubahan Fisiologi Buah Tomat (Solanum Lycopersicum) Terhadap Suhu Kamar Dan Umur Simpan Yang Memengaruhi Mutu. *Journal of Food Security and Agroindustry*, *1*(3), 97-104. https://doi.org/10.58184/jfsa.v1i3.125

Gharsallah, K., Rezig, L., Rajoka, M. S. R., Mehwish, H. M., Ali, M. A., & Chew, S. C. (2023). Moringa oleifera: Processing, phytochemical composition, and industrial applications. *South African Journal of Botany*, *160*, 180-193. https://doi.org/10.1016/j.sajb.2023.07.008

Handoyo, M., & Asri, N. (2023). Study on Food Loss and Food Waste: Conditions, Impact and Solutions. *AGRITEPA: Jurnal Ilmu Dan Teknologi Pertanian, 10*(2), 247-258. https://doi.org/10.37676/agritepa.v10i2.4579

Huzaiva, R. J., Anastasya, S., Mua, M. R., & Cahyani, R. (2025). Pemanfaatan limbah padat ampas tebu sebagai bahan bakar pembangkit listrik. *JUTIN: Jurnal Teknik Industri Terintergrasi, 8*(1), 1414-1421. https://doi.org/10.31004/jutin.v8i1.40244

Ihsan, T., & Derosya, V. (2024). Tinajuan startegi pengemasan buah dan sayur dalam memerangi food loss dalam rantai pasokan pascapanen di Indonesia. *Jurnal Ilmu Lingkungan, 22(*4), 1078-1087. https://doi.org/10.14710/jil.22.4.1078-1087

Jafarzadeh, S., Nafchi, A. M., Salehabadi, A., Oladzad-Abbasabadi, N., & Jafari, S. M. (2021). Application of bio-nanocomposite films and edible coatings for extending the shelf life of fresh fruits and vegetables. *Advances in colloid and interface science*, *291*, 102405. https://doi.org/10.1016/j.cis.2021.102405

Kamsiati, E., Herawati, H., & Purwani, E. Y. (2017). Potensi pengembangan plastik biodegradable berbasis pati sagu dan ubikayu di Indonesia. *Jurnal Litbang Pertanian*, *36*(2), 67-76. http://dx.doi.org/10.21082/jp3.v36n2.2017.p67-76

Lotfipanah, M. (2020). Utility and impact of QR codes and barcodes in scholarly journals. *International Journal of Research-GRANTHAALAYAH*, *8*(5), 51-54. http://dx.doi.org/10.29121/granthaalayah.v8.i5.2020.55

Pandya, Y., Sharma, A., & Bakshi, M. (2023). Edible Coatings in Fruits: Effectiveness and Applicability: A Review. *FoodSci: Indian Journal of Research in Food Science and Nutrition*, 01-10. http://dx.doi.org/10.15613/fijrfn/2022/v10i1/220470

Rai, I. N., Wijana, G., Sudana, I. P., Wiraatmaja, I. W., Semarajaya, C. G. A., & Astiari, N. K. A. (2016). Identifikasi dan telaah pemanfaatan sumber daya genetik buah-buahan lokal untuk meningkatkan integrasi pertanian dan pariwisata di Bali. *Jurnal Hortikultura Indonesia (JHI)*, *7*(1), 31-39. https://doi.org/10.29244/jhi.7.1.31-39

Rangkuti, M. F., Hafiz, M., Munthe, I. J., & Fuadi, M. (2019). Aplikasi pati biji alpukat (Parcea americana. Mill) sebagai edible coating buah strawberry (Fragaria sp.) dengan penambahan ekstrak jahe (Zingiber officinale. Rosc). *Agrintech: Jurnal Teknologi Pangan dan Hasil Pertanian*, *3*(1), 1-10. https://doi.org/10.30596/agrintech.v3i1.4487

Rasmi, D. A. C., & Sedijani, P. (2022). Penyuluhan Tentang Pentingnya Konsumsi Buah Untuk Menjaga Imunitas Tubuh. *Jurnal Pengabdian Magister Pendidikan IPA*, *5*(4), 6-11. http://dx.doi.org/10.29303/jpmpi.v5i4.2222

Ratnaduhita, A., Kholis, M. N., & Sumirat, R. (2025). Penghambatan Kekerutan Pada Kulit Tomat Dengan Edible Coating Limbah Ampas Tebu Dan Gathot (Singkong Terfermentasi). Jurnal Rekayasa dan Manajemen Agroindustri, 13(1), 95-107. https://doi.org/10.24843/JRMA.2025.v13.i01.p09

Risyad, A., & Permadani, R. L. (2016). Ekstraksi minyak dari biji alpukat (Persea Americana Mill) menggunakan pelarut n-heptana. *Jurnal Teknik Kimia USU*, *5*(1), 34-39. https://doi.org/10.32734/jtk.v5i1.1522

Satriyani, D. P. P. (2021). Review artikel: Aktivitas antioksidan ekstrak daun kelor (Moringa oleifera Lam.). *Jurnal Farmasi Malahayati*, *4*(1), 31-43. http://dx.doi.org/10.33024/jfm.v4i1.4263

Wahyudi, P., & Harsono, B. (2023). Identifikasi Mangga Arumanis yang Dimatangkan dengan Kalsium Karbida (CaC2) Menggunakan Metode Spektroskopi. *Techné : Jurnal Ilmiah Elektroteknika, 22*(1), 143–156. https://doi.org/10.31358/techne.v22i1.368

Widaningrum, W., Miskiyah, M., & Winarti, C. (2015). Edible coating berbasis pati sagu dengan penambahan antimikroba minyak sereh pada paprika: preferensi konsumen dan mutu vitamin c. *Agritech*, *35*(1), 53-60. https://doi.org/10.22146/agritech.9419

Widiastini, L. P., Karuniadi, I. G. A. M., & Tangkas, M. (2021). Senyawa antioksidan ekstrak etanol daun kelor (Moringa oleifera) di Denpasar Selatan Bali. *Media Kesehatan Politeknik Kesehatan Makassar*, *16*(1), 135-139. https://doi.org/10.32382/medkes.v16i1.2038

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