

The Effect of Packaging Type and Storage Duration on the Physicochemical Characteristics of Temulawak Cookies (*Curcuma xanthorrhiza* Roxb.)

Isti Handayani*, Aisyah Tri Septiana, Budi Sustriawan, Iriyanti Dyah Hapsari

Department of Food Technology, Faculty of Agricultural Technology, Universitas Jenderal Soedirman
Jl. dr. Soeparno, Karangwangkal, Purwokerto, Central Java, Kode Pos 53122, Indonesia

*Email corresponding author: isti.handayani@unsoed.ac.id

ABSTRACT

Curcuma xanthorrhiza Roxb. contains curcuminoids and essential oils with functional benefits, yet its strong aroma and taste often limit incorporation into food products. Microencapsulation can mask these sensory limitations, enabling its use in functional foods such as temulawak cookies. However, limited information is available regarding how packaging type affects the stability of microencapsulated bioactive compounds during storage, particularly in temulawak cookies, which still lack specific studies on packaging-related quality changes. This study is the first to assess packaging-storage interactions in microencapsulated temulawak functional cookies. Specifically, it examines the effects of different packaging materials and storage durations on the physicochemical and sensory characteristics of temulawak cookies stored at room temperature. The types of packaging used were aluminum foil, polyethylene, and polypropylene, with samples stored for 60 days and evaluated at 15-day intervals. Packaging type and storage duration significantly affected moisture content, total phenols, DPPH antioxidant activity, and curcumin color parameters (L^* and a^*). After 60 days, aluminum foil packaging maintained product quality most effectively, with a moisture content of 4.38% (meeting SNI), total phenols of 5.43 mg GAE/g, antioxidant activity of 68.09% inhibition, curcumin content of 1.25 mg/mL, L^* of 63.32, and a^* of 5.10. Sensory evaluation indicated that the cookies exhibited acceptable sensory attributes, characterized by a mildly perceptible temulawak aroma, a slight bitter aftertaste, and an overall pleasant taste. These findings demonstrate that aluminum foil packaging plays a crucial role in maintaining the physicochemical stability and sensory acceptability of microencapsulated temulawak cookies during storage, providing scientific evidence for the selection of appropriate packaging in functional food applications.

Keywords: Antioxidant Activity; Packaging; Storage Stability; Temulawak

INTRODUCTION

Temulawak is a plant from the Zingiberaceae family that is effective as an antioxidant that can ward off free radicals. Temulawak contains various chemical compounds such as curcumin, starch, and essential oils. Curcumin is the primary polyphenol found in temulawak, which possesses various pharmacological properties, including antioxidant, anti-inflammatory, antibacterial, antitumor, neuroprotective, nephroprotective, and hepatoprotective effects (Yonata et al., 2025). Temulawak is commonly used as a traditional medicine to maintain overall health, treat illnesses, and enhance well-being (Pandawangi et al., 2025). Despite its numerous health benefits, its use in food products remains limited due to its strong aroma and bitter taste. The aroma and bitter taste of temulawak cannot be easily eliminated when it is applied to food products, significantly affecting the desired final product.

An alternative approach to reducing the strong aroma and bitter taste of temulawak is microencapsulation. This technique involves coating active compounds to protect them from environmental factors such as moisture, oxygen, and light, while simultaneously masking undesirable sensory attributes (Yonata et al., 2025). In food applications, microencapsulation is primarily used to improve the stability of bioactive compounds during processing and storage. One application of temulawak microencapsulation is as a functional food. Therefore, the stability of microencapsulated temulawak is closely associated with subsequent packaging and storage conditions. One application of microencapsulated temulawak is in functional food products, such as cookies, which serve as a suitable food matrix due to their low moisture

content and widespread consumer acceptance (Septiani & Ratnayani, 2025). Temulawak cookies are expected to improve sensory acceptability while delivering functional benefits.

Functional foods are susceptible to quality deterioration if not stored under appropriate conditions. In microencapsulated functional foods, packaging plays a crucial role in maintaining the stability of encapsulated bioactive compounds during storage. Packaging serves as a preservation system that safeguards food products from quality deterioration, contamination, and physical stresses such as friction, impact, and vibration. Aluminum foil and various plastic materials are commonly used to maintain product stability. For instance, the quality of cookies stored using aluminum foil packaging at room temperature ($27^{\circ}\text{C}\pm 2^{\circ}\text{C}$) remains good for up to 60 days of storage, based on testing of antioxidant activity, water absorption, and dissolution rate (Shabrina et al., 2022). Johnrencius et al. (2017) stated that sukun cookies packaged using polyethylene and polypropylene packaging were more preferred and had better ability to inhibit increases in moisture content, peroxide value, and bacterial count compared to wax paper packaging. However, information on the physicochemical and sensory properties of temulawak cookies stored in aluminum foil, polyethylene, and polypropylene is still limited. This study aims to determine the effect of packaging type and storage duration on the physicochemical and sensory characteristics of temulawak cookies during room-temperature storage. It is hypothesized that packaging type significantly influences physicochemical stability and sensory acceptability of temulawak cookies during storage at room temperature.

METHODS

Material

The ingredients used consist of temulawak, aquades, and a coating agent consisting of 10% gum arabic, Tween 80 1%, and ingredients for cookie production including wheat flour, caster sugar, margarine, eggs, baking powder, salt, packaging materials (polyethylene, polypropylene, and aluminum foil), and materials for analysis including curcumin standard solution, ethanol p.a., gallic acid, Na_2CO_3 , methanol p.a., Folin Ciocalteau reagent, and DPPH powder (1,1-diphenyl-2-picrylhydrazyl) from Sigma.

Tools

The equipment used includes a R-25C1(S)IN microwave, a KBO-190RAW oven, a cabinet dryer, a magnetic stirrer hot plate, an OHAUS PX224/E analytical balance, a digital balance, a HR2115/00 blender, a HM-620 hand mixer, glass plates, filter cloth, a 100-mesh sieve, a Shimadzu UV-1800 spectrophotometer, baking paper, knife, bowl, cutting board, glassware, glass cups, plastic funnel, glass bottles, pipettes, magnets, Eba 200 centrifuge, baking tray, VM-300P vortex mixer, stopwatch, desiccator, porcelain dish, label paper, and filter paper.

Research Design

This study used an experimental method with a randomized block design (RBD) with two factors and three replications, in which batch was designated as the blocking factor to control potential differences between production batches. The first factor was the type of packaging (polyethylene, polypropylene, and aluminum foil), and the second factor was the storage period (15, 30, 45, and 60 days) at room temperature ($\pm 28^{\circ}\text{C}$) under typical laboratory conditions, with an estimated relative humidity of 60–75% and adequate ambient lighting provided by standard fluorescent/LED lamps. A day-0 (baseline) sample was not included. The variables observed in this study include physicochemical characteristics such as moisture content, total

phenols, DPPH antioxidant activity, curcumin, and color. The organoleptic characteristics tested include color, aroma, taste, aftertaste, texture, and overall preference.

Preparation of cookies temulawak

The production of temulawak cookies begins with microencapsulation, which is carried out by extracting 40 g of temulawak in 200 mL of distilled water, blending it at speed 2 for 2 minutes, extracting it using the MAE (Microwave Assisted Extraction) method, and cooling it by storing it in the refrigerator for ± 24 hours. Next, the mixture is combined with the coating agent using a magnet and stirrer for 6 minutes at 70°C and 700 rpm, then mixed for 20 minutes using a 10-minute cycle at speed 1 followed by 10 minutes at speed 2. The mixture is then dried in a cabinet dryer for 6 hours at 50°C. After drying, the mixture is ground using a blender and a sieve. Next, the temulawak cookies are made by preparing the tools and ingredients used. The ingredients are weighed, and the wet ingredients are mixed for 4 minutes at speed 2, including egg whites, egg yolks, margarine, and powdered sugar. After homogenization, the dry ingredients, salt, baking powder, flour, and temulawak microcapsules are mixed until uniform. The mixture is then shaped and baked for approximately 25 minutes at 150°C. Once baked, let it cool before packaging it in the designated containers (polyethylene, polypropylene, and aluminum foil).

Test Parameters

1. Moisture content

In determining the moisture content using the AOAC (2005) thermogravimetric method, the first step is to dry the porcelain dish in an oven at a temperature of 100-105°C for 1 hour, then cool the dish in a desiccator for ± 15 minutes, weigh the dish, and record its weight. Then, 2 g of the sample is placed in the dish, the dish containing the sample is weighed, and dried in an oven at a temperature of 100-105°C for ± 6 hours. The dish is then removed from the oven, placed in a desiccator, and left to cool until the weight of the sample is constant.

Calculation of moisture content:

$$\% \text{ moisture content} = \frac{B - C}{B - A} \times 100\% \dots\dots\dots(1)$$

Description:

A = weight of dish (g)

B = weight of dish + sample before drying (g)

C = weight of dish + sample after drying (g)

2. Total phenols

The determination of phenol concentration begins with the preparation of a 0.5% gallic acid solution by dissolving 50 mg of gallic acid in 0.5 mL of ethanol p.a., followed by a series of dilutions with distilled water to a final volume of 100 mL. The resulting gallic acid concentrations are 0; 10; 20; 30; 40; and 50 ppm. From each dilution series, 0.3 mL is taken and mixed with 1.5 mL of 10% Folin Ciocalteu reagent, vortexed until homogeneous, then incubated in the dark for 3 minutes. After incubation, 1.2 mL of 7.5% Na₂CO₃ solution was added and vortexed again until homogeneous, followed by incubation in the dark for 60 minutes. The absorbance of the solution was measured using a spectrophotometer at a wavelength of 765 nm.

Next process, total phenol analysis was performed by grinding 1 g of sample, dissolving it in 100 mL of distilled water (up to the mark on the measuring flask). The solution was then filtered and dissolved with 1.5 mL of 10% Folin Ciocalteu reagent, followed by 0.3 mL of the same reagent, and vortexed until homogeneous. The mixture was then incubated for 3 minutes in the dark. After incubation, 1.2 mL of 7.5% Na₂CO₃ solution was added, vortexed until homogeneous, and incubated for 60 minutes in the dark. The absorbance of the solution was measured at a wavelength of 765 nm.

3. Antioxidant activity (DPPH)

In testing the DPPH antioxidant activity using the method from Sheikh et al. (2009), a 0.16 nM DPPH solution was prepared by weighing 6.3 mg of DPPH powder into a 100 mL volumetric flask, then dissolving it using methanol up to the mark (homogenizing until dissolved).

The next step involved preparing a sample test solution with a concentration of 40,000 ppm, obtained by weighing 4 g of the sample and adding methanol to the volumetric flask up to the mark, followed by homogenization. The solution was then filtered using filter paper. Two milliliters of the test solution is then taken and mixed with 2 mL of 0.16 nM DPPH solution. The solution is homogenized by vortexing for 1 minute, then incubated for 30 minutes in the dark, and the absorbance is measured at a wavelength of 517 nm. DPPH antioxidant activity can be calculated using the following equation:

$$\text{Antioxidant activity (\%)} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100\% \dots \dots \dots (2)$$

Description:

A_{control} = control absorbance value (DPPH solution without sample).

A_{sample} = sample absorbance value.

4. Curcumin

Curcumin content testing was performed using a spectrophotometer. The test began with the creation of a curcumin standard curve by making a stock solution of 100 ppm by weighing 10 mg of curcumin standard and dissolving it in ethanol in a 100 mL measuring flask up to the calibration mark. A series of curcumin solutions with concentrations of 0.2, 0.4, 0.6, 0.8, and 1.0 µg/mL was prepared in ethanol solvent. These were then centrifuged (3000 rpm for 10 minutes) and filtered using filter paper. The absorbance of the resulting filtrate was measured at the maximum wavelength, and the concentration was calculated using the standard curve obtained. A regression equation was created with x as the curcumin concentration and y as the absorbance value. The wavelength of 425 nm is the maximum wavelength for curcumin compounds (Yusuf et al., 2015).

Curcumin analysis was performed by weighing 1 g of the sample, dissolving it in 5 mL of ethanol, and mixing it for 30 seconds. After mixing, centrifugation was performed (3000 rpm for 10 minutes), followed by filtration using filter paper. The filtrate obtained from the filtration process was measured for its absorbance using a spectrophotometer at a wavelength of 425 nm. The absorbance values were then quantified using a standard curve.

5. Color

According to Souripet (2015), physical color testing can be done by identifying the L* (brightness), a*, and b* values obtained from color measurements using a color reader, with each ratio repeated three times. The analysis is conducted by placing the sample on a plain white paper surface, then attaching the tip of the Color Reader to the sample and pressing

the start button until the measurement results are obtained. The L^* value indicates changes in lightness or brightness ranging from 0 (black) to 100 (white), a^* indicates the chromatic color mixture of red-green, with $+a^*$ values ranging from 0 to 100 for red, 0 to -80 for green, and b^* indicates the chromatic color mixture of yellow-blue, with $+b^*$ values ranging from 0 to +70 for yellow and $-b^*$ values ranging from 0 to -70 for blue.

6. Organoleptic test

In organoleptic testing, the human senses are used as one of the testing tools. Organoleptic responses to samples are assessed using a scoring method. Scoring tests are often used to assess the quality of materials and the intensity of certain properties, such as sweetness, hardness, and color. In scoring tests, quality levels are determined based on a scale where 1 is the lowest value and 5 is the highest value (Syarifudin et al., 2023). The organoleptic evaluation includes color, aroma, taste, texture, aftertaste, and overall preference.

Data Analysis

The physical and chemical data obtained were then analyzed using the ANOVA (Analysis of Variance Test) method at a 95% confidence level. If the treatments administered had a significant effect between treatments, a multiple comparison test was performed using the DMRT (Duncan Multiple Range Test) at a 5% level. Sensory testing was conducted using a scoring test and analyzed using the Friedman test. The determination of the best treatment was then performed using the effectiveness index method (de Garmo et al., 1984). DMRT and Friedman test calculations were performed manually using statistical formulas, and the computations were carried out using Microsoft Excel

Experimental Layout

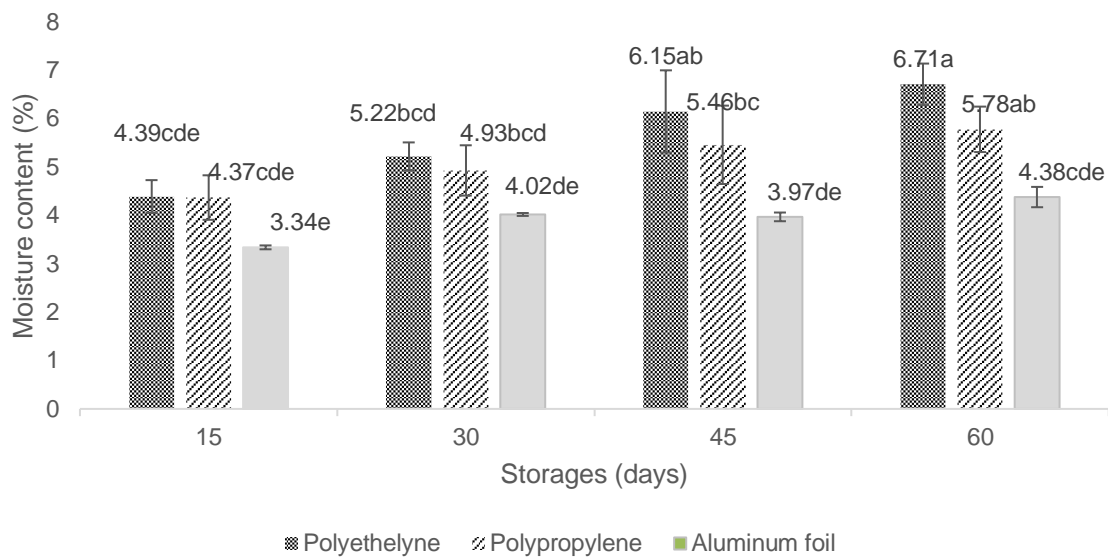
Storage (days)	Packaging types		
	C1 (Polyethylene)	C2 (Polypropylene)	C3 (Aluminum foil)
L1 (15)	L1C1	L1C2	L1C3
L2 (30)	L2C1	L2C2	L2C3
L3 (45)	L3C1	L3C3	L3C3
L4 (60)	L4C1	L4C4	L4C3

The experimental design comprised 12 treatment combinations. Each treatment combination was replicated three times, yielding a total of 36 experimental units.

RESULT AND DISCUSSIONS

1. Moisture content

Moisture content plays an important role in foodstuffs as a determinant of acceptability and freshness, and affects the shelf life of foodstuffs because it can influence texture, appearance, and taste. The average moisture content based on the effects of packaging type and storage duration on temulawak cookies is shown in Figure 1.



Different letters mean a significant difference ($P < 0.05$)

Figure 1. Average moisture content values for storage duration, packaging type, and interaction treatments for temulawak cookies.

The results showed that the interaction between the type of packaging and storage duration affected the moisture content of temulawak cookies. Figure 1 shows that the moisture content of temulawak cookies increased significantly during storage. At 60 days of storage, it can be seen that among the three types of packaging (polyethylene, polypropylene, and aluminum foil), only the aluminum foil packaging (4.38%) still meets the SNI moisture content standard for cookies, while polyethylene packaging only lasted up to 15 days of storage (4.39%) and polypropylene only up to 30 days of storage (4.93%). According to SNI 01-2973-1992, the maximum moisture content for cookies is 5%. In addition to moisture content, changes in water activity also play a critical role in determining cookie stability during storage. Although cookies generally have low moisture content, even slight increases in water activity can enhance the mobility of water molecules, accelerate moisture migration, and promote textural softening. Packaging with higher barrier properties, such as aluminum foil, is more effective in limiting moisture ingress and thus helps maintain lower water activity values, contributing to better crispness retention compared with polyethylene and polypropylene.

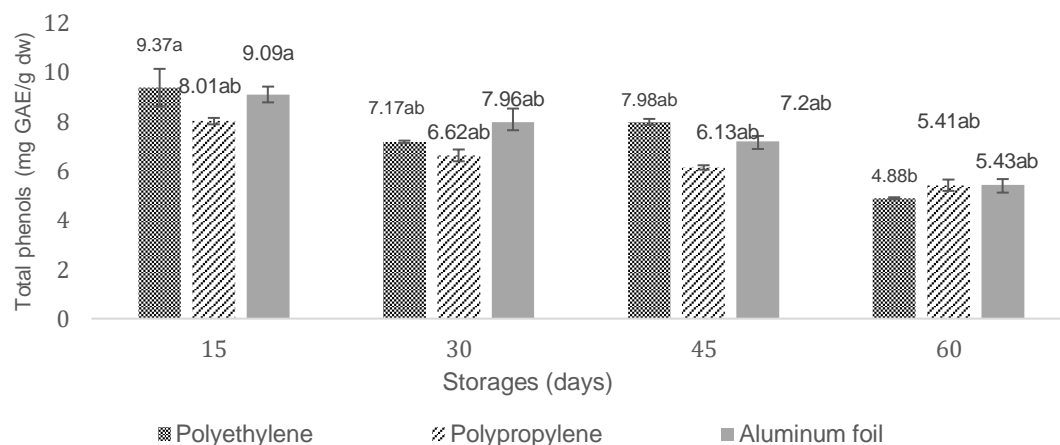
This significant increase in moisture content can be influenced by several factors, such as air humidity during storage and the type of packaging used. Astuti et al. (2023) reported similar findings, noting that elevated environmental humidity and differences in packaging permeability contribute to moisture uptake in cookies. The higher the density of the packaging material, the greater the oxygen barrier, resulting in lower packaging permeability (Lindner et al., 2017). Aluminum foil is a high-barrier packaging material with an OTR value of ≈ 0 mL/m²·day and a WVTR value of ≈ 0 mL/m²·day, while plastic packaging has an OTR value of ≈ 465 mL/m²·day and a WVTR value of ≈ 31 mL/m²·day (Labthink, 2022).

In addition to moisture content, water activity (a_w) is a critical parameter influencing the physicochemical stability, textural properties, and microbial safety of cookies during storage. Water activity reflects the availability of free water for physical, chemical, and

microbiological reactions, and even small increases in aw may accelerate moisture migration and lead to textural softening in low-moisture bakery products. In this study, the evaluation of moisture-related stability was intentionally focused on moisture content, as it represents a standardized quality parameter directly regulated for cookies and is widely used to assess moisture migration in relation to packaging performance.

2. Total phenols

Total phenols or phenolic compounds are secondary metabolites of plants with a combination of mono- and polysaccharides bound to one or more phenolic groups that provide health benefits. The purpose of the total phenol test is to determine the amount of phenolic compounds in temulawak cookies that act as antioxidants. The average total phenol content based on the effects of packaging type and storage duration on temulawak cookies is presented in Figure 2.



Different letters mean a significant difference ($P < 0.05$)

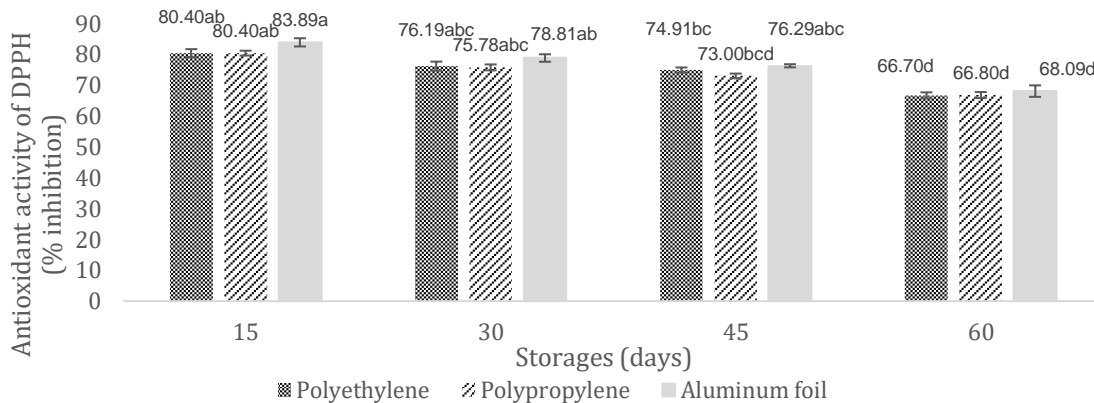
Figure 2. Average total phenol value of storage duration treatment and interaction of temulawak cookie treatment

The results showed that the interaction between the type of packaging and storage duration affected the total phenolic content of temulawak cookies. In the interaction of treatments, total phenols decreased significantly during storage. At 60 days, temulawak cookies packaged using aluminum foil (5.43 mg GAE/g dw) had the highest total phenol content compared to those packaged in polyethylene (4.88 mg GAE/g dw) and polypropylene (5.41 mg GAE/g dw). This was influenced by the permeability of the temulawak cookie packaging used. The total phenolic content in butterfly pea cookies decreased from 45.95 mg GAE/g dw to 6.19 mg GAE/g dw after 21 days of storage (Kering et al., 2023). This aligns with the research by Chikkanna et al. (2020), stating that cereal storage in aluminum foil packaging experienced less total phenolic content reduction compared to LDPE and polypropylene packaging. The total phenol content during storage decreased from 12.12 mg GAE/mL on day 0 to 5.50 mg GAE/g on day 65 (Ulma'nun et al., 2023).

2. Antioxidant activity (DPPH)

DPPH radical scavenging capacity is one method of measuring antioxidant activity, whereby antioxidant compounds reduce free radicals or oxidants (Theafelicia & Wulan., 2023). The average antioxidant activity (DPPH) based on the effects of packaging type and

storage duration on temulawak cookies is presented in Figure 3.



Different letters mean a significant difference ($P < 0.05$)

Figure 3. Average antioxidant activity (DPPH) values for different storage periods and interactions between temulawak cookie treatments.

The results showed that the interaction between packaging type and storage duration affected the antioxidant activity (DPPH) of temulawak cookies. In the interaction of antioxidant activity (DPPH), a significant decrease was observed during storage. This decrease was also evident in the reduced intensity of the purple color of the DPPH solution when mixing samples from the initially concentrated 15 to 60 days, which became increasingly faded. The highest antioxidant activity content at 60 days of storage was found in cookies packaged using aluminum foil (68.09% inhibition). This is due to the degradation of active compounds triggered by oxygen and moisture during storage, causing the active compounds in temulawak cookies to decrease gradually, as well as the permeability of the packaging used. Another cause is the Maillard reaction between reducing sugars and proteins, forming Maillard compounds that are less active as antioxidants, such as melanoidins, which form complex structures (ineffective at interacting with DPPH free radicals because complex compounds tend to be polar).

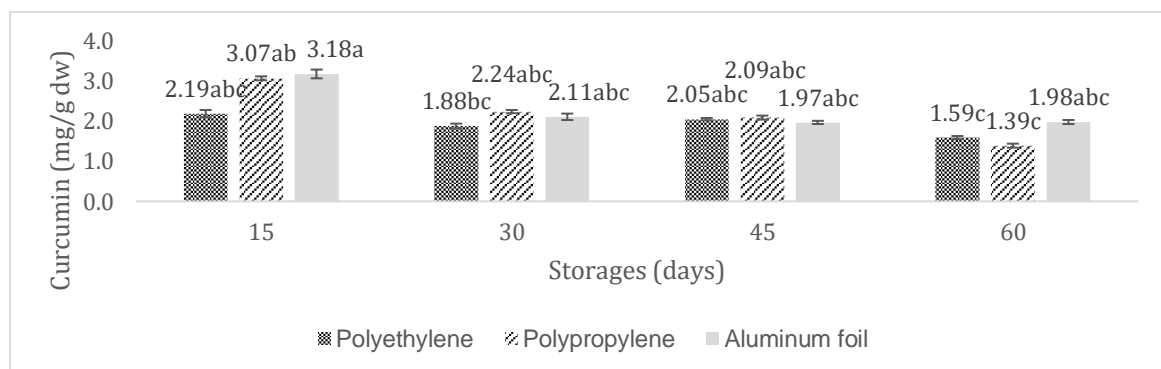
A close relationship was also observed between total phenolic content and antioxidant activity. The reduction in phenolic compounds during storage was in line with the decline in antioxidant activity, suggesting that phenolic degradation played a major role in reducing free radical scavenging capacity. This pattern is consistent with earlier studies showing strong correlations between phenolic concentration and antioxidant activity in baked products during storage.

Several studies report a pronounced decline in antioxidant activity of food products as a result of processing and storage. Astuti et al. (2022) observed that antioxidant capacity in processed apple products decreased markedly compared with fresh fruit, a reduction attributed to thermal exposure, oxidation, and polymerization reactions during processing. Similarly, Putri et al. (2022) noted changes in antioxidant activity associated with storage time and processing conditions in fermented dairy products. Rutkowska et al. (2024) reported that cookies containing 23% sucrose experienced a decrease in antioxidant activity during storage, from 0.80% on day 0 to 0.67% after 3 months of storage. This occurred due to the Maillard reaction between sugar and protein, which forms browning compounds that can reduce antioxidant activity. The water vapor and gas permeability of aluminum foil is

lower (0.098 g/day M₂/Hg) compared to PP (0.1572 g/day M₂/Hg) and PE (0.45 g/day M₂/Hg) resulting in minimal oxygen and water transfer from the environment into the packaging, thereby suppressing oxidative reactions that could reduce antioxidant content (Kering et al., 2023).

3. Curcumin

Curcumin is the dominant compound derived from curcuminoids, which give turmeric rhizomes their yellow to orange color. Curcumin belongs to the polyphenol group, which has a wide range of therapeutic effects, such as antioxidant, anti-inflammatory, antibacterial, antiviral, antifungal, antitumor, antispasmodic, and hepatoprotective properties—compounds that can protect the liver from damage caused by drugs (Hidayati et al., 2022). The average curcumin content based on the effects of packaging type and storage duration on temulawak cookies is presented in Figure 4.



Different letters mean a significant difference ($P < 0.05$)

Figure 4. Average curcumin value per long storage treatment and interaction of temulawak cookie treatment

The results of the study indicate that the interaction between packaging type and storage duration significantly affects the curcumin content in temulawak cookies. In the interaction between curcumin and packaging type, there was a significant decrease in curcumin content. The longer the storage period of temulawak cookies packaged in polyethylene, polypropylene, and aluminum foil, the greater the decrease in curcumin content within them. Among the three packaging types used, by day 60, the packaging that retained the highest curcumin content was aluminum foil at 1.25 mg/mL, while polyethylene and polypropylene packaging had values of 1.10 mg/mL and 1.09 mg/mL, respectively.

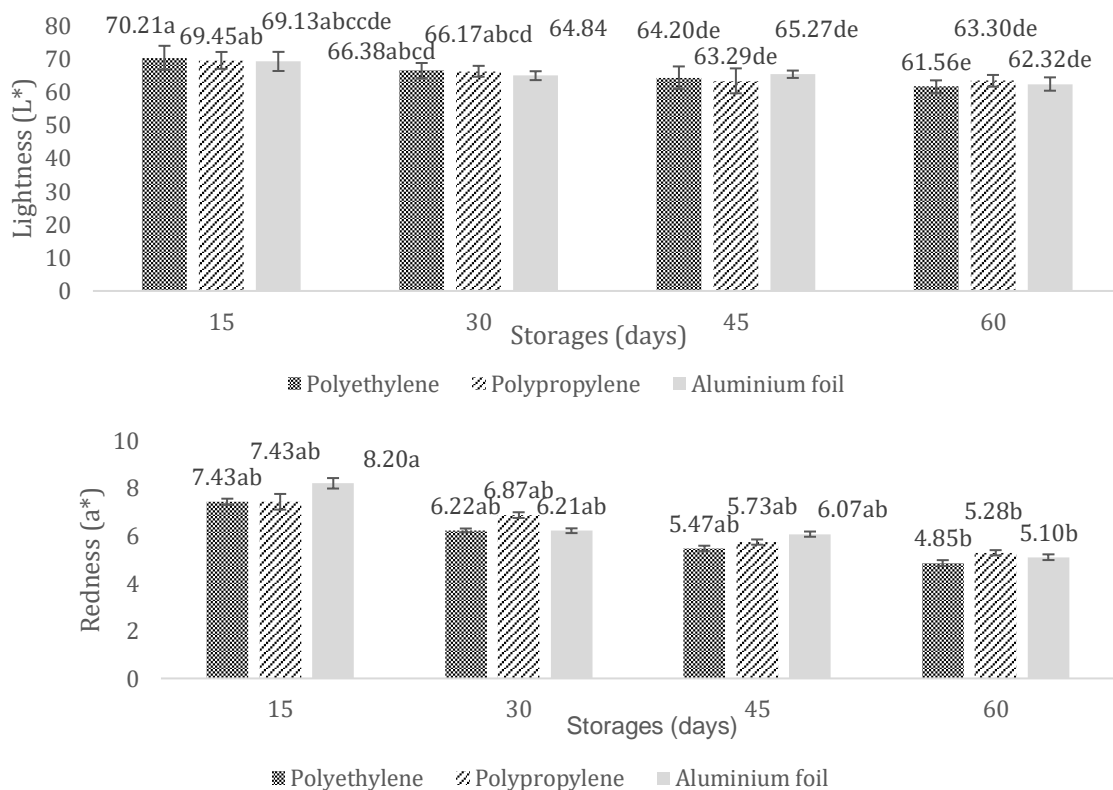
This occurs because packaging with low barrier properties allows water vapor and oxygen to diffuse into the product. In addition to oxygen exposure, curcumin is known to be highly sensitive to light, and photo-degradation may further accelerate its breakdown during storage, particularly in packaging materials with low light-blocking capacity such as polyethylene and polypropylene. Curcumin degradation is promoted when light and oxygen interact, generating reactive oxygen species that destabilize curcumin's conjugated structure, thereby reducing its concentration more rapidly in low-barrier packaging.

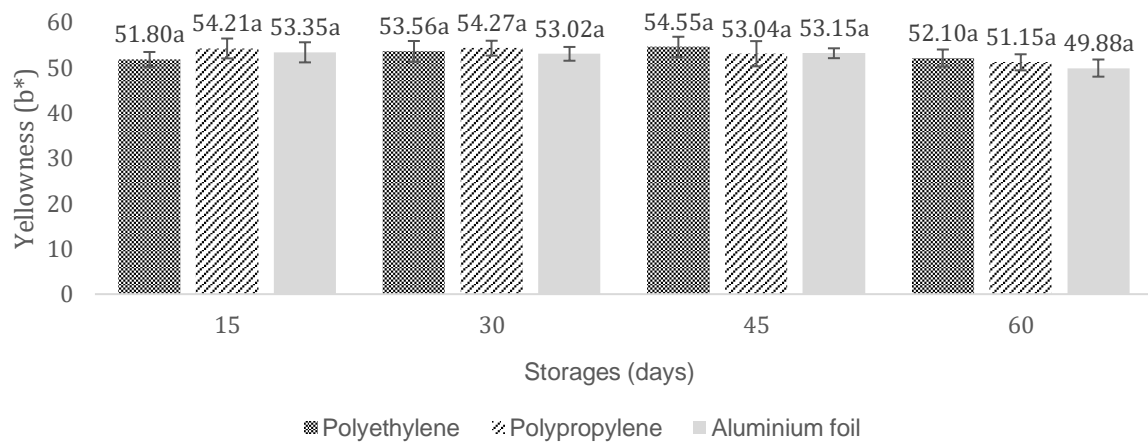
Novita et al. (2021) found that materials packaged using aluminum foil had a slower rate of quality decline than plastic packaging. Another influencing factor is the ability of aluminum foil to effectively block air and moisture from entering the product. Kutwal et al. (2024) reported that turmeric powder packaged in aluminium foil retained the highest curcumin content at the end of storage, whereas powders stored in PP-based packaging

exhibited the greatest loss of curcumin over the storage period. Specifically, aluminium foil packaging maintained both curcumin levels and low moisture content more effectively than PP or LDPE packaging. Changes in curcumin content were also reflected in color parameters, as curcumin is the primary pigment responsible for the yellow–orange coloration of temulawak, and its degradation during storage is commonly associated with a decrease in color intensity, particularly in L and a* values.

4. Color

Physical indicators of food product quality can be identified through color testing of the product. Color analysis of temulawak cookie samples was conducted by identifying the L* (lightness), a* (redness), and b* (yellowness) values obtained from color measurements using a Color Reader. The L* value indicates changes in brightness or lightness ranging from 0 (black) to 100 (white), a* indicates the chromatic color mixture of red and green, with +a* values ranging from 0 to 100 for red, 0 to -80 for green, and b* indicates the chromatic color mixture of blue and yellow, with +b* values ranging from 0 to +70 for yellow and -b* values ranging from 0 to -70 for blue. The average L*, a*, and b* values based on the effects of packaging type and storage duration on temulawak cookies are presented in Figure 5.





Different letters mean a significant difference ($P < 0.05$)

Figure 5. Average values of lightness (L^*), redness (a^*), and yellowness (b^*) per storage duration treatment and interaction of temulawak cookie treatments.

The results showed that the interaction between packaging type and storage duration affected the L^* and (a^*) of temulawak cookies, while no significant effect was observed on yellowness (b^*) values. All three types of packaging showed a significant decrease in L^* and a^* values with longer storage durations, resulting in darker colors than before. The color of temulawak cookies tends to become darker as storage time increases, which is caused by non-enzymatic reactions such as the Maillard reaction, which is a reaction between protein and sugar. In addition, an increase in water content and water activity can also trigger browning reactions (Pangestu et al., 2025). Color indicators have lower values, indicating that the color of the biscuits is becoming darker (Rahmawati et al., 2021). Furthermore, heating carbohydrates at high temperatures causes caramelization, which affects the color and aroma of the cookies (Kurniadi et al., 2019).

The interaction between packaging type and storage duration did not significantly affect the yellowness (b^*) values. This indicates that the yellow color components of the product were relatively stable and not sensitive to variations in storage conditions or differences in the barrier properties of the packaging materials. The pigments contributing to yellowness likely undergo slower degradation, resulting in no measurable differences across treatments. In contrast, lightness (L^*) and redness (a^*) are more responsive to oxidative changes, non-enzymatic browning reactions, and physical alterations occurring during storage factors that are influenced by the oxygen, moisture, and light barrier characteristics of each packaging type. Consequently, variations in packaging material and storage time produced detectable changes in L^* and a^* , but not in b^* values.

5. Organoleptic test

The results of the study indicate that the combination of treatments affects the aroma, aftertaste, and overall sensory properties of temulawak cookies. In terms of color and aroma, it was found that the aroma of temulawak cookies during storage did not undergo significant changes in polyethylene, polypropylene, and aluminum foil packaging (Table 1).

Table 1. Average sensory values for color and aroma of temulawak cookie treatments

Data	Color	Aroma
L1C1	4.40 ^a	2.50 ^a
L1C2	4.60 ^a	1.83 ^b
L1C3	4.30 ^a	2.30 ^a
L2C1	4.60 ^a	2.20 ^{ab}
L2C2	4.63 ^a	2.40 ^a
L2C3	4.63 ^a	2.50 ^a
L3C1	4.53 ^a	2.27 ^a
L3C2	4.43 ^a	2.33 ^a
L3C3	4.57 ^a	2.30 ^a
L4C1	4.27 ^a	2.47 ^a
L4C2	4.33 ^a	2.70 ^a
L4C3	4.07 ^a	2.07 ^a

The sensory values are shown as the mean scores, and different letters within columns indicate statistically significant differences ($P < 0.05$)

The organoleptic evaluation showed that the interaction between packaging type and storage duration did not result in significant differences in the color of temulawak cookies ($P > 0.05$), as reflected by the relatively consistent color scores across all treatments. This color stability suggests that microencapsulation effectively protected curcumin pigments from visually detectable degradation during storage, particularly when combined with packaging materials that limit exposure to oxygen and moisture. Although aluminum foil packaging is known to provide superior barrier properties compared to polyethylene and polypropylene, the differences among packaging types were not perceptible at the sensory level.

Among the three types of packaging, the average value at day 60 of storage was 2 (slightly characteristic of temulawak), which was because the aroma of temulawak cookies became less pronounced over time compared to shorter storage periods, such as day 15 of storage. The Maillard reaction involves reducing sugars and free amino acids, which form flavor and aroma components in food products (Sari et al., 2023). Aroma is one of the parameters of the sense of smell that can determine the palatability of food ingredients. Aroma plays a crucial role in food products; if the aroma is too overpowering or lacks distinctiveness, it may deter consumers from consuming the product (Agustina et al., 2023).

The gradual reduction in perceived temulawak aroma over time may be associated with the volatilization of aromatic compounds as well as interactions among flavor components during storage. In addition, Maillard reactions between reducing sugars and amino acids during baking and subsequent storage may generate new volatile compounds typical of baked products, thereby masking the characteristic aroma of temulawak. As a result, the aroma profile of the cookies remained balanced and acceptable to panelists throughout the storage period. Aroma is a critical sensory attribute influencing consumer acceptance, as excessively strong or insufficiently distinctive aromas may negatively affect product palatability.

The organoleptic evaluation indicated that taste scores of temulawak cookies were relatively stable across all packaging types and storage durations, with no significant differences observed among treatments (Table 2). This stability implies that the incorporation of microencapsulated temulawak successfully moderated the strong characteristic taste of temulawak, preventing excessive bitterness or undesirable flavor

development during storage.

Table 2. Average sensory values for the taste and aftertaste of temulawak cookie treatments

Data	Taste	Aftertaste
L1C1	3.83 ^a	3.90 ^{bc}
L1C2	4.03 ^a	4.37 ^{fg}
L1C3	3.80 ^a	4.43 ^b
L2C1	3.80 ^a	3.87 ^a
L2C2	3.53 ^a	4.03 ^e
L2C3	3.77 ^a	4.40 ^d
L3C1	3.87 ^a	4.03 ^{ab}
L3C2	3.83 ^a	4.17 ^{ef}
L3C3	3.83 ^a	4.47 ^c
L4C1	3.93 ^a	3.90 ^{bc}
L4C2	3.83 ^a	4.20 ^f
L4C3	3.87 ^a	4.23 ^{bc}

The sensory values are shown as the mean scores, and different letters within columns indicate statistically significant differences ($P < 0.05$).

In contrast, aftertaste exhibited slightly more variation than taste, although the changes remained within a narrow and acceptable range. At 60 days of storage, the aftertaste scores indicated a slightly bitter sensation across all packaging types, with polyethylene showing a marginally lower bitterness intensity compared to polypropylene and aluminum foil packaging. The persistence of a mild bitter aftertaste can primarily be attributed to the intrinsic sensory characteristics of temulawak, which is known to possess a bitter taste due to its essential oil fraction and curcuminoid components.

Aftertaste is defined as the lingering taste and aroma perceived in the oral cavity after swallowing food or beverages (Saleh et al., 2020). Previous studies have reported that the addition of temulawak to baked products results in a dominant temulawak-related flavor profile, mainly derived from volatile compounds such as limonene present in the essential oil fraction, which contribute to both flavor and aroma characteristics (Rahman et al., 2023). Although microencapsulation reduces the immediate release of these compounds, gradual release during mastication and storage may still contribute to a detectable bitter aftertaste.

Packaging characteristics also play a role in modulating aftertaste perception. Aluminum foil packaging, due to its superior barrier properties against oxygen, moisture, and light, is more effective in preserving flavor compounds and limiting oxidative degradation. As a result, the characteristic bitterness associated with temulawak may be retained more consistently in aluminum foil-packaged samples compared with polyethylene or polypropylene packaging, where higher permeability may accelerate flavor loss or alteration (Astuti et al., 2021).

Furthermore, the gradual decline in total phenolic content and antioxidant activity during storage may also influence taste perception, particularly bitterness. Phenolic compounds contribute not only to antioxidant capacity but also to sensory attributes, including bitterness and astringency. As these compounds undergo degradation through oxidation or interactions with other food components during storage, their transformation products—such as quinones and other oxidative byproducts—can intensify bitter sensations. This mechanism is consistent with the slightly increased bitter aftertaste detected in temulawak cookies at extended storage durations. Therefore, the observed changes in aftertaste may be partially explained by the progressive reduction in phenolic stability and antioxidant compounds over time.

The sensory evaluation demonstrated that the combination of packaging type and storage duration did not result in significant differences in texture (Table 3).

Table 3. Average sensory values for texture and overall combination of temulawak cookie treatments

Data	Texture	Overall
L1C1	1.80 ^a	3.07 ^{cd}
L1C2	1.83 ^a	3.30 ^b
L1C3	1.93 ^a	2.93 ^{de}
L2C1	2.50 ^a	3.50 ^a
L2C2	2.03 ^a	3.13 ^{de}
L2C3	2.47 ^a	3.07 ^{de}
L3C1	2.33 ^a	3.20 ^{de}
L3C2	2.07 ^a	3.17 ^d
L3C3	2.30 ^a	3.87 ^{ab}
L4C1	2.63 ^a	3.13 ^{cd}
L4C2	2.43 ^a	3.23 ^c
L4C3	2.83 ^a	3.17 ^{cd}

The sensory values are shown as the mean scores, and different letters within columns indicate statistically significant differences ($P < 0.05$)

The absence of significant differences implies that, despite moisture uptake during storage, the textural changes were not sufficiently pronounced to be clearly distinguished by panelists at the sensory level. The relatively stable texture perception can be attributed to the low initial moisture content of cookies and the presence of fat, which contributes to structural integrity and mouthfeel. Moreover, microencapsulation of temulawak may have contributed indirectly to textural stability by limiting interactions between bioactive compounds and the cookie matrix that could otherwise accelerate structural deterioration. Although aluminum foil packaging exhibited superior barrier properties in controlling moisture migration, the resulting differences in moisture content among packaging types did not translate into statistically significant differences in perceived texture.

In terms of overall acceptance, the sensory scores showed slight variations among treatment combinations. Overall acceptance represents a holistic evaluation of multiple sensory attributes, including color, aroma, taste, aftertaste, and texture, rather than a single quality parameter (Hidayati et al., 2025). Therefore, even when individual attributes did not show significant differences, their combined effects influenced the panelists' overall perception. The relatively higher overall scores observed in polypropylene-packaged samples may be associated with a balanced retention of sensory attributes, particularly taste, aftertaste, and texture, during storage. While aluminum foil packaging effectively preserved physicochemical quality, including moisture content and curcumin stability, the sensory advantages of such preservation were not always directly perceived by panelists. This finding highlights that superior physicochemical stability does not necessarily guarantee the highest overall sensory preference, as consumer acceptance is influenced by the combined and interactive perception of all sensory attributes.

Overall, the results indicate that all packaging types were capable of maintaining acceptable sensory quality of temulawak cookies during storage, with polypropylene packaging showing a slight advantage in overall acceptance. These findings suggest that packaging selection should consider not only physicochemical stability but also holistic sensory perception to optimize consumer acceptance of functional bakery products.

CONCLUSION

Aluminum foil packaging effectively preserves the physicochemical stability of temulawak cookies for up to 60 days at room temperature due to its superior barrier properties against oxygen and water vapor compared with polypropylene and polyethylene. This protective effect is achieved by limiting oxygen diffusion, moisture ingress, and light-induced degradation pathways that accelerate the loss of phenolic compounds and curcumin during storage. Future studies should investigate vacuum-sealed or multilayer biopolymer films as sustainable alternatives to further enhance product stability.

ACKNOWLEDGMENTS

The study was funded by Universitas Jenderal Soedirman through the Riset Terapan in 2024.

REFERENCES

- Anonim. (1992). *Standar Nasional Indonesia SNI 01-2973-1992: Biskuit*. Jakarta: Badan Standardisasi Nasional.
- Agustina, R., Hartuti, S., & Rubawan, P. I. (2023). Penilaian sensori pliek-u yang difermentasikan secara alami. *Jurnal Ilmiah Mahasiswa Pertanian*, 8(2), 385–391. <https://doi.org/10.17969/jimfp.v8i2.24458>
- Astuti, N. B., Raya, M. K., & Rahayu, E. S. (2023). Pengaruh suhu dan tempat penyimpanan terhadap kadar air dan mutu organoleptik biskuit substitusi tepung belut (*Monopterus albus*). *Action: Aceh Nutrition Journal*, 8(1), 81–89. <https://doi.org/10.30867/action.v8i1.811>
- Astuti, S. D., Lestari, S., Widarni, S., Wijanarko, G., & Wibawa, F. N. (2021). Shelf life prediction of carica seeds powder using accelerated method. *IOP Conference Series: Earth and Environmental Science*, 653(1), 012055. <https://doi.org/10.1088/1755-1315/653/1/012055>
- Astuti, E. J., Rafikayanti, A., Purwanto, S. T., Puspitasari, C., Rika, W. F., & Yesika, Y. (2022). The antioxidant activity comparison of *Malus sylvestris* Mill and its processed products. *Food Science and Technology Journal*, 4(2), 46–52. <https://doi.org/10.25139/fst.v5i1.4143>
- Chikkanna, G. S., Jha, S. K., Ambika, D. S., & Sadananda, G. K. (2020). Effect of packaging material and storage period on quality of amla and cereal based extruded R-T-E snack. *International Journal of Current Microbiology and Applied Sciences*, 9(1), 511–519. <https://doi.org/10.20546/ijcmas.2020.901.056>
- Dewantara, L. A. R., Ananto, A. D., & Andayani, Y. (2021). Penetapan kadar fenolik total ekstrak kacang panjang (*Vigna unguiculata*) dengan metode spektrofotometri UV–

- Visible. *Lambung Farmasi: Jurnal Ilmu Kefarmasian*, 2(1), 13–19. <https://doi.org/10.31764/lf.v2i1.3759>
- Hidayati, N., & Utami, S. S. (2025). Kesukaan konsumen terhadap bakso ayam: Perbandingan berbagai jenis daging ayam dengan tepung mocaf sebagai bahan pengisi. *Jurnal Pertanian Agros*, 27(1), 77–83. <https://doi.org/10.37159/jpa.v27i1.45>
- Johnrencius, M., Herawati, N., & Johan, V. S. (2017). Influence of packaging on the quality of breadfruit cookies. *Jurnal Online Mahasiswa Faperta UR*, 4(1), 1–15.
- Kering, B. T. C. T., Manurung, H., Naibaho, B., Manalu, T. B., & Romauli, N. D. M. (2023). Pengaruh jenis kemasan dan lama penyimpanan terhadap karakteristik mutu bunga telang (*Clitoria tematea*) kering. *Rona Teknik Pertanian*, 16(1), 81–95. <https://doi.org/10.17969/rtp.v16i1.29384>
- Kurniadi, M., Angwar, M., Miftakhussolihah, M., Affandi, D. R., & Khusnia, N. (2019). Karakteristik cookies dari campuran tepung ubikayu termodifikasi (mocaf), tempe, telur, kacang hijau dan ikan lele. *Indonesian Journal of Industrial Research*, 30(1), 1–9. <https://doi.org/10.28959/jdpi.v30i1.4096>
- Kutwal, A. M., Shirsat, B. S., Sawan, A. A., Bansode, B. P., Dhopavkar, R. V., & Kalse, S. B. (2024). Effect of packaging materials and storage period on the quality of turmeric powder. *International Journal of Advanced Biochemistry Research*, 8(12), 33–35. <https://doi.org/10.33545/26174693.2024.v8.i12Sa.3067>
- Labthink Instruments Co. Ltd. (2022). *Oxygen permeability comparative study of different aluminum-coated films*. Retrieved from <https://www.labthinkinternational.com>
- Lindner, M., & Schmid, M. (2017). Thickness measurement methods for physical vapor deposited aluminium coatings in packaging applications. *Coatings*, 7(1), 9. <https://doi.org/10.3390/coatings7010009>
- Novita, E., Purbasari, D., & Mubarak, S. (2021). Pendugaan umur simpan bubuk kopi arabika menggunakan metode Arrhenius dengan kemasan aluminium foil dan plastik (polipropilen). *Jurnal Teknik Pertanian Lampung*, 10(3), 392–401. <https://doi.org/10.23960/jtep-l.v10i3.392-401>
- Pandawangi, S., Akrom, A., Nurkhasanah, N., & Zuniarto, A. A. (2025). Antioxidant effects of temulawak and black cumin honey in stunted children: A study in Cirebon. *Journal of Public Health and Pharmacy*, 5(2), 320–330. <https://doi.org/10.56338/jphp.v5i2.5950>
- Pangestu, M. W., Wulandari, Z., & Soenarno, M. S. (2025). Physicochemical, microbiological, and organoleptic characteristics of cookies during storage with egg yolk powder formulation. *Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan*, 13(1), 28–33. <https://doi.org/10.29244/jipthp.13.1.28-33>
- Putri, E. B. P., & Ardania, M. A. I. (2022). Analysis of antioxidant activity, vitamin C, and lactic acid of yogurt made from cow and goat milk using electric shock and conventional

- methods. *Food Science and Technology Journal*, 5(2), 123–133. <https://doi.org/10.25139/fst.vi.4991>
- Rahman, R. F., & Hapsari, D. R. (2023). Karakteristik sensori, kimia, dan aktivitas antioksidan kue egg roll dengan penambahan tepung temulawak (*Curcuma xanthorrhiza* Roxb.). *Jurnal Agroindustri Halal*, 9(3), 320–331.
- Rahmawati, P. Z., & Wahyuni, A. L. (2021). Karakteristik kimia dan warna biskuit substitusi tepung cacing tanah (*Lumbricus rubellus*) dan tepung ubi jalar oranye (*Ipomoea batatas*). *Jurnal Nutrisia*, 23(1), 1–13. <https://doi.org/10.29238/jnutri.v23i1.203>
- Rutkowska, J., & Baranowski, D. (2024). Effects of storage of cookies containing xylitol or sucrose on their fluorescent, antioxidative and browning properties. *NFS Journal*, 37, 1–9. <https://doi.org/10.1016/j.nfs.2024.100202>
- Saleh, S. A., Ulfa, R., & Setyawan, B. (2020). Identifikasi kadar air, tingkat kecerahan dan citarasa kopi robusta dengan variasi lama perendaman. *Jurnal Teknologi Pangan dan Ilmu Pertanian*, 2(5), 41–48. <https://doi.org/10.36526/jipang.v2i1.1215>
- Sari, W. P., Sunarharum, W. B., & Maligan, J. M. (2023). Profiling komponen aroma kopi Robusta. In *Prosiding Seminar Nasional Teknologi Pangan* (Vol. 1, No. 1, pp. 111–120).
- Septiani, S., & Ratnayani, R. (2025). Formulation and organoleptic test on cookies made from potato peel flour. *Journal La Lifesci*, 6(1), 105–117. <https://doi.org/10.37899/journallalifesci.v6i1.2028>
- Shabrina, E. N., Saragih, B., & Rahmadi, A. (2022). Karakteristik fisik-kimia cookies formulasi tepung daun singkong (*Manihot utilissima*), umbi singkong dan tepung terigu selama penyimpanan. *Journal of Tropical AgriFood*, 4(1), 31–42. <https://doi.org/10.35941/jtaf.4.1.2022.7738.31-42>
- Sheikh, T. Z. B., Yong, C. L., & Lian, M. S. (2009). In vitro antioxidant activity of the hexane and methanolic extracts of *Sargassum baccularia* and *Cladophora patentiramea*. *Journal of Applied Sciences*, 9(13), 2490–2493. <https://doi.org/10.3923/jas.2009.2490.2493>
- Souripet, A. (2015). Komposisi, sifat fisik dan tingkat kesukaan nasi ungu. *Jurnal Teknologi Pertanian*, 4(1), 25–32. <https://doi.org/10.30598/jagritekno.2015.4.1.25>
- Syariffudin, I., Purwanti, Y., & Fera, M. (2023). Pengaruh lama perendaman ekstrak buah nanas terhadap sifat fisik dan uji sensori daging entok. *Journal of Technology and Food Processing*, 3(2), 52–61. <https://doi.org/10.46772/jtftp.v3i02.1282>
- Theafelicia, Z., & Wulan, S. N. (2023). Perbandingan metode uji aktivitas antioksidan (DPPH, ABTS dan FRAP) pada teh hitam (*Camellia sinensis*). *Jurnal Teknologi Pertanian*, 24(1), 35–44. <https://doi.org/10.21776/ub.jtp.2023.024.01.4>

- Ulma'nun, L. L., Pujimulyani, D., & Kanetro, B. (2023). Pengaruh penambahan bubuk *Curcuma xanthorrhiza* Roxb. dan baking powder terhadap sifat cookies sagu-mocaf. In *NaCIA (National Conference on Innovative Agriculture)* (pp. 274–294).
- Yonata, D., Ulvie, Y. N. S., Soesanto, E., Sulistyowati, E., Pranata, B., & Rosidi, A. (2025). Stabilization and controlled release of curcumin from temulawak by spray-drying microencapsulation. *Trends in Sciences*, 22(2), 9125. <https://doi.org/10.48048/tis.2025.9125>
- Yusuf, F. M., & Nurkhasanah, N. (2015). Evaluasi kadar kurkumin dalam jamu tradisional kunir asam. *Pharmaceutical Sciences and Research*, 2(3), 115–123. <https://doi.org/10.7454/psr.v2i3.3342>