Online [ISSN: 2716-4365]
SAGU Journal – Agri. Sci. Tech., March, 2026, Vol. 25 : No. 1 [48-60]
https://doi.org/10.31258/jsg.v25i1.78

APPLICATION OF BENENG TARO STARCH EDIBLE FILM WITH THE ADDITION OF PINEAPPLE EXTRACT IN PINEAPPLE DODOL

Trivira Wulansuci[1], Yelmira Zalfiatri[1], Yanti Nopiani[1*], Chandra Gunawan[1], Anne Mudya Yolanda[2]

[1]Department of Agricultural Technology, Faculty of Agriculture, Universitas Riau, Pekanbaru, Indonesia
[2] Department of Statistics, School of Mathematics, University of Leeds, Leeds LS2 9JT, United Kingdom
*Correspondence: yantinopiani@lecturer.unri.ac.id

ABSTRACT

The objective of this study was to determine the optimal combination of beneng taro starch and pineapple peel extract in the formulation of edible films for pineapple dodol packaging. As a semi-moist food, pineapple dodol is highly susceptible to spoilage, therefore the application of an adible film coating serves as a strategic solution to extend its shelf life. This research evaluates how varying these components affects the functional characteristics of the film to ensure maximum protection for the product. The experimental design used was a completely randomized factorial design with 2 factors, namely the addition of taro starch (2 g, 3 g, 4 g, 5 g) and the addition of pineapple peel extract (1%, 2%, 3% v/v), with 3 repetitions. Parameters observed were edible film thickness, water vapor transmission rate (WVTR), water resistance, moisture content of the dodol, total plate count (TPC), and sensory aroma evaluation. Data were statistically using Analysis of Variance (ANOVA) and continued with Duncan's Multiple Range Test (DMRT) at the 5% level. Results indicated an interaction effect between starch and extract on the WVTR and water resistance of the edible film. The individuals treatments significantly affected thickness, WVTR, water resistance, moisture, TPC, and aroma scores. The best treatment was P5K3 (5 g of beneng taro starch and 3% pineapple peel extract) with criteria of thickness 0.221 mm, WVTR 6.67 g/m²/hour, percentage swelling water resistance 81.71%, moisture content 20.50%, TPCS 3.52 log CFU/g, and descriptive aroma of pineapple dodol 1.33 (not rancid) lasts until the 6th day.

Keywords: beneng taro starch, edible film, pineapple dodol, pineapple peel extract

INTRODUCTION

Riau Province is one of the major pineapple-producing regions in Indonesia. According to Badan Pusat Statistik (2024), pineapple production in Riau Province reached 355.181 tons in 2024. Pineapple can be consumed fresh or processed into various products such as jam, candied fruit, sauce, chips, syrup, jelly, and pineapple dodol (Syah et al., 2018). According to the Indonesian National Standard (SNI 01–4296–1996), pineapple dodol is a food product made from mashed ripe pineapple pulp, which is then cooked with sugar and other additives. Dodol is classified as a semi-moist food with a moisture content of approximately 10–40% and a water activity (aW) ranging from 0.60 to 0.80, making it susceptible to spoilage (Afifah et al., 2019). Therefore, appropriate packaging is required to extend the shelf life of pineapple dodol.

Packaging is used to protect products from heat, moisture, oxygen, mechanical damage, and contaminants that may deteriorate product quality (Widiati, 2019). Based on its structure, packaging is classified into three types: primary, secondary, and tertiary packaging. Primary packaging is in direct contact with food products, and one example of primary packaging is edible film. Edible film is a thin layer of food packaging that can be consumed together with the food product it covers (Adlin et al., 2020). The three main components of edible films are hydrocolloids, lipids, and composites. According to Muin et al. (2017), hydrocolloids used in edible film formulation are primarily polysaccharides. One of the polysaccharides commonly utilized as a raw material for edible film production is starch.

Starch is a type of complex carbohydrate, typically white in color, derived from plants and insoluble in water. One underutilized source of starch is beneng taro starch. Beneng taro (*Xanthosoma undipes* K. Koch), also known as Banten taro or “big elephant’s ear,” derives its name from the words *besar* (large) and *koneng* (yellow), reflecting its large size and yellowish color. Unlike most taro varieties whose corms grow underground, beneng taro corms develop above the soil surface (Rukmana & Yudirachman, 2015). Beneng taro corms contain approximately 84.88% carbohydrates, 6.29% protein, 1.12% fat, and provide 374.69 kcal of energy (Agustin et al., 2022). According to Wahjusaputri et al. (2018), the starch content in beneng taro corms accounts for approximately 15.21% of the total carbohydrate content.

Thin edible film packaging made from organic materials such as starch can serve as a nutrient source for spoilage microorganisms. Therefore, the incorporation of additives or antimicrobial compounds is necessary to prevent product deterioration. Antimicrobial packaging is designed to control, reduce, or inhibit the growth of pathogenic microorganisms, thereby minimizing the risk of contamination in food products. According to Zary et al. (2023), one material with antifungal and antibacterial properties is pineapple peel extract.

Pineapple peel extract contains secondary metabolites such as bromelain enzymes, tannins, saponins, and flavonoids, which contribute to its antimicrobial potential (Sinaga et al., 2024). This extract has been reported to inhibit the growth of the fungus *Trichophyton mentagrophytes* (Juariah et al., 2018), as well as the bacteria *Staphylococcus aureus* and *Escherichia coli* (Rini et al., 2017). Tannins present in pineapple peel extract act as antifungal agents by inhibiting chitin synthesis in fungal cell walls, disrupting cell membranes, and suppressing cell growth (Juariah et al., 2018). Flavonoids inhibit bacterial cell wall formation, while bromelain enzymes degrade peptide bonds in bacterial proteins (Husniah & Gunata, 2020). This study aims to determine the optimal treatment combination of beneng taro starch and pineapple peel extract addition on the characteristics of edible films used as packaging for pineapple dodol.

METHODS

Materials

The materials used in this study included beneng taro corms obtained from Desa Manggala Sakti, pineapple peels of the Queen variety sourced from Pasar Simpang Baru, and pineapple dodol purchased from Toko Hanisun Cake Oleh-Oleh Pekanbaru. The chemicals used included glycerol, distilled water, carboxymethyl cellulose (CMC), 90% ethanol solution, plate count agar (PCA) (Merck), and buffered peptone water (BPW) (Merck). The equipment used in this study consisted of an analytical balance, beakers, graduated cylinders, stirring rods, spatulas, a hot plate, plastic containers, Petri dishes, test tubes, test tube racks, a Bunsen burner, porcelain crucibles, Erlenmeyer flasks, filter cloth, an autoclave, a laminar air flow cabinet, an incubator, a drying oven, droppers, an oven, a desiccator, a blender, a thermometer, a manual micrometer, a pH meter, aluminum foil, knives, glass jars, plastic clip bags, a sealer, and an 80-mesh sieve.

Research Methodology

The experimental design used in this study was a Completely Randomized Design (CRD) arranged in a factorial scheme with two treatment factors. The first factor was the concentration of beneng taro starch, consisting of four levels: P2 = 2 g, P3 = 3 g, P4 = 4 g, and P5 = 5 g of beneng taro starch. The second factor was the concentration of pineapple peel extract, consisting of three levels: K1 = 1%, K2 = 2%, and K3 = 3%. Each treatment combination was conducted in triplicate, resulting in a total of 36 experimental units.

Research Implementation

Preparation of beneng taro starch

The preparation of beneng taro starch was carried out according to the method described by Melani et al. (2017). A total of 2 kg of beneng taro corms were peeled, washed, and soaked in a salt solution for 1.5 hours, followed by rinsing. The corms were then blended with 4 L of water and filtered to obtain the first starch suspension. The residue was re-blended with 2 L of water and filtered to obtain the second starch suspension. Both suspensions were combined and allowed to settle for 24 hours to separate the liquid from the starch. The resulting starch sediment was then dried under sunlight and sieved using an 80-mesh sieve.

Preparation of pineapple peel extract

The extraction of pineapple peel simplicia was carried out following the method of Ayu et al. (2022). A total of 2 kg of pineapple peels were washed, cut into small pieces, and shade-dried for 3 days, then ground into powder. A total of 500 g of pineapple peel simplicia was macerated with 1500 mL of 90% ethanol in a dark glass container for 3 days with daily stirring, followed by filtration. The filtrate was then concentrated using a rotary evaporator at 78°C to obtain pineapple peel extract.

Preparation of edible film

The preparation of edible film was conducted according to the method described by Putri et al. (2023). Beneng taro starch was weighed at 2 g, 3 g, 4 g, and 5 g for each treatment and dissolved in 93 mL of distilled water in a beaker. The starch solution was heated using a hot plate while continuously stirred at approximately 55°C for 20 minutes. Glycerol (3 g) was then added, and the temperature was increased to 70°C, followed by the gradual addition of 1 g of carboxymethyl cellulose (CMC) while stirring until a homogeneous solution was obtained. Subsequently, pineapple peel extract was added at concentrations of 1%, 2%, and 3% (v/v) of the total film-forming solution and stirred for 1 minute. A total of 80 mL of the film-forming solution was poured into a plastic mold (22 × 17 cm) and dried in a drying oven at 50°C for 24 hours. After drying, the edible film was cooled at room temperature for 15 minutes, removed from the mold, and then analyzed for its physical characteristics and applied to pineapple dodol.

Application to pineapple dodol

The application of edible film to pineapple dodol was carried out according to the method of Harini et al. (2020). Pineapple dodol was cut into pieces measuring 3 × 3 × 1.5 cm. The edible film was then applied to completely cover the surface of the dodol and sealed, after which the samples were stored in plastic clip bags for 6 days. Observations of the pineapple dodol were conducted on storage days 0, 3, and 6.

Thickness measurement

Thickness measurement was carried out according to Kasmawati (2018). The thickness of the edible film was measured using a manual micrometer with a precision of 0.01 mm at five different points, namely at the four corners and the center of the film. The obtained values were then averaged to determine the final thickness of the edible film. The thickness of the edible film was expressed in millimeters (mm) and calculated using the following equation:

$$Thickness\ (mm) = \frac{t_1+t_2+t_3+t_4+t_5}{5} \tag{1}$$

where t_1–t_5 represent the thickness measurements at five different positions (four corners and the center) of the edible film, expressed in millimeters (mm).

Water vapor transmission rate (WVTR)

The water vapor transmission rate (WVTR) was determined using the gravimetric method according to ASTM E96 (1997). The edible film was cut into a circular shape corresponding to the surface area of the cup. A porcelain cup containing 3 g of silica gel was weighed to obtain the initial weight prior to use. The edible film was then sealed onto the surface of the cup. The cup containing the edible film sample was weighed again to obtain the initial measurement and then placed in a desiccator containing distilled water. The cup was removed and weighed at 1-hour intervals over a period of 7 hours. The water vapor transmission rate was calculated using the following equation:

$$\text{WVTR} = \frac{\text{slope of weight gain (g/hour)}}{\text{surface area (m}^2\text{)}} \tag{2}$$

Water resistance test

The water resistance of the edible film was evaluated using a swelling test according to Listiyaningsih (2013). The edible film was cut into 1 × 1 cm pieces, weighed, and the initial weight was recorded. After determining the dry weight, the sample was immersed in 10 mL of distilled water and removed after 1 minute. The excess water on the surface of the edible film was gently removed using tissue paper. This procedure was repeated until a constant weight was obtained. The water resistance of the film was expressed as swelling percentage and calculated using the following equation:

$$S\ (\%) = \frac{W - W0}{W0}\ x\ 100 \tag{3}$$

Note:
S = *Swelling* (%)
W_0 = initial dry weight of the sample (g)
W = the weight of the sample after immersion in water (g)

Total plate count (TPC) analysis

The total microbial count of pineapple dodol was determined according to Afifah et al. (2019). Aseptically, 1 g of sample was weighed and added to 9 mL of buffered peptone water (BPW), then homogenized to obtain a 10^{-1} dilution. From this dilution, 1 mL was transferred into a test tube containing 9 mL of BPW to obtain a 10^{-2} dilution. Aliquots of 1 mL from the 10^{-1} and 10^{-2} dilutions were pipetted into sterile Petri dishes, followed by the addition of Plate Count Agar (PCA) using the pour plate method. The medium and sample were mixed by gently swirling the Petri dish in a figure-eight motion. After the medium solidified, the plates were incubated at 37°C for 24 hours, and the number of colonies was counted. The total plate count was calculated using the following equation:

$$\text{Colony count (CFU/g)} = \text{Number of colonies} \times \frac{1}{\text{Dilution factor}} \tag{4}$$

Descriptive aroma evaluation

The descriptive sensory evaluation was conducted according to Setyaningsih et al. (2010). The aroma of pineapple dodol coated with edible film was evaluated on storage days 0, 3, and 6 using a 4-point scale. The evaluation was carried out by 30 semi-trained student panelists from the Department of Agricultural Technology, Universitas Riau, through questionnaire-based assessment. The numerical scale used for aroma evaluation consisted of four levels: 4 = very rancid, 3 = rancid, 2 = slightly rancid, and 1 = not rancid.

Data Analysis

Analysis of variance (ANOVA) was used to statistically analyze the data obtained using IBM SPSS Statistics version 25. Additional tests were conducted by applying Duncan's multiple range test (DMRT) at the 5% level when the calculated F-value was greater than or equal to the critical F-value.

RESULTS AND DISCUSSION

Thickness

The thickness of edible film refers to the measurement of the film layer's thickness, expressed in millimeters (mm). Table 1 shows that there was no interaction between the addition of beneng taro starch and pineapple peel extract on the thickness of the edible film. However, each treatment factor beneng taro starch and pineapple peel extract individually had a significant effect ($p<0.05$) on the thickness of the edible film. The resulting thickness of the edible film ranged from 0.13 to 0.22 mm.

Table 1. Thickness values of edible films

Beneng Taro Starch	**Pineapple Peel Extract**			**Mean of Beneng Taro Starch (mm)**
	K1 (1%)	**K2 (2%)**	**K3 (3%)**	
P2 (2 g)	$0.130^{a}\pm0.002$	$0.134^{a}\pm0.002$	$0.149^{b}\pm0.001$	0.14^{A}
P3 (3 g)	$0.157^{c}\pm0.001$	$0.172^{d}\pm0.002$	$0.177^{d}\pm0.001$	0.17^{B}
P4 (4 g)	$0.187^{e}\pm0.001$	$0.195^{f}\pm0.002$	$0.199^{f}\pm0.001$	0.19^{C}
P5 (5 g)	$0.205^{g}\pm0.006$	$0.215^{h}\pm0.007$	$0.221^{i}\pm0.003$	0.21^{D}
Mean of Pineapple Peel Extract (mm)	0.17^{A}	0.18^{B}	0.19^{C}	

Note: Values followed by different lowercase letters (within the same row) and uppercase letters (within the same column) indicate significant differences ($p<0.05$).

The thickness values presented in Table 1 indicate that increasing the concentration of beneng taro starch and pineapple peel extract resulted in thicker edible films. A higher concentration of beneng taro starch increases the amylose content and the amount of dissolved solids in the film-forming solution, thereby producing a thicker film. An increase in starch concentration enhances the polymer matrix-forming components, leading to a higher total solid content in the edible film and consequently a greater film thickness (Warkoyo et al., 2014). This finding is consistent with the study by Masru'ah et al. (2023), which reported that higher concentrations of film-forming components increase total solids and, in turn, the thickness of edible films. According to Yulianti and Ginting (2012), thicker edible films exhibit better barrier properties against water vapor transmission, thereby extending the shelf life of the packaged product. The addition of pineapple peel extract concentration also influenced the thickness of the edible film. Increasing the concentration of pineapple peel extract resulted in a higher thickness of the edible film. This is attributed to the increase in total dissolved solids within the film-forming solution, which enhances the amount of polymers contributing to film formation, thereby increasing film thickness. This finding is supported by Moomin and Sulistijowati (2021), who reported that higher extract concentrations increase the total dissolved solids in the suspension, leading to a greater amount of polymers forming the edible film matrix and consequently producing thicker films. The incorporation of more extract increases the total solid content after drying and contributes to a denser polymer matrix structure in the edible film. According to the Japanese Industrial Standard (JIS), the maximum allowable thickness of edible film is 0.25 mm. The thickness values obtained from the combinations of beneng taro starch and pineapple peel extract in this study comply with the JIS standard.

Water Vapor Transmission Rate (WVTR)

Water vapor transmission rate (WVTR) is a parameter used to determine the ease with which water vapor passes through a material. Table 2 shows that there was a significant interaction between the addition of beneng taro starch and pineapple peel extract. This indicates that increasing the combination levels of both components influences the film's ability to inhibit water vapor transmission. An increase in beneng taro starch concentration leads to higher amylose content and total dissolved solids in the edible film, thereby increasing the number of polymers that can reduce the void spaces within the gel matrix formed in the film. Furthermore, higher concentrations of pineapple peel extract contribute to an increased polymer content, resulting in higher total solids and film thickness, as well as improved film density. This denser structure reduces the permeability of the film, making it more resistant to water vapor transmission.

Table 2. Water vapor transmission rate (WVTR) of edible films

Beneng Taro Starch	**Pineapple Peel Extract**			**Mean of Beneng Taro Starch (mm) (g/m²/h)**
	K1 (1%)	**K2 (2%)**	**K3 (3%)**	
P2 (2 g)	$13.30^{k}\pm0.202$	$12.48^{j}\pm0.046$	$12.05^{i}\pm0.042$	12.61^{D}
P3 (3 g)	$11.36^{h}\pm0.102$	$11.03^{g}\pm0.002$	$10.59^{f}\pm0.003$	10.99^{C}
P4 (4 g)	$9.84^{e}\pm0.037$	$9.12^{d}\pm0.025$	$8.92^{d}\pm0.055$	9.29^{B}
P5 (5 g)	$7.88^{c}\pm0.006$	$7.08^{b}\pm0.013$	$6.67^{a}\pm0.005$	7.21^{A}
Mean of Pineapple Peel Extract (g/m²/h)	10.60^{C}	9.93^{B}	9.56^{A}	

Note: Values followed by different lowercase letters (within the same row) and uppercase letters (within the same column) indicate significant differences ($p<0.05$).

The water vapor transmission rate (WVTR) of the edible films ranged from 6.67 to 13.30 g/m²/h. The WVTR values presented in Table 2 indicate that increasing the concentration of beneng taro starch resulted in lower WVTR values. Higher concentrations of beneng taro starch promote the formation of stronger polymer networks, thereby reducing water vapor transfer through the edible film. A thicker and more compact film matrix is relatively less permeable to water vapor, thus decreasing the WVTR due to the increased resistance to diffusion. According to Rizkyati and Winarti (2022), higher starch concentrations increase amylose content and total dissolved solids in the edible film, leading to a greater number of polymers that can reduce void spaces within the gel matrix. This condition is also attributed to stronger intermolecular interactions among polymer chains, resulting in lower water vapor permeability. Furthermore, stronger intermolecular bonding within the polymer matrix reduces the permeability of the film to both water vapor and gases, thereby enhancing the film's effectiveness as a water vapor barrier (Ilah, 2015).

Increasing the concentration of pineapple peel extract also contributed to a reduction in the water vapor transmission rate (WVTR) of the edible film. The incorporation of pineapple peel extract into the edible film matrix reduces its hydrophilic properties and enhances its hydrophobic characteristics. Ulfa et al. (2024) reported that higher extract concentrations lead to a reduction in pore size within the edible film, thereby limiting water vapor diffusion and decreasing the WVTR. This finding is consistent with the study by Harini et al. (2020), which demonstrated that increasing the concentration of turmeric filtrate reduced water vapor transmission due to increased film thickness, resulting in a denser film structure that is more resistant to water vapor permeation. According to Deden et al. (2020), WVTR is closely related to film thickness; thicker films exhibit lower permeability, leading to reduced water vapor transmission. Lower WVTR values indicate better barrier properties of the film against water vapor diffusion into the material.

Water Resistance (Swelling Test)

The water resistance of the edible film was evaluated using a swelling test, which reflects the film's ability to absorb water and swell when immersed in a solution. Table 3 shows that the interaction between the addition of beneng taro starch and pineapple peel extract had a significant effect ($p<0.05$) on the water resistance of the edible film. Beneng taro starch, as the main film-forming material, has a polysaccharide structure capable of forming a dense matrix, thereby increasing the thickness and mechanical strength of the film. The addition of pineapple peel extract introduces bioactive compounds such as flavonoids and tannins, which contain hydroxyl groups and can interact with starch molecules through hydrogen bonding. These interactions result in a more compact starch matrix, reducing water vapor permeability and enhancing the water resistance of the film. In addition, the phenolic compounds present in pineapple peel extract contribute to increasing the hydrophobicity of the film, thereby limiting water absorption.

Table 3. Water resistance of edible films (swelling test)

Beneng Taro Starch	Pineapple Peel Extract			Mean of Beneng Taro Starch (%)
	K1 (1%)	**K2 (2%)**	**K3 (3%)**	
P2 (2 g)	$251.33^{j}\pm3.65$	$222.81^{i}\pm3.69$	$220.84^{i}\pm2.22$	231.66^{D}
P3 (3 g)	$192.36^{h}\pm1.91$	$164.35^{g}\pm1.75$	$160.14^{f}\pm1.87$	172.28^{C}
P4 (4 g)	$158.24^{f}\pm1.63$	$132.63^{e}\pm1.01$	$119.69^{d}\pm0.77$	136.86^{B}
P5 (5 g)	$101.16^{c}\pm1.28$	$86.18^{b}\pm0.70$	$81.71^{a}\pm1.05$	89.68^{A}
Mean of Pineapple Peel Extract (%)	175.77^{C}	151.49^{B}	145.59^{A}	

Note: Values followed by different lowercase letters (within the same row) and uppercase letters (within the same column) indicate significant differences ($p<0.05$).

The water resistance values of the edible films ranged from 81.71 to 251.33%. Table 3 shows that increasing the concentration of beneng taro starch resulted in a lower swelling percentage. Higher concentrations of beneng taro starch increase the amylopectin content, which is capable of strongly retaining water within the starch matrix, thereby limiting water mobility within the edible film. This finding is consistent with Utomo et al. (2023), who reported that amylopectin can effectively entrap water during starch gelatinization and retain it within the edible film matrix, thus reducing the availability of free spaces for additional water absorption. Although starch is inherently hydrophilic, increasing its concentration leads to the formation of thicker films with a more compact structure, which enhances water resistance. The increased thickness and reduced porosity limit water penetration, thereby improving the film's resistance to water (Setiani et al., 2013). Furthermore, increasing the concentration of pineapple peel extract also reduced the swelling percentage.

The incorporation of pineapple peel extract enhances the hydrophobic characteristics of the edible film, resulting in improved water resistance. These results are in agreement with Ulfa et al. (2024), who reported that the addition of extracts containing secondary metabolites such as tannins can increase film density, leading to a more complex and stronger matrix due to interactions between tannins and other film components. Pineapple peel extract contains secondary metabolites such as flavonoids and tannins (Juariah et al., 2018). The interaction of these compounds within the film matrix contributes to a more compact structure, thereby reducing the water absorption capacity of the edible film.

Moisture Content of Pineapple Dodol

Moisture content refers to the amount of water present in a food product. Table 4 shows that there was no interaction between the addition of beneng taro starch and pineapple peel extract on the moisture content of pineapple dodol. However, each factor beneng taro starch and pineapple peel extract individually had a significant effect ($p<0.05$) on the moisture content of the dodol. The results indicated that the moisture content of the dodol increased during storage (Table 4).

Table 4. Moisture content of pineapple dodol during storage

Storage Time	Beneng Taro Starch	Pineapple Peel Extract			Mean of Beneng Taro Starch (%)
		K1 (1%)	K2 (2%)	K3 (3%)	
Day 0	P2 (2 g)	19.33±0.32	19.43±0.41	19.05±0.04	19.27
	P3 (3 g)	19.28±0.26	19.01±0.41	19.29±0.06	19.19
	P4 (4 g)	19.09±0.06	19.48±0.16	19.28±0.06	19.28
	P5 (5 g)	19.37±0.13	19.24±0.03	19.33±0.10	19.31
Mean of Pineapple Peel Extract (%)		19.27	19.29	19.24	
Day 3	P2 (2 g)	23.49^{c}±0.22	23.32^{c}±0.14	23.05^{c}±0.12	23.29^{C}
	P3 (3 g)	23.01^{c}±0.07	22.74^{bc}±0.28	22.19^{bc}±0.39	22.65^{C}
	P4 (4 g)	22.17^{ab}±0.35	21.64^{ab}±0.47	20.77^{a}±0.76	21.53^{B}
	P5 (5 g)	20.75^{a}±1.21	20.72^{a}±0.82	20.50^{a}±0.82	20.66^{A}
Mean of Pineapple Peel Extract (%)		22.36^{B}	22.10^{AB}	21.63^{A}	
Day 6	P2 (2 g)	27.73^{g}±0.44	27.54^{fg}±0.34	27.18^{ef}±0.18	27.49^{D}
	P3 (3 g)	27.11^{ef}±0.18	26.85^{e}±0.13	26.09^{d}±0.18	26.68^{C}
	P4 (4 g)	26.02^{cd}±0.08	25.51^{c}±0.25	24.65^{b}±0.31	25.39^{B}
	P5 (5 g)	24.56^{b}±0.11	24.41^{b}±0.35	23.79^{a}±0.13	24.25^{A}
Mean of Pineapple Peel Extract (%)		26.35^{C}	26.08^{B}	25.43^{A}	

Note: Values followed by different lowercase letters (within the same row) and uppercase letters (within the same column) indicate significant differences ($p<0.05$).

Based on Table 4, treatment P5K3 (5 g beneng taro starch and 3% pineapple peel extract) exhibited the lowest moisture content on day 3 (20.50%) and day 6 (23.79%). This phenomenon is likely due to the release of free water resulting from starch retrogradation in the dodol, as well as the production of metabolic water by microorganisms that becomes retained due to the low water vapor permeability of the edible film. The starch in glutinous rice flour gradually loses its ability to bind water, leading to an increase in free water within the dodol (Harini et al., 2020). Furthermore, edible films with low water vapor permeability tend to retain moisture by preventing water evaporation, thereby increasing the moisture content of the packaged product (Nurhakim et al., 2021).

Increasing the concentration of beneng taro starch leads to an increase in film thickness, which consequently reduces the rate of water vapor transfer. According to Setiani et al. (2013), films with greater thickness are more effective in resisting water vapor penetration. Nurhakim et al. (2021) reported that thinner edible films shorten the diffusion path of water vapor to the food product, resulting in faster contact, whereas thicker films extend this path and slow down the diffusion process.

Similarly, increasing the concentration of pineapple peel extract contributes to greater film thickness, and thicker films are able to retain more incoming water vapor. This result is consistent with the findings of Harini et al. (2020), which indicated that lower moisture content is associated with thicker edible films possessing lower water vapor transmission rates, thereby inhibiting moisture increase. The thickness of the edible film plays a crucial role in determining its ability to control the transfer rate of water vapor and volatile compounds between the internal and external environments of the food (Septiati & Karmini, 2023). The thicker the edible film, the longer the diffusion path of water vapor to the food product, resulting in a slower rate of moisture transfer.

Total Plate Count (TPC) of Pineapple Dodol

Total plate count (TPC) is a method used to quantify the number of bacterial colonies in food samples or products. Table 5 shows that there was no interaction between the addition of beneng taro starch and pineapple peel extract on the TPC values of pineapple dodol. However, each factor beneng taro starch and pineapple peel extract individually had a significant effect ($p<0.05$) on the TPC values. The results indicated that the TPC of pineapple dodol increased during storage (Table 5).

Table 5. Total plate count (TPC) of pineapple dodol during storage

Storage Time	Beneng Taro Starch	Pineapple Peel Extract			Mean of Beneng Taro Starch (log CFU/g)
		K1 (1%)	**K2 (2%)**	**K3 (3%)**	
Day 0	P2 (2 g)	2.53±0.13	2.56±0.15	2.52±0.19	2.54
	P3 (3 g)	2.61±0.05	2.57±0.09	2.59±0.09	2.59
	P4 (4 g)	2.65±0.07	2.62±0.05	2.61±0.06	2.63
	P5 (5 g)	2.63±0.14	2.60±0.09	2.57±0.10	2.60
Mean of Pineapple Peel Extract (log CFU/g)		2.61	2.59	2.57	
Day 3	P2 (2 g)	$3.91^{e}\pm0.05$	$3.74^{cd}\pm0.07$	$3.61^{ab}\pm0.03$	3.75^{B}
	P3 (3 g)	$3.86^{e}\pm0.06$	$3.74^{cd}\pm0.07$	$3.59^{a}\pm0.04$	3.73^{AB}
	P4 (4 g)	$3.82^{de}\pm0.02$	$3.73^{cd}\pm0.05$	$3.53^{a}\pm0.03$	3.69^{A}
	P5 (5 g)	$3.81^{de}\pm0.01$	$3.70^{bc}\pm0.03$	$3.52^{a}\pm0.02$	3.68^{A}
Mean of Pineapple Peel Extract (log CFU/g)		3.85^{C}	3.73^{B}	3.56^{A}	
Day 6	P2 (2 g)	$4.49^{d}\pm0.02$	$4.38^{bc}\pm0.03$	$4.24^{a}\pm0.02$	4.37^{B}
	P3 (3 g)	$4.47^{d}\pm0.03$	$4.35^{b}\pm0.03$	$4.21^{a}\pm0.02$	4.34^{AB}
	P4 (4 g)	$4.44^{cd}\pm0.02$	$4.34^{b}\pm0.08$	$4.19^{a}\pm0.01$	4.33^{AB}
	P5 (5 g)	$4.43^{cd}\pm0.04$	$4.32^{b}\pm0.05$	$4.16^{a}\pm0.03$	4.30^{A}
Mean of Pineapple Peel Extract (log CFU/g)		4.46^{C}	4.35^{B}	4.20^{A}	

Note: Values followed by different lowercase letters (within the same row) and uppercase letters (within the same column) indicate significant differences ($p<0.05$).

Based on Table 5, treatment P5K3 (5 g beneng taro starch and 3% pineapple peel extract) exhibited the lowest TPC values on day 3 (3.52 log CFU/g) and day 6 (4.16 log CFU/g). Microbial growth in food is influenced by factors such as temperature, humidity, moisture content, and the availability of nutrients. According to Septiati & Karmini (2023), one of the factors affecting the shelf life of processed products is moisture level. The water content in food materials affects their susceptibility to microbial growth, which is commonly expressed as water activity (aW), representing the amount of free water available for microbial proliferation (Wulansari et al., 2023). These findings are consistent with the observed increase in moisture content of pineapple dodol during storage. As moisture content increases, it promotes microbial growth, leading to higher TPC values over time.

Increasing the concentration of beneng taro starch results in thicker edible films. The thickness of the packaging material plays an important role in determining the quality of the packaged food. Edible films with greater thickness can provide better protection for dodol against microbial contamination (Septiati & Karmini, 2023). Film thickness also determines the ability of the film to control the transfer rate of water vapor and volatile compounds between the internal and external environments of the food, as well as to prevent environmental contamination such as bacteria, temperature fluctuations, and humidity.

Furthermore, increasing the concentration of pineapple peel extract led to lower TPC values in pineapple dodol. This is attributed to the presence of bioactive compounds in pineapple peel extract that inhibit microbial growth. Pineapple peel extract contains secondary metabolites such as bromelain enzymes, tannins, saponins, and flavonoids, which exhibit antimicrobial properties (Sinaga et al., 2024). According to Putri et al. (2016), bromelain alters the physicochemical properties of bacterial cell membranes, thereby inhibiting and killing bacteria. Juariah et al. (2018) reported that tannins, which are lipophilic, inhibit chitin synthesis in microbial cell walls, disrupt cell membranes, and suppress microbial growth. Saponins (Rijayanti et al., 2014) reduce the surface tension of bacterial cell walls in a detergent-like manner, causing leakage of proteins and enzymes and damaging membrane permeability. Flavonoids Ayu et al. (2022) form soluble complexes with extracellular proteins, disrupt cell membranes, and lead to the release of intracellular components. Higher extract concentrations result in greater antimicrobial activity. As reported by Juariah et al. (2018), higher concentrations are more effective in inhibiting and damaging microbial growth.

Aroma of Pineapple Dodol

Aroma is one of the parameters in sensory evaluation assessed using the sense of smell. Table 6 shows that there was no interaction between the addition of beneng taro starch and pineapple peel extract on the aroma of pineapple dodol. However, each factor—beneng taro starch and pineapple peel extract—individually had a significant effect ($p<0.05$) on the aroma of pineapple dodol. Based on Table 6, the results of the aroma evaluation of pineapple dodol coated with edible film during storage indicated a decline in organoleptic quality over time. Treatment P5K3 (5 g beneng taro starch and 3% pineapple peel extract) exhibited the lowest aroma scores on storage days 3 and 6. The deterioration in aroma quality was characterized by the development of rancidity. This rancid odor is attributed to the oxidation of fats present in coconut milk, which is one of the main ingredients used in pineapple dodol production. Lipid oxidation in pineapple dodol leads to the formation of aldehydes and peroxides, which are responsible for the development of rancid off-odors (Sutrisno et al., 2016). Increasing the concentration of beneng taro starch can improve the aroma quality of pineapple dodol. The permeability of packaging materials plays an important role in determining the barrier properties of the packaging against oxygen transfer. Sutrisno et al. (2016) reported that longer storage periods lead to increased lipid oxidation in pineapple dodol due to prolonged exposure to oxygen.

The results of the descriptive aroma test are consistent with the water vapor transmission rate (WVTR) results, where increasing starch concentration resulted in lower WVTR values. Packaging with low water vapor permeability enhances product stability and reduces the rate of quality deterioration. Furthermore, increasing the concentration of pineapple peel extract also improved the aroma quality of pineapple dodol. Pineapple peel extract functions as an active component in the edible film and contains flavonoids with antioxidant properties. Antioxidants act as retardants, inhibitors, and preventers of lipid oxidation by interrupting the initiation stage of oxidative chain reactions, thereby reducing the rate of oxidation between oxygen and pineapple dodol (Rollando, 2018). The mechanism of flavonoids in pineapple peel extract involves donating hydrogen ions, which neutralize the toxic effects of free radicals (Santoso & Mahardika, 2023). Aroma plays a crucial role in consumer acceptance of food products, as it determines palatability and serves as a primary indicator in the sensory evaluation of food quality.

Table 6. Descriptive aroma scores of pineapple dodol during storage

Storage Time	Beneng Taro Starch	Pineapple Peel Extract			Mean of Beneng Taro Starch
		K1 (1%)	K2 (2%)	K3 (3%)	
Day 0	P2 (2 g)	1.00±0.00	1.03±0.18	1.00±0.00	1.01
	P3 (3 g)	1.03±0.18	1.03±0.18	1.03±0.18	1.03
	P4 (4 g)	1.03±0.18	1.03±0.18	1.03±0.18	1.03
	P5 (5 g)	1.03±0.18	1.03±0.18	1.03±0.18	1.03
Mean of Pineapple Peel Extract		1.03	1.03	1.03	
Day 3	P2 (2 g)	1.83^{b}±0.64	1.83^{b}±0.69	1.60^{ab}±0.66	1.76^{C}
	P3 (3 g)	1.80^{b}±0.65	1.70^{ab}±0.64	1.53^{ab}±0.67	1.68^{BC}
	P4 (4 g)	1.67^{ab}±0.70	1.57^{ab}±0.56	1.40^{a}±0.49	1.61^{AB}
	P5 (5 g)	1.60^{ab}±0.71	1.47^{ab}±0.50	1.33^{a}±0.47	1.51^{A}
Mean of Pineapple Peel Extract		1.73^{B}	1.64^{B}	1.47^{A}	
Day 6	P2 (2 g)	3.30^{c}±0.64	3.27^{c}±0.57	3.13^{c}±0.62	3.23^{B}
	P3 (3 g)	3.20^{c}±0.65	3.13^{c}±0.62	2.87^{bc}±0.85	3.07^{B}
	P4 (4 g)	2.67^{ab}±0.83	2.63^{ab}±0.95	2.47^{ab}±0.85	2.59^{A}
	P5 (5 g)	2.63^{ab}±0.75	2.40^{a}±1.02	2.33^{a}±0.91	2.46^{A}
Mean of Pineapple Peel Extract		2.95^{B}	2.86^{AB}	2.72^{A}	

Note: Values followed by different lowercase letters (within the same row) and uppercase letters (within the same column) indicate significant differences ($p<0.05$).

CONCLUSION

The results of this study indicate that the interaction between the addition of beneng taro starch and pineapple peel extract had a significant effect on the water vapor transmission rate and water resistance of the edible film. The individual treatments of beneng taro starch and pineapple peel extract significantly affected the thickness, water vapor transmission rate, and water resistance of the edible film, as well as the moisture content, total plate count, and descriptive aroma of pineapple dodol. The best treatment in this study was P5K3 (5 g beneng taro starch and 3% pineapple peel extract), which exhibited the following characteristics: thickness of 0.221 mm, water vapor transmission rate of 6.67 g/m^{2}/h, water resistance (swelling) of 81.71%, moisture content of 20.50%, total plate count of 3.52 log CFU/g, and an aroma score of 1.33 (not rancid), with product stability maintained up to 6 days of storage.

REFERENCES

Adlin, I. A., Sebastiani, Y., & Hidayanti, T. N. (2020). Karakteristik pembuatan edible film dengan variabel kombinasi tepung konjak dan keragenan serta konsentrasi gliserol. *Jurnal Ilmiah Teknik Kimia*, *4*(2), 88–95.

Afifah, N., Ratnawati, L., & Darmajana, D. A. (2019). Pengaruh jenis pati dan lipid terhadap sifat fisikokimia edible film komposit serta aplikasinya sebagai pengemas dodol nanas. *Jurnal Riset Teknologi Industri*, *13*(2), 217–229.

Agustin, A. N., Indriyani Syafutri, M., Yanuriati, A., Malahayati, N., Aryani, D., & Airlangga, T. (2022). Penurunan kadar oksalat pati talas beneng (*Xanthosoma undipes* K. Koch) pada berbagai konsentrasi NaCl dan lama perendaman. *Prosiding Seminar Nasional Lahan Subotimal*, 199–207.

ASTM E96. (1997). *ASTM (American Society fot Testing and Materials) Annual book of ASTM standards.* Philadelphia, USA.

Ayu, D. F., Sari, A. P., & Zalfiatri, Y. (2022). Aktivitas antibakteri sabun transparan dengan penambahan ekstrak kulit nanas. *Jurnal Teknologi dan Industri Hasil Pertanian*, *27*(2), 118–130.

Badan Pusat Statistik. (2024). *Produksi tanaman buah-buahan menurut jenis dan kota/kabupaten.* Badan Pusat Statistika Provinsi Riau. Pekanbaru.

Badan Standardisasi Nasional. (1996). *SNI syarat mutu dodol nangka, dodol nanas, dodol sirsak.* Badan Standardisasi Nasional. Jakarta.

Deden, M., Rahim, A., & Asrawaty, A. (2020). Sifat fisik dan kimia edible film pati umbi gadung pada berbagai konsentrasi. *Jurnal Pengolahan Pangan*, *5*(1), 26–33.

Harini, N., Wachid, M., & Hirgawati, T. A. (2020). Kajian penambahan filtrat kunyit dan tartrazin pada edible film berbasis pati talas serta aplikasinya untuk mempertahankan mutu dodol substitusi rumput laut (*Eucheuma cottonii*). *Jurnal Teknologi Pangan dan Sains Halal*, *3*(1), 34–46.

Husniah, I., & Gunata, A. F. (2020). Ekstrak kulit nanas sebagai antibakteri. *Jurnal Penelitian Perawat Profesional*, *2*(1), 85–90.

Ilah, F. M. (2015). *Pengaruh penambahan ekstrak etanol daun salam (Eugenia polyantha) dan daun beluntas (Pluchea indica) terhadap sifat fisik, aktivitas antibakteri, dan aktivitas antioksidan pada edible film berbasis pati jagung* (Undergraduate thesis, Universitas Islam Negeri Maulana Malik Ibrahim).

Juariah, S., Irawan, M. P., & Yuliana, Y. (2018). Efektifitas ekstrak etanol kulit nanas (*Ananas comosus* L. Merr) terhadap *Trichophyton mentaghrophytes*. *Journal of Pharmacy and Science*, *1*(2), 1–9.

Kasmawati. (2018). *Karakteristik edible film pati jagung (Zea mays L.) dengan penambahan gliserol dan ekstrak temu putih (Curcuma zedoaria*) (Undergraduate thesis, Universitas Islam Negeri Alauddin Makassar).

Listiyaningsih, D. (2013). Pembuatan dan karakterisasi biofilm pati gembili-kitosan dengan plasticizer polivinil alkohol (PVA) (Undergraduate thesis, Universitas Negeri Semarang).

Masru'ah, S. A., Warkoyo, W., Manshur, H. A., Putri, D. N., & Mujianto, M. (2023). Karakteristik fisik edible film berbasis pati garut dengan penambahan gel lidah buaya (*Aloe vera*). *Jurnal Penelitian Ilmu Teknologi Pangan*, *12*(2), 37–46.

Melani, A., Herawati, N., & Kurniawan, A. F. (2017). Bioplastik pati umbi talas melalui proses melt intercalation. *Distilasi*, *2*(2), 53–67.

Moomin, D. W., & Sulistijowati, R. (2021). Mutu edible film karaginan kompleks ekstrak buah mangrove (*Sonneratia alba*) dan hambatanya terhadap bakteri pembentuk histamin pada tuna loin. *Jambura Fish Processing*, *3*(1), 27–37.

Muin, R., Anggraini, D., & Malau, F. (2017). Karakteristik fisik dan antimikroba edible film dari tepung tapioka dengan penambahan gliserol dan kunyit putih. *Jurnal Teknik Kimia*, *23*(3), 191–198.

Nurhakim, I., Hermalena, L., & Fitria, E. A. (2021). Aplikasi edible film dari pati talas dengan penambahan gelatin ceker ayam pada makanan tradisional "Bareh Randang". *Journal of Scientech Research and Development*, *3*(2), 162–178.

Putri, A. S., Johan, V. S., & Efendi, R. (2023). Addition of cinnamon extract in making edible film of sago starch as packaging for lempok durian. *IOP Conference Series: Earth and Environmental Science, 1182*(1).

Putri, R. M. A., Yuanita, T., & Roelianto, M. (2016). Daya antibakteri ekstrak kulit nanas (*Ananas comosus*) terhadap pertumbuhan bakteri *Enterococcus faecalis*. *Conservative Dentistry Journal*, *6*(2), 61–65.

Rijayanti, R. P., Luliana, S., & Trianto, H. F. (2014). Uji aktivitas antibakteri ekstrak etanol daun mangga bacang (*Mangifera foetida* L.) terhadap *Staphylococcus aureus* secara in vitro. *Jurnal Mahasiswa PSPD FK Universitas Tanjungpura*, *1*(1), 1–18.

Rini, A. R. S., Supartono, & Nanik Wijayati. (2017). Hand sanitizer ekstrak kulit nanas sebagai antibakteri *Staphylococcus aureus* dan *Escherichia coli*. *Indonesian Journal of Chemical Science*, *6*(1), 61–66.

Rizkyati, M. D., & Winarti, S. (2022). Pengaruh konsentrasi pati garut dan filtrat kunyit putih sebagai antimikroba terhadap karakteristik dan organoleptik edible film. *Teknologi Pangan*, *13*(2), 208–220.

Rollando, R. (2018). Penelusuran potesi aktifitas antioksidan jantung pisang kepok (*Musa paradisiaca* L.). *Jurnal Ilmu Farmasi dan Farmasi Klinik*, *15*(1), 37–44.

Rukmana, R., & Yudirachman, H. (2015). *Untung berlipat dari budidaya talas tanaman multi manfaat*. Lily Publisher: Yogyakarta.

Santoso, J., & Mahardika, M. P. (2023). Formulasi gummy candy dari ekstrak etanol kulit nanas madu (*Ananas comosus* L. Merr) sebagai sumber antioksidan. *Jurnal Ilmiah Farmasi*, *12*(2), 201–208.

Septiati, Y. A., & Karmini, M. (2023). *Bioplastik berbasis pati kulit singkong karakteristik dan kemampuan melindungi makanan*. PT Nasya Expanding Management: Pekalongan.

Setiani, W., Sudiarti, T., & Rahmidar, L. (2013). Preparasi dan karakterisasi edible film dari poliblend pati sukun-kitosan. *Jurnal Kimia Valensi*, *3*(2), 100–109.

Setyaningsih, D., Anton, A., & Maya, P. S. (2010). *Analisis sensori untuk industri pangan dan agro.* IPB Press Bogor. Bogor.

Sinaga, H. F., Apriliana, E., Septiani, L., & Kurniati, I. (2024). Potensi ekstrak kulit nanas (*Ananas comosus*) sebagai antimikroba. *Medula*, *14*(11), 2153–2160.

Sutrisno, A. D., Darmajana, D. A., & Ayu, S. P. (2016). *Pendugaan umur simpan dodol nanas (Ananas comosus L.) dengan pengemas edible film tapioka* (Undergraduate thesis, Universitas Pasundan).

Syah, S. U., Zakya, I., Williyati, G. R., & Pato, U. (2018). Potensi dan pengembangan produk turunan nanas sebagai produk unggulan di Provinsi Riau. *Jurnal Kebijakan Pembangunan dan Inovasi*, *4*(1), 37–46.

Ulfa, E. D., Yana, Y., & Khatimah, N. (2024). Pengaruh penambahan ekstrak daun sungkai (*Peronema canescens* Jack) terhadap karakteristik edible film pati kulit singkong (*Manihot utilissima* Pohl). *Jurnal Teknik Kimia Vokasional*, *4*(1), 16–27.

Utomo, A. R., Yulita, M. M., & Setijawaty, E. (2023). Pengaruh konsentrasi meizena terhadap karakteristik fisikokimia edible spoon berbasis tepung bekatul. *Journal of Food Technology and Nutrition*, *22*(2), 143–152.

Wahjusaputri, S., Fitriani, S., & Bunyamin. (2018). Budidaya talas beneng menuju industri kreatif bagi kelompok Tani Desa Juhut, Kecamatan Karang Tanjung, Banten. *Prosiding PKM-CSR*, *1*, 1468–1478.

Warkoyo, Rahardjo, B., Marseno, D. W., & Karyadi, J. N. W. (2014). Sifat fisik, mekanik dan berrier edible film berbasis pati umbi kimpul (*Xanthosoma sagittifolium*) yang diinkorporasi dengan kalium sorbat. *Agritech*, *34*(1), 72–81.

Widiati, A. (2019). Peranan kemasan (packaging) dalam meningkatkan pemasaran produk usaha mikro kecil menengah (UMKM) di "Mas Pack" Terminal Kemasan Pontianak. *Jurnal Audit Dan Akuntansi*, *8*(2), 67–76.

Wulansari, R., Sabahannur, S., & Ralle, A. (2023). Pengaruh perbandingan gula merah dan gula pasir terhadap mutu dodol buah naga merah. *Jurnal Agrotekmas*, *4*(1), 93–103.

Yulianti, R., & Ginting, E. (2012). Perbedaan karakteristik fisik edible film dari umbi-umbian yang dibuat dengan penambahan plasticizer. *Penelitian Pertanian Tanaman Pangan*, *31*(2), 131–136.

Zary, R. Q., Ulpah, S., & Sabli, T. E. (2023). Uji efektivitas antijamur ekstrak kulit nanas terhadap jamur tular benih dan pertumbuhan bibit cabai merah (*Capsicum annum* L.). *Jurnal Ekoagrotrop*, *1*(2), 26–33.