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Characteristics of Edible Film from Sago Starch and Glycerol as Instant Coffee Packaging

Erika[(1)], Y. Erning Indrastuti[(1)*], Ledy Purwandani[(1)], Susana[(1)]
[(1)] Department of Agricultural Technology, Politeknik Negeri Pontianak
*E-mail: teties@yahoo.co.id

Abstract
The purpose of this study was to determine the concentration of glycerol that produces sago starch-based edible film used as primary packaging for single-served instant coffee with the best physicochemical and hedonic organoleptic properties. Making edible film from 4% sago starch with the addition of 0, 1, 2, and 3% glycerol. The variables observed in the edible film were water content, thickness, and solubility, while hedonic analysis of taste, aroma, color, and viscosity was carried out on instant coffee that had been packaged with sago starch-based edible film. Based on the results of the observation data, the best sago starch edible film based on the effectiveness index analysis was sago starch edible film with the addition of 1% glycerol. Edible film with a 1% glycerol addition has a water content of 17.48%, a thickness of 0.21 mm, a solubility of 81.78%. Moreover, it has a taste attribute scale of 4.00 (like), aroma 4.24 (like), color 4.08 (like), and viscosity 2.65 (neutral). Edible film without glycerol (0%) cannot be used as instant coffee packaging because it is too fragile.

Keywords: *sago starch, edible film, glycerol, primary packaging*.

Karakteristik Edible film Pati Sagu dan Gliserol sebagai Pengemas Kopi Instan

Abstrak
Kemasan primer kopi instan biasanya terbuat dari plastik yang non-biodegradable, oleh karena itu dibuat kemasan primer menggunakan *edible film* berbasis pati sagu. *Edible film* membutuhkan *plasticizer*, namun belum diketahui konsentrasi gliserol membuat kemasan kopi instan. Tujuan dari penelitian ini adalah menentukan konsentrasi gliserol yang menghasilkan *edible film* berbasis pati sagu yang digunakan sebagai pengemas primer kopi instan porsi sekali pakai dengan sifat fisikokimia dan organoleptik hedonik yang terbaik. Pembuatan *edible film* dari pati sagu 4% dengan penambahan gliserol 0, 1, 2, dan 3%. Variabel yang diamati pada *edible film* adalah kadar air, ketebalan, kelarutan, sedangkan analisis hedonik rasa, aroma, warna dan kekentalan dilakukan pada kopi instan yang telah dikemas dengan *edible film* berbasis pati sagu tersebut. Berdasarkan hasil data pengamatan *edible film* dari pati sagu yang terbaik berdasarkan analisis indeks efektivitas adalah *edible film* pati sagu dengan penambahan gliserol 1%. *Edible film* dengan penambahan gliserol 1% memiliki kadar air 17,48%, ketebalan 0,21 mm, kelarutan 81,78%, serta memiliki atribut rasa skala 4,00 (suka); aroma 4,24 (suka); warna 4,08 (suka)dan kekentalan 2,65 (netral). *Edible film* tanpa gliserol (0%) tidak bisa digunakan sebagai pengemas kopi instan karena terlalu rapuh.

Kata Kunci: *pati sagu, edible film, gliserol, kemasan primer.*

Introduction

Food packaging plays a crucial role in protecting products from environmental factors such as light, oxygen, humidity, microorganisms, insects, dust, odors, and physical impacts to ensure food safety, quality, and shelf life (National Agency of Drug and Food Control, 2020). Plastic packaging is popular due to its lightweight, protective properties, and low cost; however, it poses environmental concerns due to its poor biodegradability and potential migration of plastic components into food. One alternative that is biodegradable and safe for direct food contact is edible film. Edible film can be made from plants, animals, microorganisms, or biopolymers such as lipids, proteins, and polysaccharides (Gupta et al., 2024). Besides maintaining food quality, edible films function as barriers against moisture, oxygen, and flavor loss (Venkatachalam et al., 2024). Plant-derived edible films are a recent research trend, particularly those utilizing readily available, affordable, biodegradable, and sustainable local materials. One promising local polysaccharide for edible film production is sago starch. Sago starch from West Kalimantan has a high amylose content ranging from 38.63% to 41.80% (Maherawati et al., 2012).

Starch consists of amylose, a linear chain structure with α-1,4 glycosidic bonds, and amylopectin, a branched chain structure with α-1,4 glycosidic bonds for the main chains and α-1,6 bonds for the branches. The linear structure of amylose enables the formation of strong films with good mechanical strength and gas barrier properties (Sartika et al., 2022). Therefore, sago starch has the potential to be used as an edible film material. Despite its advantages, edible films made from starch tend to be brittle and lack flexibility. One way to address this limitation is by adding a hydrophilic polyol plasticizer, such as glycerol. The addition of plasticizers to polymers can influence physical properties, such as viscosity, degree of crystallinity, glass transition temperature (Tg), hardness, and density. Plasticizers increase free volume, thereby enhancing polymer molecular mobility (Eslami et al., 2023). Glycerol helps reduce intermolecular forces and increases polymer mobility, thereby enhancing film flexibility and extensibility (Chisenga et al., 2020). However, the optimal glycerol concentration required to produce a high-quality sago starch-based edible film remains unknown.

One application of edible films is in the packaging of single-serve portions of dry food products. This application benefits both industry and consumers, as it provides pre-measured and clean product servings (Gamboni et al., 2023). Edible films for this purpose need to be converted into single-serve pouches or sachets capable of holding the product. The primary advantage of such packaging systems is that the single-serve packages can be consumed along with the product, thereby reducing waste (Liu et al., 2020). For this application, edible films must provide protection, dissolve instantly and completely, and possess adequate sealing strength to prevent the contents from spilling during storage (Janjarasskul et al., 2020).

Previous studies on sago starch-based edible films have been conducted (Zhu, 2015; Wattimena et al., 2016; Sondari et al., 2018) and used for coffeemix packaging (Hanjaya, 2019). These studies have analyzed parameters such as thickness, tensile strength, elongation percentage, moisture content, water vapor transmission rate, water solubility, and color. However, a hedonic organoleptic analysis of sago starch-based edible film for instant coffee packaging has yet to be conducted. Therefore, this study aims to determine the glycerol concentration that produces sago starch-based edible film with the best physicochemical and hedonic organoleptic properties for instant coffee packaging.

Method

Equipment and Materials

This study used a Memmert oven, Shimadzu analytical balance, cabinet dryer, hot plate, magnetic stirrer bar, desiccator, sealer, micrometer screw gauge, shaker, and standard glassware. The materials used were sago starch sourced from a local market in Pontianak, distilled water (aquadest), glycerol, and instant coffee.

Edible Film Preparation

The edible film was prepared based on the method of Wattimena et al. (2016) with modifications. A total of 4 grams of sago starch was dissolved in 100 ml of aquadest, stirred using a magnetic stirrer, and heated on a hot plate at 70 °C with continuous stirring. After the solution formed a gel, glycerol was added at concentrations of 1%, 2%, and 3% (w/v). The gel was then poured into molds measuring 25x17 cm and dried in an oven at 40 °C for 7 hours. The edible film was stored in a desiccator before use. Thickness, moisture content, and water solubility analyses were performed on the films.

Instant Coffee Packaging

The edible films were cut into 5x10 cm pieces. One long edge of each piece was folded and sealed on three sides using a sealer. A total of 2 grams of instant coffee was inserted into the open side of the package, which was then sealed to form a complete pouch. The packaged instant coffee was prepared for hedonic analysis.

Moisture Content Analysis (Thermogravimetric Method)

Weighing bottles with lids were pre-heated in an oven at 105 °C for 1 hour, cooled in a desiccator for 15 minutes, and then weighed (W_0). A 2-gram sample was placed in the weighing bottle (W_1). The uncovered bottle was heated at 105 °C for 3 hours. After heating, the lid was placed on the bottle inside the oven, and the sample was transferred to a desiccator for 15 minutes before weighing. Heating and weighing were repeated in 1-hour increments until a constant weight (W_2) was achieved. The moisture content was calculated using the following equation:

$$\text{Moisture content (\%)} = \frac{W_2 - W_0}{W_1 - W_0} \, x \, 100\% \quad (1)$$

Thickness Analysis

The thickness of the edible films was measured using a micrometer screw gauge with an accuracy of 0.01 mm. Measurements were taken at three different points for each film sample, and the average thickness was calculated.

Solubility Analysis

Samples measuring 2x2 cm were cut, and filter paper was dried at 105 °C for 24 hours and weighed separately with the sample. The sample was immersed in 50 ml of aquadest for 24 hours and stirred using a shaker. Filtration was performed using filter paper, and the insoluble portion of the edible film was dried at 105 °C for 24 hours and then weighed to determine the dry matter insoluble in water. The solubility percentage was calculated as follows:

$$\text{Solubility (\%)} = \frac{\text{(filter paper+sampl mass)} - \text{filter paper mass}}{\text{sample mass}} \text{x } 100\% \quad (2)$$

Hedonic Analysis

The sensory evaluation of instant coffee packaged in edible films was conducted by 25 semi-trained panelists, following the methodology described by Chopra et al. (2018). The instant coffee was brewed with 150 ml of hot water (85 °C). Panelists were asked to rate their impressions based on criteria including color, aroma, taste, and thickness of the brewed coffee. Scores were given on a scale from 1 (dislike very much) to 5 (like very much).

Data Analysis

Data were analyzed using Microsoft Excel 2010 and SPSS Statistics 23. Results were presented as mean values and standard deviations. Hedonic organoleptic data were analyzed using the Kruskal-Wallis test, followed by the Mann-Whitney test for pairwise comparisons. The best treatment was determined using the effectiveness index method (De Garmo et al., 1984).

Results and Discussion

Moisture Content of Edible Film

The moisture content of edible films plays a crucial role in determining their durability and ability to protect packaged products. Ideally, edible films should have low moisture content to better preserve the packaged product over a longer period. Films with high moisture content are more susceptible to microbial deterioration (Apriliyani et al., 2020).

The moisture content of sago starch-based edible films ranged between 16.90% and 19.41%. Figure 1 illustrates the effect of glycerol concentration on the moisture content of the sago starch edible film. It was observed that increasing the glycerol concentration led to an increase in the film's moisture content. Glycerol is hygroscopic (Apriliani et al., 2019), meaning it readily absorbs and retains water from the environment. Consequently, the addition of higher glycerol concentrations increases the moisture content of the edible film. Furthermore, glycerol can increase the free space between polymer chains (Lau & Sarbon, 2022), allowing water molecules to interact more easily with the starch polymers in the film. This finding aligns with Riza and Putri (2014), who noted that starch has hydrophilic properties, enabling it to trap water through its polymeric structure.

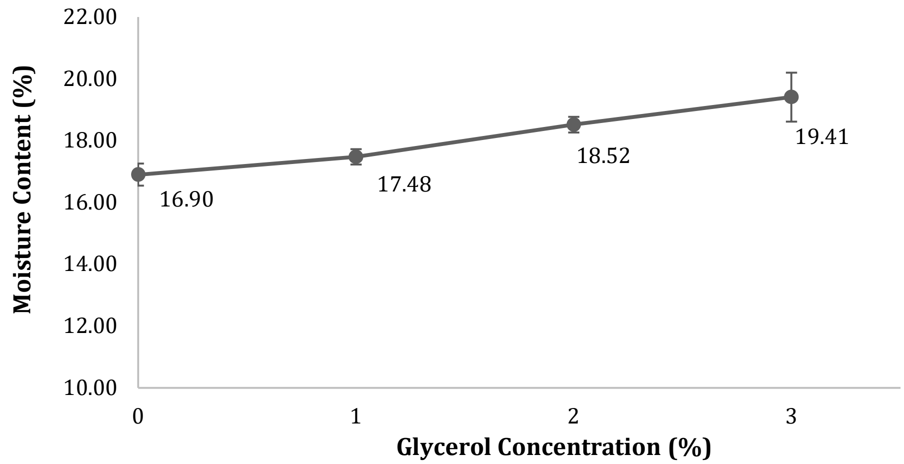

Figure 1. Average moisture content of sago starch edible film at different glycerol concentrations

Edible Film Thickness

Thickness affects the mechanical properties, opacity, permeability, and protective ability of edible films for stored materials (Ramadhia et al., 2024). The thickness of the sago starch edible film ranges from 0.15 to 0.27%. According to Chisenga et al. (2020), the ideal thickness of edible films is 0.254 mm, indicating that the addition of 0%, 1%, and 2% glycerol yields appropriate values. Figure 2 illustrates the effect of glycerol concentration on the thickness of the sago starch edible film. The higher the glycerol concentration, the greater the film thickness.

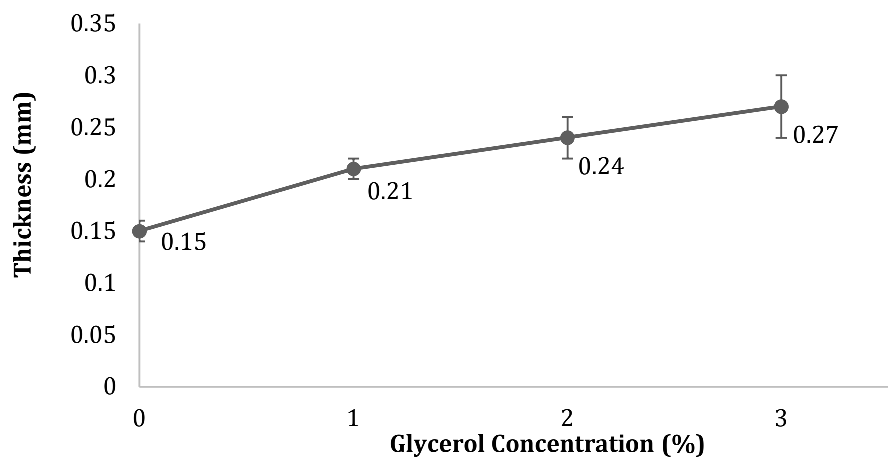

Figure 2. Average thickness of sago starch edible film at different glycerol concentrations

The increased thickness of the edible film is attributed to glycerol's ability to retain water, leading to thicker films after drying. This observation aligns with the finding that moisture content rises with greater glycerol additions. The dispersion of glycerol plasticizer molecules in the film matrix increases the distance between polymer chains, thereby enhancing film thickness. Glycerol contains three -OH groups, and its low molecular weight allows it to penetrate polymer chains, increasing the polymer's free volume by forming secondary bonds with the chains and filling void spaces. This process reduces intermolecular interactions between polymer chains, making the polymer more flexible.

Solubility of Edible Film

The solubility of edible film is an indicator that determines its ability to dissolve in water (Sandi et al., 2024). High solubility is a crucial parameter for edible film used as a primary packaging for instant coffee that is directly brewed. Solubility is related to the hydrophilic and hydrophobic properties of the raw materials used in the edible film. The solubility of the edible film ranges from 74.75% to 95.06%. Figure 3 shows that the higher the glycerol concentration, the higher the solubility. The increased solubility is due to the hydrophilic nature of glycerol. Glycerol is a liquid containing three hydroxyl groups (Quispe et al., 2013). These hydroxyl groups can form hydrogen bonds with water molecules, contributing to its hydrophilic properties and water solubility. Edible film used as a single-serve primary packaging for instant coffee requires high solubility to dissolve completely upon brewing.

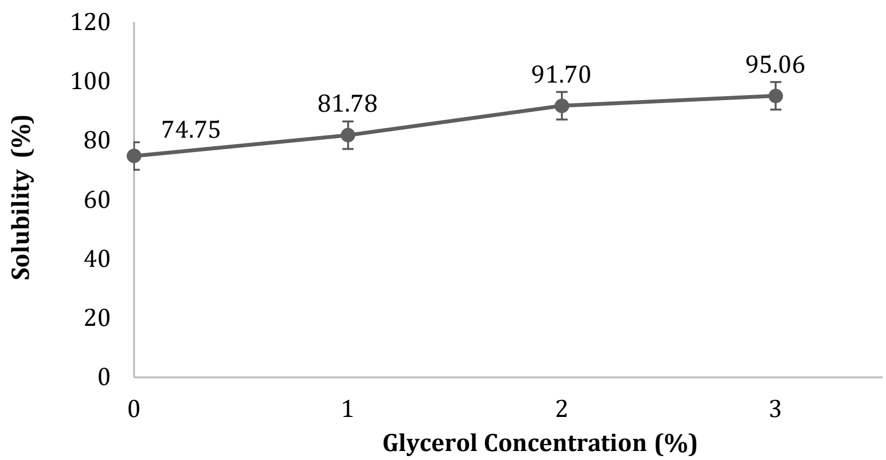

Figure 3. Average solubility of sago starch-based edible film at different glycerol concentrations

Hedonic Analysis of Instant Coffee

The film with 0% glycerol was highly brittle and unsuitable for packaging instant coffee. Therefore, only edible films containing 1%, 2%, and 3% glycerol were used for the hedonic analysis. The results of the sensory evaluation, including taste, aroma, color, and thickness, are presented in Table 1.

Table 1. Hedonic analysis results

Glycerol Concentration (%)	Taste	Aroma	Color	Thickness
1	4.00	4.24[a]	4.08	2.68[a]
2	3.96	4.12[a]	4.08	2.40[a]
3	4.24	3.56[b]	3.96	2.16[b]

Note: The attribute scale ranges from 1 = strongly dislike, 2 = dislike, 3 = neutral, 4 = like, and 5 = strongly like. Identical letters within the same column indicate no significant difference ($p < 0.05$).

Taste is one of the key attributes determining whether a food product is accepted by consumers. The attribute scale for taste ranged from 3.96 to 4.24, indicating a preference level between "like" and "strongly like." However, the Kruskal-Wallis analysis showed no significant difference among treatments ($p > 0.05$). According to Quispe et al. (2013), glycerol has a syrup-like sweet taste. It is suspected that the glycerol added to the edible film was insufficient to create a noticeable taste difference in the brewed instant coffee.

Aroma is detected by the sense of smell and results from chemical changes and the formation of compounds with other ingredients. In addition to identifying food products, aroma can also indicate product spoilage due to poor packaging or storage methods (Agustina et al., 2021). Coffee aroma is complex and determined by its chemical composition and roasting methods, with over 1,000 volatile compounds identified in coffee (Toci & Boldrin, 2018). The attribute scale for aroma ranged from 3.56 to 4.24, indicating a preference level between "neutral" and "strongly like." The Kruskal-Wallis analysis showed a significant difference ($p < 0.05$) among treatments. Glycerol at 3% concentration resulted in a lower hedonic score compared to 1% and 2% concentrations, indicating that panelists' preference for aroma decreased with higher glycerol concentrations. Glycerol is odorless (Quispe et al., 2013); therefore, the aroma of the packaged instant coffee was not directly influenced by the glycerol in the edible film. However, the volatile coffee aroma may have penetrated the edible film. This finding aligns with Dea et al. (2022), who noted that higher plasticizer levels increase the transmission rate of vapor or gas due to the less dense polymer network, allowing the volatile coffee aroma to pass through the film.

Color is an essential attribute in sensory evaluation, as it influences consumer perception by creating the first impression of a product. The attribute scale for color ranged from 3.96 to 4.08, indicating a preference level of "like." The Kruskal-Wallis analysis showed no significant difference among treatments ($p > 0.05$). According to Quispe et al. (2013), glycerol is colorless, thus not affecting the color of coffee packaged with edible film. Furthermore, the results also showed that the attribute scale for thickness ranged from 2.16 to 2.68, indicating a preference level between "dislike" and "neutral." The Kruskal-Wallis analysis showed a significant difference among treatments ($p < 0.05$). Higher glycerol concentrations led to lower panelist preferences for thickness. According to Quispe et al. (2013), glycerol is viscous, which affected the thickness of coffee packaged with edible film. Coffee that became excessively thick due to the sago starch-based edible film with added glycerol was less favored by the panelists.

Effectiveness Index

The best edible film was determined using an effectiveness index analysis based on variables including water content, thickness, solubility of the edible film, and hedonic analysis of instant coffee packaged with the film (taste, aroma, color, and thickness). The analyzed edible films were those with 1%, 2%, and 3% glycerol concentrations since the film without glycerol was unsuitable for packaging instant coffee. The effectiveness index analysis indicated that the optimal treatment was the sago starch-based edible film with 1% glycerol, which had the highest total score of 0.68 compared to treatments with 2% and 3% glycerol. The edible film with 1% glycerol addition had a water content of 17.48%, thickness of 0.21 mm, solubility of 81.78%, and hedonic attributes for taste (4.00 - "like"), aroma (4.24 - "like"), color (4.08 - "like"), and thickness (2.65 - "neutral").

Conclusion and Suggestions

Sago starch-based edible film with glycerol has the potential to be used as a primary single-portion packaging material for instant coffee. Films with glycerol concentrations of 1%, 2%, and 3% were feasible as primary packaging for instant coffee, as they could be shaped into pouches using a heat sealer. The optimal concentration for producing sago starch-based edible film with the best physicochemical and hedonic sensory properties was 1% glycerol. This formulation yielded an edible film with a water content of 17.48%, thickness of 0.21 mm, solubility of 81.78%, taste attribute scale of 4.00 ("like"), aroma 4.24 ("like"), color 4.08 ("like"), and thickness 2.65 ("neutral"). Further studies are needed to investigate the shelf life of instant coffee packaged using sago starch-based edible films.

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