Effect of using cassava and glycerol as food storage on the quality of bioplastic packaged food

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Abstract

Food packaging today often involves the migration of monomer substances from petroleum-based plastics into the food. This study aimed to determine the effects of storing food in bioplastic on moisture content and peroxide levels. The study design employed a post-test experimental design with a control group. *Dodol* samples were selected for this study using a simple random sampling method. The bioplastics used were made from cassava peel starch, and the food storage conditions included temperature-humidity variations of 10-15°C and 85.3-90.8% relative humidity and 25-29°C and 46.5%-80.4% relative humidity. Data were collected through laboratory tests and analyzed using the SPSS program. The study found a significant effect of glycerol dosage on the thickness of the bioplastic ($p<0.001$). There was a significant influence of temperature-humidity storage on moisture content with glycerol dosages of 3 mL ($p=0.002$), 4 mL ($p<0.023$), and 5 mL ($p=0.007$), as well as on the peroxide content of *dodol*. This effect was particularly pronounced with glycerol dosages of 3 mL ($p=0.001$), 4 mL ($p<0.001$), and 5 mL ($p=0.008$). The results indicate that cassava peel starch bioplastic can serve as a viable alternative for food packaging, provided that temperature and humidity conditions during food storage are carefully controlled.

Introduction

Plastic packaging for food is an integral part of everyday life. The food industry stands as the largest user of packaging, with packaging accounting for approximately 40% of plastic production.[1] Plastic compounds, including additives and plasticizers, can freely migrate into food.[2] Temperature plays a crucial role in the migration of melamine compounds in food.[1,3] Moreover, plasticizers such as Dibutyl phthalate (DBP) and dioctyl phthalate (DOP) from PVC can migrate into olive oil, corn oil, cottonseed oil, and soybean oil when stored at room temperature (30°C) for 60 days, with migrated DBP or DOP additives ranging from 155-189 mg. The plasticizer DEHA (di(2-ethylhexyl) adipate) in PVC can migrate into wrapped meat with fat content between 20-90%, reaching migrated DEHA levels of 14.5-23.5 mg per dm2 during cold storage (4°C) for 72 hours.[4] Monomer migration is influenced by factors like food type, storage temperature, contact time, and fat content; higher temperatures result in increased monomer migration into food.[3,5] It's important to note that most of these cases are associated with non-biodegradable plastics, which pose health risks due to additive diffusion and migration. Research findings suggest that vinyl chloride and acrylonitrile monomers have the potential to be carcinogenic to humans.

Bioplastics represent an environmentally friendly alternative.[6,7] They can serve as suitable food packaging materials, particularly when low moisture content is required, as is the case with *dodol*. *Dodol*, a traditional food, is often found as souvenirs, typically sold with primary packaging made of oil paper and non-biodegradable LDPE (Low-density Polyethylene) plastic.[8] The use of LDPE for primary packaging is prohibited,[8] as there is concern that LDPE monomers might migrate during storage, affecting the quality of *dodol*, including texture, fat oxidation processes, and mold growth, rendering it unsafe for consumption. In contrast, bioplastics are considered safe for food packaging.[9,10] Their protective properties depend primarily on their mechanical and physical characteristics. Bioplastics can prolong the shelf life of food and preserve food quality, particularly for certain types of products. Bioplastics produced from banana starch and gelatin with a glycerol plasticizer are notable for their tightly sealed pores, making them suitable for food packaging.[11,12] Cassava peel, rich in starch, serves as a hydrocolloid component that can be employed to create safe bioplastics for primary packaging. Starch-based edible films, used as packaging for peeled apples, have been shown to extend shelf life beyond that of non-packaged items.[12–14]

Utilizing bioplastics for food packaging necessitates a thorough consideration of their mechanical and physical properties, allowing for the estimation of product shelf life and the selection of appropriate food types or products for packaging.[15] The storage of food requires careful attention to temperature, humidity, and storage duration.[10] The conditions of food storage in the field significantly influence the effectiveness of food packaging and the overall shelf life of products, potentially reducing that shelf life.[16] This study aims to investigate the impact of using bioplastics made from cassava peel and glycerol plasticizer as food packaging on the moisture content and peroxide value of *dodol*.

Materials and Methods

Design study

The research design is experimental, employing a post-test with a control group design. This research investigates the impact of temperature and humidity on food storage when using bioplastic as food packaging over a 28-day storage period. The hypotheses explored in this study include the influence of glycerol dosage on the thickness of bioplastic and the effects of temperature and humidity during the storage of *dodol* packaged in bioplastic on the quality of *dodol*. The independent variables encompass the dose of glycerol plasticizer, which consists of three levels, namely 3 mL, 4 mL, and 5 mL, and the temperature and humidity conditions during food storage. The dependent variables include the thickness of the bioplastic, peroxide number, and moisture content of the food.

Population and sample

The population under consideration was Garut *dodol*. For this study, *dodol* obtained from establishments selling food souvenirs in Garut, West Java, were selected as the samples. These samples were chosen using a simple random sampling method. As for the bioplastic material, it was sourced from cassava peels. These peels were processed by blending, adding moisture, squeezing, and leaving them to stand for 24 hours. The resulting residue was then collected and dried to obtain dry starch. The bioplastics were created by mixing 10 grams of cassava peel starch with 100 mL of moisture, along with the addition of 2 mL of acetic acid and a glycerol plasticizer with varying doses of 3 mL, 4 mL, and 5 mL.

Data collection

Data collection in this study was carried out through three methods: the examination of bioplastic thickness, measurement of moisture content, and assessment of peroxide levels in the food. The data for the study were obtained through laboratory testing, using physical methods to measure bioplastic thickness, gravimetric techniques to assess moisture content, and iodometric titration to determine peroxide levels in the *dodol*.

Data analysis

Collected data were entered into a computer and analyzed using the SPSS program. The Shapiro-Wilk test was employed to assess the normality of variable distribution. The t-test was used for comparing two quantitative variables with a normal distribution, specifically the temperature-humidity storage variable and moisture content or peroxide levels. In cases where the data did not exhibit a normal distribution, the Kruskal-Wallis test was applied to compare the quantitative variable of bioplastic thickness.

Results

The findings reveal that the average thickness of bioplastic in the control group (ranging from 0.010 to 0.011) is smaller than the average thickness of the bioplastic in the treatment group with glycerol doses of 3 mL (0.028 mm), 4 mL (0.025 mm), and 5 mL (0.027 mm). These results demonstrate that different glycerol doses of 3 mL, 4 mL, and 5 mL have an effect on the thickness of bioplastic (Table 1).

Table 2 illustrates that, under temperature-humidity conditions of 10-15°C and 85.3-90.8%, the lowest Peroxide Numbers were recorded at 0.5500 meq/kg with the addition of 5 mL of glycerol. Under temperature-humidity conditions of 25-29°C and 46.5-80.4%, the smallest peroxide number was 0.3678 meq/kg. When storing food at 10-15°C and 85.3-90.8% humidity, the mean peroxide number in the control group is smaller than the mean peroxide number in the treatment group. Conversely, when storing food at 25-29°C and 46.5%-80.4% humidity, the mean peroxide number in the control group is greater than that in the treatment group. T-test results for glycerol doses of 3 mL ($p=0.001$), 4 mL ($p<0.001$), and 5 mL ($p=0.008$) indicate that there is a significant difference in peroxide levels among food storage conditions at each glycerol dosage (3 mL, 4 mL, and 5 mL).

Table 3 reveals that, under various temperature-humidity conditions, the mean moisture content of food in the control group exceeds the mean moisture content in the treatment group. T-test results for glycerol doses of 3 mL ($p=0.002$), 4 mL ($p<0.023$), and 5 mL (p-=0.007) suggest that there is a significant difference in moisture content among food storage conditions at each glycerol dosage (3 mL, 4 mL, and 5 mL).

Discussion

The physical properties of bioplastics include thickness, a crucial factor that determines their suitability for use in food packaging. Thickness is a vital parameter that affects the application of film in shaping products for packaging due to its influence on gas permeability. In this study, the thickness of bioplastic was influenced by the addition of glycerol. The maximum bioplastic thickness, in the sequence of adding 3 mL, 4 mL, and 5 mL of glycerol, is 0.023 mm, 0.026 mm, and 0.028 mm, respectively. Greater amounts of glycerol lead to increased bioplastic thickness and an augmented film thickness, responding to the rising glycerol concentration. A thicker starch-based vegetable film layer results in higher gas permeability, water resistance, and improved product protection.[17,18] These highly soluble solids elevate the viscosity of the bioplastic material solution. Starch is utilized to produce bioplastic thickness.[15,19] The polymer content and solution viscosity increase in tandem with the addition of plasticizers, which impacts the thickness of bioplastics.[19,20] Glycerol plasticizers are employed to reconfigure the intermolecular polymer chain network.[21–23] Similar research has also been conducted to assess the influence of sorbitol and glycerol plasticizers on starch film thickness. The thickness of edible film typically falls between 0.02-0.03 mm, and the addition of different glycerol-to-sorbitol ratios enhances the interaction between the plasticizer and polysaccharides.[24] Film thickness, humidity contact angle, water content, solubility, tensile strength, elongation, and antimicrobial properties are examined in composite film solutions, which are employed as coating solutions to extend the shelf life of ivy gourd (Coccinia indica).[12] The thickness of bioplastic increases with greater glycerol concentrations, responsive to the escalating glycerol content.[25] Starch films filled with crystals also offer increased protection against ultraviolet radiation.[18] The weakening of starch molecular bonds signifies the flexibility of bioplastics, enhanced by the addition of glycerol. Proper attention to the starch-to-glycerol ratio is crucial.

In this study, it was observed that the peroxide levels in *dodol* stored at a temperature-humidity of 10-15°C and 85.3-90.8% were higher than those stored at a temperature-humidity of 25-29°C and 46.5-80.4%. Furthermore, aside from the glycerol dosage during storage, variations in peroxide levels were also noticed, with the lowest peroxide levels recorded when 5 mL of glycerol was used. This indicates the impact of bioplastic packaging on the rate of oxidation and hydrolysis of *dodol* fat, which can be controlled by adjusting the temperature and humidity during *dodol* storage.

Table 1. Effect of glycerol dosage on thickness of bioplastic (mm).

Dose plasticizer	n	Mean (SD)	Min- Max	Normalitas+	p
Glycerol 3 mL	18	0.02850(0.000786)	0.020-0.023	0.001	<0.001
Glycerol 4 mL	18	0.02528(0.000575)	0.024-0.026		
Glyserol 5 mL	18	0.02744(0.000511)	0.027-0.028		
Control	18	0.01050(0.000511)	0.010-0.011		

*Shapiro wilk.

Table 2. Effect of temperature-humidity on the peroxide number (meq/kg) of food on storage for 28 days.

Temperature-humidity	N	Mean(SD)	Min-Max	Normalitas	p
Dose of Glyserol 3 mL				0,200	0,001
- 10-15°C, 85,3-90,8%	9	0,6878 (0.10035)	0,55-0,87		
- 25-29°C, 46,5%-80,4%	9	0,5167 (0.07984)	0,43-0,63		
- control	9	0,5744 (0.07316)	0.50-0,72		
Dose Glyserol 4 mL				0,200	<0,001
- 10-15°C, 85.3-90.8%	9	0.5844 (0.02651)	0.42-0.49		
- 25-29°C, 46.5-80,4%	9	0.3711 (0.04226)	0.32-0.43		
- control	9	0.5556 (0.06064)	0.47-0.65		
Dose Glyserol 5 mL				0,093	0,008
- 10-15°C, 85.3-90.8%	9	0.5500 (0.05612)	0.45-0.60		
- 25-29°C, 46.5-80.4%	9	0.3678 (0.07138)	0.30-0.50		
- control	9	0.5156 (0.07568)	0.41-0.65		

Table 3. Effect of temperature-humidity on food's Moisture content (%) on storage for 28 days.

Temperature-humidity	N	Mean(SD)	Min-Max	Normalitas	p
Dose of Glyserol 3 mL				0.200	0.002
- 10-15°C, 85.3-90.8%	9	2.3611 (0.22718)	1.38-1.74		
- 25-29°C, 58.5-80.4%	9	2.2878 (0.12979)	1.40-1.96		
- control	9	2.5844 (0.18709)	2.25-2.78		
Dose Glyserol 4 mL				0.200	0.023
- 10-15°C, 85.3-90.8%	9	2.5122 (0.12050)	2.62-2.90		
- 25-29°C, 58.5-80.4%	9	2.4900 (0.12824)	2.62-2.90		
- control	9	2.5689 (0.20829)	2.55-2.90		
Dose Glyserol 5 mL				0.168	0.007
- 10-15°C, 85.3-90.8%	9	1.3367 (0.06464)	1.64-1.85		
- 25-29°C, 58.5-80.4%	9	1.3056 (0.06144)	1.63-1.90		
- control	9	2.5833 (0.20273)	2.14-2.90		

Increasing the glycerol content led to the production of thicker starch-based bioplastics, resulting in enhanced O_2 gas and moisture permeability. It's worth noting that bioplastics made from starch with glycerol plasticizer exhibit a high resistance to water and O2 gas.[26,27] Therefore, bioplastics using 5 mL of glycerol provide superior food protection since they can withstand more water vapor and O2 gas, effectively shielding the food from external factors. The combination of starch and glycerol in the bioplastic formulation contributes to slowing down damage, resulting in lower peroxide levels.

In this study, it was observed that bioplastics exhibited greater absorption of water vapor from the storage environment at low temperatures and high humidity, characterized by higher water vapor content when compared to room temperature and humidity conditions across all glycerol doses. The abundance of water vapor in the storage environment can diminish the bioplastics' ability to protect *dodol*, eventually causing saturation.[15,21] Comparatively, the addition of 5 mL of glycerol to cassava starch skin enhanced the bioplastics' capacity to impede the flow of water vapor and O2 gas. Glycerol, known for its hydrophilic properties, contributes to increased water absorption within the bioplastics when its dosage is increased, thus reducing the water content within the food or storage environment. By adding glycerol, bioplastics effectively hinder water vapor from reaching the *dodol*, reducing the overall moisture content under room temperature and humidity conditions.

As the thickness of bioplastics increased in tandem with the addition of glycerol, the influx of O_2 gas and water vapor into the food decreased. Thicker and more flexible bioplastics were found to slow down the rate of O_2 gas and water vapor permeating through the packaging, thus affecting the quantities entering the packaging space and interacting with fats and oils in the food. This study aligns with the fact that bioplastics made from cassia gum combined with ethyl cellulose significantly enhance the film's moisture barrier properties and reduce the oxidation of fat components in food.[28] However, storage environments with low temperatures and high humidity could potentially hinder these functions due to elevated water vapor from the environment,[29] while also causing damage to *dodol* due to moisture absorption within the packaging space.[30] Based on this research, the optimal conditions for preserving food quality entail minimizing both water vapor and peroxide parameters within the bioplastics.

In cold temperatures and high humidity storage conditions, the permeability of bioplastics to O_2 gas decreases due to starch grains undergoing retrogradation, resulting in molecular bond changes that allow more O_2 to pass through the bioplastic.[30] Consequently, bioplastics become saturated more rapidly due to external environmental factors, diminishing their effectiveness in protecting food, ultimately leading to food spoilage.

Conclusions

Utilizing bioplastics while meticulously regulating storage temperature and humidity conditions, both at room temperature and under controlled levels, can significantly enhance the efficacy of bioplastics as packaging. This approach strengthens the bioplastics' capacity to fortify barriers against environmental factors, contributing to superior protection for the packaged contents.

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