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Banana Hump Starch and Ginger Extract as Edible Coating to Extend the Shelf-life of Red Chili Peppers

Edible Coating *Pati Bonggol Pisang dengan Penambahan Ekstrak Jahe untuk Memperpanjang Masa Simpan Cabai Merah*

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Abstract

Fresh red chili peppers is a product that spoils easily and has a concise shelf-life. Coating a natural edible coating on fresh red chili peppers will significantly increase their shelf-life. This research aims to obtain the best concentration of ginger extract in the edible coating of banana hump starch to extend the shelf-life of red chili peppers. The research was carried out experimentally using a completely randomized design with five treatments and three replications. The treatment in this research was an edible coating of banana hump starch with the addition of various concentrations of ginger extract; J0 (0%), J1 (1%), J2 (3%), J3 (5%), and J4 (7%); which were applied on red chili peppers for 15 days of storage. The parameters observed were weight loss, vitamin C, total microbes, and sensory assessment. The best treatment in this study was J4 (addition of 7% ginger extract). On the 15th day of storage, red chili peppers coated with edible coating treated with J4 experienced a reduction in weight loss of 41.20%, with 18.54 mg/100g of vitamin C and 5.89 log CFU/g of total microbes. Descriptive tests showed that on the 15th day of storage, red chili peppers had a red color, started to smell and taste rotten, and had a slightly hard texture.
Keywords: edible coating, ginger extract, red chili peppers

Abstrak

Cabai merah segar merupakan produk yang sangat mudah membusuk dan memiliki umur simpan yang sangat pendek. Pelapisan edible coating *alami pada cabai merah segar akan sangat efektif dalam upaya meningkatkan umur simpan dari cabai merah. Penelitian ini bertujuan untuk mendapatkan konsentrasi terbaik ekstrak jahe dalam* edible coating *pati bonggol pisang untuk memperpanjang masa simpan cabai merah. Penelitian dilaksanakan secara eksperimen menggunakan rancangan acak lengkap dengan lima perlakuan dan tiga ulangan. Perlakuan dalam penelitian ini adalah* edible coating *pati bonggol pisang dengan penambahan berbagai konsentrasi ekstrak jahe, yaitu J0 (0%), J1 (1%), J2 (3%), J3 (5%), dan J4 (7%) yang diaplikasikan pada cabai merah selama 15 hari penyimpanan. Parameter yang diamati adalah susut bobot, vitamin C, total mikroba, dan penilaian sensori. Perlakuan terbaik pada penelitian ini adalah J4 (penambahan ekstrak jahe 7%). Pada penyimpanan hari ke-15, cabai merah yang dilapisi* edible coating *perlakuan J4 mengalami penurunan susut bobot 41,20%, dengan 18,54 mg/100g vitamin C dan 5,89 log CFU/g total mikroba. Uji deskriptif menunjukkan bahwa pada penyimpanan hari ke-15, cabai merah memiliki warna merah, mulai berbau dan berasa busuk, serta tekstur agak keras.*
Kata Kunci*:* edible coating, *ekstrak jahe, cabai merah*

INTRODUCTION

Red chili peppers (*Capsicum annum* L.) is a horticultural product commonly used for spice and cooking seasoning. The increase in various food types and menus increases the need for chilies. According to Indonesia Statistics, red chili peppers production in Riau Province in 2022 was 2.31 tonnes (Badan Pusat Statistik, 2022). Kurniasari et al. (2022) stated that red chili peppers are a horticultural commodity that is easily damaged and has a relatively short shelf-life.

According to Megasari & Mutia (2019), red chili peppers at harvest have a high water content (55-85%), posing a risk of damage during storage. Damage to red chili peppers is caused by metabolic activities called respiration and transpiration, which continue even though the red chili peppers have been harvested. The high water content also makes red chili peppers more susceptible to attack by rotting bacteria, which can cause damage to them. Rizeki (2016) stated that the shelf-life of red chili peppers ranges from 2-5 days after harvest. Therefore, it is necessary to reduce the damage level and extend red chili peppers' shelf-life by using an edible coating.

The edible coating is a thin layer made from food ingredients that functions as a barrier to mass transfer and a carrier for food additives to improve food quality and shelf-life (Anggara et al., 2015). One of the ingredients that can be used to produce edible coating is banana hump starch. Banana plants are generally grown for their fruit and leaves, while the stems and humps are rarely used and usually thrown away. Banana hump starch can be used for edible coating because it contains high carbohydrates. Robiana et al. (2016) stated that banana humps contain 76% starch and 20% water. The high starch content in banana humps can be the main ingredient to produce edible coatings.

Edible coatings can be enriched by adding ingredients such as antimicrobials in ginger extract, which will help prevent spoilage bacteria and increase the shelf-life of red chili peppers. According to Sari et al. (2013), the substances contained in ginger rhizomes are phenol, flavonoid, terpenoid, and essential oil compounds, a group of bioactive compounds that can inhibit microbial growth. The gingerol and shogaol content in ginger rhizomes can also maintain food quality because they are antimicrobial (Styawan et al., 2022). Research by Rangkuti et al. (2019) indicates that adding 8% ginger extract to the edible coating of avocado seeds applied to strawberries can maintain shelf-life based on weight loss, vitamin C content, organoleptic taste, and aroma tests. Erviani et al. (2017) stated that applying an edible coating made from sago starch with 7% ginger filtrate can increase the shelf-life of red chili peppers by maintaining their color and texture during storage. Therefore, this research aims to obtain the best concentration of ginger extract in the edible coating of banana humps to extend the shelf-life of red chili peppers.

METHODS

The main ingredient used in this research was the *kepok* banana (*Musa acuminata* × *Musa balbisiana*) hump obtained from Nyatuh Village, Merbau Island District, Meranti Islands Regency, Riau Province, Indonesia. The type of ginger used is *Zingiber officinale* Rosc with a harvest age of 10-12 months obtained from Simpang Baru Market, Tuah Madani District, Pekanbaru, Riau Province, Indonesia, and red chili peppers (*Capsicum annum* L.) obtained from the experimental garden, Faculty of Agriculture, Riau University, Pekanbaru, Riau Province, Indonesia. Other ingredients are glycerol, 0.01 N iodine solution, 96% ethanol, nutrient agar, 1% starch indicator, physiological salt, and water.

Research Methods

This research was performed experimentally using a completely randomized design (CRD) with five treatments and three tests. The treatment in this study was an edible coating of banana hump starch with the addition of various concentrations of ginger extract (w/v); J0 (without adding ginger extract), J1 (1%), J2 (3%), J3 (5%), J4 (7%) applied to red chili peppers for 15 days of storage. Five treatments of banana hump starch edible coating formulation with the addition of ginger extract in various concentrations are presented in Table 1.

Table 1. Edible coating formulation of banana hump starch with ginger extract addition

Treatment	Concentration of Ginger Extract in Edible Coating Banana Hump Starch (w/v)
J0	0% (0 mg/mL)
J1	1% (10 mg/mL)
J2	3% (30 mg/mL)
J3	5% (50 mg/mL)
J4	7% (70 mg/mL)

The absolute amount of ginger extract was calculated based on the standard volume of edible coating film solution applied to red chili peppers at a fixed weight. A 10 mL coating solution was applied for every 100 g of red chili peppers with 1% coating containing 10 mg of ginger extract per mL of coating (0.1 mg of ginger extract per 1 mL). The observation parameters were weight loss, vitamin C content, color, aroma, and texture of coated red chili peppers during 15 days of storage. All tests were carried out with three replications for each treatment group.

Production of Banana Hump Starch

The material used is a banana hump, whose fruit has been harvested. The banana hump is separated from the stem, washed clean, and cut into small pieces. Banana hump was then mashed using a mechanical blender until creamy, then filtered using a filter cloth. The filtered yield was left for 24 hours until a starch precipitate was obtained, and then the water was separated from the starch precipitate. The starch obtained is dried under the sun for two days. Dry starch was sieved with an 80 mesh sieve.

Production of Ginger Extract

Ginger extract production refers to research by Saragih et al. (2015). Ginger rhizomes are washed clean, peeled, and thinly sliced. Ginger rhizomes were dried in an oven at 60 °C for 12 hours and then ground using a blender. 250 g dried ginger was dissolved in 96% ethanol with a ratio of 1:5 and then left for 24 hours. The mixture was filtered using filter paper until ginger filtrate was obtained. The filtrate was thickened using a rotary vacuum evaporator at 70 °C until ginger extract was obtained.

Production of Edible Film

The edible film was made by modifying the method used by Galus et al. (2020) and Kamal (2019) research. Banana hump starch was weighed at 32 mg using an analytical balance and transferred into a 500 mL beaker. 4 g of glycerol was added to the beaker as a plasticizer, and distilled water was added to make it exactly 320 ml. This solution is stirred until homogeneous to form a 10% (w/v) banana hump starch edible coating solution with a 1.25% glycerol content. The ginger extracts were weighed individually and then put into five beakers to make an edible ginger extract coating by adding the starch solution according to the treatment concentration (0, 10, 30, 50, or 70 mg/mL). The solution was heated to 70 °C while stirred at 500 rpm for 15 minutes until the starch thickened. The edible coating solution was then removed from the hot plate and allowed to cool to room temperature (25 °C) before being applied to the red chili peppers.

Application of Edible Coating on Red Chili Peppers

The application of edible coating on red chili peppers refers to Widaningrum et al. (2015). The fresh red chili peppers used in this research were cleaned with a tissue to remove any remaining dirt stuck to the surface of the red chili peppers. Red chili peppers were then dipped in the edible coating formulation for 1 minute and placed on a stainless steel wire drying rack. The drying rack containing the coated red chili peppers was left at room temperature (25 °C) for 24 hours so that the excess coating solution dripped off and the coating set completely. A small fan is directed at the rack to facilitate airflow and drying, but the red chili peppers are not actively heated. The surface of red chili peppers has formed an edible thin layer after drying for 24 hours at room conditions. The coated red chili peppers that had been wholly set were then transferred into a styrofoam container to be stored at room temperature for 15 days of experimentation. Observations were made on days 0, 3, 6, 9, 12, and 15 of storage.

Observation Parameters

<u>Weight Loss</u>

Weight loss measurements refer to Darmajana et al. (2017) by weighing the sample during storage. Red chili peppers coated with edible coating were weighed before being stored to determine the initial weight. Weighing was performed again after storage to determine the final weight. The weight loss calculation is based on the percentage of weight loss from the initial storage until the end of storage. Weight loss is expressed in weight percent (%), which is calculated using the following equation:

$$\text{Weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\% \quad (1)$$

<u>Vitamin C</u>

Vitamin C is susceptible to oxidation, and its retention is an essential indicator of fruit and vegetable quality. Decreased levels of vitamin C indicate that oxidative damage has occurred in food (Wibawa et al., 2020). Vitamin C, as an antioxidant, can contribute to shelf-life extension by protecting against oxidation and free radical damage. Ginger extract provides antioxidant effects, and vitamin C status must still be monitored in fresh red chili peppers. Vitamin C measurements refer to Yusa et al. (2017). A 10 g of red chili peppers sample was taken from each treatment and then ground. The sample was put into a 100 mL volumetric flask and added with distilled water until it reached the 100 mL terra mark, then filtered using filter paper to separate the filtrate from the residue. 10 mL of the filtrate was taken and put into an Erlenmeyer. 2 mL of 1% starch indicator was added into the Erlenmeyer and mixed with the filtrate until homogeneous, then titrated with 0.01 N iodine solution with a dilution factor (f_p) of 0.1 until the color changed to blue. The dilution factor depends on the solution concentration to be measured. The f_p value becomes smaller as the solution becomes concentrated. The vitamin C content of red chili peppers (mg/100 g) is calculated using the equation:

$$\text{Vitamin C (\%)} = \frac{\text{mL iodium} \times 0{,}01\text{N} \times 0{,}88 \times \text{fp} \times 100}{\text{Sample weight (g)}} \quad (2)$$

Total Microbes

The total microbial test refers to Gupta et al. (2017), with modifications to the dilution and media used. 1 g of crushed sample was put into a test tube containing 9 mL of 0.85% physiological salt solution and mixed until homogeneous. The solution is diluted with a dilution factor (f_p) between 10^{-1} and 10^{-5}. The 8 mL agar nutrient medium was prepared in a petri dish and left to solidify. The media in the petri dish was then incubated for 24 hours at 37 °C in an incubator. Total microbial results are expressed in CFU/g log units. Total microbes are calculated using the equation:

$$\text{Total colonies per mL} = \text{number of colonies} \times \frac{1}{\text{fp}} \times 10 \quad (3)$$

Sensory Test

The sensory test was performed descriptively by the panelists. A descriptive test was conducted to determine the panelists' assessment of each treatment sample's color, aroma, and texture. The descriptive test was carried out by 15 semi-trained panelists (SNI 01-2346-2006; Dari & Junita, 2021; Khairunnisa & Syukri Arbi, 2019; Rahmadhani & Fibrianto, 2016) who came from students from the Department of Agricultural Technology, Riau University. Sensory assessments were conducted every three days during 15 days of storage. According to Hudgins (1971), the number of semi-trained panelists used in sensory testing ranged from 15 to 25 people. Meanwhile, Ruiz-Capillas et al. (2003) suggest 6 to 15 semi-trained panelists for sensory descriptive analysis. There are no provisions regarding the number of semi-trained panelists required for organoleptic tests.

Statistical Test to Measure the Significance of Treatment Differences

A significant difference test analysis was conducted to measure the significant differences between treatments. The tests performed were Analysis of Variance (ANOVA) and Duncan's New Multiple Range Test (DNMRT) using IBM SPSS Statistics 23.0 software. The test procedure begins by performing a one-way ANOVA to test the effect of treatment (J0, J1, J2, J3, and J4) on the response parameters. DNMRT was conducted if the ANOVA results showed a significant effect (P value < 0.05). The DNMRT test is performed by comparing each treatment's mean value with the other treatments' mean value. The calculated mean values are sorted from highest to lowest. If the difference between the two middle values is more significant than the table DNMRT value, then the two middle values are significantly different. Based on the DNMRT test, the treatment group is displayed using notation, for example, letters a, b, c, and so on. Treatment with the same notation shows no significant difference. Conclusions regarding the treatment effect were made based on group differences in notations from the DNMRT test. The effect of treatment is significant if there are more notation groups (Nugroho, 2018).

RESULTS AND DISCUSSION

Banana hump has a fibrous structure with high cellulose content (Pappu et al., 2015). Banana hump has the potential as a raw material to be developed as a sustainable food packaging material because of its high cellulose content. Banana weevil exhibits beneficial properties, such as edible, biocompatible, non-toxic, and cost-effective (Othman et al., 2020). The fibrous morphology of banana hump precludes their sole use in food packaging. Adding additional biopolymers, such as starch, enables the production of biodegradable composite food packaging from banana hump biomass (Laoubol et al., 2022; Othman et al., 2020).

The starch content of banana hump is approximately 15-20% by weight, comparable to the results of extracting corn, cassava, or potato starch. The use of pure starch to produce biodegradable food packaging films is limited by poor mechanical and barrier properties (Othman, 2014; Othman, Kechik, et al., 2019; Othman, Majid, et al., 2019; Zahiruddin et al., 2019). An effective way to overcome this limitation is to combine other biopolymers (for example, fibrous biopolymer from banana hump starch) with pure starch films to produce biocomposite films. Combining biopolymers with other biopolymers (biocomposites) has been widely used to improve film properties (Alzate et al., 2023; Sharma et al., 2023).

Cellulose, contained in banana hump starch, acts as a potential biopolymer that can be combined with starch due to its superior mechanical properties. Cellulose can be added to starch films to improve the mechanical properties and resistance of the film barrier (Alzate et al., 2023; Sheydai et al., 2023; Zahiruddin et al., 2019). Cellulose has proven promising as a biocomposite material in packaging films and shows satisfactory physical properties, such as relatively high tensile strength, stiffness, and high Young's modulus (Zahiruddin et al., 2019).

Weight Loss

Weight loss is one of the parameters used to evaluate the quality and shelf-life of red chili peppers during storage. Weight loss is caused by continuous transpiration and respiration so that food loses water content (Kurniasari et al., 2022; Lu et al., 2021; Shin et al., 2021; Sondari, 2019; Sudjatha & Wisaniyasa, 2017). The results of ANOVA showed that edible coating treatment with various concentrations of ginger extract significantly affected the weight loss of red chili peppers during 15 days of storage. Data on red chili peppers weight loss are presented in Table 2.

Table 2. Weight loss of red chili peppers coated with edible coating from banana hump starch and ginger extract (%)

Treatment	Storage Period (Days)					
	0	3	6	9	12	15
J0 (ginger extract 0%)	0.00	10.40^{c}	19.97^{d}	25.67^{c}	36.77^{c}	44.02^{d}
J1 (ginger extract 1%)	0.00	9.45^{b}	16.98^{c}	22.64^{b}	32.23^{b}	42.76^{c}
J2 (ginger extract 3%)	0.00	7.65^{a}	16.31^{c}	22.24^{b}	31.54^{b}	42.36^{c}
J3 (ginger extract 5%)	0.00	7.27^{a}	14.06^{b}	21.94^{b}	31.37^{b}	41.49^{b}
J4 (ginger extract 7%)	0.00	7.06^{a}	12.43^{a}	20.80^{a}	30.00^{a}	40.57^{a}

Note: Numbers followed by the same superscript letters in columns indicate non-significant differences according to the DNMRT test at the 5% level.

Table 2 shows that the weight loss value for red chili peppers is more significant if the storage period is extended. This increase in weight loss is caused by the transpiration and respiration processes during storage, making the water content lost from the red chili peppers. Adding ginger extract to edible coatings can suppress the rate of transpiration and respiration, thereby inhibiting increased weight loss.

Edible coating acts as a thin layer on the surface of red chili peppers, which functions as a barrier to the diffusion of water vapor and gas. The edible coating covers the pores of the red chili peppers peel, thereby reducing water loss. The formed edible coating layer becomes thicker if more concentration of ginger extract is added, so the diffusion of water vapor and gas is increasingly hampered, and the red chili peppers weight loss will be less. Treatment J4, with the addition of 7% ginger extract, showed the lowest significant weight loss compared to other treatments during 15 days of storage. This result shows that adding 7% ginger extract to the edible coating is most effective in significantly suppressing the rate of transpiration and respiration of red chili peppers and minimizing weight loss. The weight of red chili peppers was relatively stable, and several treatments did not show significant differences in weight at the beginning of storage. This condition is because water loss and respiration processes, which result in weight loss, may not have occurred significantly at the beginning of storage (Beristain-Bauza et al., 2019; Iotsor et al., 2019).

Antimicrobial compounds in ginger extract are thought to contribute to the increased edible coatings capacity to limit the diffusion of O_2 into red chili peppers by inhibiting the activation of respiratory enzymes (Beristain-Bauza et al., 2019; Iotsor et al., 2019). In this study, limiting the diffusion of O_2 into red chili peppers can effectively reduce the weight percentage of red chili peppers treated with edible coating. The ginger extract contains phenolic compounds such as gingerol and shogaol, which have antimicrobial properties against foodborne pathogens and spoilage microorganisms. These antimicrobial compounds create an unfavorable environment for aerobic microbes on the coated surface of red chili peppers, thus inhibiting their growth and reproduction (Mao et al., 2019). Aerobic microbes can damage plant tissue and release enzymes that damage cell walls and membranes. This tissue damage allows greater diffusion of oxygen into the red chili peppers. Antimicrobial ginger extract helps suppress microbial growth, thereby keeping the coated surface of red chili peppers more intact and reducing gaps in oxygen entry (Shaukat et al., 2023). Ginger extract compounds can also induce the production of phytoalexin and other defense compounds in red chili peppers peel, which can then strengthen and protect tissues from oxygen ingress. The antimicrobial effect and capacity to limit aerobic degradation of the red chili peppers' outer tissue is more significant if the concentration of ginger extract added is higher, thereby maintaining the oxygen barrier function (Mao et al., 2019; Shaukat et al., 2023). The research results of Rahmasari & Yemis (2022) show that ginger flour edible coating treated with ultrasonic treatment and added coconut shell liquid smoke (CSLS) has antibacterial activity against *E. coli* and does not harm the sensory attributes of ground beef. This coating also has better mechanical, permeability, thermal, and antibacterial properties.

Increasing the incorporation of ginger extract into edible coating formulations made from banana hump starch may also increase the effectiveness of the film in reducing transpiration, water loss, and respiratory activity. According to Gupta et al. (2017), increased respiration, transpiration processes, and weight loss can be caused by microorganisms' activity that damages cell structures, especially microorganisms that use carbohydrates as their substrate. Research by Rangkuti et al. (2019) on applying avocado seed starch as a coating material for strawberries with the addition of ginger extract shows that coating can prevent transpiration or evaporation. Therefore, using ginger extract as an ingredient of banana hump starch coating can help to reduce the material's respiration rate process so that the weight loss is low.

Vitamin C

Vitamin C is known to be easily damaged during storage. A decrease in vitamin C levels indicates damage to red chili peppers. The ANOVA results showed that the treatment significantly affected the vitamin C content of red chili peppers during 15 days of storage. Data on vitamin C levels are presented in Table 3. Table 3 shows that the vitamin C content of red chili peppers is significantly lower if the storage period is extended. The results showed an inverse correlation between the ginger extract concentration in edible film and the degradation of vitamin C in red chili peppers treated with edible coating during a 15-day storage period. These results show that adding more ginger extract can reduce vitamin C loss significantly. The decrease in vitamin C is caused by damage due to oxidation processes and microbial growth. The addition of ginger extract to edible coatings can slow down the rate of vitamin C degradation because it acts as an antioxidant and antimicrobial (Kurniasari et al., 2022; Martínez et al., 2005; Parreidt et al., 2018; Widaningrum et al., 2015).

Table 3. Vitamin C content of red chili peppers coated with edible coating from banana hump starch and ginger extract (mg/100 g)

Treatment	Storage Period (Days)					
	0	3	6	9	12	15
J0 (ginger extract 0%)	32.86	29.35[a]	24.73[a]	22.98[a]	19.43[a]	14.74[a]
J1 (ginger extract 1%)	32.67	30.01[b]	25.56[b]	23.72[a]	20.33[b]	16.18[b]
J2 (ginger extract 3%)	32.69	30.43[b]	26.07[b]	24.83[b]	21.92[c]	17.44[c]
J3 (ginger extract 5%)	32.81	30.85[b]	27.30[c]	25.15[b]	22.01[c]	17.67[c]
J4 (ginger extract 7%)	32.87	32.61[c]	27.84[c]	25.87[c]	23.94[d]	18.54[d]

Note: Numbers followed by the same superscript letters in columns indicate non-significant differences according to the DNMRT test at the 5% level.

J4 treatment with the addition of 7% ginger extract was most effective in maintaining the vitamin C content of red chili peppers during storage. The decrease in vitamin C is thought to be caused by the oxidation process in red chili peppers through direct contact with oxygen. According to Sembara et al. (2021), oxidation can cause vitamin C to be degraded into L-dehydroascorbic acid so that the vitamin C content in red chili peppers decreases until they become damaged. According to Dewi et al. (2021), adding ginger extract can reduce the decrease in vitamin C in fruit during storage. Compounds found in ginger rhizomes, such as gingerol and shogaol, can act as antioxidants in inhibiting oxidation. The respiration rate will decrease if oxidation is inhibited so that the degradation of organic compounds becomes slow and the rate of vitamin C degradation becomes low.

This research results align with Dewi et al. (2021)regarding coating aloe vera gel and ginger extract on tomatoes (*Lycopersicum esculentum* Mill). This research shows that adding ginger extract to the edible coating of aloe vera gel reduces the vitamin C content in tomatoes during storage. Erviani et al. (2017) also examined the addition of ginger filtrate to edible sago starch coating materials. This research showed that adding ginger filtrate with a concentration of 7% reduced the loss of vitamin C levels in red chili peppers' during storage.

Total Microbes

The total microbial test aims to evaluate the microbiological damage of red chili peppers during storage. The ANOVA results showed that edible coating treatment with various concentrations of ginger extract significantly affected the total microbial properties of red chili peppers during 15 days of storage. Total microbial data is presented in Table 4.

Table 4. Total microbes of red chili peppers coated with edible coating from banana hump starch and ginger extract (colonies/100 g)

Treatment	Storage Period (Days)					
	0	3	6	9	12	15
J0 (ginger extract 0%)	5.39	5.58[b]	5.85[b]	6.00[c]	6.21[c]	6.42[c]
J1 (ginger extract 1%)	5.39	5.47[ab]	5.70[ab]	5.92[bc]	6.10[bc]	6.23[bc]
J2 (ginger extract 3%)	5.38	5.45[ab]	5.69[ab]	5.90[bc]	6.04[ab]	6.16[b]
J3 (ginger extract 5%)	5.36	5.40[a]	5.53[a]	5.82[ab]	5.91[ab]	6.14[b]
J4 (ginger extract 7%)	5.35	5.30[a]	5.50[a]	5.74[a]	5.78[a]	5.88[a]

Note: Numbers followed by the same superscript letters in columns indicate non-significant differences according to the DNMRT test at the 5% level.

Table 4 shows that the total microbes in red chili peppers significantly increased during 15 days of storage. Red chili peppers are usually harvested fresh with few microbes, so the total number of microbes that need to be inhibited by ginger extract at the beginning of storage still does not show significant differences in several treatments. This increase in total microbes was caused by the growth of contaminant microbes from red chili peppers and the storage environment. Adding ginger extract to edible coatings has been proven to reduce the increase rate of total microbes significantly. J4 treatment with 7% ginger extract was most effective in suppressing the increase of total microbes during storage (Ainunnisa et al., 2020; Jemilakshmi et al., 2020; Parreidt et al., 2018; Sedyadi et al., 2019; Shaukat et al., 2023; Vásconez et al., 2009; Widaningrum et al., 2015).

Edible coating treatment with added ginger extract showed fewer microbes than the one that did not. Edible coating treatment with ginger extract, which contains antimicrobial compounds, can slow or inhibit the growth of microbial contaminants in red chili peppers. Ginger extract contains antimicrobial compounds such as gingerol and shogaol, which can inhibit microbial growth by interfering with the formation of microbial cell walls and membranes.

According to Sari et al. (2013), ginger rhizomes contain antimicrobial compounds, including phenols, flavonoids, terpenoids, and essential oils, a group of bioactive compounds that can inhibit microbial growth. Mao et al. (2019) also stated that the biological activity of ginger is related to various phenolic compounds (including 6-gingerol, 8-gingerol, 10-gingerol, quercetin, zingerone, gingerenone-A, and 6-dehydrogingerdione) and terpenes (such as β-bisabolene, α-curcumene, zingiberene, α-farnesene, and β-sesquiphellandrene). Several studies have shown the potent antioxidant and antimicrobial properties of ginger rhizomes, especially the content of gingerenone-A and 6-shogaol, which shows an in vitro inhibitory effect on Staphylococcus aureus through specific inhibition of the enzyme 6-hydroxymethyl-7,8-

dihydropterin pyrophosphokinase (Mao et al., 2019; Teles et al., 2019). The terpenoid group can bind to proteins and lipids in cell membranes and even cause cell lysis. Damage to the bacterial cell membrane will disrupt the transport of nutrients, so the cell will experience a lack of nutrients needed for the growth process. This study's findings align with research by Shaukat et al. (2023) which shows that a layer of chitosan enriched with bioactive compounds from glycerol ginger extract (GGE) is effective in maintaining the quality of walnuts during storage. GGE-chitosan coating significantly reduced lipid oxidation and peroxide levels in walnuts stored at a high temperature of 45 °C compared with uncoated control walnuts and chitosan-only coated walnuts. These results indicate that enriched GGE coatings can potentially extend the shelf-life of lipid-rich foods susceptible to oxidative damage and fungal spoilage.

Sensory Descriptive Assessment

Color

Color is an essential criterion for consumer product acceptance and a parameter for whether a material or product is still suitable for consumption. The red color in red chili peppers comes from carotenoid pigments, which are easily damaged by oxidation. The assessment was carried out descriptively by observing the red chili peppers' surface color. The average red chili peppers color assessment score is presented descriptively in Table 5.

Table 5 shows that if the storage period is extended, the descriptive value of red chili peppers color changes is higher, which means the color fades from red to brown. The average color score of red chili peppers on days 0 to 6 of storage still did not show a significant color change. Red chili peppers may have a natural defense mechanism at the beginning of storage that helps maintain the carotenoid pigment stability that gives rise to red. Hence, the effect of adding ginger extract on color changes is not significantly different in several treatments. The red chili peppers color on the 15th day of storage for treatment J0 was rotting red-brown (3.53). The red chili peppers color for treatment J4 on the 15th day of storage was still fresh red, with a score of 2.27. Treatment J4 is a coating red chili peppers treatment with banana hump starch edible coating containing 7% ginger extract concentration.

Table 5. Color descriptive score of red chili peppers coated with edible coating from banana hump starch and ginger extract

Treatment	Storage Period (Days)					
	0	3	6	9	12	15
J0 (ginger extract 0%)	1.13	1.53	2.27	2.53^{c}	3.33^{c}	3.53^{c}
J1 (ginger extract 1%)	1.27	1.40	2.00	2.40^{bc}	2.53^{b}	3.33^{bc}
J2 (ginger extract 3%)	1.27	1.33	2.33	2.13^{bc}	2.47^{ab}	3.13^{bc}
J3 (ginger extract 5%)	1.33	1.40	1.87	1.87^{ab}	2.13^{ab}	2.80^{b}
J4 (ginger extract 7%)	1.27	1.33	1.87	1.53^{a}	2.00^{a}	2.27^{a}

Note: Score: 1= Intense red; 2= Red; 3= Reddish brown; 4= Brown; 5= Intense brown. Numbers followed by the different superscript letters in columns indicate significant differences according to the DNMRT test at the 5% level.

J0 J1 J2 J3 J4

Figure 1. Red Chili Peppers After 15 Days of Storage

Red chili peppers coated with edible coating still experienced a color change from red to brown after being stored for 15 days. Red chili peppers have a red color that comes from carotenoid pigments. The changes in red chili peppers color are caused by oxidation in direct contact with oxygen during storage so that the carotenoid pigment is damaged (Berry et al., 2019, 2021). The color changes in red chili peppers after 15 days of storage are shown in Figure 5. J4 treatment with the addition of 7% ginger extract was most effective in maintaining the red color of red chili peppers during storage. This result shows that ginger extract can prevent damage to carotenoid pigments due to the oxidation process.

Aroma

Aroma is a sensory parameter tested with the nose as the sense of smell. Aroma is also one of the factors supporting product taste that determines product quality. Table 6 shows that the descriptive score for red chili peppers aroma is low, and the aroma becomes more rancid as the storage period is extended. Some treatments do not show significant differences in aroma because fruit and vegetable aroma tends to be stable at the beginning of storage and only begins to degrade significantly when the ripening and rotting process occurs (Farneti et al., 2015). Adding ginger extract has been proven to slow the decrease in aroma. The J4 treatment was most effective in maintaining the aroma of red chili peppers during storage because ginger extract contains antimicrobial and antioxidant compounds.

Table 6. Aroma descriptive score of red chili peppers coated with edible coating from banana hump starch and ginger

Treatment	Storage Period (Days)					
	0	3	6	9	12	15
J0 (ginger extract 0%)	1.20	1.53	2.47^{b}	3.46^{c}	4.13^{d}	4.20^{d}
J1 (ginger extract 1%)	1.07	1.47	2.07^{b}	3.20^{c}	3.60^{c}	3.73^{c}
J2 (ginger extract 3%)	1.07	1.20	1.53^{a}	3.00^{bc}	3.00^{b}	3.33^{b}
J3 (ginger extract 5%)	1.00	1.13	1.47^{a}	2.53^{ab}	2.53^{a}	3.27^{b}
J4 (ginger extract 7%)	1.13	1.13	1.33^{a}	2.33^{a}	2.40^{a}	2.86^{a}

Note: Score 1= Not rancid; 2= Somewhat not rancid; 3= Slightly rancid; 4= Rancid; 5= Intensely rancid. Numbers followed by the different superscript letters in columns indicate significant differences according to the DNMRT test at the 5% level.

The rancid aroma of red chili peppers is caused by microbiological damage and fat oxidation, which produces volatile compounds. Red chili peppers coated with edible coating in the J0 treatment had a foul smell on the 15th day of storage, with the highest score of 4.20. The lowest score was in the J4 treatment with the addition of a 7% ginger extract concentration, with a score of 2.86 (starting to smell bad) on the 15th day of storage. The aroma change of red chili peppers was due to the unique compounds in red chili peppers during storage. These compounds are volatile compounds such as alcohol, capsaicin, and ketones. According to Puspitasari & Pramardika (2019), red chili peppers experience an aroma change due to oxidation. Oxidation of unsaturated fatty acids in red chili peppers produces hydroperoxides. Further reactions, such as polymerization, dehydration, or oxidation, produce ketones, aldehydes, and acids, which cause unpleasant odors. The unpleasant aroma of red chili peppers is also caused by their respiration process, resulting in spoilage during storage (Puspitasari & Pramardika, 2019; Shaukat et al., 2023).

Red chili peppers coated with edible coating with added ginger extract can maintain a better aroma than those without adding ginger extract. Ginger extract in edible coatings can maintain the aroma of red chili peppers because the essential oils contained are antimicrobial and antioxidant, so they can prevent spoilage by inhibiting the respiration rate. The results of this research are in line with research by Erviani et al. (2017), who stated that edible coating sago starch with a 7% ginger filtrate concentration had a better aroma than the one without ginger filtrate when storing red chili peppers for 15 days.

Texture

Texture is an important quality attribute of a product to determine the product's suitability for consumption. Texture assessment will also influence product acceptability. The average score for assessing the texture of red chili peppers is presented in Table 7. Texture changes are physiological changes directly caused by water loss in red chili peppers. The texture changes of red chili peppers during storage have been identified as a leading indicator of damage, mainly caused by water loss through respiration and transpiration processes (Alvarez et al., 2020; Kurniasari et al., 2022). Evaporation of water causes weight loss and volume reduction, which affects the appearance of fruit freshness. According to Shin et al. (2021), pectin, as a cell wall component, plays a role in changing the cell wall's texture. Pectin transforms during the fruit ripening process. This condition increases the solubility of pectin in water so that the fruit texture gradually softens. Puspitasari & Pramardika (2019) also explained the role of microorganisms in damaging texture. Microbial activity in fruit can cause cell and tissue damage, often facilitated by the secretion of enzymes that break down cell walls. This damage further contributes to the red chili peppers' softening.

Table 7. Texture descriptive score of red chili peppers coated with edible coating from banana hump starch and ginger

Treatment	Storage Period (Days)					
	0	3	6	9	12	15
J0 (ginger extract 0%)	1.20	1.53	2.47^{b}	3.46^{c}	4.13^{d}	4.20^{d}
J1 (ginger extract 1%)	1.07	1.47	2.07^{b}	3.20^{c}	3.60^{c}	3.73^{c}
J2 (ginger extract 3%)	1.07	1.20	1.53^{a}	3.00^{bc}	3.00^{b}	3.33^{b}
J3 (ginger extract 5%)	1.00	1.13	1.47^{a}	2.53^{ab}	2.53^{a}	3.27^{b}
J4 (ginger extract 7%)	1.13	1.13	1.33^{a}	2.33^{a}	2.40^{a}	2.86^{a}

Note: Score: 1= Hard; 2= Slightly hard; 3= Slightly soft; 4= Soft; 5= Very soft. Numbers followed by different letters in the same row indicate significant difference based on DNMRT test at 5% level

All treatments during the 15-day storage period showed a red chili peppers texture decrease. Generally, the texture degradation process involving tissue softening and cell damage occurs gradually. These changes may be minimal in the early stages of storage, so some treatments have no significant differences in texture. Red chili peppers coated with edible coating without the addition of ginger extract (J0) showed a very significant decrease in texture during 15 days of storage. The rate of texture degradation is lower if the concentration of ginger extract added is high. Edible coating with ginger extract can maintain the texture of red chili peppers or inhibit the softening process due to respiration and transpiration. This research result is in line with Erviani et al., (2017), who stated that applying edible coating made from sago starch with the addition of 7% ginger filtrate could maintain the red chili peppers' texture.

CONCLUSIONS

The addition of ginger extract to the edible coating of banana hump starch had a significant effect on weight loss, vitamin C levels, total microbes, and organoleptic quality of red chili peppers during 15 days of storage. The optimum concentration of ginger extract added to banana hump starch as a coating for red chili peppers is 7%. The addition of 7% ginger extract to the banana hump starch edible coating was most effective in maintaining the physical, chemical, microbiological, and organoleptic quality of red chili peppers during storage compared to other treatments. Edible coating banana hump starch with the addition of 7% ginger extract can reduce weight loss, inhibit the decline in vitamin C levels, suppress the increase in total microbes, and maintain the red color, aroma, and texture of red chili peppers after 15 days of storage. Banana hump starch and ginger extract have the potential to be used as environmentally friendly biodegradable materials for food coatings.

The concentration of ginger extract in edible coating formulations needs to be optimized through research with wider concentration variations. It is essential to determine the best concentration of ginger extract to increase the product's shelf-life. The application of edible coatings based on banana hump starch and ginger extract can also be tested on various types of fresh fruit and vegetables other than red chili peppers. The characteristics of each commodity need to be considered in evaluating the edible coatings' effectiveness. An in-depth study of the interactions between components in edible coating formulations can be conducted, especially between banana hump starch and bioactive compounds in ginger extract. Understanding these interactions can facilitate the optimization of edible coating formulations. The process of isolating banana hump starch needs to be standardized and scaled up to enable the production of banana hump starch in large quantities for the commercialization of edible coatings.

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