Development of Bio-Based Smart Edible Food Packaging Using Roselle Flower Extract and Eggshell Powder as Active Agents

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Abstract. Recent trends revealed smart edible film can improve safety and extend the shelf life of food packaged. Cassava starch, gelatine, glycerol, roselle flower extract, and eggshell powder can be used to produce bio-based smart edible film. This study aimed to develop a bio-based smart edible film using roselle flower extract and eggshell powder. In this research, A total of six treatment were used, which was cassava starch, gelatine, glycerol (CGG) as control; control + eggshell (CGGE); control + roselle extract 15 ppm (CGGR); control + eggshell + roselle extract (15 ppm) (CGGER15); control + eggshell + roselle extract 10 ppm (CGGER10); control + eggshell + roselle extract 5 ppm (CGGER5). Parameters examined included total phenol, antioxidant activity, anthocyanins, tensile strength, elongation, water vapor transmission rate (WVTR), the color of edible film, and color, aroma, and pH of chicken meat samples. The results showed that the addition of roselle flower extract and eggshell powder had a significant effect on the parameters measured. The smart edible film has a total phenol of 367.9814-526.0559 mg GAE/100 g sample, total anthocyanins of 1.9872–4.2457 mg cy-3-glu-eq/100 g sample, antioxidant activity of 40.5488-96.2946%, WVTR of 96.2412-149.6401g/m2/24 hours, tensile strength of 1.4020-13.0243 N/mm2, and percent elongation of 2.242-94.7725%. Based on the parameters measured the best treatment is the CCGER15. Moreover, the smart edible film can act as indicator for the steamed chicken during storage.

1 Introduction

Food packaging protects food from physical, chemical, and microbiological damage. Plastic is the most widely used material for food packaging due to its cost-effectiveness and versatility. However, the use of plastic raises concerns due to its negative impact on the environment. Plastic waste cannot naturally decompose, leading to soil and water pollution and an imbalance in the ecosystem [1]. Reports suggest that plastic waste has become a global environmental crisis. Furthermore, microplastics have been found in aquatic organisms, which may threaten human health when consumed [2]. Therefore, raising awareness about

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reducing plastic waste and developing alternative packaging materials that are biodegradable and eco-friendly is crucial. One such alternative is edible packaging, which has been used for decoration for a long time.

Edible film is a thin layer that serves as the primary packaging for food products. It is made from edible biopolymers and can minimize moisture and gas transmission from the environment to the packaged products [3]. Edible film can be made from hydrocolloids, lipids, and composites. Gelatin, carrageenan, gum arabic, agar, and starch are common hydrocolloids used to produce edible film, while natural waxes, oleic acid, and lauric acids are examples of lipids [4]. Cassava starch is the most common ingredient for edible film, containing 17% amylose and 83% amylopectin. The amylopectin content affects the stability of the edible film, while amylose plays a role in producing a sturdy structure. However, edible film made solely with cassava starch is less able to withstand loads and tear easily [5]. The texture of the edible film can be strengthened by adding a non-starch material, such as gelatin, to increase binding strength, uniform granules, and compressibility. Plasticizers can also be added to reduce intermolecular and intramolecular interactions in polymers and increase elasticity. Glycerol is a common plasticizer used for edible film production [6].

Packaging technology has experienced rapid development so that edible film innovations emerge as smart packaging or smart edible packaging. Smart packaging or smart edible packaging is a packer that actively maintains the quality of food products and can carry out intelligence functions, such as detecting, finding, and providing information about the condition of packaged food products to extend shelf life, improve safety and quality, and warn changes in the quality of packaged products [7]. Active ingredients or smart agents can be added to produce smart edible packaging.

Anthocyanin can be used as a smart agent due to its pH sensitivity and capability to act as an antioxidant [8]. Anthocyanins are water-soluble pigments that belong to a class of flavonoids and are responsible for the red, purple, and blue colors of many fruits, vegetables, and flowers. Anthocyanin changes its color in response to changes in pH levels. They can change their molecular structure and shift their absorption spectrum as the pH of their environment changes, causing a visible color change. This property makes them useful as natural indicators [9]. Anthocyanins are also powerful antioxidants known for their ability to scavenge free radicals and protect cells from oxidative damage. Among many, the roselle flower is a rich source of anthocyanin [10]. Roselle or Hibiscus sabdariffa is a plant species that is native to Africa. It is commonly used in traditional medicine and as a food ingredient in various cultures worldwide. The plant is rich in anthocyanins, particularly cyanidin-3-sambubioside, responsible for its deep red color. These anthocyanins have been shown to possess several health benefits, such as antioxidant and anti-inflammatory properties and potential anti-cancer effects. Due to its potential health benefits, Roselle extract is often used as a natural food colorant, as well as in functional foods and dietary supplements. Due to its unique characteristics, anthocyanin has been investigated to be used as smart agent in packaging technology, such as anthocyanin from sweet potato, butterfly pea, mangosteen and red dragon fruit peel were applied in gelatin film [9], anthocyanin from Chinese bayberry was applied in cassava starch based film [5], and anthocyanin from blackberry was used in carboxymethyl cellulose based film [11]. Nevertheless, limited research is available in the utilization of roselle extract combined with cassava starch as smart packaging.

Another active agent that can be incorporated into edible film is eggshell. Chicken eggshells are the hard outer covering of chicken eggs commonly consumed as food. They are composed mainly of calcium carbonate and small amounts of other minerals, such as magnesium, potassium, and phosphorus. Chicken eggshells are a rich source of calcium, which is important for bone health, muscle function, and nerve transmission [12]. They can be ground into a fine powder and added to foods or supplements as a natural source of calcium. In addition, eggshells have been used in producing various products, such as fertilizers, feed, and as a source of calcium for plants. The presence of calcium could benefit the edible film by strengthening the network and improving the physical characteristics of the edible film as reported by Jiang et al. [13] on the utilization of eggshell powder to strengthen the physical properties of corn starch-based edible film.

Numerous research studies have been published on cassava-based edible film and the use of anthocyanin as an indicator of smart packaging. Nevertheless, combining the smart agent's anthocyanin-rich roselle extract and eggshell powder in the formulation of smart edible film has never been conducted. Therefore, this study aimed to develop a bio-based smart edible film using roselle flower extract and eggshell powder, examining the physical properties and the capability to be used as smart packaging in food models.

2 Materials and methods

2.1 Materials

The edible film was made using a combination of cassava starch, gelatin, glycerol, and eggshell powder. The cassava starch was purchased from Rosebrand Co. located in Jakarta, Indonesia. The eggshell powder was obtained from organic farmers in the Depok district of Banten Province, Indonesia. Gelatin with 150 blooms and size 30 mesh was acquired from Cartino Gelatin Factory Limited. Glycerol, on the other hand, was obtained from a food and chemical distributor based in Surabaya. Additional materials such as methanol, Na_2CO_3, KCl, HCl, and CH_3COONa were obtained from Merck in Germany. Gallic acid, Folin ciocalteu, and DPPH (2,2-diphenyl-1-picrylhydrazyl) were obtained from Sigma Chemical in Singapore. The chicken breast utilized for the experiment was sourced from a traditional market in Surabaya.

2.2 Methods

2.2.1 The extraction of roselle flower

The roselle flower was first sorted and washed thoroughly with water to get rid of any unwanted materials. After that, the flower was spread out on a tray and put into a cabinet dryer at a temperature of 60°C for 24 h until it was completely dried. The dried flower was then powdered using a grinder. Then, the powder was put into an Erlenmeyer flask and mixed with water at a temperature of 90°C for one hour in a shaker, using the proportions of 1:10 (w/v). The resulting extract was then filtered through Whatman filter paper no. 42. The supernatant was collected and stored in a brown bottle in the refrigerator until needed.

2.2.2 The production of smart edible film

A 3% (w/v) cassava starch solution was created by combining 3 g of cassava starch with 100 mL of roselle extract (at concentrations of 5, 10, and 15 ppm). For the control, water was used instead of extract. This mixture was stirred and heated at 75°C for 2 minutes, then cooled to room temperature. Meanwhile, a 20% (w/v) gelatin solution was made by mixing 20 g of gelatin with 100 mL of water. The mixture was stirred at room temperature for 3 minutes, then heated at 70°C for 2 minutes. To produce the edible film, 87 mL of the 3% cassava starch solution was mixed with 13 mL of gelatin. 2.25 mL of glycerol was added as a plasticizer, and 0.3 g of eggshell powder was thoroughly incorporated into the mixture. Then, 20 mL of the solution was pipetted and placed in an aluminum sheet mold to ensure the film was of uniform size and thickness. The solution was cast using stainless steel tools. Finally, the edible film was stored in a storage room at 23°C and 60% relative humidity for 24 hours, released from the mold, and stored for analysis. A total of six treatment were used, which was cassava starch, gelatin, glycerol (CGG) as control; control + eggshell (CGGE); control + roselle extract 15 ppm (CGGR); control + eggshell + roselle extract (15 ppm) (CGGER15); control + eggshell + roselle extract 10 ppm (CGGER10); control + eggshell + roselle extract 5 ppm (CGGER5).

2.2.3 The extraction of smart edible film

The following method was used to extract edible film, as described by previous research [14]. First, a 1.5 g sample was weighed and sliced into smaller pieces, which were then placed in an Erlenmeyer flask. Next, 30 mL of distilled water and 15 mL of methanol were added, and the mixture was stirred for one minute. The Erlenmeyer flask was then placed in a shaking water bath set at 40°C for one hour. The extract was filtered, and the supernatant was stored in a brown bottle in the refrigerator until needed.

2.2.4 Total phenolic content

The edible film's total phenolic content (TPC) was determined following the method described previously [15]. Briefly, 1 mL of extract was mixed with 9 mL of distilled water, and the resulting mixture was vortexed thoroughly. Then, 1 mL of the diluted extract was combined with 0.5 mL of Folin ciocalteu's phenol reagent. The reaction tube was wrapped with aluminum foil, homogenized, and placed in a dark room for 8 minutes. After that, 4.5 mL Na_2CO_3 2% was added, and the tube was stored for another hour. The absorbance of the sample was measured spectrophotometrically at 765 nm, using gallic acid as a reference standard. The phenolic content of the sample (given in mg Gallic Acid Equivalent per 100 g of sample) was calculated using the equation (1).

$$TPC\ (\text{mg GAE/100 g sample})=$$

$$\frac{total\ phenolic\ (ppm)}{1000\ mL} \times \frac{sample\ (mL)}{sample(g)} \times 100\ g\ sample \times Dilution\ Factor \qquad (1)$$

2.2.5 Total anthocyanin content

The pH differential method [15] was used to determine the anthocyanin content. Firstly, 1 mL of edible film extract was pipetted into two reaction tubes, tubes A and B. Then, 10 mL of buffer pH 1 solution and 10 mL of buffer pH 4.5 solution were added into tubes A and B respectively. Both tubes were homogenized using a vortex and stored for 8 minutes. After that, the absorbance of the mixtures was measured using a spectrophotometer at 530 and 700 nm. Finally, the total anthocyanin content was calculated using Equation (2).

$$Total\ anthocyanin\ content\ \left(\text{mg cy} - 3 - \text{glu}\frac{\text{equivalent}}{100}\text{g sample}\right)$$

$$= \frac{A \times MW \times DF \times 1000)}{(\varepsilon \times l)} \times \frac{sample\ (mL)}{sample\ (g)} \times 100\ g\ sample \qquad (2)$$

Note:

A = absorbance $(A_{530\,nm} - A_{700\,nm})_{pH\,1{,}0} - (A_{530\,nm} - A_{700\,nm})_{pH\,4{,}5}$
MW = molecular weight of cyanidin -3-glucoside = 449.2 g/mol
DF = dilution factor
ε = molar absorbtivity of cyanidin -3-glucoside = 26900 L/(mol.cm)
l = length of the cuvette = 1 cm

2.2.6 DPPH radical scavenging activity

The DPPH radical scavenging activity (RSA) test was conducted in accordance with previous method [16]. To perform the test, 0.25 mL of an edible film extract is mixed with 0.5 mL of a 0.1 mM DPPH solution in a glass tube, followed by the addition of 4 mL of methanol. The tube is then wrapped with aluminum foil, homogenized, and stored in a dark room for 30 minutes. Afterward, the absorbance of the mixture is measured at 517 nm. Water is used in place of the extract for the control. Finally, the DPPH radical scavenging activity is calculated using Equation (3).

$$\%\,RSA = \frac{Absorbance\ of\ control - Absorbance\ of\ sample}{Absorbance\ of\ control} \times 100\% \tag{3}$$

2.2.7 Tensile strength and elongation

The ASTM D 882-18 method was used to measure the tensile strength and elongation of the edible film. A Universal Testing Machine (Zwick I Model Z0.5, UK) was utilized for this purpose. First, the film was cut into pieces that were 145 mm in length and 10 mm in width. Then, the equipment was calibrated with a preload value of 2N, a test speed of 50 mm/min, and an initial grip distance of 100 mm.

2.2.8 Water vapor transmission rate (WVTR)

The WVTR was determined by using the gravimetric method [17]. In brief, 10 grams of dry silica gel were placed in a glass container and tightly sealed with an edible film measuring 19.3 cm2. The sealed container was then stored in a desiccator that contained saturated NaCl (with an RH of 75%) at a temperature of 27°C. The weight of the container was measured every day for four days to determine the amount of water absorbed through the film (g/m2 per day).

2.2.9 Application of edible film for steamed chicken packaging

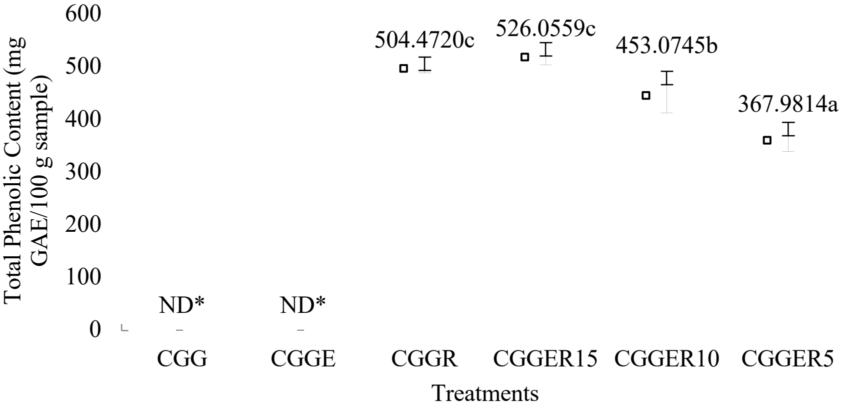
First, the boneless chicken breast was cut into 2 x 2 cm pieces and steamed for 30 minutes. The freshly prepared steamed chicken was used for each replication. After steaming, the chicken was placed in a container that was sealed with an edible film and stored at room temperature for 2 days.

Meanwhile to measure the pH of steamed chicken, the sample was finely chopped, and distilled water was added to it in a ratio of 1:2 (w/v) and stirred thoroughly. The mixture was then filtered, and the pH of the resulting supernatant was measured using a digital pH meter (Mettler Toledo, USA).

Moreover, the color of the edible film and the aroma and color of the steamed chicken were assessed daily for three days (0, 1, 2 days) through qualitative analysis. Ten semi-trained panelists were involved in measuring the changes in color and aroma of the edible film and chicken sample. The results were expressed as a (+) sign, indicating the intensity of the native color of the edible film. Similarly, the number of (+) signs indicated the intensity of unwanted aroma and brown color of the chicken sample.

3 Result and discussion

Total phenolic content determination revealed that the TPC of smart edible film ranged from 367.98-526.05 mg GAE/100 g sample as presented in Fig. 1



*ND: not determined

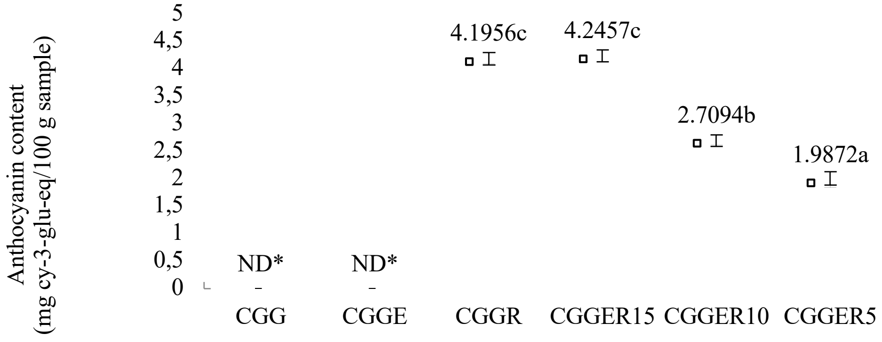
Fig. 1. Total phenolic content of smart edible film

Based on the results, the highest total phenol content was obtained in the CGGR and CGGER15 treatments with a higher roselle flower extract concentration. The high total phenolic content of the extract is influenced by the phenolic compounds found in rosella flowers, such as alkaloids, flavonoids, anthocyanins (delphinidin 3-glucoside and cyanidin 3-glucoside), ascorbic acid, sterols and tannins [18]. Apart from that, there are other types of phenolics such as hibiscetin, gossypetin, kaempferitrin, gallocatechin, quercetin, and luteolin, as well as phenolic acids (hibiscus acid, protocatechuic acid, gallic acid, chlorogenic acid, caffeic acid), and organic acids (citric acid) [19].

The higher the total phenolic content, the stronger the antioxidants' ability to donate electrons to suppress the development of free radicals [20]. These results are in line with previous research [11] on the addition of blackberry fruit extract from 10% to 50% in the formulation of edible film made from carboxymethyl cellulose, which can increase the total phenolic from 400 to 1200 mg GAE/100 g sample. The higher concentration of blackberry extract in the formulation increases the total phenolic content. These results are also in line with a report by Moghadam et al.[21], which used *Echium amoenum* flower extract on mung bean protein-based edible film and showed that the addition of anthocyanin extract from 0% to 10% increased the total phenolic content from 300.89 to 1100.47 mg GAE/100g.

The addition of eggshell flour to the smart edible film showed that there was no significant difference (α = 5%) in the CGGR and CGGER15 treatments because eggshell flour does not contain phenol but only contains calcium carbonate, magnesium carbonate, calcium phosphate and other organic materials [22].

Meanwhile, the results of the anthocyanin determination ranged from 1.9872–4.2457 mg cy-3-glu-eq/100 g sample. The results of the total anthocyanin content of smart edible film can be seen in Fig. 2.



*ND: not determined

Fig. 2. Total anthocyanin content of smart edible film

The results showed that the highest total anthocyanin content was obtained in the CGGR and CGGER15 treatments. A smart edible film with a higher concentration of roselle flower extract produces higher anthocyanin content. Anthocyanin compounds in smart edible film can extend and maintain the quality of packaged food products. Anthocyanin pigments that are often found in roselle flower petals (*Hibiscus sabdariffa* L.) are delfinidin-3-glucoside, cyanidin-3-glucoside, cyanidin-3-sambubioside, and delfinidin-3-sambubioside [19].

The results of this study on anthocyanin determination are consistent with several other studies. For instance, Sganzerla et al. [11] found that incorporating blackberry fruit anthocyanin extract in edible films made from carboxymethyl cellulose can increase total anthocyanins from 300.39 to 1100.59 mg cy-3-glu -eq/100 g sample when the concentration of the extract ranges from 10% to 50%. Similarly, Nogueira et al. [23] used blackberry extract in the production of arrowroot starch-based edible films and found that a 20% to 40% addition of the extract could increase total anthocyanin from 47.53 to 76.47 mg/100g total ingredients.

Another study by Chambi et al. [24] showed that adding 1.5% (w/w) jambolan juice in edible film production made from polysaccharides and CMC could increase total anthocyanins from 100.02 to 300.10 mg/100 g sample. The addition of eggshell flour to the CGGER15 treatment did not result in a significant difference ($\alpha = 5\%$) compared to the CGGR treatment. This implies that adding eggshell flour did not influence total anthocyanins because eggshell flour does not contain anthocyanins. Instead, eggshell flour contains high levels of calcium (Ca), magnesium (Mg), and phosphorus (P) [25]. It is worth noting that the total anthocyanin value is directly linked to the total phenol value since anthocyanins are derivatives of phenolic compounds known as flavonoids [26]. Flavonoid compounds act as primary antioxidants, chelators, and scavengers against free radicals like superoxide anion radicals (O2-), peroxyl radicals (ROO*), alkoxyl radicals (RO*), and hydroxyl radicals (*OH). The antioxidant properties of anthocyanins are attributed to their high reactivity as hydrogen or electron donors and their ability to stabilize and delocalize unpaired electrons, making them effective in neutralizing free radicals [27].

The analysis of antioxidant activity in smart edible film produced results ranging from 40.5488 to 96.2946%, as shown in Fig. 3. The study revealed that the treatments CGGR and CGGER15 had the highest antioxidant activity.

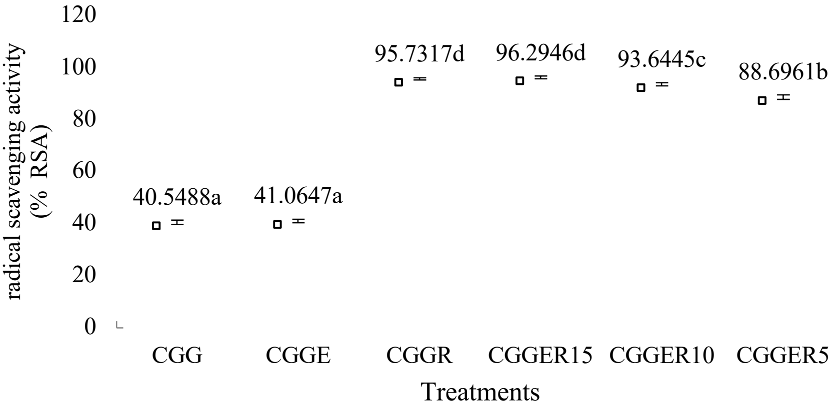


Fig. 3. Antioxidant activity of smart edible film

The greater the concentration of roselle flower extract, the higher the antioxidant components produced, indicating that the antioxidant activity of smart edible film is influenced by the antioxidant compounds in the materials used and their ability to reduce free radicals. This finding is consistent with previous research by Dordevic et al. [28], who discovered that adding blueberry extract from 5% to 20% in the formulation for edible films significantly increased antioxidant activity from 2.16% to 5.39%. As the concentration of blueberry extract added increased, so did the antioxidant activity. Similarly, Sganzerla et al. [11] discovered that using blackberry anthocyanin extract from 10% to 50% in the edible film formulation made from carboxymethyl cellulose resulted in higher antioxidant activity, ranging from 2.64% to 12.12%. The higher the concentration of blackberry extract added, the higher the antioxidant activity of smart edible film.

The tensile strength of the smart edible film, which added the active ingredients of roselle flower extract and eggshell flour, ranged between 1.4020–13.0243 N/mm2. The highest tensile strength value was obtained in the CGG treatment, a basic formula without adding the active ingredients of roselle flowers and eggshell flour. This shows that adding active ingredients will reduce the tensile strength of the edible film. The results of the tensile strength test on smart edible film can be seen in Table 1.

Table 1. Tensile strength, elongation, and WVTR of smart edible film

Treatments	**Tensile Strength (N/mm^2)**	**Elongation (%)**	**WVTR ($g/m^2/24$ h)**
CGG	13.0243±3.02^c	2.24±0.78^a	105.2727±0.31^b
CGGE	5.0333±0.21^b	2.39±0.28^a	96.2412±0.55^a
CGGR	1.4020±0.10^a	94.77±5.22^d	149.6401±0.76^f
CGGER15	2.0338±0.07^a	75.80±6.03^c	134.9990±0.73^e
CGGER10	2.3500±0.13^a	74.53±10.19^c	119.8983±0.75^d
CGGER5	1.7065±0.05^a	21.03±5.49^b	116.3295±0.49^c

Smart edible film treated with CGGE has a lower tensile strength than CGG. Eggshell powder is rich in calcium carbonate ($CaCO_3$), which can enhance the bonding between the film matrix and eggshell particles. This leads to a decrease in the mobility of the matrix chains and an increase in the film's stiffness. However, this stiff structure can also make the smart edible film too brittle and prone to breakage. Adding eggshell powder in a specific concentration can increase the density of the smart edible film's matrix molecular structure, ultimately leading to an increase in tensile strength [29]. Nevertheless, if the concentration of eggshell powder is too high, it can reduce the tensile strength of the film. This is because excessive cross-linking can disrupt the interconnections in the matrix structure, making the smart edible film too stiff and brittle [30].

A smart edible film with roselle flower extract and eggshell flour has a lower tensile strength value than the CGG and CGGE treatments. This is because adding active ingredients will weaken the interactions between starch molecules. Roselle flowers contain phenolic compounds, which can act as a plasticizer. Plasticizer molecules will disrupt the compactness of starch by entering the polysaccharide network and being located between polymer bonds, causing a decrease in intermolecular interactions [31]. Adding phenolic compounds to smart edible films will affect the polymer-polymer interactions in the film matrix. This will result in hydrogen and covalent bonds between phenolic compounds in roselle flower extract and polypeptides, disrupting protein-protein interactions and weakening the film network [32].

Meanwhile, the results for the elongation of smart edible film ranged from 2.242-94.7725%. Smart edible film without the addition of roselle flower extract has a lower elongation compared to smart edible film with the addition of roselle flower extract. Roselle flower extract contains anthocyanin compounds which cause an increase in the mobility of the film matrix which can weaken intermolecular interactions and affect the mechanical properties of the film, one of which is the percent elongation. This shows that smart edible film without the addition of CGG and CGGE roselle flower extracts has stiffer characteristics. The results of the percent elongation test on smart edible film can be seen in Table 1.

The addition of eggshell powder affects the elongation percentage of smart edible film which will produce a lower elongation percentage. Eggshell acts as a filler which will form a matrix that tightens and provides a mechanical effect on smart edible film [29]. Eggshell flour contains calcium which can increase the stiffness of smart edible film so that the percentage elongation will be inversely proportional to the tensile strength value. Eggshell flour contains calcium carbonate ($CaCO_3$). Ca^{2+} in eggshell flour will form cross-links with starch and gelatin in the smart edible film matrix which can disrupt the interconnections in the matrix structure and produce a film that is stiffer and less elastic, causing a decrease in percent elongation.

The results show that smart edible film with the addition of roselle flower extract has a higher WVTR than the treatment without roselle flower extract (CGG and CGGE) (Table 1). The higher WVTR value indicates that more water vapor will come out of or enter the packaging, so the packaged product will experience a decline in quality. Adding roselle flower extract will cause low intermolecular interactions in the film network, increasing pores and water vapor diffusion. Additionally, adding roselle flower extract containing phenolic compounds to smart edible film will affect the polymer interactions in the film matrix. Hydrogen and covalent bonds between phenolic compounds in roselle flower extract and polypeptides in gelatine disrupt protein-protein interactions, weakening the film network [33]. A smart edible film with the addition of eggshell powder produces a lower WVTR value than without eggshells. The factor that influences the transmission of water vapor in edible film is film thickness. The thicker the edible film, the more difficult it is for water vapor to penetrate. It shows a denser and stronger structure, able to withstand gas migration and protect the product from physical influences. Adding eggshell powder plays a role in improving resistance to water vapor. This is due to the cross-linking between the hydroxyl group (-OH) of starch and the functional group of eggshell powder (Ca^{2+})' which reduces the active site for water adsorption and the free space between the tissues, thereby inhibiting the penetration of water molecules in the smart edible film. [34]. The lower the WVTR, the packaging can prevent water entry from the product, thereby preventing product damage due to hydrolysis and damage to microorganisms [35].

Table 2 shows the results of color, aroma, and pH determination conducted on steamed chicken meat during storage.

Table 2. pH, aroma, and color of the steamed-chicken and the smart edible packaging

Treatments	Parameters	Storage days		
		0	1	2
CGG	pH	6.07±0.03	6.56±0.02	6.72±0.02
	Aroma	-	+	++++
	Color of chicken	cream	Brownish cream (+1)	Brownish cream (+4)
	Color of edible film	Translucent	Translucent	Translucent
CGGE	pH	6.47±0.01	6.61±0.02	7.20±0.01
	Aroma	-	+	++++
	Color of chicken	cream	Brownish cream (+1)	Brownish cream (+4)
	Color of edible film	Translucent	Translucent	Translucent
CGGR	pH	6.40±0.02	6.63±0.05	6.97±0.03
	Aroma	-	+	++
	Color of chicken	cream	Brownish cream (+1)	Brownish cream (+4)
	Color of edible film	Purplish red (+4) *	Purplish red (+2)*	Purplish red (+1)*
CGGER15	pH	6.32±0.02	6,47±0.02	6.94±0.05
	Aroma	-	+	++
	Color of chicken	cream	cream	Brownish cream (+2)
	Color of edible film	Purplish red (+4)*	Purplish red (+3)*	Purplish red (+3)*
CGGER10	pH	6.39±0.04	6.49±0.03	7.02±0.02
	Aroma	-	+	++
	Color of chicken	cream	cream	Brownish cream (+2)
	Color of edible film	Purplish red (+3)*	Purplish red (+4)*	Purplish red (+3)*
CGGER5	pH	6.50±0.02	6.58±0.04	7.16±0.02
	Aroma	-	+	++
	Color of chicken	cream	cream	Brownish cream (+2)
	Color of edible film	Purplish red (+2)*	Purplish red (+1)*	Purplish red (+1)*

* Changes in the red color; + intensity of unwanted aroma

The initial creamy color of the meat changes to a brownish hue due to an increase in ammonia and pH levels, which also cause the meat to become darker. Additionally, the aroma of steamed chicken meat turns rancid due to fat oxidation, producing unpleasant compounds like aldehydes and acids. Enzymes and bacteria break down the main ingredients of chicken meat, causing the production of unwanted aromas like ammonia, hydrogen sulfide, and methyl mercaptan. However, using smart edible film with roselle flower extract can reduce the intensity of these unwanted odors. Roselle flower extract contains antioxidant compounds that have antimicrobial properties, which can reduce oxidation and bacterial growth. Adding roselle flower extract to smart edible film can help protect packaged products from oxidation. During storage, the pH of chicken meat increases, becoming more alkaline due to bacterial metabolism and the formation of alkaline ammonia (NH_3). However, smart edible film with the addition of eggshell powder can maintain the quality of packaged chicken meat products better than smart edible film without eggshell powder. The addition of eggshell powder improves the packaging's resistance to water vapor and inhibits water entry from the product, thereby preventing product damage caused by microorganisms and due to oxidation.

4 Conclusion

The smart edible film can be developed using cassava starch and enriched with active agents such as roselle flower extract and eggshell powder. The formulation produces smart edible film with improving quality parameters such as phenolic content, anthocyanin content, antioxidant activity, and also tensile strength, elongation, and water vapor transmission rate. Smart edible film can delay the degradation of steamed chicken quality as observed from the color, aroma, and pH. Moreover, roselle extract can potentially be used as indicator in smart edible packaging due to its susceptibility to the changes of pH.

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