Characteristics of corn starch-based edible coating enriched with curry leaf extract on quality of the strawberry (*Fragaria x ananassa* Duch.)

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Abstract Strawberry is one of the most popular tropical fruits in Indonesia. The fruit has a concise shelf life and quickly deterioration after harvesting due to mechanical injury, physiological disorders, water loss, fungal growth, and high respiration rates. Postharvest technology is one technique that can maintain fruit quality and extend shelf life, one of which is a coating technique called edible coating. The edible coating layer of corn starch with the addition of curry leaf extract has antibacterial activity that can inhibit the growth rate of microorganisms. This study aimed to determine the characteristics of the edible coating solution produced from corn starch with the addition of curry leaf extract to produce the best edible coating layer. This study used a factorial completely randomized design experimental method, which consisted of treatment with curry leaf extract concentration (8%, 10%, and 12%) and dipping time (4, 5, and 6 minutes) with three repetitions. The result showed a significant delay in weight loss and total dissolved solids in strawberries compared to the uncoated control strawberries. In addition, the edible coatings had positive results in organoleptic based on panelists' acceptance of color, aroma, taste, texture, and overall. These findings suggest that using 8% curry leaf extract with 4 minutes dipping time could be favorable to extend the shelf-life and maintain the quality of strawberry fruit.

1. Introduction
Strawberry (*Fragaria x ananassa* Duch.) is one of the most popular tropical fruits in Indonesia. This fruit is easily damaged after harvesting, caused by mechanical, physiological, water loss, fungal growth, and high respiration rates [1]. An extended supply chain and inadequate technology during transportation may deteriorate the quality of strawberries. Strawberry also can decrease in quality after being stored for 72 hours at room temperature [2]. In addition, environmental conditions in tropical areas can decrease the quality of strawberries [3].

Postharvest technology is one technique that can maintain fruit quality and extend shelf life, one of which is a coating technique called edible coating. The edible coating is a thin layer used to coat products to protect and maintain the quality of the coated products against product deterioration. Corn starch is a polysaccharide widely used for packaging material (edible coating) on agricultural products because of its low price and accessibility. Corn starch has a characteristic of white color, resulting in an (edible) layer of which will be more transparent along with the addition of corn starch [4]. The stability of edible coatings can be increased by adding antioxidants and antibacterial substances to maintain the quality of fruits and vegetables. Antioxidants and antibacterials function as protectors to avoid quality deterioration, including the quality of the coated product. Curry leaves (*Murraya koenigii* L. Spreng) are natural antioxidants and antibacterials that are mostly found and popular in Aceh province, Indonesia. The leaves are used traditionally as a spice in Acehnese cuisine [5]. These leaves contain active substances, such as flavonoids, saponins, tannins, and essential oils, that can inhibit bacteria [6].
A study conducted by Unita and Voon [7] on the inhibition of curry leaf extract on the growth of *Staphylococcus aureus* showed that curry leaf extract concentrations of 2.5%, 5%, 7.5%, and 10% were able to inhibit the growth rate of *Staphylococcus aureus*. The higher the concentration of curry leaf extract, the higher the antibacterial activity. According to the antibacterial activity test of curry leaf against *E. coli* and *S. aureus* bacteria as well as the antioxidant activity test against the free radical DPPH (1,1-Diphenyl-2-pycrilhydrazil) conducted by Mustanir et al. [8], it founded that Curry leaf extract can inhibit the growth rate of microorganisms and can prevent the occurrence of free radical activity. Based on the description above, this study tries to utilize corn starch with the addition of curry leaf extract in the process of making edible coatings, and it is necessary to study the amount of curry leaf extract added and the effect on the characteristics of the edible coating produced on the strawberries quality. This study aims to determine the characteristics of the edible coating solution produced from corn starch with the addition of curry leaf extract and the duration of dipping time on the strawberries quality.

2. **Materials and methods**

The materials used in this study were strawberry from Aceh Tengah, corn starch with the Maizenaku Brand and curry leaf from Banda Aceh. The chemicals used for the analysis were obtained from the Laboratory of Food and Agricultural Product Analysis, Laboratory of Microbiology, Department of Agriculture Product Technology, Syiah Kuala University. The chemicals used for the analysis were ethanol 70%, aquadest, NaOH 0.01N, Plate Count Agar (PCA), glycerin 5%, and phenolphthalein.

The equipment needed in this research includes oven, desiccator, ethylene analyzer, rotary evaporator, incubator, enumerator, pH meter, blender, hot plate, analytical balance, mixer, petri dish, styrofoam box, plastic wrap, and other glass equipment in laboratory.

2.1 **Edible coating solution characteristics**

2.1.1 **pH analysis.** The edible coating solution was poured into a 10 ml beaker glass, then the pH was measured using a pH meter. Before the pH meter is used, the sensitivity of the pointer must be calibrated with a pH seven buffer solution. The amount of pH is the reading of the pH needle after the needle of the scale is constant in position [9].

2.1.2 **Transparency analysis.** The edible coating solution was tested using a spectrophotometer with a wavelength of 550 nm. The transparency of edible coatings is measured by the following formula [10]:

\[
T = \frac{A_{550}}{x}
\]  

Where:

- \( T \) = Transparency
- \( A_{550} \) = Absorbance at a wavelength of 550 nm
- \( x \) = Film thickness

2.1.3 **Viscosity analysis.** The edible coating solution was measured at room temperature with a Brookfield Digital Viscometer. Measurement of viscosity on a viscometer in an edible coating solution [11].

2.2 **Main research**

2.2.1 **Preparation of curry leaves extract.** Fresh curry leaves are dried under the sun. Then the leaves are put into a maceration bottle vessel with added 70% ethanol. After that, the bottle is allowed to stand for five days. The mixture is removed from the bottle and filtered by using filter paper. The curry leaf filtrate is evaporated by using a rotary evaporator with a temperature 65°C for 4 hours to obtain a concentrated extract [12].
2.2.2 Preparation of edible coating solution. Corn starch with concentration of 3% is mixed with the addition of 100 ml of aquadest into a solution. The solution is added with 0.4% CMC & 5% glycerol. Then the solution is stirred on a hot plate stirrer with the temperature of 70°C for 6 minutes. The solution is cooled until the temperature reaches 40°C. After the solution was cooled, then curry leaf extract with concentration of 8%, 10%, and 12% is added until homogeneous [13].

2.2.3 Edible coating application. Strawberries are washed and dipped in edible coating for 4.5, and 6 minutes. Then the strawberries are drained for 3-5 hours using a fan and then packaged by placing the strawberries in a styrofoam box at room temperature (25°C) [14].

2.3 Experimental analysis
The strawberries with application of edible coating would be tested its sensory characteristics by using hedonic test (color, aroma, texture, taste, and overall), weight loss [15], total plate count (TPC), and total dissolved solids (TDS) [16]. Determination of selected formula was conducted by using Bayes method.

2.4 Statistical analysis
Data resulted from this experiment were analyzed statistically by using randomized design experimental with two factors. The first factor is the concentration of curry leaf extract with three levels, 8%, 10%, 12% and control treatment 0%. Whereas the second factor is the dipping time with three levels, 4 minutes, 5 minutes, and 6 minutes. Duncan Multiple Range Test (DMRT) was carried out to get more insight about a significant difference among several formulas at the level of 5%.

3. Results and discussion

3.1. Edible coating solution characteristics
The results of the curry leaf extract effect on the pH, transparency, viscosity of corn starch-based edible coatings as shown in Table 1.

| Edible coating solutions | pH   | Transparency | Viscosity |
|--------------------------|------|--------------|-----------|
| 0%                       | 6.8  | 1.37         | 128.9     |
| 8%                       | 6.7  | 1.74         | 115.9     |
| 10%                      | 6.6  | 2.09         | 107.5     |
| 12%                      | 6.5  | 2.83         | 93.8      |

The pH value decreases as the curry leaf extract increases because it contains vitamin C [17]. Vitamin C is acidic so that it lowers the pH of the edible coating produced [18]. The pH value of the edible coating solution should be close to 6-7 [19]. The edible coating solution with curry leaf extract added in this study has a pH that tends to be neutral, so it is suitable for edible coating application.

Transparency shows the level of edible clarity. The higher value indicates that the edible is not transparent [20]. The solution clarity level was decreased as the curry leaf extract increases. The more curry leaves added will produce an edible with a greater degree of greenness, raising the bar for increased transparency [21].

Viscosity is the flow power of molecules in a particular tested to determine the viscosity of the solution at a certain concentration and temperature [22]. The viscosity of the edible coating solution decreases as the curry leaf extract increases because the curry leaf extract contains water. This study is in line with the research conducted by Hendrawan et al. [23] stated that the addition of green extract concentration caused the decreased viscosity value. It can occur due to the water content in the green grass jelly extract; the more added, the smaller the viscosity of the edible coating solution. The optimal...
viscosity value of the edible coating solution ranges from 113-225 cP [19]. Based on the results of this study, the best viscosity of edible coating solution was found in a solution with an additional concentration of 8% curry leaf extract concentration.

3.2. Characteristics of fresh coated strawberry

3.2.1 Weight loss. In this study, the weight loss of fresh coated strawberries ranged from 1.22 to 23.19%, with an average of 8.71%. The control weight loss was 33.33%. The results of the analysis of variance showed that the concentration of curry leaf extract had a significant effect (P≤0.05), and the dipping time had a very significant effect (P≤0.01) on the depreciation of strawberries.

Edible coating with 8% curry leaf extract can reduce the weight loss of fresh coated strawberries because the viscosity of edible coating is thicker compared than 10% and 12% (Figure 1a). Viscosity of the edible coating solution could influence the capacity of the solution to cover the fruit surface. Mahfudin et al. [24] illustrated that fruit weight loss increased with the decrease in viscosity of edible coating solution. Therefore, the thick solution will form a perfect and well spread layer for edible coating application on fruit surface. Otherwise, it will lead the oxygen to easily penetrate in high quantities and causes an increase in respiration [25].

Figure 1b, showed that edible coating with 4 minutes of immersion can reduce the most weight loss of strawberries. The longer dipping time, more increase the adhesion on the fruit surface so that it may damage the surface of the fruit. This is corresponding with the research of Hendrawan et al. [23], who stated that prolonged immersion of edible coating on strawberries with a concentration of green grass jelly extract causes the strawberry fruit to experience a high weight increase.

3.2.2 Total dissolved solid. In this study, strawberries' total dissolved solid (TDS) values before coating ranged from 5.2 to 5.6°Brix, and the TDS values after coating ranged from 5.2 to 6.6°Brix with an average of 5.82°Brix, while the control TDS value is 7.4°Brix. The concentration of curry leaf extract and period of dipping time had a very significant effect (P≤0.01) on the TDS value of fresh coated strawberries.
Interaction of using curry leaf extracts concentration of 12% with a dipping time of 4 minutes has the highest TDS value of 6.4°Brix. Meanwhile, curry leaf extracts concentration of 8% and dipping time of 6 minutes has the lowest TDS value of 5.4°Brix due to the dipping time of the edible coating, which can protect the strawberry surface against oxygen penetration. Furthermore, the respiration process can trigger the sugar formation, and the rate of increase in the TDS is inhibit the strawberries. The effect of dipping time speed can cause the strawberries are incompletely coated, and the use of high level of curry leaves extract concentration can generate the edible coating solution to have a low viscosity and induce bad last coating. However, all treatments of fresh coated strawberries had a lower total dissolved solids value compared to control strawberries. This research is in line with existing research, which stated the edible layer on the Tongka Langit banana is protect the fruits, and the respiration process is inhibit to triggers the formation of sugar [26].

3.2.3 *Total plate count.* The total plate count (TPC) is a method of estimating the total microorganism number (mold, yeast, bacteria) in an ingredient [27]. Knudsen et al. [28] stated that fresh strawberries might contain *Escherichia coli* and *Staphylococcus aureus* caused by cross-contamination from human hands, animal waste, soil, and water on strawberry fruit or leaves [29]. The total TPC analysis without curry leaf extract on fresh coated strawberries is ranged 0.1-9.7x10⁶ cfu/g. Meanwhile, the total TPC with curry leaf extract on fresh coated strawberries is ranged between 0.1-9.7x10⁶ cfu/g (Table 2).

| Treatment                  | 8% (4 min) | 8% (5 min) | 8% (6 min) | 10% (4 min) | 10% (5 min) | 10% (6 min) | 12% (4 min) | 12% (5 min) | 12% (6 min) |
|----------------------------|------------|------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Without curry leaf extract | 1.59 x 10⁶ | 3.4 x 10⁶  | 0.4 x 10⁶  | 9.9 x 10⁶   | 9.8 x 10⁶   | 10.9 x 10⁶  | 11.7 x 10⁶  |             |             |
| With curry leaf extract    | 0.3 x 10⁶  | 0.1 x 10⁶  | *          | *           | 7.4 x 10⁶   | 9.7 x 10⁶   |             |             |

Note: TBUD*>300 cfu/g

Table 2 shows that the highest reduction in microbes was found at curry leaf extract concentration 8% and dipping time of 5 minutes. These results indicate that the ability to prevent microbes is
performed with 8% of curry leaf extraction with a dipping time of 6 minutes. The longer dipping time of strawberries coating, the shorter contamination caused by microbes. Meanwhile, the use of curry leaf extract with a concentration of 12% and an dipping time of 4 minutes prevented the growth of microbes because of curry leaf extract concentration. The number of microbial colonies can be consumed on the fruit lower than 6x10⁶ cfu/g [30]. The results of the TPC analysis of edible coating on strawberries which safe for consumption are curry leaf extract concentration 8% with period of dipping time from 4-6 minutes and curry leaf extract concentration 10% with dipping time of 4 minutes.

3.2.4 Organoleptic characteristics. The color attribute of the fresh coated strawberries in this study ranged from 4.10-4.54 (neutral) with an average value of 4.28 (neutral). The results illustrated that curry leaves extract concentrations had a very significant effect (P≤0.01) on the color preference value of the strawberry with edible coating. The fresh coated strawberries with curry leaf extract concentration of 8% has a higher mean value (4.54) compared than 10% and 12%. Based on the transparency of the edible coating solution, curry leaves extract will increase the solution concentration and the color will become darker and reduced clarity due to the color of the extract used [31]. The value of transparency has impact on the fresh coated strawberries of panelist acceptance. This study showed that panelist preference is increase by dipping time. Panelist gives low score for fresh coated material in 4 minutes dipping time. Research is in accordance with Hendrawan et al. [23] where strawberries dipped in an edible coating solution for 5 minutes preferred for 4.15 (neutral) color. The color of fresh coated strawberry with long dipping time can fully cover red color of strawberry skin surface. In addition, the color also affects panelists perception of the fresh coated strawberries.

| Curry leaf extract concentration (%) | Dipping time (minutes) | Color | Aroma | Taste | Texture | Overall |
|-------------------------------------|------------------------|-------|-------|-------|---------|---------|
| 8                                   | 4                      | 4.64a | 4.26a | 4.18b | 4.36c   | 4.48c   |
| 8                                   | 5                      | 4.73a | 4.36a | 4.28b | 4.38c   | 4.75c   |
| 8                                   | 6                      | 4.27a | 4.13a | 4.21b | 4.24c   | 4.45c   |
| 10                                  | 4                      | 4.43a | 4.30a | 4.26b | 4.46c   | 4.52c   |
| 10                                  | 5                      | 4.16a | 3.97a | 3.85b | 3.81bc  | 3.92bc  |
| 10                                  | 6                      | 3.72a | 3.72a | 3.52ab | 3.43b   | 3.73b   |
| 12                                  | 4                      | 4.40a | 4.32a | 4.03b | 4.11c   | 4.35c   |
| 12                                  | 5                      | 4.15a | 4.08a | 4.35b | 4.18c   | 4.32c   |
| 12                                  | 6                      | 3.99a | 3.61a | 3.10a | 2.52a   | 3.24a   |

The aroma attribute of the fresh coated strawberries in this study ranged from 4.00-4.25 (neutral) with an average value of 4.08 (neutral). The results showed that the concentration of curry leaf extract had a very significant effect (P≤0.01) on the aroma score of fresh coated strawberry. Fresh coated strawberries with 8% curry leaf extract are a panelists favorite value, which has more preferred than the addition of 10% and 12%. The amount of curry leaves extract will affect the panelist acceptance score. The same trend is going with dipping time. Short dipping time give higher score for aroma (Table 3). Fresh coated strawberries with 6 minutes dipping time make the layer is thicker and give more aroma compared than fresh coated strawberries with 4-5 minutes dipping. The intense specific aroma of curry leaf will decrease the panelist preference score on fresh coated strawberries in this study. The previous study conducted by Hendrawan et al. [23] stated that the length of dipping time causes the fruit aroma to be less favorable.
The taste attribute of the fresh coated strawberries has an average value of 3.98 (neutral). The results showed that the interaction between curry leaf extract concentration and dipping time had a very significant effect (P≤0.01) on the taste of fresh coated strawberry. The interaction of using curry leaf extract 12% and 6-minutes dipping time has the lowest mean value of fresh coated strawberries taste hedonic score (Table 3). This occurred due to the interaction between the curry leaf extract with long dipping time. In addition, curry leaves have a slightly spicy, bitter taste and a weak sour taste [32]. So that curry leaf extract used in dipping solution will affect coated strawberries taste. Furthermore, long dipping time produces a thick layer of coated strawberries. The thick edible coating can accelerate the process of decay, speed up fruit maturity, and affect the fruit taste [33].

The texture attribute of the fresh coated strawberries is ranged from 2.52 (slightly disliked) – 4.46 (neutral). The results showed that the interaction between the curry leaf extract concentration and dipping time had a very significant effect (P≤0.01) on the texture of the strawberry’s edible coating. The panelist disliked fresh coated strawberries with curry leaf extract 12% - and 6-minutes dipping time. It turns out due to high amount of curry leaf extract used, low viscosity value and produce strawberries are not fully covered. The incompletely covered surface of strawberries increases air loss, fungal contamination, damaged fruit cells and accelerates the aging process. Furthermore, the aging process causes pectin hydrolysis and polymer degradation; hence, the strawberries hardness decreases [34]. According to research conducted by Hendrawan et al. [23] on edible coatings, strawberries with a period of 5 minutes dipping time had a favorite texture ranging from 3.10 (slightly disliked) - 4.05 (neutral) due to more extended dipping time to attach dipping solution to the surface of the strawberry skin.

The overall attribute of the fresh coated strawberries is ranged from 3.24 (slightly disliked) - 4.75 (somewhat liked). The interaction between curry leaf extract concentration and dipping time had a very significant effect (P≤0.01) on fresh coated strawberries. The panelists dislike curry leaf extract 12% and 6 minutes of dipping time (Table 3). The curry leaf extract and the higher dipping time were not favored overall by the panelists. With the increase of curry leaf extract and dipping time, the panelists may feel the strong taste of curry leaves. Based on existing research by Widaningrum et al. [35] who stated that citronella oil concentration in edible coating did not affect the panelist's preference value because only a tiny amount of extract was added [36].

4. Conclusion

Corn starch-based edible coating enriched with curry leaf extract has been efficient in reducing weight loss and total dissolved solids in strawberries compared to the uncoated control strawberries. Furthermore, the sample of all treatments received positive results in organoleptic properties (slightly liked - slightly disliked). Based on the characterization of edible coating solution with TDS, TPC, and organoleptic on strawberries can be formed that the best coating treatment is curry leaf extract concentration of 8%- and 4-minutes dipping time, which could be favorable to extend the shelf-life and maintain the quality of strawberry fruit.

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