Performance evaluation of cassava peels starch-based edible coating incorporated with chitosan on the shelf-life of fresh-cut pineapples (*Ananas comosus*)

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**Abstract.** Postharvest treatment is one of the important factors that affected the shelf-life of fresh-cut pineapples (*Ananas comosus*). Pineapples have a short shelf life, that is 2-3 days after harvest without cold storage. Recently, the application of edible coatings is widely used to extend the shelf-life of pineapples. The edible coating can be produced from alginate, starch, chitosan, or aloe vera as the main composition. In this study, it is purposed to prolonged the storability of pineapples using starch-based edible coating combined with chitosan. Starch is obtained from cassava peels because they contain 44-59% of starch. On the other hand, chitosan acts as a stabilizer and antimicrobial agent. Furthermore, glycerol is added as a plasticizer in order to increase the elasticity of the edible film. The edible coating was prepared using various compositions of starch and glycerol (in % w/v), then 1% w/v of chitosan dissolved in ascorbic acid was added to the solution. The fresh-cut pineapples were dip-coated into the mixture. Subsequently, they were stored in the refrigerator at 12°C. Physicochemical properties of cassava peels starch-based edible coating were examined by functional groups analysis, solubility analysis, and pH measurement. The results showed that chitosan-modified edible coating with 5% w/v of starch-0.6 ml/gr of glycerol can prolong the shelf-life of pineapples to 14 days. It had 58.46% solubility and 18% of increasing pH within 14 days. In addition, this variable obtained the highest score of overall acceptance in organoleptic evaluation, which was 5.47 out of 7.

1. **Introduction**

Nowadays, consumers in Indonesia prefer to consume fresh fruits or vegetables due to their awareness of the importance of healthy foods. Based on data from BPS [1] people have spent around 80% to consume fresh fruits and vegetables compared to that on rice in 2013. Fresh-cut fruits and vegetables are described as fruits or vegetables that have been altered physically but remains in a fresh state [2]. Indonesia is one of the highest producers of pineapples in ASEAN. However, fresh-cut pineapples can be stored for only up to four days in the refrigerator. Recently, one of the technologies to enhance the shelf-life of fresh-cut pineapples is by applying edible coating on it.

There are several main materials to produce edible coating, they are lipid, hydrocolloids (protein and polysaccharides), or resin [3]. In this study, the edible coating is prepared by cassava peels starch. Cassava peels are recognized as waste despite they contain 44-59% (dry basis) of starch [4]. Previously, several additives were poured into the starch-based coating solutions to improve the purpose of coatings.
Aloe vera, ascorbic acid, citric acid, and calcium lactate are examples of additives that have been developed to modify the starch-based edible coatings for fresh-cut pineapples [5][6]. A recent study, cassava peels starch is added by glycerol as the plasticizer. The advantage of glycerol is to increase the elasticity by reducing hydrogen bonding, hence shorten the intermolecular distance in the polymer. The composition of starch in the edible coating is proportional to glycerol addition. Hence, the best composition is evaluated to obtain the longest shelf-life. Furthermore, chitosan dissolved in ascorbic acid is also added to the various edible coating solutions as a variable. Beforehand, the adding of chitosan into corn starch-based films was studied [7]. The result showed that chitosan-modified film had a plasticizing effect, thus resulting in degradation resistance. It is purposed to obtain an edible coating that improves the shelf-life of fresh-cut pineapples by delaying the microbial growth, after comparing results between chitosan adding and no chitosan adding edible coatings.

2. Materials and Methods
Cassava peels and pineapples were obtained in a traditional market in Balikpapan, Indonesia. Chitosan (food grade, deacetylation degree is 87.5%, MW is 50,000-80,000 M/w) was purchased from Monodon, vegetable glycerol (food grade, 99.9% purity) was bought from TnT Chemical, ascorbic acid (food grade, 99.9% purity) was acquired from Fadjar Kimia, and distilled water.

2.1. Preparation of cassava peels starch
Cassava peels or cortexes were separated from the bark or periderm part. Peels were washed, then they were sun-dried for one hour. Water was added into dried peels with a weight ratio 1:1. The mixture was blended, filtered, and settled in sequence for 30 minutes. The sediment was filtered for the second time and it was dried in an oven at temperature of 50oC for six hours. The starch powder was analyzed by using Fourier Transform Infrared Spectroscopy (FTIR) to obtain the functional groups in it.

2.2. Application of edible coating on fresh-cut pineapples
There were two kinds of preparation for producing edible coating solutions, those were with and without additions of chitosan, with the total volume of the mixtures were 100 ml respectively. Cassava peels starch and water were mixed according to the variables (3 %w/v, 5 %w/v, 7 %w/v) based on the previous study [8] at a temperature of 70oC for around 45 minutes. Then, glycerol was added to the mixture. The preparation of another variable was by adding 50 ml of chitosan solution before pouring glycerol into cassava peels starch-water mixture [9]. Chitosan solution was made by dissolving 1 gr chitosan powder into 2 %w/v of ascorbic acid while stirring at a temperature of 40oC for 45 minutes. Furthermore, those two types of solutions were stirred for 20 minutes before they were homogenized in an ultrasonic bath at room temperature. Fresh-cut pineapples with size of 3 x 3 x 3 cm³ are dipped for two minutes into edible coating solutions. They were dried at room temperature for two minutes [10], afterward; they were stored in the refrigerator at a temperature of 12°C.

2.3. Performance evaluations of edible coating on fresh-cut pineapples
Edible solutions were cast on a petri dish, thereafter were dried in the oven at a temperature of 50°C for eight hours to obtain films [11]. This form was used as a sample in functional groups characterization and solubility testing. Functional groups of edible coatings were examined by FTIR. Solubility testing was performed using Gontard et al. [12]. Samples were cut with a size of 3 x 3 cm², subsequently were dried in an oven at a temperature of 100°C for 30 minutes. Afterward, samples were weighed before they were soaked into 30 ml of distilled water for 24 hours. The remaining parts of the films were dried in an oven at 100°C for two hours, and then they were weighted. Percentage solubility was calculated by the difference between the initial and final dry weight of films divided by the initial weight of films. The value of pH is the initial indication of microbial growth. This evaluation was conducted by measuring pH of mashed pineapples with and without coatings by pH meter within 14 days [13]. The effect of edible coating on the acceptance of panelists was assessed through organoleptic testing. The evaluation was applied based on Meilgaard et al. method [14]. The parameters included color, odor,
texture, taste, and overall acceptance of pineapples coated by cassava peels starch-based edible coatings. The organoleptic assessment had been held on the third day of coated pineapples storage time. The testing was applied to 30 untrained panelists with 1-7 of hedonic scale. The criteria of 1, 2, 3, 4, 5, 6, and 7 scales were very dissatisfied, moderately dissatisfied, slightly dissatisfied, neutral, slightly satisfied, moderately satisfied, and very satisfied respectively.

3. Results and Discussion
The edible coating can be recognized as a thin layer on the surface of fresh-cut pineapples by optical microscope with 10x magnification, as presented in Figure 1 (b).

![Figure 1](image_url)

**Figure 1.** The surface of pineapple (a) without coating and (b) with coating, as the coating layer is inside the red box.

The variables and the results are shown in Table 1. Variables A-I are modified by chitosan, while the rest are edible coating without the addition of chitosan. The color parameter was observed by visual comparison. Meanwhile, the coated pineapples were pricked by a toothpick to evaluate the texture. The adding of chitosan results in better physical features and a longer shelf-life of pineapples than the other treatments. This phenomenon corresponds to the ability of chitosan as an antimicrobial agent. In general, antimicrobial agent destroys the primary structures of microbes, like cell wall, cytoplasm, and ribosome, hence microbes run into protein denaturation. It consequences to enzyme inactivation of microbes, that metabolism of microbes is broken. This mechanism obstructs the microbial growth in the pineapples [15]. Based on a preliminary assessment, the best and the worst variables of chitosan-modified edible coatings are Variable D and Variable I respectively, while Variable O and Variable R are the best and the worst compositions from edible coatings without addition of chitosan. The texture was categorized as hard when there was no presence of water when the fruit was pricked by a toothpick. In this state, generally, the pineapples had a fresh or slightly sour odor. Fresh odor defined that the fruit still had pineapple special aroma, whilst slightly sour identified that pineapple aroma combined with sour. However, when the water comes out from pineapples while it was poked by a toothpick, the coated pineapple texture was classified as tender. The tender results were followed by a sour odor that was as strong as the odor of fermented cassava.
Table 1. The effect of edible coating on physical features and shelf-life of pineapples.

| Variables | Composition | Parameters |
|-----------|-------------|------------|
| A | 3 %w/v of starch, 0.6 ml/gr of glycerol, and chitosan | Browning in the 12th day | Hard | Fresh | 12 days |
| B | 3 %w/v of starch, 0.8 ml/gr of glycerol, and chitosan | Browning in the 12th day | Hard | Fresh | 12 days |
| C | 3 %w/v of starch, 1 ml/gr of glycerol, and chitosan | Browning in the 12th day | Hard | Fresh | 12 days |
| D | 5 %w/v of starch, 0.6 ml/gr of glycerol, and chitosan | Still fresh | Hard | Fresh | 14 days |
| E | 5 %w/v of starch, 0.8 ml/gr of glycerol, and chitosan | Browning in the 13th day | Hard | Fresh | 13 days |
| F | 5 %w/v of starch, 1 ml/gr of glycerol, and chitosan | Browning in the 13th day | Hard | Fresh | 13 days |
| G | 7 %w/v of starch, 0.6 ml/gr of glycerol, and chitosan | Browning in the 11th day | Hard | Fresh | 11 days |
| H | 7 %w/v of starch, 0.8 ml/gr of glycerol, and chitosan | Browning in the 11th day | Hard | Fresh | 11 days |
| I | 7 %w/v of starch, 1 ml/gr of glycerol, and chitosan | Browning in the 11th day | Hard | Fresh | 11 days |
| J | 3 %w/v of starch-0.6 ml/gr of glycerol | Browning in the 11th day | Hard | Slightly sour | 11 days |
| K | 3 %w/v of starch-0.8 ml/gr of glycerol | Browning in the 11th day | Hard | Slightly sour | 11 days |
| L | 3 %w/v of starch-1 ml/gr of glycerol | Browning in the 11th day | Hard | Slightly sour | 11 days |
| M | 5 %w/v of starch-0.6 ml/gr of glycerol | Browning in the 11th day | Hard | Slightly sour | 11 days |
| N | 5 %w/v of starch-0.8 ml/gr of glycerol | Browning in the 11th day | Hard | Slightly sour | 11 days |
| O | 5 %w/v of starch-1 ml/gr of glycerol | Browning in the 11th day, however, it has the brightest color | Hard | Slightly sour | 11 days |
| P | 7 %w/v of starch-0.6 ml/gr of glycerol | Browning in the 11th day | Tender | Sour | 11 days |
| Q | 7 %w/v of starch-0.8 ml/gr of glycerol | Browning in the 11th day | Tender | Sour | 11 days |
| R | 7 %w/v of starch-1 ml/gr of glycerol | Browning in the 11th day | Very tender | Sour | 11 days |

3.1. Functional groups analysis

Cassava peels starch was analysed using FTIR to confirm that starch was successfully extracted from cassava peels. The result in Figure 2 shows that cassava peels starch has the same dominant functional groups with general starch. The functional groups are O-H alcohol, C-H alkanes, and C-C. The appearance N-H functional group indicates that protein is also extracted from cassava peels.
The functional groups' analysis for Variable D and Variable I are provided in Figure 3. Strong absorbance of the functional groups is the same as the cassava peels starch ones. It is because starch is a dominant part of the edible coating solution. In addition, chitosan also contributes to the presence of N-H groups, as similar to glycerol contributes to the presence of O-H groups. Moreover, Figure 3 shows that Variables D and I have identical functional groups. Qualitatively, it indicates that the compositions of both variables were the same.

3.2. Solubility analysis
Cassava peels starch composition is proportional to the composition of glycerol. When the composition of both materials increases, it leads to the increasing of O-H groups. The higher O-H group quantity results in the edible coating to be more polar. This polarity increases the solubility of edible coating in water. It represents in Figure 4, that higher compositions of starch and glycerol in edible coatings have tendency to get higher solubility in water. All variables have solubility of more than 50%. It indicates that the edible coating can be consumed as a food product. Overall, there is no significant difference while chitosan is added into the mixture. It is because chitosan is a natural hydrophilic polymer [16], hence the addition of a small amount of chitosan has no great effect on solubility properties.
3.3. Measurement of pH

The increasing of pH in a certain system is an initial indication that bacteria can adapt to the environment. The spoilage bacteria, like proteolytic bacteria and gram-negative ones grow in an optimum pH of 6.5-7.5. However, those kinds of bacteria cannot grow in the acid environment, especially in acid food production. The increasing of pH is presented in Figure 5. It can be concluded that Variable D has the smallest change in pH value within 14 days. Ascorbic acid acts as a buffer and also stabilizer, hence it can keep the pH of pineapples increases around 18% for two weeks, compared to Variables O and without coating that pH increase 23% and 34% within 14 days, respectively.

3.4. Organoleptic testing

Figure 6 represents the organoleptic results of panelist satisfaction on the odor, texture, color, taste, and overall acceptance of several variables, like Variables D, I, O, and R. Panellist has a tendency to be satisfied on Variable D. In addition, chitosan dissolved in ascorbic acid has kept the natural color of pineapples. Browning is delayed due to obstruction of polyphenol oxidase by chitosan-ascorbic acid combination. The overall results show that chitosan modified edible coating is more satisfied than without chitosan variable. It is because antimicrobial and anti-browning materials have kept the texture of the pineapple still hard and the color is still fresh. These correspond to satisfying taste and odorless pineapples because there is no microbial metabolism. The highest overall acceptance is Variable D, while the lowest overall acceptance is Variable R. The results also have a pattern, that higher compositions of starch-glycerol obtain less satisfaction than lower compositions of that. It is mentioned because Variable D gets higher satisfaction than Variable I, like Variable O is more satisfying than
Variable R. This phenomenon is due to the O-H groups contributed by starch and glycerol increase by the higher compositions of starch-glycerol. The higher O-H compounds initiate the edible coating to be polar and it easily can be wet, hence spoilage bacteria can grow rapidly. It has been proved from Table 1 that Variable I and R are browning on the 11th days.

Figure 6. Organoleptic results of variables D, I, O, and R.

4. Conclusions
Variable O that contains 5 % w/v of starch-1 ml/gr of glycerol has ability to extend the fresh-cut pineapples shelf-life duration up to 11 days with 59.26% solubility. However, by adding chitosan into the solution, the shelf-life is longer than Variable O. Variable D is the best composition with a solubility result of 58.46%. It can prolong the shelf-life of pineapples to 14 days with a pH rise of 18% within those days. These results correspond to the highest overall acceptance obtained by Variable D, with approximately 5.46 out of 7 scales.

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