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Preface

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Proceeding

THE 4th INTERNATIONAL CONFERENCE ON FOOD SCIENCE AND ENGINEERING (ICFSE) 2022
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Preface

ICFSE is a biannual conference held by the Department of Food Science and Technology, Faculty of Agriculture, Universitas Sebelas Maret since 2016. This event is in collaboration with partner universities and/or organizations around the world. This conference covers the field of Food Science and Engineering. It aims to drive collaboration between scholars, practitioners, private sectors, and policy makers within the field. The conference is mainly supported bythe Department of Food Science and Technology, Universitas Sebelas Maret, Indonesia.

This proceeding contains the papers presented in the 4th ICFSE organized in 2022. The papers involve sessions on physical modification of foods, food chemistry and analysis, instrumental techniques for food analysis, food microstructure development and characterization, food properties including thermal, chemical, and mechanical properties, rapid detection of food contamination, macronutrient, micronutrient, and functional properties, chemistry of food additives and preservatives, food processing and engineering, food packaging, sustainable food production, food waste utilization, mathematical modeling and software development for food processing purposes, application of artificial intelligence in food engineering, food supply chain management system and food nutrigenomics for health.

We would like to thank all the participants attending this conference and also the committees for their contributions to this conference and its overall success. We would also like to thank the reviewers for their positive contribution to maintaining the quality of the articles presented in this proceeding.

Dimas Rahadian Aji Muhammad, Ph.D.

General Chair of the 4th ICFSE

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THE 4th INTERNATIONAL CONFERENCE ON FOOD SCIENCE AND ENGINEERING (ICFSE) 2022

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Preface

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The development of *Aloe vera*-based edible film with the addition of sago starch and glycerol for food packaging

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The development of *Aloe vera*-based edible film with the addition of sago starch and glycerol for food packaging

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Abstract. The edible film is a thin sheet material made of carbohydrates, protein or fat compounds. Research on the development of edible film is promising due to the increased plastic waste, which could disturb the environmental balance. The biodegradable nature of edible film provides an environmental-friendly material for packaging. Nevertheless, creating an edible film with similar properties to plastic will require extensive research. This research aims to develop *Aloe vera*-based edible film with the addition of sago starch as a texture enhancer and glycerol as a plasticizer and investigate the effect of different concentrations of sago starch on the physicochemical properties of edible film. In this research, six different concentration of sago starch was applied, which are 2.5%; 3%; 3.5%; 4%; 4.5%; and 5% (w/w). Each treatment was repeated four times. The result shows that the increase of sago starch concentration could increase the tensile strength and percent of elongation of edible film. On the contrary, the moisture content, water activity, and water vapor transmission rate (WVTR) were decreased. The range of tensile strength, percent of elongation, moisture content, water activity, and WVTR were 0.0254-0.4827 N/cm2, 46.67%-61,79%, 13.39%-16.65%, 0.559-0.636, and 5.6460-10.0810 g/m2/hour, respectively.

1. Introduction

The Plastic is the most commonly used packaging material because it can protect products from contamination, minimize quality changes, have flexible characteristic, is lightweight, and possess affordable price [1]. However, the enormous utilization of plastic harms the environment because plastic is responsible for increasing non-biodegradable waste [2]. Based on the National Waste Management Information System (2021), the amount of plastic waste in Indonesia is the second largest after food waste, with approximately 27,717 tons per year. The accumulation of plastic waste will disturb the environmental balance, creating the problem of microplastic and water and soil pollution [3]. Efforts that can be taken to decrease the risk of environmental damage due to plastic waste are developing biodegradable materials as plastic alternatives, such as edible film.

Edible film is a thin layer material that can be utilized as food packaging and consumed along with the packaged product [4]. The materials used to make edible films are economically inexpensive, biodegradable, and simple to be produced. Edible films can be made from polymers, which are categorized into three groups, which are hydrocolloids (proteins, polysaccharides, and alginates), fats (fatty acids, acylglycerols, and waxes), and composites of both [5]. The polymer can be decomposed, so it is environmentally friendly. *Aloe vera* is one of the hydrocolloids that can be used to produce edible film because it contains carbohydrate. Moreover, *A. vera* possesses high antioxidant and antimicrobial properties. Other components in *A. vera* are water, polysaccharides, amino acids, lipids, sterols, tannins, and enzymes [6]. Glucomannan is the polysaccharide in *A. vera* responsible for the ability to form a film. Glucomannan can bind a substantial amount of water, thus helping create a thin layer of film. Furthermore, glucomannan provides elasticity to the edible film [7]. Nevertheless, *A. vera* gel could not create a rigid characteristic of the film due to the limited number of substances responsible for constructing the structure. Therefore, *A. vera*-based film is commonly applied as an edible coating in various fruits and vegetables to prevent postharvest loss and prolong the shelf life of the commodities [8]. In order to increase the strength of *A. vera*-based edible film, compounds such as starch can be incorporated. Starch can act as a filler and matrix-forming substance in the edible film. Therefore, various starch such as cassava, corn, wheat and sago starch were widely reported as edible film ingredients [9]. Starch consists of two components, which are amylose and amylopectin. Amylopectin plays a role in the stability of edible films. Meanwhile, amylose plays a role in the compactness of edible films[10]

Sago starch that can be used to produce edible film has an amylose and amylopectin ratio of 27:73. Due to the high level of amylopectin, the edible film produced has a high permeability due to the effect of branched amylopectin structure [11]. In addition to amylopectin, sago starch has high amylose content (> 25%). Thus, it can produce a robust edible film because amylose can form hydrogen bonds among glucose molecules. When heated, it will form a three-dimensional network that can trap water. Due to starch retrogradation, high amylose content in sago starch incorporated into *A. vera*-based edible film will form a compact and stiff edible film [12]. An excessively firm edible film structure negatively affects the elasticity of the film. It can easily crumble when folded to create a packaging design. Therefore, adding plasticizer is crucial to improve the characteristics of edible films.

The presence of plasticizers will reduce the affinity of intra-molecular bonds among starch structures by forming hydrogen bonds between starch and plasticizers to improve the mechanical properties of edible films [13]. A plasticizer is an organic material with a low molecular weight that is applied to increase the flexibility of the polymer [14], such as glycerol and sorbitol. The capability of the hydrophilic group of glycerol to bind water is better than sorbitol. Therefore, the inclusion of glycerol in the edible film system could produce plastic-like film due to the ability to retain the moisture content in the edible film. Research on *A. vera* as an edible fruit and vegetable coating is widely reported. Meanwhile, the development of starch-based edible film using tapioca and corn starch are previously established. However, limited research is available on the inclusion of sago starch in the formulation of *A. vera*-based edible film enriched with glycerol. Therefore, this research aims to determine the effect of different concentrations of sago starch on the physicochemical properties of *A. vera*-based edible film using glycerol as a plasticizer.

2. Materials and Methods

2.1. Materials

A. vera was grown in Madiun District, East Java, and purchased Han Indo Jaya a national *A. vera* supplier in Sidoarjo District, East Java Province, Indonesia. The *A. vera* was harvested at six months, possesses a clean green skin color, is approximately 45±4.5 cm long, weighs around 350±35 g for each rind, and has the absence of injury on the surface of the rind. Meanwhile, the sago starch was purchased from the local market in Surabaya, and glycerol was obtained from Sigma Aldrich (Singapore).

2.2. Edible film preparation

Materials used in the formulation of *A. vera*-based edible film were *A. vera* gel, sago starch and glycerol. The formulation of ingredients is presented in Table 1. First, the *A. vera* rind was washed to remove the impurities. Then, trimmed, and the thick outer skin was peeled. Next, the gel fraction was washed with warm water to remove the yellow sap. The gel was then crushed using a blender and filtered through 80 mesh sieves to separate the gel from the solid fraction. The gel was then heated in an iron cast pot using a stove at 80 °C for 5 min. After heating, the *A. vera* gel was allowed to cool to room temperature. Next, the *A. vera* gel, sago starch, and glycerol were placed in a beaker according to the formulation and gently stirred until a homogenous mixture was achieved. The mixture was then heated on a stove at 75 °C, kept for 3 minutes, and then cooled at room temperature until it reached 50 °C. After that, 25 g of the mixture was placed in a tray and spread uniformly in the size of 10 x 10 cm wide and 0.05 cm thick. The tray was placed in an air-conditioned room (18 °C) for 30 h. After completely drying, the film was removed from the tray, placed in polypropylene plastic, and stored until further used.

Table 1. Formulation of *A. vera*-based edible film

Materials	F1	F2	F3	F4	F5	F6
A. vera gel (g)	195	194	193	192	191	190
Sago starch (g)	5	6	7	8	9	10
Glycerol (g)	3.7	3.7	3.7	3.7	3.7	3.7
Total (g)	203.7	203.7	203.7	203.7	203.7	203.7

Note: The concentrations of sago starch (F1: 2.5%; F2: 3%; F3: 3.5%; F4: 4%; F5: 4.5%; and F6

2.3. Moisture content
The method used to analyze the moisure content of *A. vera*-based edible film was thermogravimetric [15]. In brief, the edible film was cut, and 0.5 g of the sample was put in a weighing bottle. The sample was then placed in the drying oven at 105 °C for 2 h. After that, the sample was cooled in a desiccator for 10 minutes before weighing. Repeat the step until the constant weight of the sample was achieved. Finally, the sample's moisture content is expressed as the moisture percentage within the sample.

2.4. Water Activity
The water activity of *A. vera*-based edible film was measured using an Aw meter (HygroPalm AW1, Rotronic AG, Switzerland) [16]. Briefly, the edible film was cut into small pieces. 5 g of the edible film was placed in the specific chamber for the equipment. The machine was started and calibrated. Placed the chamber in the equipment, stored it, and let the equipment read the Aw value of the edible film.

2.5. Water Vapor Transmission Rate (WVTR)
The WVTR determination was conducted according to previous method [17]. A total of 5 small glass chambers for each treatment were weighed to determine the initial weight of the glass. After that, 10 g of silica gel was put into the glass chamber. The mouth of the glass chamber was sealed using an edible film sample. The sealed glass was placed in the desiccator containing saturated sodium chloride solution. The edible film lid was removed every hour for 5 hours. Silica gel inside the glass chamber was removed, placed in a plastic container, and weighed. After that, the difference between the initial weight of silica gel and its final weight was determined. The data obtained were then analyzed using linear regression, and the slope was computed. The water vapor transmission rate was calculated using the following formula

$WVTR = slope$ of the difference in weight of silica gel (g/h)/area of the mouth of the glass (m_2)

2.6. Tensile Strenght and Percentage of Elongation
The experiment was conducted according to the ASTM D-882 method [18], the standard method to examine the tensile characteristic of plastic film. A texture analyzer equipment was used to measure the tensile strength. In brief, the sample was prepared by cutting the edible film into 145 x 10 mm size, and then each tip of the sample was clipped into the machine, and the machine will then drag the edible film in the opposite direction. The tensile strength of the edible film is calculated as the force needed to drag it until it breaks. Meanwhile, the elongation is the percentage of edible film length difference before and after being dragged by the texture analyzer.

2.7. Statistical Analysis

This research has 6 treatments, and each treatment was repeated four times. Data were analyzed using Analysis of Variance in α=5% and Duncan Multiple Range Test (DMRT) to determine which treatments are significantly different. The statistical analysis was conducted using SPPS ver 23. The data were presented as means ± standard deviation.

3. Result and Discussion

3.1. Moisture content

The results of moisture content determination of *A. vera*-based edible film with different concentrations of sago starch (F1-F6) were in the range of 13.39%-16.65%. Further analysis revealed a significant difference in the effect of sago starch concentration on the edible film's moisture content. The effect of sago starch concentration on the moisture content of *A. vera*-based edible films with the addition of glycerol can be seen in Figure 1.

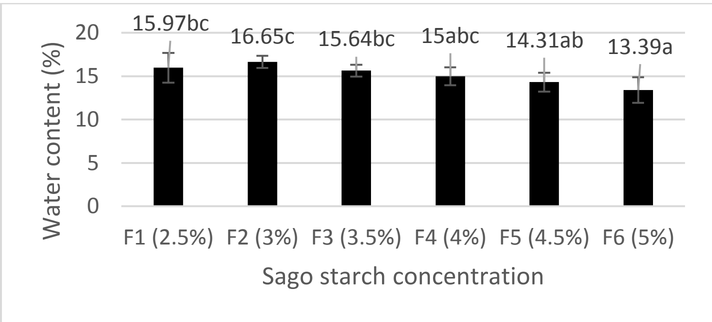

Figure 1. The moisture content of *A. vera*-based edible film

Based on Figure 1, the moisture content of the edible film tends to decrease along with the increase in the concentration of sago starch. The moisture content of edible film at 5% sago starch concentration was not significantly different from 4% and 4.5% sago starch concentrations (F4 and F5) but significantly different from 2.5%-3.5% sago starch concentrations (F1-F3). The difference is because, at 5% sago starch concentration (F6), the amount of water from the *A. vera* gel absorbed in the starch structure during gelatinization is higher due to the starch network activity to entrap water. The edible film was let dry at room temperature for 30 h. This process provides sufficient time for the edible film to dry and experience further retrogradation. In this process, a substantial amount of water is evaporated. Therefore, the moisture content in edible film in the F6 treatment is lower. At the concentration of sago starch 2.5%-3.5% (F1-F3), the amount of *A. vera* gel available in the formulation was higher compared to edible film with 5% sago starch concentration (F6), so the final moisture content at the concentration of 2.5%-3.5% (F1-F3) was higher and significantly different from the 5% sago starch concentration (F6). The phenomena could be due to *A. vera*, which contains glucomannan, a hydrocolloid, so it has better water binding ability [12]. It thus could absorb a substantial amount of water. Therefore, when the edible film was air dried at room temperature, the moisture content was retained in the film, thus resulting in higher moisture content.

The variation of starch concentration influencing the number of starch-glucomannan bonds formed leads to significant differences in the moisture content of the edible film, thus affecting their characteristic. For example, the edible film with a sago starch concentration of 2.5% (F1) has better characteristics than the 5% sago starch concentration (F6). Glucomannan contained in edible films has a vital role in binding and trapping water, thus could inhibit the transfer of water vapor from the environment to the product and vice versa. Edible film with a higher proportion of *A. vera* gel or a lower concentration of starch experienced a low rate of water evaporation. Therefore, the moisture content of the edible film is higher [19]. The results of this experiment are also supported by previous work by

Pinzon et al. [20]. They investigated the effect of starch incorporations on the characteristics of *A. vera*-based edible films. Increasing starch concentration in the edible film formulation will reduce the product's moisture content. The higher starch concentration increases the polymer available and gel viscosity during heating. The increasing number of polymers leads to the high absorption of water. The water available will then evaporate during the drying of edible film, resulting in a decrease in the moisture content. Based on the JIS standard [21], the maximum moisture content of the edible film is 13%. The *A. vera*-based edible film produced in this experiment had a moisture content ranging from 13.39%-16.65%. Therefore, the moisture content of *A. vera*-based edible film with different concentrations of sago starch produced is still higher than the existing standard.

3.2. Water Activity

A. vera-based edible film's water activity (Aw) results ranged from 0.559-0.636. The results were analyzed using ANOVA (α=5%), which shows a significant difference in the effect of the concentration of sago starch on the water activity of the edible film. The analysis was then continued with the DMRT test (α=5%), presented in Figure 2. The result shows that the lowest water activity value of the edible film was at 5% sago starch concentration (F6). The water activity tends to decrease when the starch concentration increases due to an increase in the amount of water bound to starch during gelatinization. During starch gelatinization, hydrogen bonds are broken so that more water will be absorbed by the starch granules, which is indicated by an increase in the viscosity of the gel mixture. Sago starch has approximately 35-38% amylose content [22]. Therefore, edible films with higher concentrations of sago starch will produce a physically dried film due to the retrogradation of gelatinized starch. At a lower concentration of sago starch, the amount of water bound to the starch is less than that of a more significant starch concentration so that at a similar drying time, it will produce high moisture content edible film due to the free water available.

Moreover, hydrocolloids added to the edible film formulation would reduce the product's water activity [23]. A study on the effect of sago starch concentration on the characteristic of products suggested that the increase of starch concentration leads to a decrease in the water activity of the products [24]. The lower water activity value in edible films indicates that there is limited free water available in edible films. Therefore, the lower Aw value could prolong the shelf life of the edible film. On the other hand, the higher water activity value increases the susceptibility of edible films to microorganism growth due to free water. Based on the results, *A. vera*-based edible film with various concentrations of sago starch has a water activity value higher than 0.6 as a critical Aw value for moulds, so proper cautions must be applied in the storage of the edible film.

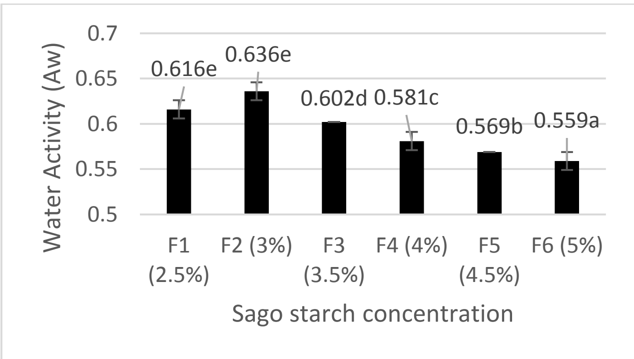

Figure 2. Water activity of *A. vera*-based edible film

3.3. Water Vapor Transmission Rate (WVTR)

The water vapor transmission rate (WVTR) was examined based on the changes in the weight of silica gel placed in a shot glass protected by *A. vera*-based edible film [25]. The WVTR aims to determine the permeability of edible films to water vapor in order to investigate its potential to be used as food packaging. It is crucial to measure the WVTR because the water transmission rate of edible films can affect the shelf life of packaged products.

The results of the WVTR test of *A. vera*-based edible film with various concentrations of sago starch (F1-F6) and glycerol ranged from 5.6460-10.0810 g/m2/hour. The results of this WVTR test were analyzed using ANOVA (α=5%), which shows a significant difference in the effect of the concentration of sago starch on the WVTR of edible film. The analysis was then continued with the DMRT test (α=5%). The result of WVTR of *A. vera*-based edible films can be seen in Figure 3. The highest WVTR was achieved by the 2.5% and 3% of sago starch concentrations (F1-F2), and the lowest transmission rate was obtained by 4.5% and 5% of sago starch concentrations (F5-F6). The results show that the increase of sago starch concentration leads to the decrease of WVTR.

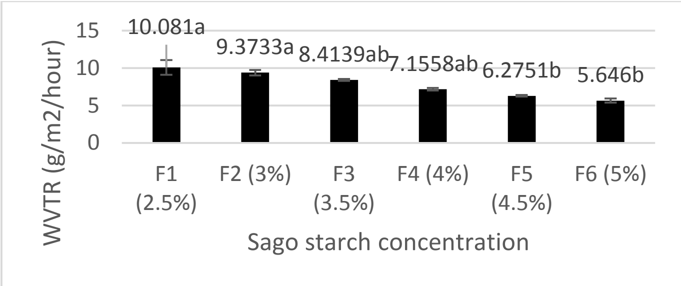

Figure 3. Water Vapor Transmission Rate (WVTR) of *A. vera*-based edible film

The amount of amylose and amylopectin influences the WVTR in the edible film. Based on the formulation, the increase in the concentration of sago starch was accompanied by a decrease in the *A. vera* gel so that the solids content in the mixture of 5% sago starch concentration treatment (F6) was the highest. The amylose content creates a network using hydrogen bonds to form a rigid structure. The presence of amylopectin that binds to glucomannan of *A. vera* plays an essential role in reducing the WVTR by forming a cross-linking network to minimize the exposure of amylopectin hydrophilic groups [26].

Meanwhile, Siskawardani et al. [27] examined the characteristics of edible films made of gembili tuber starch and *A. vera*. Zheng et al. [28] investigated the characteristics of edible films from starch and chitosan. Both studies showed that low concentrations of sago starch increase the WVTR, while the WVTR decreased with the increase of starch concentration. The presence of hydrogen bonds and cross-linking network at high concentrations of sago starch produces a rigid structure-edible film, causing a decrease in permeability. WVTR of edible films F1-F4 is higher than the JIS standard, while for F5 and F6, the WVTR is lower than the Japanese Industrial Standard (7 g/m2/hour) [21].

3.4. Tensile Strength and Percentage of Elongation

The results of the tensile strength ranged from 0.0254-0.4827 N/cm2. Based on the analysis of variance (α=5%), a significant difference was observed and the analysis continued with DMRT. The result is presented in Figure 4. The highest tensile strength of the edible film was at 5% of sago starch concentration treatment (F6), and the lowest tensile strength was at 2.5% and 3% sago starch concentrations. The higher concentration of sago starch increased the tensile strength.

The tensile strength of edible films is influenced by two factors: the amount of amylose presents in the starch and the amount of glucomannan that interacts to form a cross-linking network with amylopectin. The higher starch concentration in edible film formulation provides more amylose so that the number of hydrogen bonds increases and can improve the tensile strength of edible films due to the strong hydrogen bonds formed [29]. The cross-links formed between amylopectin and acetyl groups in glucomannan also increase the edible film's tensile strength due to its solid and flexible properties.

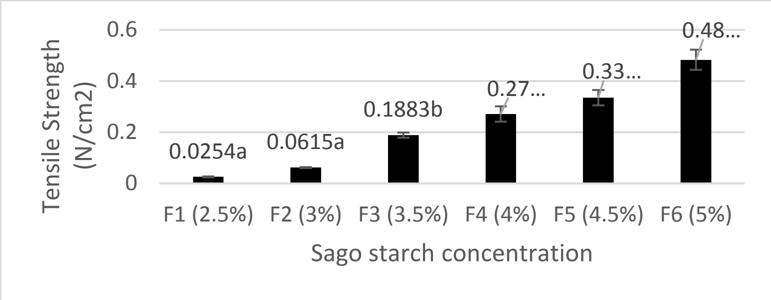

Figure 4. Tensile strength of *A. vera* based edible film

The results follow the previous work by Purnavita et al. [30] on the bioplastic characteristics of starch and glucomannan, as well as work by Zheng et al. [28] on the characteristics of edible films from starch and chitosan. Both studies showed that a low starch concentration had a lower tensile strength and would improve with the increase of sago starch concentration. Based on the Japanese Industrial Standard, the standard value of the tensile strength of edible films is at least 30 N/cm2 (0.3 Mpa). Therefore, the tensile strength in *A. vera*-based edible films was still below the JIS standard.

Meanwhile, the principle of elongation measurement is to determine the optimum length of the edible film to a certain point before it breaks. The elongation test is essential because of the need to produce flexible edible film packaging. The results show that the percent elongation ranged from 46.67-61.79% (Figure 5). The percent elongation of the edible film at a concentration of 3.5% to 5% (F3-F6) was not significantly different. The higher concentration of sago starch tends to increase the percentage of edible film elongation [29]. The elongation percentage of an edible film with 2.5% sago starch concentration was not significantly different from the 3% of the edible film with the lowest elongation percentage. Purnavita et al. [30] suggested that the higher content of amylose accompanied by the presence of glycerol in the edible film will produce a more flexible and robust film. In addition, cross-linking between glucomannan and amylopectin also plays a role in shaping the flexibility of the film. The number of polysaccharides that form the edible film determines its stretchability. The higher the polysaccharides present, the higher the film's resistance to fracture. Meanwhile, glucomannan and amylopectin will form a cross-linking network, and the presence of bonds between the hydroxyl groups on amylose and glycerol will improve the flexibility of the edible film. Based on the Japanese Industrial Standard, the standard value of the percent elongation of the edible film is less than 10% indicating an unfavorable elongation characteristic. Therefore, the percent elongation higher than 50% can be considered a suitable material. Compared to the JIS, *A. vera*-based edible films produced at 2.5%-5% sago starch concentration could be categorized as excellent material.

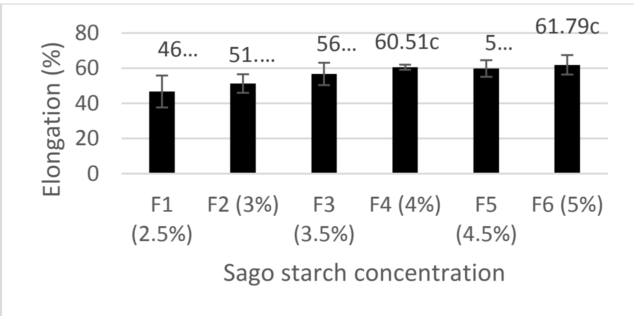

Figure 5. Percentage of Elongation of *A. vera* based edible film

4. Conclusions

Different concentrations of sago starch in the production of *A. vera*-based edible films with the addition of glycerol had a significant effect on moisture content, water activity (Aw), water vapor transmission rate (WVTR), tensile strength (tensile strength), and percentage of elongation. For example, sago starch with concentrations of 2.5% to 5% tends to reduce the water content, water activity, and WVTR of *A. vera*-based edible film. On the other hand, the tensile strength and percentage of elongation were increased. Based on the result, *A. vera* gel could be used to produce the edible film by adding other hydrocolloids to improve its characteristics.

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