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Correlation Study on Type and Concentration of Antimicrobial Materials on the Quality of Starch-Based Edible Film

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Abstract :
The purpose of this study was to determine the correlation between antimicrobial materials and several parameters of edible film quality, obtain edible film quality parameters that are likely to be affected by the use of antimicrobial materials, and determine the types of antimicrobial materials that can be used in making of starch-based edible film and their effect on the characteristics of edible film. The data used in this study were secondary data obtained from searching scientific publications. The data that were analyzed for correlation were the data on the type and concentration of antimicrobial materials and the parameters of edible films, namely water vapor transmission rates (WVTR), thickness, solubility, elongation, tensile strength, and moisture content. Pearson's correlation was applied in the statistical analysis using SPSS 25 statistical software application. The research showed that there was a moderate correlation between the type of antimicrobial substance and WVTR and thickness of edible film. There was also a moderate correlation between the concentration of antimicrobial substance and the solubility of edible film. No correlation (level of correlation was either low or very low) was found between both types and concentration of antimicrobial substances and the elongation, tensile strength, and moisture content. Water vapor transmission rate, thickness, and solubility are parameters of edible film quality that are likely to be affected by the use of antimicrobial materials. White turmeric filtrate with a concentration of 0.8% is better type and concentration of antimicrobial material for use in making cassava starch-based edible films compared to other antimicrobial materials because it affects thickness value, as well as decrease in the value of WVTR and tensile strength.

Keywords: Antimicrobial Material, Edible Film, Concentration, Starch, Type.

1. Introduction

Packaging is one thing that is widely used in all aspects of life, especially in the food sector. Plastic is one of the packages with the highest level of use in society (Handayani and Nurzanah, 2018) and reaches 80% of total packaging in the Indonesian food industry (Nasution, 2015). The high level of use of plastic packaging is due to the nature of plastic which is flexible, transparent, resistant to water vapor, easy to find, light, and relatively cheap (Muin et al, 2017). However, plastic packaging is generally made from synthetic polymers which have several weaknesses, including being difficult to biodegrade, and can react with food ingredients when packaged hot, which can have a negative impact on health (Sholehah et al, 2016). Synthetic plastic packaging can decompose within 200-400 years, and takes up to 1000 years to decompose completely (Muin et al, 2017). Plastic packaging that is difficult to decompose naturally can cause a buildup of plastic waste which has an impact on environmental damage and pollution.

Environmentally friendly packaging made from natural materials is an alternative to reduce the level of environmental pollution due to the accumulation of synthetic plastic waste. Not only is it environmentally friendly, plastic from natural materials has also been developed into active packaging. Active packaging is an innovation in packaging technology which has the concept of combining certain active ingredients into the packaging system so that they can react with the product being packaged or the environment so that it can extend the shelf life of food products while also being able to decompose naturally in the environment (Anwar, 2019). According to Utami., et al (2013), active packaging that can be eaten directly with the packaged product or known as edible packaging is divided into 2 types, namely edible coating (in layer form) and edible film (in sheet form).

Polysaccharides such as starch are often used in making edible films. The use of starch as a material for making edible films is because starch is renewable, easy to obtain, has the advantage of protecting products from oxygen, carbon dioxide, fat, and adds to the unity of the film structure (Anandito et al., 2012). Starch used in making edible films also has disadvantages, namely low water strength and high water vapor transmission because starch is hydrophilic (Supeni et al., 2015). The hydrophilic nature of starch causes the intermolecular tension in the edible film matrix to decrease which results in the space between the molecules becoming larger so that water vapor and microbes can enter the edible film (Fatnasari et al., 2018). The addition of antimicrobial substances in making edible film is also a form of active packaging properties to extend the shelf life of the product and inhibit the growth of microorganisms that cause damage to the product (Iriani et al., 2014).

There are several types of antimicrobial ingredients that can be mixed into making edible films, including essential oils, spices or plants in powder form or oleoresin, chitosan, and bacteriocin (Muin et al., 2017). Several studies show that the types of antimicrobial ingredients added to edible films have activity in inhibiting the growth of pathogenic microorganisms or spoiling food products. In several studies, the addition of antimicrobial ingredients to edible films not only plays a role in inhibiting the growth of microorganisms, but also has an influence on the characteristics of the films produced (Wu et al., 2017). According to research by Syaichurrozi., et al (2012), the addition of turmeric and garlic powder affects the characteristics of canna starch edible film, namely causing a decrease in water content, tensile strength and percent elongation of the film but does not affect the film thickness. The interactions that occur between the active compounds contained in antimicrobial materials and the polymers that make up edible films can influence the characteristics of the films produced.

This research aims to determine the correlation between antimicrobial materials and several edible film quality parameters, obtain edible film quality parameters that are likely to be influenced by the use of antimicrobial materials, and determine the types of antimicrobial materials that can be used in making edible films and their influence on the characteristics of edible films.

2. Research Methods

Research Design

This research was designed using the Systematic Literature Review (SLR) method, a systematic, clear and comprehensive literature study by identifying, evaluating and collecting existing research data.

Sources and Methods of Data Collection

The data used in this research is secondary data obtained through searching scientific publications. This research data comes from the results of research that has been carried out and published in scientific publications at both national and international levels, which can be in the form of journals, theses, theses, dissertations and various scientific articles whose source content is relevant to the research or study being carried out. Scientific searches were carried out on the ScienceDirect, Researchgate, and Google Scholar databases. The keywords used in research article searches were "edible film", "starch", "type", "concentration", and "antimicrobial ingredients".

Data Collection

The research was carried out by screening based on predetermined criteria. The inclusion and exclusion of article data collection criteria can be seen in Table 1.

Data Analysis

The data obtained was then analyzed using Pearson's Correlation. Pearson correlation analysis is used to measure the closeness of the relationship between two or more variables. This analysis was carried out to find out whether there was a relationship between the type and concentration of antimicrobial ingredients on edible film parameters and to find out how strong this relationship was. Data analysis in this research uses the help of a statistical software application, namely SPSS 25 (Statistical Package for the Social Science version 25). The analytical approach in this research uses a quantitative descriptive approach.

The closeness of the relationship or correlation between these variables is determined based on the values of the KK as a reference. KK or correlation coefficient is an index or number used to measure the degree of relationship, including the strength of the relationship and the shape/direction of the relationship. The strength of the relationship from the correlation coefficient value is between +1 and -1. The shape/direction of the relationship from the correlation coefficient value is expressed as positive (+) and negative (-), or ($-1 \leq KK \leq +1$) (Misbahudin and Hasan, 2013).

Table 1. Inclusion and exclusion criteria for collecting scientific articles.

Criteria	Inclusion	Exclusion
Time period	The last 10 years starting from 2011 to 2021	Under the last 10 years
Language	Indonesian and English	Apart from Indonesian and English
Subject	Antimicrobial ingredients and edible film characteristics	Not about antimicrobial ingredients and edible film characteristics
Article type	- Original articles, such as journals, proceedings, theses or theses. - Articles in full text form. - There is a link between articles regarding the type and concentration of antimicrobial ingredients on the characteristics of edible film	- Not a research article. - Articles are not in full text form. - There is no link between articles regarding types and the concentration of antimicrobial ingredients on the characteristics of edible films.
Contents of the article	- The formulation of the use of materials and methods used is quite clear. - There is a minimum of 1 parameter for testing the characteristics of edible film - Research results data are reported clearly in the form of numbers in results tables or graphs	- The formulation of the use of materials and methods used is not clear enough. - There are no suitable parameters for testing edible film characteristics - Components used other than starch, glycerol and antimicrobial ingredients - Research data is reported unclearly, not in the form of numbers, only graphs

Table 2. Interval of correlation coefficient values and strength of relationship.

No.	Value Interval	The Power of Relationships
1.	KK= 0.00	There is no correlation
2.	$0.00 < KK \leq 0.20$	Very low or very weak correlation
3.	$0.20 < KK \leq 0.40$	Weak or low correlation
4.	$0.40 < KK \leq 0.70$	Moderate or fair correlation
5.	$0.70 < KK \leq 0.90$	High or strong correlation
6.	$0.90 < KK < 1.00$	Correlation is very high or very strong
7.	KK = 1.00	Perfect correlation

Ref: Misbahudin and Hasan (2013).

3. Results and Discussion

Starch Based Edible Film

Edible film is a type of primary packaging that is environmentally friendly because it is made from materials that can be decomposed by the environment and can be eaten directly with the packaged product because it is made from certain natural ingredients. Apart from that, edible film has the ability to act as a carrier for certain substance components such as antimicrobials, antioxidants and other food additives (Huri and Nisa, 2014).

The main groups of ingredients in making edible films are polysaccharides, proteins and hydrocolloids. According to Kusumawati and Putri (2013), the class of polysaccharides that have the potential to be used as raw material for edible films is starch. This polysaccharide-based edible film has a role as a selective permeable membrane for O2 and CO2 gases to reduce the respiration rate. Several applications of edible films made from polysaccharides can be used to prevent dehydration, fat oxidation and enzymatic browning, and reduce respiration rates (Moulia, 2018). Apart from that, edible film made from polysaccharides can also improve flavor, texture and color, increase stability during storage and reduce the level of spoilage (Kroctha and Johnston, 1997).

The types of starch used in several research articles obtained are natural starch such as tapioca starch, corn starch, canna starch, bentul starch, millet starch, banana starch, potato starch, arrowroot starch, and taro starch, as well as modified starch, namely wikao starch. maombo. The amylose and amylopectin molecules in each starch play a role in forming the characteristics of edible films. Edible films made from starch with high amylose content are less transparent, have low strength and elasticity, but have high density. On the other hand, with high amylopectin levels, edible films are transparent, have high strength and elasticity, but have low density. The ratio of amylose and amylopectin greatly determines the characteristics of starch-based edible films. Therefore, the characteristics of the edible film produced by each type of starch are different, depending on the levels of amylose and amylopectin (Santoso, 2020).

Several types of starch in the research article obtained have the potential to be used as the main ingredient in making edible films. The minimum value of starch content based on industrial starch quality is 75% (Widowati et al., 1997). Based on dry basis starch content, arrowroot tubers have a greater starch content, namely 98.1% (Abun, 2018) compared to cassava starch, namely 96.04% (Andarwulan et al., 2021), canna starch, namely 55.32% (Lathifa , 2013), corn starch 86.7% (Utomo et al., 2017), bentul starch 77.69% (Astuti et al., 2017), millet starch 66% (Al-Hashimi et al., 2020), starch potato starch 75% (Hui, 2006), taro starch 88.93% (Ulfiasari et al., 2021), and wikao maombo starch 27% (Mutakabbir et al., 2020), so millet starch, canna starch, and wikao maombo starch does not meet industrial starch quality standards.

Cassava starch is a starch that has the potential to be used as a raw material for making edible films compared to other types of starch. This is because cassava starch contains the highest amylose content, namely 35.45% compared to the amylose content in other types of starch. According to Purwitasari (2001), the selection of good starch to use in making edible film is determined by the amylose content. The results of research conducted by Yulifianti and Ginting (2009) regarding the physical characteristics of edible film produced from several tuber starches showed that cassava starch with the addition of glycerol gave relatively high yields compared to arrowroot starch, canna starch and sweet potato starch in terms of brightness. color L* 81.5, thickness 0.03 mm, tensile strength 0.88 N, and elongation 2.0%.

Antimicrobial Edible Film

Based on the 16 research literature obtained, research has been carried out regarding the addition of antimicrobial ingredients to starch-based edible film packaging systems, including kaffir lime leaf essential oil, cinnamon leaf oleoresin, gambier filtrate, papaya leaf filtrate, kenikir extract, turmeric filtrate white, clove essential oil, olive extract, lemongrass essential oil, rosemary essential oil, lavender essential oil, black cumin oil, oregano oil, beluntas leaf extract, cinnamon oil, Zanthoxylum bungeanum essential oil, white turmeric filtrate, lemongrass extract, turmeric ethanol extract , as well as galangal essential oil.

The addition of antimicrobial ingredients in the form of clove essential oil in making films from millet starch produces film characteristics with the best concentration, namely 3%, where there is an increase in film thickness values, and a decrease in solubility, elongation and tensile strength values. A film thickness value of 0.150 mm and a tensile strength value of 6.25 MPa are characteristics of millet film that meet the JIS 1975 standards.

Based on the 5 research articles obtained, the addition of antimicrobial ingredients in making films from corn starch produces film characteristics with the best concentration, namely, where the concentration of Zanthoxylum bungeanum essential oil is 2%, olive extract 0.2%, beluntas leaf extract 20%, gambier filtrate 2 .5% & 2.5% papaya leaf filtrate, 2% black cumin oil, and 2% oregano oil, resulting in characteristics namely an increase in thickness values, as well as a decrease in solubility, elongation and film water content values for each material, as well as increasing the WVTR value when adding gambier filtrate and papaya leaf filtrate. The thickness value is 0.285 mm; 0.11mm; 0.16mm; 0.174mm; 0.11mm; and 0.11 mm obtained from the addition of each ingredient and a wvtr value of 0.88 g/m2/hour with the addition of gambier filtrate and papaya leaf filtrate are film characteristics that meet JIS 1975 standards in Widodo., et al (2019).

The addition of antimicrobial ingredients in the form of gambier filtrate and kenikir extract in making films from canna starch produces film characteristics with the best combined concentration, namely 2.5% gambier filtrate and 2.5% kenikir extract, with an increase in WVTR and thickness values, as well as a decrease in film elongation values. The wvtr value is 0.90 g/m2/hour and a film thickness value of 0.12 mm are characteristics of canna starch film that meets the JIS 1975 standard.

Based on the 3 research articles obtained, the addition of antimicrobial ingredients in making cassava starch-based films produces film characteristics with the best concentration, namely cinnamon oil concentration of 2.5% & sodium bentonite 0.75%, kaffir lime leaf essential oil 2%, and leaf oleoresin. cinnamon is 1%. The addition of belly orange leaf essential oil caused an increase in the thickness value, as well as a decrease in the WVTR value, solubility and water content of the film. Addition of cinnamon leaf oleoresin to the manufacture of cassava starch based edible film causes an increase in the value of wvtr, elongation, and tensile strength, as well as a decrease in the value of film thickness. The elongation value is 72.79% and the tensile strength is 0.51 MPa which is obtained by adding cinnamon oil & sodium bentonite, then the wvtr value is 0.29 g/m2/hour and the thickness is 0.16 mm which is obtained by adding orange leaf essential oil. kaffir lime, as well as a thickness value of 0.13 mm and an elongation of 283.27% obtained by adding cinnamon leaf oleoresin are film characteristics that meet the JIS 1975 standard in Widodo., et al (2019).

The addition of the antimicrobial ingredient lavender essential oil in making films from potato starch produces film characteristics with the best concentration, namely 6%, with an increase in thickness and elongation values, as well as a decrease in the solubility, tensile strength and water content of the film after adding the antimicrobial agent. A thickness value of 0.21 mm and a tensile strength value of 50.80 MPa are characteristics of potato starch film that meets the JIS 1975 standard.

The use of the antimicrobial ingredient lemongrass extract in making films from arrowroot starch produces film characteristics with the best concentration, namely 30%. The thickness value obtained before and after the addition of antimicrobial material was relatively the same, namely 0.20 mm, and there was a decrease in the film water content value. This thickness value is a characteristic of arrowroot starch film which meets the JIS 1975 standard.

The antimicrobial material white turmeric filtrate added to the film making from bentulic starch produces film characteristics with the best concentration, namely 0.8%, where the wvtr value is 0.11 g/m2/hour, thickness is 0.12 mm, and tensile strength is 0.63 MPa is a characteristic of bent starch film that meets JIS 1975 standards.

The addition of antimicrobial ingredients in the form of lemongrass essential oil and rosemary essential oil in making films from banana starch produces film characteristics with high concentration.Yield is the percentage of the final weight of the sample per initial weight of the sample. The yield calculation is used to determine the loss that occurs during the processing process. The yield is expressed in percent (%) (Apriyanto et al., 1989). The results of the analysis of variance showed that temperature had a very significant effect on the yield of Dayak onion bulb extract. The length of heating time has a significant effect on the yield of Dayak Dayak onion bulb extract. There is an interaction between temperature and heating time on the yield of Dayak onion bulb extract. The average yield value of Dayak onion bulb extract at various temperature treatments and heating times can be seen in Table 2.

The addition of antimicrobial ingredients in the form of galangal essential oil in making taro starch films produces film characteristics with the best concentration, namely 1.25%. The characteristics produced from taro starch with antimicrobial ingredients in the form of galangal essential oil still do not meet JIS standards (1975) in Widodo., et al (2019).

The use of antimicrobial materials in the form of turmeric ethanol extract in making Wikao Maombo starch films produces film characteristics with the best concentration, namely 15%, where the tensile strength value of 0.99 MPa obtained after adding turmeric ethanol extract is a film characteristic that meets JIS (1975) standards in Widodo. ., et al (2019).

Based on 16 research articles obtained regarding the addition of antimicrobial materials in making starch-based edible films, antimicrobial materials in the form of white turmeric filtrate are better antimicrobial materials for use in making starch-based edible films. This is because the content contained in the white turmeric filtrate with a concentration of 0.8% is able to produce film characteristics that meet the standards of the Japanese Industrial Standard (1975) in Widodo., et al (2019), namely a wvtr value of 0.11 g/m2 / hour, thickness 0.12 mm, and tensile strength 0.63 MPa.

Correlation of Type and Concentration of Antimicrobial Materials on Edible Film Parameters
Water Vapor Transmission Rate (WVTR)

Water vapor transmission rate is the speed of movement of water vapor through a unit area of material with a certain thickness, under specific conditions. According to the Japanesse Industrial Standard (JIS), a good edible film for food packaging is one that has a maximum water vapor transmission rate of 10 g/m2/hour.

Based on the results of the correlation analysis in Table 3, it is known that the type of antimicrobial material and the rate of water vapor transmission has a moderate relationship strength with a correlation value of -0.598. The correlation results between the concentration of antimicrobial ingredients and the characteristics of WVTR have a low strength of relationship with a correlation value of -0.362. The results of Pearson correlation analysis obtained p-values of 0.000 and 0.045, which are smaller than 5%, meaning that the correlation between the type and concentration of antimicrobial material on the water vapor transmission rate characteristics of edible film is statistically significant. The concentration of antimicrobial substances and the transmission rate of water vapor have an opposite relationship, indicated by a negative correlation value. This means that the higher the concentration of the antimicrobial agent, the greater the tendency to reduce the value of the water vapor transmission rate.

The types of antimicrobial ingredients used in several research articles include kaffir lime leaf essential oil, cinnamon leaf oleoresin, gambier filtrate, papaya leaf filtrate, white turmeric filtrate, and kenikir extract. These ingredients contain active compounds in the form of a-citronellal, linalool (Putra et al., 2017), eugenol, oleic acid amide, benzyl benzoate (Utami et al., 2017), catechin (Rahmawati et al., 2011), alkaloids , carpaine (Julianti et al., 2014), as well as flavonoids, tannins, triterpenoids (Rita, 2010) where the content of these active ingredients is hydrophobic. According to Apriani (2020), the addition of ingredients that have hydrophobic active compounds can play a role in reducing the water vapor transmission rate of edible film. This is because water vapor migration generally occurs in the hydrophilic part and depends on the ratio of hydrophilic and hydrophobic components. This opinion is in line with one of the results of research conducted by Tomara (2019), where the addition of clove oil to making edible film from uwi starch can produce low water vapor transmission rate values.

According to Katili., et al (2013), water vapor transmission is greatly influenced by temperature, RH (Relative Humidity), film thickness, type and concentration of plasticizer, as well as the nature of the basic ingredients that make up edible film. Santoso., et al (2012) also argue that the transmission rate of water vapor is influenced by several factors, namely the structure of the edible film (homogeneity, emulsions, multilayers), crystal type, shape, size, and distribution of lipids. The rate of water vapor transfer will decrease as the thickness of the edible film increases. As the concentration of antimicrobial material increases, there is a tendency for the thickness to increase. The added concentration of antimicrobial ingredients will cause the formation of a denser and denser edible film matrix. The compact structure can inhibit the diffusion of water vapor through the edible film. In line with the opinion of Mulia & Ardiansyah (2016), adding more and more concentrations of antimicrobial ingredients can increase the thickness of the edible film produced because the essential oil molecules are able to fill the cavities of the polymer chains so that they are able to withstand the rate of water vapor transmission.

Table 3. Correlation results between the type and concentration of antimicrobial ingredients on edible film parameters.

Variables	Correlation	Parameter edible film					
		WVTR	Thickness	Solubility	Elongation	Tensile strength	Water content
Types of Antimicrobial Ingredients	Correlation value	-0.598	0.410	-0.556	-0.358	-0.151	-0.112
	Significance value	0.000	0.000	0.002	0.004	0.417	0.569
	The power of relationships	Currently	Currently	Currently	Low	Very Low	Very Low
Antimicrobial Ingredient Concentration	Correlation value	-0.362	0.332	-0.435	-0.162	-0.048	-0.091
	Significance value	0.045	0.005	0.021	0.209	0.799	0.646
	The power of relationships	Low	Low	Currently	Very low	Very low	Very low

Hydrophobic compounds contained in essential oils are able to limit the interaction between the polymer film and the bound water. Increasing the binding force between polymers will reduce the edible film's transmission of gas, vapor and porosity. An increase in solid granules in a polymer will reduce the spaces between the cells of the gel formed. This narrowing of the spaces between cells causes a decrease in the rate of water vapor transmission (Ilah, 2015).

Thickness

Film thickness is an important characteristic in determining the suitability of edible film as food product packaging because thickness greatly influences the physical and mechanical properties of other edible films. Film thickness is usually influenced by the surface area of the mold and the total amount of solids in the solution. The viscosity of edible film after heating is also a factor that influences film thickness apart from the printing plate (Supeni et al., 2015).

Based on the results of the correlation analysis in Table 3, it is known that the type of antimicrobial material and thickness have a moderate relationship strength with a correlation value of 0.410. The correlation results between the concentration of antimicrobial material and thickness have a low strength of relationship with a correlation value of 0.332. The results of the Pearson correlation analysis obtained a p-value of 0.000 and 0.005, which is less than 5%, meaning that the correlation between the type and concentration of antimicrobial material on the thickness of the edible film is statistically significant. The concentration of antimicrobial material and thickness have a unidirectional relationship, indicated by a positive correlation value. This means that the higher the concentration of antimicrobial ingredients, the greater the tendency to increase the thickness value.

The types of antimicrobial ingredients used in several research articles include kaffir lime leaf essential oil, cinnamon leaf oleoresin, clove essential oil, olive extract, lemongrass essential oil, rosemary essential oil, lavender essential oil, black cumin oil, oregano oil, beluntas leaf extract, gambier filtrate, papaya leaf filtrate, cinnamon oil, zanthoxylum bungeanum essential oil, kenikir extract, white turmeric filtrate, and lemongrass extract. These ingredients contain active compounds in the form of a-citronellal, linalool (Putra et al., 2017), eugenol, oleic acid amide, benzyl benzoate (Utami et al., 2017), oleuropein (Samet et al., 2014), citral, geraniol (Harris, 1993), cineol, α-pinene (Jiang et al., 2013), linalool, camphor, linalyl acetate (Lansida, 2017), ρ-cymene, thymoquinone (Harzallah et al., 2011), carvacrol , thymol (Stefanaki et al., 2016), alkaloids, tannins, flavonoids (Susetyarini, 2009), catechins (Rahmawati et al., 2011), carpaine (Julianti et al., 2014), and cinnamaldehyde (Verdini et al., 2022).

The antimicrobial ingredients and active components contained therein can play a role in increasing the thickness of the edible film. Like one of the active components in this antimicrobial ingredient, namely catechin. Catechin is a component that is slightly insoluble in cold water but very soluble in hot water and catechin that has undergone dissolution can form a crystalline solid when dry. The increase in gambier filtrate in the edible film suspension causes the total amount of solids contained in the edible film to increase, so that after the edible film suspension is dried, the thickness of the resulting edible film increases (Maisarah et al., 2014). Apart from that, according to Amaliya and Putri (2014), the addition of total solids can come from white turmeric starch which is not completely filtered so that suspended compounds such as starch can increase the thickness of the edible film.

The positive correlation resulting from the analysis shows that the increasing concentration of antimicrobial ingredients added means the thickness of the resulting edible film will also increase. This is due to the increase in the total amount of solids in the edible film solution. An increase in the total amount of solids in the solution causes the polymers that make up the matrix in edible films to also increase due to the filling of the matrix cavities by antimicrobial molecules and other film-making materials (Muin et al., 2017).

Thickness is a physical property of edible film that determines other properties such as tensile strength, elongation and the ability to withstand water vapor transmission. The thicker the edible film, the stronger the barrier properties or ability to resist water vapor migration because the structure is denser. However, if it is too thick it will affect the appearance, taste and texture of the food product when consumed (Yulianti and Ginting, 2012).

Solubility

The solubility of edible film is one of the factors that determines the biodegradability of a film that will be used as a packaging material. Solubility of edible film in water is the percentage of dry weight of edible film that has been dissolved in water for 24 hours (Warkoyo et al., 2014).

Based on the results of the correlation analysis in Table 3, it is known that the type and concentration of antimicrobial ingredients on solubility have a moderate relationship strength with correlation values of -0.556 and –0.435. The results of Pearson correlation analysis obtained p-values of 0.002 and 0.021, which are smaller than 5%, meaning that the correlation between the type and concentration of antimicrobial ingredients on the solubility of edible film is statistically significant. The concentration of antimicrobial ingredients and solubility have an opposite relationship, indicated by a negative correlation value. This means that the higher the concentration of antimicrobial ingredients, the greater the tendency to reduce the solubility value of edible film.

The types of antimicrobial ingredients used in this article include kaffir lime leaf essential oil, clove essential oil, lemongrass essential oil, rosemary essential oil, lavender essential oil, turmeric ethanol extract, and zanthoxylum bungeanum essential oil. These antimicrobial ingredients contain active compounds such as a-citronellal, linalool (Putra et al., 2017), eugenol (Hadi, 2012), citral, geraniol (Harris, 1993), cineol, α-pinene (Jiang et al., 2013) , linalool, camphor, linalyl acetate (Lansida, 2017), as well as curcumin, sesquiterpenes, zingiberene (Bagchi, 2012). Active compounds such as linalool, eugenol, cineol, geraniol are less soluble in water due to their nonpolar hydrocarbon structure but are very soluble in organic solvents (alcohol, chloroform, ether) (Ilc et al., 2016).

Solubility is influenced by the hydrophilic and hydrophobic properties of the material. Most essential oils belong to the group of terpene and terpenoid organic compounds which are difficult to dissolve in water or are non-polar. Solubility will be higher if the hydrophilic value is high, and will be lower if the hydrophobic value is high (Muin et al., 2017). This opinion is in accordance with the results of the correlation analysis obtained where the use of antimicrobial materials can play a role in reducing the solubility value of the film because the antimicrobial materials used have non-polar active compounds.

The low solubility value is due to the hydrophobic ability of antimicrobial materials which can reduce the hydroxyl groups in edible film. According to Santoso., et al (2012), the higher the concentration of antimicrobial ingredients can cause a decrease in the solubility of edible film. Essential oils contain compounds composed of carbon chains which are hydrophobic in nature so that the more carbon chains in edible film, the more difficult it will be to dissolve in water (Putra et al., 2017). According to Harumarani., et al (2016), the lower the solubility value of edible film, the better it is used as a packaging material and is biodegradable.

Elongation

Percent elongation or percent elongation is one of the mechanical properties of edible film by measuring the change in maximum length experienced by the edible film until it tears or a situation where the edible film breaks after being stretched. The criteria for a good edible film is to have a high elongation percentage, because this will affect the strength of the edible film in physical contact with other objects so that it is not easily torn and the coated material is durable.

Based on the results of the correlation analysis in Table 3, it is known that the type of antimicrobial material and elongation have a low relationship strength with a correlation value of –0.358. This is based on the opinion of Misbahudin and Hasan (2013), who stated that the correlation coefficient value ranges from 0.20 to 0.40, which means the correlation is low or weak. The results of the Pearson correlation analysis showed that the p-value = 0.004 was smaller than 5%, meaning that the correlation between the type of antimicrobial material and the elongation of edible film was statistically significant.

The results of the correlation analysis obtained a p-value of 0.209 which was greater than 5%, meaning that the correlation value between the concentration of antimicrobial ingredients and elongation was statistically insignificant. This shows that there is variation

The data collected is so large that no conclusions can be drawn regarding the correlation between the concentration of antimicrobial agents and the film elongation value.

The types of antimicrobial ingredients used in several research articles are cinnamon leaf oleoresin, clove essential oil, olive extract, lemongrass essential oil, rosemary essential oil, lavender essential oil, turmeric ethanol extract, galangal essential oil, beluntas leaf extract, gambier filtrate, papaya leaf filtrate, cinnamon oil, kenikir extract, and white turmeric filtrate. The antimicrobial ingredients contain eugenol, oleic acid amide, benzyl benzoate (Utami et al., 2017), oleuropein (Samet et al., 2014), citral, geraniol (Harris, 1993), cineol, α-pinene (Jiang et al., 2013), linalool, camphor, linalyl acetate (Lansida, 2017), curcumin, sesquiterpenes, zingiberene (Bagchi, 2012), methyl cinnamate (Redy, 2018), alkaloids, tannins, flavonoids (Susetyarini, 2009), catechins (Rahmawati et al., 2011), carpaine (Julianti et al., 2014), cinnamaldehyde (Verdini et al., 2022), and polyphenols (Rita, 2010).

According to Benavides et al., (2012), the use of essential oils will generally reduce the bond strength of the film matrix due to the expansion of the heterogeneous structure of the film, so that the elongation of the film can increase. Active components such as eugenol, oleuropein, cineol, geraniol, α-pinene, polyphenols, flavonoids contain OH groups in their structure (Zuhra et al., 2011). According to Santoso et al., (2018), essential oils that are active as antibacterials generally contain hydroxyl (-OH) functional groups. The greater the concentration of essential oil, the higher the amount of OH in the edible film matrix. According to Mulyadi., et al (2016), the addition of a composition that has the –OH functional group will support the interaction between glycerol-polymer. The addition of OH groups plays a role in increasing the mobility of the polymer chains in the edible film matrix so that the elongation of the film will be greater.

Other results show a decrease in the film elongation value due to an increase in the concentration of antimicrobial agents. This can be caused by the higher the concentration of antimicrobial materials, the tendency is to increase the total dissolved solids which can strengthen the film matrix. A dense film matrix can reduce film elasticity. This is also in accordance with research by Kusumawati and Putri (2013), where adding the concentration of black ginger extract reduces the elongation value because black ginger juice still contains total dissolved solids which strengthen the film matrix. Jacoeb et al., (2014) also argue that an increase in total dissolved solids can cause the space between polymers to become increasingly filled, thereby reducing the movement of polymer molecules which ultimately increases the glass transition temperature (change from liquid to solid). If the glass transition temperature increases, the polymer formed will become stiffer, this will cause the film to be inflexible and break easily when stretched.

Essential oils are a form of plasticizer (Paramawati, 2001). The addition of more and more plasticizers will influence the cohesive bonds between polymers to become smaller and the film formed will become softer so that the edible film formed will be easily broken and its value will decrease (Jacoeb et al., 2014).

Tensile Strength

Tensile strength is the maximum pull that the film can withstand during the measurement until the film begins to break (Diova et al., 2013). The film with the highest tensile strength value is expected to be able to withstand maximum physical damage, so that the damage the product will receive is minimal.

Based on the results of the correlation analysis in Table 3, it is known that the type and concentration of antimicrobial material on tensile strength has a very low relationship strength with correlation values of –

0.151 and –0.048. The results of the Pearson correlation analysis obtained a p-value = 0.417 and 0.799 which was greater than 5%, meaning that the correlation value between the type and concentration of antimicrobial material on the tensile strength of edible film was statistically insignificant. This shows that there is a very large variation in the data collected so that no conclusions can be drawn regarding the correlation between the type and concentration of antimicrobial material on the tensile strength value of the film.

The types of antimicrobial ingredients used in several research articles include cinnamon leaf oleoresin, clove essential oil, lemongrass essential oil, rosemary essential oil, lavender essential oil, turmeric ethanol extract, cinnamon oil, and white turmeric filtrate. These ingredients have active components in the form of eugenol, oleic acid amide, benzyl benzoate (Utami et al., 2017), citral, geraniol (Harris, 1993), cineol, α-pinene (Jiang et al., 2013), linalool, camphor, linalyl acetate (Lansida, 2017), curcumin, sesquiterpenes, zingiberene (Bagchi, 2012), cinnamaldehyde (Verdini et al., 2022), as well as polyphenolic flavonoids and triterpenoids (Rita, 2010).

The addition of antimicrobial ingredients can generally strengthen the structure between the bonds of the edible film matrix due to the closure of cavities. Closing the cavity can reduce water absorption and thickness expansion and an increase in inter-bonding will increase the tensile strength of the edible film. Antimicrobial active compounds have the ability to bind macromolecules such as structural carbohydrates and starch (Abrar and Fariani, 2018). Polar properties (-OH) such as eugenol, oleuropein, cineol, geraniol, α-pinene, polyphenols, flavonoids can add hydrogen bonds to the polysaccharide polymer matrix thereby increasing film flexibility.

Other results show that there is a decrease in tensile strength values along with increasing concentrations of antimicrobial agents. This can be caused by the reduction of intermolecular interactions of polymer chains by other antimicrobial active compounds which can reduce the stability of the solid dispersion system so that less film matrix is formed (Rodriguez et al., 2006). In addition, the greater the concentration of antimicrobial agent added while the amount of solids in the solution remains constant, the smaller the percentage of starch in the solution. Rate

High amylose in starch has the ability to form a sturdy gel, gel formation is the result of combining starch polymers after the heating or retrogradation process (Putra, 2014).

The decreasing value of tensile strength along with increasing concentration of antimicrobial ingredients shows that antimicrobial ingredients can weaken hydrogen bonds in the intermolecular matrix and break amylose bonds (Sari et al., 2013). The breaking of amylose bonds causes damage to the edible film gel network so that the tensile strength of the film decreases. This is supported by Moghimi., et al (2017) who stated that the addition of essential oils causes distance between the polymer chain bonds to form. The bond between polymer-essential oil is weaker than the polymer-polymer bond, so the addition of essential oil will cause the tensile strength to decrease

Water Content

The water content of edible film greatly influences the quality of the edible film produced. High water content can make edible film more easily damaged, providing a means for the growth of microorganisms, besides that it can also cause its elasticity and plasticity to decrease (Diova et al., 2013).

Based on the results of the correlation analysis in Table 3, it is known that the type and concentration of antimicrobial materials and water content have a very low relationship strength with correlation values of –0.112 and –0.091. The results of Pearson correlation analysis obtained p-values = 0.569 and 0.646 greater than 5%, meaning that the correlation between the type and concentration of antimicrobial ingredients on the water content of edible film is statistically insignificant. This shows that there is a very large variation in the data collected so that no conclusions can be drawn regarding the correlation between the type and concentration of antimicrobial agents and the value of film water content.

The types of antimicrobial ingredients used in several research articles include kaffir lime leaf essential oil, olive extract, lavender essential oil, black cumin oil, oregano oil, zanthoxylum bungeanum essential oil, and lemongrass extract. These ingredients contain active compounds in the form of α-citronellal, linalool (Putra et al., 2017), oleuropein (Samet et al., 2014), cineol, camphor, linalyl acetate (Lansida, 2017), ρ-cymene, thymoquinone (Harzallah et al., 2011), carvacrol, thymol (Stefanaki et al., 2016), geraniol (Ginting et al., 2022), and citral (Harris, 1993). According to Guenther (1996), essential oils are hydrophobic because essential oils contain long carbon chain terpene compounds so their ability to bind water is small.

Several analysis results show that as the concentration of antimicrobial ingredients increases, there is a tendency to reduce the water content value of edible film (Karyantina et al., 2021). Edible films that have been added with antimicrobial ingredients in the form of essential oils will have fewer hydroxyl groups because they have been replaced by hydrophobic groups from the antimicrobial ingredients. The higher concentration of essential oils or antimicrobial ingredients will increase the adhesive properties between essential oil molecules so that the amount of water bound to polysaccharide compounds will decrease, causing the water content to be lower (Wiramukti, 2012).

Other results show that there is an increase in the water content value along with an increase in the concentration of antimicrobial ingredients. Based on research by Rizkyati & Winarti (2022), it shows that the higher the concentration of white turmeric filtrate can increase the water content value of arrowroot starch edible film. The addition of a high amount of white turmeric filtrate can also increase the amount of starch contained in the edible film so that increasing the amount of turmeric filtrate added can increase the water bound in the edible film. According to Evizal (2013) white turmeric contains 8% starch. Starch has hydroxyl groups which are able to bind water during the heating process in the edible film solution, so that increasing starch will increase the water bound in the edible film (Rosida & Tahya, 2017).

Antimicrobial compounds such as tymol and carvacrol belong to the phenol group (Bouhdid et al., 2008). Phenol has water-soluble properties because it can form hydrogen bonds in water. Adding the extract concentration to edible film has an effect on increasing the water content of the edible film because the phenol contained in the extract forms hydrogen bonds in water, so the more extract concentration is added, the more phenol content will cause the hydrogen bonds to increase, therefore the water content value increasing (Ilah, 2015).

Potential Use of Antimicrobial Ingredients on Edible Film Quality

The quality parameters of edible film currently still refer to the 1975 JIS (Japanese Industrial Standard) standards, namely a maximum film thickness of 0.25 mm, a minimum tensile strength of 0.39 MPa, a minimum elongation of 70%, and a maximum water vapor transmission rate of 7 g/m2/day (Widodo et al., 2019).

Based on the results of the correlation analysis carried out between the type and concentration of antimicrobial materials on edible film parameters, it is known that water vapor transmission rate (WVTR), thickness and solubility are edible film quality parameters that are likely to be influenced by the use of antimicrobial materials, so these parameters need to be paid attention to when using antimicrobial ingredients in making starch-based edible films. This is because the use of the type and concentration of antimicrobial material has a relatively strong relationship with these parameters seen from the correlation results obtained, so there is a tendency for the antimicrobial material to influence the quality of edible film. The results of the correlation analysis show that elongation, tensile strength and water content are edible film quality parameters that have a low chance of being influenced by the use of materials antimicrobial. This is due to the use of antimicrobial ingredients and concentrations that have relatively low strength in these parameters.

Based on data from 5 research articles obtained, it is known that the antimicrobial material that has the opportunity to reduce the value of the water vapor transmission rate is white turmeric filtrate. This is because the use of a small concentration of white turmeric filtrate, namely 0.8%, is able to produce a low water vapor transmission rate value, namely 0.11 g/m2/hour compared to the water vapor transmission rate value with other types of antimicrobial ingredients (Putri et al. , 2022). This value meets the standard characteristics of edible film according to JIS (1975), namely a maximum water vapor transmission rate value of 7 g/m2/hour.

Based on data from 16 research articles obtained, it is known that the thickness value of the edible film produced at each concentration of antimicrobial material used is not significantly different. This can be seen from the use of the smallest concentration of antimicrobial ingredients compared to the concentration of other ingredients, namely 0.025% with the antimicrobial ingredient oleoresin cinnamon leaves producing a thickness value of 0.11 mm, while the use of the largest concentration of antimicrobial ingredients, namely 30% with the antimicrobial ingredient beluntas leaf extract, produces a value thickness 0.30 mm. The thickness of edible film according to JIS standards (1975) is a maximum of 0.25 mm. The edible film thickness value of the concentration of each antimicrobial ingredient that meets Japanesse Industrial Standards is between 0.01 – 0.25 mm. The antimicrobial ingredients of beluntas leaf extract, cinnamon oil, and zanthoxylum bungeanum essential oil do not meet the standard characteristics of edible film thickness according to JIS (1975) because there are values greater than 0.25 mm.

Based on data from 7 research articles obtained, it is known that the antimicrobial ingredient that has the potential to reduce the film solubility value is Zanthoxylum bungeanum essential oil. This is because using the smallest concentration, namely 0.5%, can result in a decrease in solubility value of 18.30% compared to the smallest concentration of other antimicrobial ingredients. The solubility value with the highest concentration, namely 25%, of the antimicrobial ingredient turmeric ethanol extract was only able to reduce the solubility value by 17.06%. This value is inversely proportional to the opinion of Santoso., et al (2012), where the higher concentration of antimicrobial ingredients should cause a decrease in the solubility of edible film because the more carbon chains in edible film are hydrophobic.

The interactions that occur between the active compounds contained in antimicrobial materials and the polymers that make up edible films can affect the characteristics of the film. This is because the various types of antimicrobial materials or compounds that are mixed into the edible film solution each have unique properties, so they can affect the quality of the edible film produced. The addition of different antimicrobial ingredients to the edible film solution will produce different properties and characteristics. This really depends on the ingredients that make up the edible, whether the main ingredients or additional ingredients, as well as the type and amount used (Warkoyo et al., 2014).

Conclusion

Based on the results of the research that has been carried out, it can be concluded that there is a moderate correlation between the type of antimicrobial material and the water vapor transmission rate (WVTR), thickness and solubility of edible film. There is a moderate correlation between the concentration of antimicrobial ingredients and the solubility of edible film. There is no correlation (low or very low level of correlation) between the type and concentration of antimicrobial ingredients and the elongation, tensile strength and water content of edible film. Water vapor transmission rate (WVTR), thickness and solubility are parameters of edible film quality that are likely to be influenced by the use of antimicrobial ingredients. White turmeric filtrate with a concentration of 0.8% is a better type and concentration of antimicrobial material to be used in making cassava starch-based edible films compared to other antimicrobial materials because it can have an effect on increasing the thickness value, as well as reducing the value of the water vapor transmission rate (WVTR) and tensile strength of the film that meets the Japanese Industrial Standard (1975).

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