Optimization of Making Edible Film from Glucomannan Flour with the Addition of CaCO3, Gelatin, Glycerol, Coconut Oil, and Tea Tree Oil

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Article Information

Manuscript Received 2023-03-23
Manuscript Revised 2023-05-07
Manuscript Accepted 2023-05-12
Manuscript Online 2023-06-30

ABSTRACT

Plastic is a material used by the food industry as a food wrapper or packaging. This plastic packaging is generally petroleum-based which can pollute food and the environment because it is difficult to be decomposed by nature. The edible film is a thin and transparent layer of food material that can be used as packaging material and is environmentally friendly. The three constituent components of edible film are starch, protein, and lipid. In this study, glucomannan was used for starch, gelatin for protein, and coconut oil for lipids, tea tree oil as an anti-microbial, $CaCO_3$ and glycerol served as fillers. The process of making the edible film was carried out by mixing the independent variables, namely the concentration of $CaCO_3$, gelatin, coconut oil, and glycerol, then testing the product in the form of tensile strength, elongation, water vapor transmission rate, and thickness. The objectives of this study were first, to determine the effect of each independent variable on tensile strength, elongation, water vapor transmission rate, thickness, biodegradation, and the number of microbes. Second, to obtain the optimum composition through RSM. The optimum results obtained from RSM resulted in the composition of each variable and response, namely gelatin 7 grams, $CaCO_3$ 0.8 grams, coconut oil 3 ml, and glycerol 2 ml, and resulted in a minimum thickness response of 0.1 mm, a minimum water vapor transmission rate of 1 g.m^2 /day, a maximum tensile strength of 86 kgf/cm^2, and a maximum elongation of 43%.

Keywords: *Edible film, Independent Variable, Product Test, Pareto Chart, Optimum*

1. INTRODUCTION

The use of edible film as a safe and environmentally friendly alternative packaging material is becoming increasingly important in today’s era of increasing awareness of the need to protect the environment and human health. The use of edible films has also grown rapidly worldwide in recent years, especially in developed countries such as the United States, Japan, and Europe. In Indonesia, the use of edible film as an alternative packaging material is still quite new, but it has already begun to be developed and applied to some products such as rice, fish, and vegetables. The use of edible films has many advantages such as extending the shelf life of products, improving food safety, and dining product quality. Nevertheless, the use of edible films as alternative packaging materials also has some challenges such as still high production costs and limited availability of raw materials. Therefore, efforts from industry, government, and research institutions are needed to develop and expand the use of edible films as more affordable and accessible alternative packaging materials. The increasing number of residents also causes an increase in the level of basic needs, one of which is in terms of food. Where most, the food industry uses petroleum-based plastic packaging because it has advantages, for example, it is not easily broken and the price is relatively cheap. However, the use of these materials can contaminate food because of the nature of chemicals that easily mix with the products they pack. In addition, it can also affect the environment, where its presence that accumulates in nature can cause pollution and environmental damage. This is due to the nature of plastics that are not environmentally friendly and difficult to decompose in nature. Therefore, there needs to be packaging technology that is safe and does not damage the environment, for example edible film[1].

Edible film is a thin arrangement made of edible materials. Edible film acts as a barrier to mass transfer as well as a carrier of foodstuffs and additives to improve food quality. Edible film must have the same properties as packaging films such as plastic because the purpose is to reduce the use of plastic, is to have the property of retaining water so that it can avoid product moisture, have selective permeability to certain gases, regulate the transfer of dissolved solids to maintain patterns, melamine natural and nutritional, and become a carrier of additives such as blush, preservatives and aroma enhancers that correct the quality of foodstuffs[2].

Edible film can act as a barrier to mass transfer (such as moisture, oxygen, lipids, and solutes), so as to maintain the quality and shelf life of foodstuffs or products. Examples of the use of edible film include as candy wrappers, sausages, fruit, and dry soups [3]. The advantages of using edible film as food packaging to extend the shelf life of the product and not pollute the area because edible film can be eaten with the products it packs. The three basic constituent components of edible film are hydrocolloids (proteins, polysaccharides, alginates), lipids (fatty acids, asyl glycerol, wax or paraffin) and composites (a combination of hydrocolloids and lipids) [4]

2.RESEARCH SIGNIFICANCE

Edible films have the potential to help reduce plastic consumption and pollution while also increasing the quality and safety of food items. As a result, the future development and usage of edible films may be a sustainable solution with a good influence on the environment and package engineering.

Stink lily is economically developed as a cultivated plant in various regions of Indonesia, particularly in Kalimantan and Sulawesi, because to its relatively high economic value. Stink lily's glucomannan content is ideal for edible film due to its high water solubility, mechanical strength, transparency, flexibility, high water absorption, and biodegradability.

3. RESEARCH METHODS

3.1. UNIDIRECTIONAL EXPERIMENT

Making edible film from glucomannan flour with the addition of $CaCO_3$ fillers is then also added proteins in the form of gelatin, lipids in the form of coconut oil, plasticizers in the form of glycerol, and antimicrobials in the form of tea tree oil. Each of these free variables (concentrations of $CaCO_3$, gelatin, glycerol, and coconut oil) was conducted in the first unidirectional experiment with a total of 16 experiments, the parameter used was the tensile strength. The purpose of the unidirectional experiment was to look at the trend relationship of each variable to the strong pull and expected to produce nonlinear data.

Table 1. Unidirectional Trial Design

Gelatin (g)	Glycerol (mL)	$CaCO_3$ (g)	Coconut Oil (mL)
4 5 6 7	2	0,4	1
4	1,2 1,6 2 2,4	0,4	1
4	2	0,2 0,4 0,6 0,8	1
4	2	0,4	1 2 3 4

3.2. RSM OPTIMIZATION

RSM Optimization is one of the optimization methods used in the industry to improve production efficiency, reduce costs, and improve product quality. RSM (Response Surface Method) is a mathematical technique used to build a math model that is able to predict the response or output of a system by considering the factors that affect the system. RSM Optimization integrates RSM techniques with optimization methods to maximize response or output from the system.

In the RSM Optimization application, the first step is to identify the factors that affect the system and determine the limits or range of each of those factors. Subsequently, data collection is carried out through experiments using a combination of these factors. The data was then used to build mathematical models using RSM techniques.

Once the mathematical model is built, optimization is performed to find a combination of factors that can provide the best response or output. The optimization methods commonly used in RSM Optimization applications are simplex, gradient descent, and simulated annealing. Once an optimal combination of factors is found, the results of optimization are validated through re-experimentation.

RSM Optimization applications can be applied in a variety of industries, such as the food, pharmaceutical, cosmetic, and chemical industries. An example of the application of RSM Optimization in the food industry is to optimize the product formulation to have the desired taste and texture, improve the nutritional content of the product, and reduce production costs. By using the RSM Optimization app, the industry can improve production efficiency and increase customer satisfaction with high-quality products. The next stage is optimization using RSM. The first thing to get from optimization using RSM is the variation of experimental design as many as 27 variations of experiments. All variations of the experiment were carried out to obtain edible film, followed by product tests in the form of strong tensile, elongation, water vapor transmission rate, and thickness. The test results of such products are used as response variables in advanced analysis using RSM. The results of the follow-up analysis showed the influence of each variable changed on the response variable and the model equation that describes the relationship between the variables. After that, validation is carried out between the actual value and the predicted value of the response variable obtained from the equation of the RSM advanced analysis model.

3.3. EDIBLE FILM MAKING

An edible film is a thin sheet of edible material that can be used as a food wrap or coating. Films are made from a variety of materials, including proteins, polysaccharides, and lipids, to provide a protective barrier to food, extend shelf life, and improve appearance and taste. \

In this study, the fundamental material employed is stink lily, which has a high enough protein and amylose content to increase the quality of the edible film created. Additionally, stink lilies has amino acids that the body need. Stink lily contains glucomannan, a water-soluble dietary fiber with gelling characteristics. These properties make stink lily an excellent candidate for use as a baseline material in the production of edible films with the capacity to form films and enhance moisture resistance. Other components, specifically :

1. Gelatin: Gelatin is one type of hydrocoloid that is often used in the making of edible films. The function of gelatin is to give strength and elasticity to the film, so it can protect the packaged products. In addition, gelatin can also increase its resistance to water and oxygen. Gelatin is generally derived from the remains of collagen produced from animal skins.
2. Glycerol is an organic compound that is often used as a binder or plasticizer in the making of edible films. The function of glycerol is to increase the flexibility and softness of the film, making it easy to form and apply to the product. In addition, glycerol can also increase its resistance to water vapor and extend the shelf life of the product.
3. Coconut Oil: Coconut oil is one of the types of lipids that are often used in the making of edible films. The function of coconut oil is to increase the strength of the film and water vapor resistance. In addition, coconut oil also has antimicrobial and antioxidant properties, so it can help maintain product quality and prevent damage caused by microorganisms.
4. Tea Tree Oil: Tea tree oil is an essential oil derived from the leaves of the tea tree. The function of tea tree oil in the making of edible film is to give antimicrobial properties to the film, so it can help maintain the quality of the product and prevent the growth of harmful microorganisms. In addition, tea tree oil can also give the product a refreshing aroma and taste.

Making edible film from glucomannan flour with the addition of fillers in the form of $CaCO_3$ and tea tree oil as [5], with different types of raw materials. 3 grams of glucomannan flour and $CaCO_3$ (0.2%;0.4%0.6%;0.8%) (b/v. dissolved into 100 ml of aquades while heated to a temperature of 80°C and stirring for 3 minutes 27 and then cooled to a temperature of 50ºC. Then the addition of gelatin (4%;5%;6%;7%) (b/v). After that, constant stirring is carried out for 5 minutes.

Plasticizer in the form of glycerol with concentration (30%;40%;50%;60%) (b/v gelatin) is added and the addition of lipids in the form of coconut oil with a concentration (1%;2%;3%;4%) (v/v). Then added tea tree oil as an antimicrobial with a concentration of 20% (b / v glucomannan) and stirred for 3 minutes. After that, printing is done on the film plate and drying with a 60 watt bulb (resulting in a temperature of ±60 °C) for ±8 hours. Then the product test is carried out in the form of strong tensile, elongation, thickness, water vapor transmission rate, biodegradation, number of microbes, and edible film structure.

3.4. EDIBLE FILM ANALYSIS

3.4.1. TENSILE STRENGHT

Tensile testing machine, the purpose of tensile testing machine measurement is to find out the mechanical properties of edible sheet film produced in the study. These mechanical properties are a factor to determine the classification of edible film utilization as a product protector [6]. The value of tensile strength obtained by the maximum force is divided by the cross-sectional area or F / A in kgf / cm^2 units.

3.4.2 ELONGATION

Break extension is measured using a tensile testing machine, the purpose of measuring the break extension is to find out the percentage of increase in the length of the film at the time it is pulled until it is torn or broken [5]. The elongation value is obtained from the final length minus the initial length of youth divided by the initial length and multiplied by 100%.

3.4.3. WATER VAPOR TRANSMISSION RATE

The transmission rate of water vapor is defined as the large rate of flow of water vapor through the area at a certain time and condition. The rate of transmission of water vapor indicates the speed at which water vapor penetrates (per gram per second) of widespread union of edible film [6]. The nature of the barrier to moisture in edible film is indispensable to keep the product in good condition. The transmission rate of water vapor is obtained by the formula:

Water vapor transmission rate = "m" /"A.t"

Description:
m = The mass of water vapor passing through the material (g)
t = Measurement time (hour)
A = The cross-sectional area of edible film (m^2)

3.4.4. THICKNESS

Thickness is measured using a screw micrometer tool, the purpose of measuring thickness to find out the thickness of each point of edible film sheet. Thickness affects the quality of the resulting edible film sheet, the thicker the sheet. Edible film then likely the stronger its inhibitory power in protecting the quality of the product, so that it can last longer.

3.4.5. BIODEGRADATION TEST

The biodegradation test was carried out with a sample of edible film measuring 2 x 2 cm soaked in EM4 for 6 days. Degradation that occurs in plastic is characterized by a decrease in the mass of plastic after soaking. This reduction occurs due to the decomposition process of organic matter with EM4 molecules.

3.4.6. NUMBER OF MICROBES

Microbial growth will be calculated per day so that the number of microbes will be obtained. Calculations using a tool in the form of a colony counter.

3.4.7. EDIBLE FILM STRUCTURE

Edible film is adjusted to the size of the preparation. Then the appearance of edible film surface will be seen using a microscope with 1600x magnification

4. RESULTS AND DISCUSSIONS

4.1 Single-direction test

Single-direction test are conducted with the aim of seeing each variable trend freely and are expected to get nonlinear data. The concentration of the free variables entered comes from the journal with the best value. The concentration with the best value as the optimum value then determines the range of data to be entered into rsm. The parameter of the unidirectional experiment is the tensile strength test value because the higher the tensile strength value will be able to protect the packaged product from mechanical interference well. Where the tensile strength will indicate the maximum value of the force produced [7]

Table 2. Unidirectional Trial Results

Variable	Addition	Tensile strength (kg/cm^2)
$CaCO_3$	0.2 g	51,2
	0.4 g	64
	0.6 g	64
	0.8 g	51,2
Gelatin	4 g	64
	5 g	57,6
	6 g	112
	7 g	76,8
Glycerine	1.2 ml	100
	1.6 ml	247,5
	2 ml	64
	2.4 ml	51,2
Coconut Oil	1 ml	64
	2 ml	76,8
	3 ml	100
	4 ml	60,8

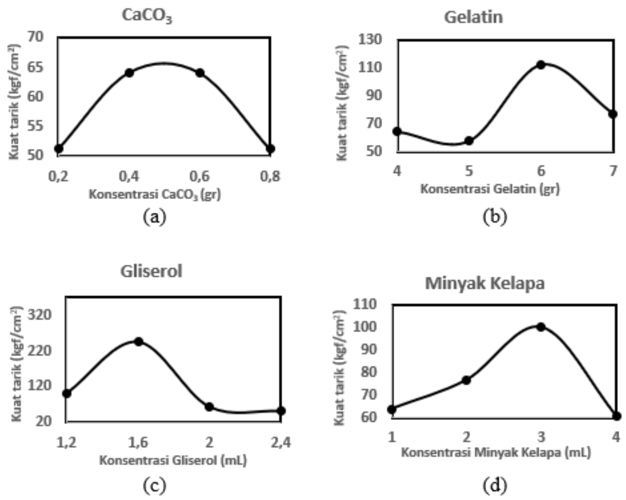

Figure 1 (a) $CaCO_3$ Single-direction test graph, (b) Gelatin Single-direction test graph, (c) Glycerol Single-direction test graph, (d) Coconut oil Single-direction test graph.

Figure 1 (a), showing that as the concentration of $CaCO_3$ increases, the strong value of attraction decreases this indicates that the molecular structure of edible film is amorphous. In amorphous molecular structures, the chains branch but are not arranged tightly so that the distance between molecules becomes farther and the strength of the molecular bonds becomes weakened. The weak strength of the molecular bonding in edible film leads to the lower force needed to break the edible film [3].

Figures 1 (b) and (c), show that the greater the concentration added, the stronger the tensile value also decreases this is because the saturation point has passed so that the excess welding molecules in their own phases outside the polymer phase and decrease the intermolecular force between polymer chains [8]. Plasticizers have hydrophilic properties, which cause the onset of bending properties in edible films due to the formation of cavities that can interfere with inter-molecular tensile forces. The increasingly flexible film causes the force needed to pull the small film, so the tensile strength is also small [9].
Figure 1 (d), shows that the increasing concentration of coconut oil, the stronger the value of attraction will decrease. This is because lipids create a polymer cohesion force and result in a break in film resistance.

4.2 Response Surface Methodology (RSM)

RSM has the ability to reduce the number of experiments required and evaluate the effects of multiple variables. Where in this study the RSM design used is Box-Behnken Design (BBD) with 4 variables at three levels. The three levels are numbers consisting of -1, 0, and 1. The number -1 indicates the lowest variable value, the number 0 indicates the value of the medium variable, and the number 1 indicates the highest variable value.

$CaCO_3$, gelatin, glycerine, and coconut oil were added to a single-direction test variable with the best point results for each variable. The BBD model and RSM statistical analysis are used to process the optimal point. The data from the optimal point is then modeled and tested again using the test parameters tensile strength, elongation, thickness, and vapor transmission rate.

Table 3 Identifying Research Free Variables

Variable	Symbol	Range and Level		
		-1	0	1
Gelatin	A	5	6	7
$CaCO_3$	B	0,2	0,4	0,6
Coconut oil	C	2	3	4
Glycerol	D	1,2	1,6	2

4.2.1 TENSILE STRENGHT

The analysis of variance of the RSM model is derived based on the findings of the range and level of free parameters acquired using the Box-Behnken technique, as shown in Tables 4 and 5. This data indicates the response analysis, and the R^2 coefficient provides information regarding a model's adequacy. The coefficient of determination is between 0 and 1, which means that if R^2 is near to 1, the independent variable has a substantial effect on the dependent variable.

Table 5 shows that the analysis of tensile strength tests performed in the study yielded an R^2 value of 68.27 percent, indicating that the model employed has high reliability since the closer the R^2 value approaches 1, the more reliable the model utilized [10]. The pull against lack of fit Pvalue is 0.307, which implies that a value larger than 0.05 suggests that the lack of fit is unimportant. An modest lack of fit value is a need for a successful model since it reflects the model's compliance with the strong response data pull [10].

Variabel gelatin has a P_{value} of <0.05. This explains that these variables have an influence on the strong attractiveness of edible films. Where gelatin contains proteins with hydrophobic amino acids available, the more the amount of amino acids, the more protein interactions that occur. [11]. The high concentration of proteins in the film solution will form a strong bond between polymers, so it takes a greater tensile force to break the film.[12]

Table 4: Variable Effects on Tensile Strength Using F Ratios and P Values

Source	DF [a]	Adj SS [b]	Adj MS [c]	F_{Value} [d]	P_{Value} [e]
Model	14	6336.93	452.64	1.84	0.147
Linear	4	1704.34	426.09	1.74	0.207
A	1	1300.12	1300.1	5.3	0.04
B	1	2.38	2.38	0.01	0.923
C	1	0.56	0.56	0	0.963
D	1	391.84	391.84	1.6	0.23
Square	4	1963.38	490.85	2	0.159
A*A	1	433.52	433.52	1.77	0.209
B*B	1	288.84	288.84	1.18	0.299
C*C	1	491.52	491.52	2	0.182
D*D	1	310.68	310.68	1.27	0.283
2-Way Interaction	6	1000.37	166.73	0.68	0.67
A*B	1	316.06	316.06	1.29	0.279
A*C	1	0.33	0.33	0	0.971
A*D	1	420.25	420.25	1.71	0.215
B*C	1	145.36	145.36	0.59	0.456
B*D	1	114.37	114.37	0.47	0.508
C*D	1	4	4	0.02	0.901

[a] Degree of freedom, [b] Sum of squares, [c] Mean Sum of squares, [d] p values <0.05 is significant, [e] ns not significant

Table 5: Variance Analysis of the RSM Tensile Strength Model

Source	DF [a]	Adj SS [b]	AdjMS [c]	F_{Value} [d]	P_{Value} [e]	Coeff
Error	12	2945.21	245.43			
Lack-of-Fit	10	2736.97	273.7	2.63	0.307	
Pure Error	2	208.24	104.12			
R-sq						68.27%
R-sq(adj)						31.25%

4.2.2 ELONGATION

The results of the analysis of variance on the elongation test performed in the study, as shown in Tables 6 and 7, demonstrate that the model used has high reliability since the closer the R^2 value approaches one, the more trustworthy the model used [10]. In this research, the R^2 value was 78.07 percent. The P_{value} for elongation vs lack of fit is 0.169, suggesting that a value greater than 0.05 indicates that the lack of fit is unimportant.

Variable glycerol mixture with glycerol and glycerol has a P_{value} of <0.05. This explains that these variables have an influence on the elongation of edible films. Where glycerol acts as a plasticizer. Glycerol as a plasticizer has hydrophilic properties, which cause the onset of bending properties in edible films due to the formation of cavities that can interfere with the molecular tensile force of the film [13]. Plasticizers can reduce the internal hydrogen bonds of molecules and cause a weakening of the intermolecular tensile force of adjacent polymer chains thereby reducing the tenuous strength of breaking.

Table 6: Variable Effects on Elongation Using F Ratios and P Values

Source	DF [a]	Adj SS [b]	Adj MS [c]	F_{Value} [d]	P_{Value} [e]
Model	14	0.346706	0.024765	1.62	0.203
Linear	4	0.220524	0.055131	3.61	0.037
A	1	0.025975	0.025975	1.7	0.216
B	1	0.013675	0.013675	0.9	0.362
C	1	0.013809	0.013809	0.91	0.36
D	1	0.134927	0.134927	8.85	0.012

Source	DF [a]	Adj SS [b]	Adj MS [c]	F_{Value} [d]	P_{Value} [e]
Square	4	0.207845	0.051961	3.41	0.044
A*A	1	0.01318	0.01318	0.86	0.371
B*B	1	0.000208	0.000208	0.01	0.909
C*C	1	0.043718	0.043718	2.87	0.116
D*D	1	0.167584	0.167584	10.99	0.006
2-Way Interaction	6	0.114977	0.019163	1.26	0.346
A*B	1	0.039422	0.039422	2.58	0.134
A*C	1	0.001406	0.001406	0.09	0.767
A*D	1	0.012177	0.012177	0.8	0.389
B*C	1	0	0	0	1
B*D	1	0.039621	0.039621	2.6	0.133
C*D	1	0.02235	0.02235	1.47	0.249

[a] Degree of freedom, [b] Sum of squares, [c] Mean Sum of squares, [d] p values <0.05 is significant, [e] ns not significant

Table 7: Variance Analysis of the RSM Elongation Model

Source	DF [a]	Adj SS [b]	AdjMS [c]	F_{Value} [d]	P_{Value} [e]	Coeff
Error	12	0.18302	0.015252			
Lack-of-Fit	10	0.176353	0.017635	5.29	0.169	
Pure Error	2	0.006667	0.003333			
R-sq						65.45%
R-sq(adj)						25.14%

4.2.3 WATER VAPOR TRANSMISSION RATE

Tables 8 and 9 presented the variable impact and analysis variance values from the study's water vapor transmission rate test. Using RSM models, an R^2 value of 69.07 percent was obtained. This result indicates that the model employed is very reliable, because the closer the R^2 value is to 1, the more reliable the model utilized [9]. The test result of the water vapor transmission rate against lack of fit P_{value} is 0.124, indicating that the lack of fit is negligible.

Variabel mixture of $CaCO_3$ with coconut oil and coconut oil has a Pvalue of <0.05. This explains that these variables have an influence on the transmission rate of edible film water vapor. Where $CaCO_3$ (calcium carbonate) as a filler to overcome the lack of edible film properties. The addition of fillers can increase the rigidity of overly supple plastics, increase strength, reduce solubility and tendency to bend [14], [15]. Calcium content causes the matrix tissue to form more tightly and the trapped water will be less so that the rate of transmission of water vapor is smaller[16].

Likewise, coconut oil can reduce the value of the rate of transmission of water vapor due to the interaction between hydrophobic substances. Coconut oil has hydrophobic characteristics will provide barrier properties to moisture. With the addition of $CaCO_3$ and coconut oil is expected to improve the ability as a coating material that can maintain the quality of food products coated[17].

Table 8: Variable Effects on Water Vapor Transmission Rate Using F Ratios and P Values

Source	DF [a]	Adj SS [b]	Adj MS [c]	F_{Value} [d]	P_{Value} [e]
Model	14	92.952	6.6394	1.91	0.133
Linear	4	23.646	5.9115	1.7	0.213
A	1	4.398	4.3984	1.27	0.282
B	1	0.026	0.0258	0.01	0.933
C	1	18.432	18.4317	5.31	0.04
D	1	0.676	0.6755	0.19	0.667
Square	4	13.795	3.4486	0.99	0.448
A*A	1	7.135	7.1345	2.06	0.177
B*B	1	1.51	1.5095	0.44	0.522
C*C	1	0.001	0.001	0	0.987
D*D	1	0.629	0.6286	0.18	0.678
2-Way Interaction	6	75.155	12.5258	3.61	0.028
A*B	1	0.157	0.1568	0.05	0.835
A*C	1	7.702	7.702	2.22	0.162
A*D	1	2.05	2.0498	0.59	0.457
B*C	1	56.287	56.2872	16.23	0.002
B*D	1	0.818	0.8181	0.24	0.636
C*D	1	8.141	8.1405	2.35	0.151

[a] Degree of freedom, [b] Sum of squares, [c] Mean Sum of squares, [d] p values <0.05 is significant, [e] ns not significant

Table 9: Variance Analysis of the RSM Water Vapor Transmission Rate Model

Source	DF [a]	Adj SS [b]	AdjMS [c]	F_{Value} [d]	P_{Value} [e]	Coeff
Error	12	41.616	3.468			
Lack-of-Fit	10	40.528	4.0528	7.45	0.124	
Pure Error	2	1.088	0.5438			
R-sq						69.07%
R-sq(adj)						32.99%

4.2.4 THICKNESS

Based on the analysis of thickness tests performed in the study, an R^2 value of 78.07 percent indicates that the model employed has high reliability since the closer the R^2 value is to 1, the more reliable the model utilized [10].This value is seen in tables 10 and 11. Furthermore, the thickness test against lack of fit table result is 0.688, indicating that a value larger than 0.05 suggests that the lack of fit is minor.

Variabel glycerol and glycerol mixtures have a P_{value} of <0.05. This explains that these variables have an influence on the thickness of edible film. Where plasticizer increases the thickness value of edible film, because the more concentration of plasticizer added will increase the total solids in the solution which will affect the thickness of edible film [18]. The addition of the plasticizer concentration will increase the polymer constituents of the film matrix as the total increase of dissolved solids in the film solution, thereby causing the thickness of the film.

The results are proven that the greater the concentration of plasticizer will increase the viscosity of an edible film so that the thickness of the film will increase. The thickness of edible film is affected by the process of equalization of the film before drying. Edible film can be adjusted in thickness from the amount of solution poured on the mold and the area of the mold used. The more volume of edible film solution poured, the thicker the edible film obtained, this is because the total solids in the edible film solution will be greater [19].

Table 10: Variable Effects on Thickness Using F Ratios and P Values

Source	DF [a]	Adj SS [b]	Adj MS [c]	F_{Value} [d]	P_{Value} [e]
Model	14	0.032016	0.002287	3.05	0.03
Linear	4	0.017492	0.004373	5.84	0.008
A	1	0.000281	0.000281	0.38	0.552
B	1	0.001204	0.001204	1.61	0.229
C	1	0.000007	0.000007	0.01	0.925
D	1	0.017198	0.017198	22.95	0
Square	4	0.022566	0.005641	7.53	0.003
A*A	1	0.000268	0.000268	0.36	0.561
B*B	1	0.00107	0.00107	1.43	0.255
C*C	1	0.000181	0.000181	0.24	0.632
D*D	1	0.016379	0.016379	21.86	0.001
2-Way Interaction	6	0.0061	0.001017	1.36	0.307
A*B	1	0.0004	0.0004	0.53	0.479
A*C	1	0.0016	0.0016	2.14	0.17
A*D	1	0.000225	0.000225	0.3	0.594
B*C	1	0.001225	0.001225	1.63	0.225
B*D	1	0.002025	0.002025	2.7	0.126
C*D	1	0.000625	0.000625	0.83	0.379

[a] Degree of freedom, [b] Sum of squares, [c] Mean Sum of squares, [d] p values <0.05 is significant, [e] ns not significant

Table 11: Variance Analysis of the RSM Thickness Model

Source	DF [a]	Adj SS [b]	AdjMS [c]	F_{Value} [d]	P_{Value} [e]	Coeff
Error	12	0.008992	0.000749			12
Lack-of-Fit	10	0.007125	0.000712	0.76	0.688	10
Pure Error	2	0.001867	0.000933			2
R-sq						78.07%
R-sq(adj)						52.49%

4.3 RSM OPTIMUM RESULTS

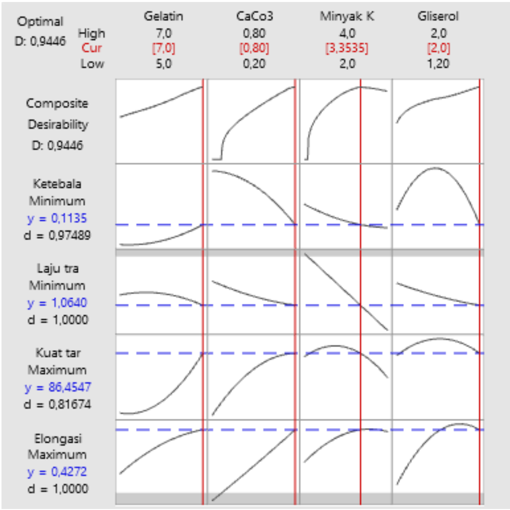

Figure 2. Response Optimization

The optimum results obtained through RSM are gelatin 7 grams, $CaCO_3$ 0.8 grams, coconut oil 3 ml, and glycerol 2 ml and is expected to produce a minimum thickness response of 0.1 mm, a minimum water vapor transmission rate of 1 g.m ^{2} / day, a maximum tensile strength of 86 Kgf / cm^2, and a maximum elongation of 43%.

It will then produce response values in the minimum and maximum as in Figure 2. The desirability value obtained is 0.9446. Where the closer one is, the more it shows the value of optimization accuracy. The desirability value is to indicate the level of fulfillment of the established criteria.

4.4 VALIDATION OF RSM OPTIMUM RESULTS

Validation of optimum results by RSM compares response prediction values with actual values. Validation is carried out by making edible films with variable concentrations according to RSM results, namely gelatin 7 grams, $CaCO_3$ 0.8 grams, coconut oil 3 ml, and glycerol 2 ml and is expected to produce a minimum thickness response of 0.1 mm, minimum water vapor transmission rate of 1 g.m ^{2} / day, maximum tensile strength of 86 Kgf / cm^2, and a maximum elongation of 43%. In actual conditions the response obtained is not much different, namely the thickness of 0.17 mm, the transmission rate of water vapor is 1.37 g.m ^{2} / day, the tensile strength is 83.91 Kgf / cm^2, and the elongation is 30%. This means that the condition of the process of making edible films with maximum and minimum values of each response is quite consistent.

4.5 ADVANCED TESTS

4.5.1 BIODEGRADATION TEST

The biodegradation test was carried out with a sample of edible film measuring 2 x 2 cm soaked in EM4 for 6 days. Then the calculation was carried out, with an initial period of 0.4768 grams and after 6 days to 0.2896 grams. Resulting in a degradation percentage of 43%. Degradation that occurs in plastic is characterized by a decrease in the mass of plastic after soaking. This reduction occurs due to the decomposition process of organic matter with EM4 molecules. Microorganisms in EM4 degrade edible film by breaking the polymer chain into monomers of chitosan that decompose and consequently the bioplastic mass is reduced [20].

4.5.2 NUMBER OF MICROBES

The number of microbes is calculated per day. Calculations using a tool in the form of a colony counter. But as long as edible film has become a product from April 26, 2021 to July 5, 2021, it is still not overgrown with colonies. This happens because of two possible factors. First is from the antimicrobials added, namely tea tree oil works well, secondly because drying is done so that there is no water as a colony medium to grow.

4.5.3 EDIBLE FILM STRUCTURE

Edible film structure is done with a microscope with 1600x magnification. The edible film obtained is still rough unlike the plastic sold in the market. This happens because of two things, namely, the added material is not mixed well and carelessness during the printing process. Figure 3 depicts the structural appearance of the resulting edible film:

(a) **(b)**

Figure 3 (a) Experimental edible film (b) Structure of edible film using a 1600 x magnification microscope.

5. CONCLUSION

Each of these variables has an influence on each affects the strength of the tensile, glycerol affects the elongation, coconut oil and $CaCO_3$ affect the transmission rate of water vapor, and glycerol affects thickness. In biodegradation tests it can be known that the resulting edible film can be degraded and for the number of microbes no microbes are found that grows microbes.

The optimum results obtained from RSM produce the composition of each variable and response, namely gelatin 7 grams, $CaCO_3$ 0.8 grams, coconut oil 3 ml, glycerol 2 ml and produce a minimum thickness response of 0.1 mm, a minimum water vapor transmission rate of 1 g.m ^{2} / day, a maximum tensile strength of 86 Kgf / cm^2, and a maximum elongation of 43%.

To achieve homogenous results, a mixing process appropriate for the nature of the components being combined is required, as well as a molding tool capable of producing edible films of the same thickness.

6. ACKNOWLEDGEMENTS

Thanks from the author to Edible film team'2021 (Fathur, Fransisca, Novi and Rifa) who have contributed or supported the research or writing of the article.

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8. REFERENCES

[1] R. M. S. Cruz *et al.*, Bioplastics for Food Packaging: Environmental Impact, Trends and Regulatory Aspects, *Foods*, vol. 11, no. 19. 2022.

[2] E. Díaz-Montes, R. Castro-Muñoz, Edible films and coatings as food-quality preservers: An overview, *Foods*, vol. 10, no. 2. 2021.

[3] M. E. Kramer, Structure and Function of Starch-Based Edible Films and Coatings, in *Edible Films and Coatings for Food Applications*, 2009.

[4] S. Galus, J. Kadzińska, Food applications of emulsion-based edible films and coatings, *Trends in Food Science and Technology*, vol. 45, no. 2. 2015.

[5] C. A. Campos, L. N. Gerschenson, S. K. Flores, Development of Edible Films and Coatings with Antimicrobial Activity, *Food and Bioprocess Technology*, vol. 4, no. 6. 2011.

[6] M. Lacroix, Mechanical and Permeability Properties of Edible Films and Coatings for Food and Pharmaceutical Applications, in *Edible Films and Coatings for Food Applications*, 2009.

[7] R. J. Kerekes, J. O. Heymer, J. D. McDonald, Refining pulp for tensile strength, *Nord. Pulp Pap. Res. J.*, vol. 36, no. 4, 2021.

[8] D. Gerogiorgis, S. Pistikopoulos, Book Review, *Chem. Eng. Res. Des.*, vol. 84, no. 11, pp. 1087–1089, 2006.

[9] P. C. Painter, M. M. Coleman, Essentials of Polymer Science and Engineering, *Essentials of Polymer Science and Engineering*. 2009.

[10] R. Christensen, *Analysis of variance, design, and regression: Linear modeling for unbalanced data, second edition*. 2015.

[11] J. Qi *et al.*, Thermal degradation of gelatin enhances its ability to bind aroma compounds: Investigation of underlying mechanisms, *Food Hydrocoll.*, vol. 83, 2018.

[12] A. Jangchud, M. S. Chinnan, Peanut protein film as affected by drying temperature and pH of film forming solution, *J. Food Sci.*, vol. 64, no. 1, 1999.

[13] A. B. Prasetyo, E. Suprayitno, The Effect of Glycerol Plasticizer Concentration on Physical-Chemical Characteristics of Edible Film from Catfish Skin Gelatin (Pangasius sp.), *Int. J. Sci. Res. Publ.*, vol. 11, no. 10, 2021.

[14] Y. Darni, H. Utami, R. Septiana, R. A. Fitriana, COMPARATIVE STUDIES OF THE EDIBLE FILM BASED ON LOW PECTIN METHOXYL
 WITH GLYCEROL AND SORBITOL PLASTICIZERS, *J. Bahan Alam*

Terbarukan, vol. 6, no. 2, 2017.

[15] J. Shen, Z. Song, X. Qian, F. Yang, Carboxymethyl cellulose/alum modified precipitated calcium carbonate fillers: Preparation and their use in papermaking, *Carbohydr. Polym.*, vol. 81, no. 3, 2010.

[16] S. N. Lesmana, T. I. P. S, N. Kusumawati, PENGARUH PENAMBAHAN KALSIUM KARBONAT SEBAGAI FORTIFIKAN KALSIUM TERHADAP SIFAT FISIKOKIMIA DAN ORGANOLEPTIK PERMEN JELI SUSU, *J. Teknol. Pangan dan Gizi*, vol. 7, no. 1, pp. 28–39, 2008.

[17] M. Mikriukova, J. Lahti, J. Kuusipalo, Permeation of vegetable oils and slippery properties of extrusion coated paperboard, *Packag. Technol. Sci.*, vol. 35, no. 5, 2022.

[18] R. Arham, M. T. Mulyati, M. Metusalach, S. Salengke, Physical and mechanical properties of agar based edible film with glycerol plasticizer, *Int. Food Res. J.*, vol. 23, no. 4, 2016.

[19] F. Maruddin, R. Malaka, S. Baba, H. Amqam, M. Taufik, S. Sabil, Brightness, elongation and thickness of edible film with caseinate sodium using a type of plasticizer, in *IOP Conference Series: Earth and Environmental Science*, 2020, vol. 492, no. 1.

[20] A. L. Charles, N. Motsa, A. A. Abdillah, A Comprehensive Characterization of Biodegradable Edible Films Based on Potato Peel Starch Plasticized with Glycerol, *Polymers (Basel).*, vol. 14, no. 17, 2022.