Optimization of bioplastic’s tensile strength

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Abstract. The amount of plastic waste is increasing every year. Indonesia per year produces around 5.4 million tons plastic waste, which is 43.4% of plastic packaging waste. Every person throws 700 plastic bags per year and continues due to an increase in consumption of bottled water in each year by 10%. Indonesia is the second of world rank after China, as the largest plastic waste maker in the World with 3.2 million tons of waste. 87 percent of the 3.8 million tons of plastic waste is disposed in each year and dumped into the sea. Hence Indonesian population in the coastal area is responsible for 17.2 kilograms of plastic waste that floats and poison the animals inside. In Indonesia, the potential in developing research and development on bioplastic technology is enormous. Furthermore the biodiversity of agricultural and marine products owned by Indonesia can be used as biopolymers that is very large, including corn, cassava, soybeans, potatoes, and seaweed. Among these natural polymers, material to be carried out in this research is corn. The choice of corn material is based on the abundance of corn in Indonesia. The experimental design was to examine the optimal composition of bioplastic samples made from corn starch and glycerin. The Surface Response method is proposed for optimizing composition materials which are used. D-Optimacy response was obtained by the value of the desirability function. The optimal conditions were 0.5 ml glycerin and 4.72 g corn starch with a tensile strength of 17.18 Mpa.

1. Introduction

Plastic is a material that is now widely favoured and widely used in people's lives, because plastics can be used as light aids and more importantly, plastics can withstand liquids, therefore plastics are much favoured by the public. Plastic is a material that is non-biodegradable, therefore the use of plastic must be considered so as not to damage the environment given the amount of waste produced. Nowadays, biodegradable plastic is developed, it is called bioplastics. In general, bioplastic packaging can be interpreted as packaging that can be recycled and can be destroyed naturally. Bioplastic is a material under certain conditions, a certain time will experience a change in its chemical structure [1].

Potential of research and development on bioplastic technology is very large, because the biodiversity of agricultural and marine products owned by Indonesia that can be used as biopolymers is very large, including corn, cassava, soybeans, potatoes, and seaweed [2]. Among these natural polymers, the material to be researched is corn because of the abundance of corn in Indonesia. Corn has a harvest period of 60 days, the price of IDR 4,500 per kg and fibre content is 7 grams. The availability of corn is also abundant, transparent, odourless, tasteless, semipermeable to CO2, resistant to O2, and capable to be degraded in non-toxic residues. Procedures for making bioplastics were:

1. Corn starch composition are 20, 30, 40 mg;
2. Glycerin composition are 1.5%, 2%, and 2.5% mixed with 100 ml of distilled water (water) then stirred for 5 minutes with 900 rpm rotation;
3. heated over a hotplate (pan) with a temperature of about 70-90 °C. While stirring for 45 minutes;
4. poured into the mold, then dry it over the oven at 50 °C for 7 hours;
Let it stand at room temperature.

2. Literature review

2.1. Bioplastic
Biodegradability of plastic depends on the chemical structure of the forming material. Bioplastics can be made from natural or synthetic resins. Natural bioplastics come from renewable resources, for example derived from starch. Synthetic bioplastics are from non-renewable resources, such as petroleum. Bioplastics is a plastic made of plants, for instance derived from flax oil, soybean oil or starch. Bioplastics have properties that easily decomposed. Bioplastics can be decomposed by CO2, methane, water, inorganic compounds or biomass where the main mechanism is the activity of enzymes produced by a microorganism [3].

2.2. Corn
Corn is an important source of protein in people's lives. Corn contains several components needed by the body, including food fibre, essential fatty acids, isoflavones, minerals, (Ca, Mg, K, Na, P, Ca, and Fe), anthocyanin, beta carotene (pro-vitamin A), composition essential amino acids, etc. [4]. Corn protein levels of ± 9% are much lower than the requirements of broiler chickens that reach up to 22% or laying hens that are above 17%. In some countries, corn is also used as livestock fattening material, namely cattle. To increase the nutritional value, corn is processed further by heating it with steam and pressing it. Either by using dry rolled techniques or by wet technique using steam. Corn also contains starch which is relatively high enough. So that corn can also be used as a raw material in making bioethanol by fermentation. Ethanol is produced through a process of catalytic hydration of ethylene or through a process of fermentation of sugar using Saccharomyces cerevisiae yeast.

The chemical analysis of corn kernels can show that each fraction has different properties. In the processing process by removing some of the fraction of corn seeds, it will affect the nutritional quality of the final product. The Composition of corn seeds based on dry weight can be referred bellow [5]:

| Composition | Whole Seed | Endosperm | Kernel | Epidermis |
|-------------|------------|-----------|--------|-----------|
| Protein (%) | 3.7        | 8         | 18.4   | 3.7       |
| Fat (%)     | 1          | 0.8       | 33.2   | 1         |
| Fiber (%)   | 86.7       | 2.7       | 8.8    | 86.7      |
| Ash (%)     | 0.8        | 0.3       | 10.5   | 0.8       |
| Starch (%)  | 71.3       | 87.6      | 8.3    | 7.3       |
| Sugar (%)   | 0.34       | 0.62      | 10.8   | 0.34      |

2.3. Glycerin
Glycerin/glycerol is a side production of biodiesel production from transestrification reactions and an alcoholic compound with three hydroxyl groups. Glycerol is a colorless, thick liquid that has a sweet taste. Glycerol can be purified by a distillation process so that it can be used in the food industry. Pharmacy. Glycerol has a low selling price because it has not been treated properly and correctly. Glycerol is a dual function compound in which there are several cyclic carbonate groups, and a nucleophilic hydroxy group. The two-function compound described above can be used as a polar protic solvent, besides also supported by the nature of having a very high boiling point and safe for the
environment. The solvent can be applied with organic and inorganic compounds such as comestics, paints, accumulators, etc. [6].

2.4. Response surface method
Response surface method is a set of mathematical and statistical methods used in modeling and analysis, which determine the influence of several quantitative variables on a response variable and can optimize the response variable [7], for instance are glycerine concentration ($X_1$) and corn starch concentration ($X_2$). As for the response to this design is tensile strength in bioplastics ($Y_{corn}$). Surface response method is a statistical and mathematical technique that can be useful for the development, improvement and optimization of processes in the main response caused by variables and aims to optimize the response itself. This study aims to optimize composition between corn-glycerin and cassava-glycerin. Using the surface response method is expected to optimize in the manufacture of bioplastics. The experimental design is the central composite design will consist of two factors, using two levels of each variable that is given code -1 and +1. The polynomial modeling, which has been constructed, can be tested for the accuracy of the model. It is necessary to repeat the observation with the center point which is coded 0.

The optimum point on the response surface can be obtained by using one factor - one factor, for instance, if $X_2$ is fixed while $X_1$ changes, then $X_1$ will optimize $Y$. After $X_1$ and $X_2$ have been found, the experiment can be done to get an optimum point. However, the method is not all successful, depending on the shape of the response surface, moreover usually the shape of the response surface is unknown. The researcher uses a simple and efficient method to get the optimum point around the optimum point. Usually the assumption of optimum point will be far from the actual value. Then it will be assumed that the first order is a good enough approach to suspect the real surface. To overcome the problems described above, the Steepest Ascent method is used which is a method that works sequentially along the surface of the fast moving response by increasing the response to the optimum point. Whereas to find the minimum point, using the steepest descent method. This method does not determine the specific optimum point value, but is only able to direct to the area around the optimum point [8].

3. Methodology
The experimental design was carried out, so the data generated from the experimental results could be processed using the response surface method. The design of the experiment was conducted to examine the optimal composition of making bioplastic samples from corn starch and glycerin. This experiment was conducted at the Industrial Computing and Simulation Laboratory, Industrial Engineering, Trunojoyo Madura University. The independent variables used were glycerin concentration ($X_1$) and corn starch concentration ($X_2$). The dependent variables to be optimized was tensile strength of bioplastics ($Y_{corn}$). The complete experimental design was as follows:

1. Variables :
   a) Glycerin concentration, notated by $X_1$, range from 0.5 to 1.5%;
   b) Corn starch, notated by $X_2$, range 20 to 40 mg.

2. Response :
Tensile Strength ($Y_{corn}$)

| Treatment | Codes |
|-----------|-------|
| Glycerin concentration (%) | -1,828 | 0,5 | 1 | 1,5 | 3,828 |
| Corn Starch (mg) | 27,172 | 20 | 30 | 40 | 32,828 |

Table 2. Treatments.
3. Composite design of corn sample was based on the initial experiments that have been carried out where $X_1$ was the concentration of glycerin (%) and $X_2$ was the concentration of the corn (mg), and $Y_{corn}$ was the bioplastic’s tensile strength. This experiment used response surface method which was a central composite design experiment model. Minitab was used for data processing.

4. Result and discussion
Measurement of tensile strength test used texture analyzes (Taxt Plus, Stable micro System, UK) Mr. Bioplastics was placed on the device, then the device pulled the plastic to be tested. As long as the bioplastic pulled tool, the force was automatically be printed on the computer screen. The force was continue to increase until the bioplastic breaks. When broke up, it was automatically stop instantly. To determined the tensile strength of the bioplastic, the force that enters the test computer before the force was at point 0. Table 3 was a recapitulation of tensile strength test data:

| No | Variables Code | Real X1 | X2 | G (ml) | T (g) | $Y_{corn}$ (MPa) |
|----|----------------|--------|----|--------|------|-----------------|
| 1  | 0              | 0      | 0  | 1      | 3    | 4.64            |
| 2  | 0              | 0      | 0  | 1      | 3    | 5.33            |
| 3  | 0              | 0      | 0  | 1      | 3    | 4.55            |
| 4  | 0              | 0      | 0  | 1      | 3    | 4.19            |
| 5  | 0              | 0      | 0  | 1      | 3    | 5.30            |
| 6  | -1.414         | 0      | 1  | 3      |      | 8.80            |
| 7  | 1.414          | 0      | 2  | 3      |      | 0.26            |
| 8  | 0              | -1.414 | 1  | 2      |      | 1.70            |
| 9  | 0              | 1.414  | 1  | 5      |      | 1.53            |
| 10 | -1             | -1     | 0.5| 2      |      | 6.86            |
| 11 | 1              | -1     | 1.5| 2      |      | 5.18            |
| 12 | -1             | 1      | 0.5| 4      |      | 17.80           |
| 13 | 1              | 1      | 1.5| 4      |      | 2.32            |

Through ANOVA calculations using Minitab, it obtained for tensile strength tests was as follows:
Analysis of Variance

| Source                  | df | Adj SS  | Adj MS  | F-Value | F-Value |
|-------------------------|----|---------|---------|---------|---------|
| Model                   | 5  | 192.46  | 38.491  | 5.39    | 0.015   |
| Linear                  | 2  | 142.52  | 71.262  | 11.83   | 0.006   |
| X1                      | 1  | 142.01  | 142.009 | 23.58   | 0.002   |
| X2                      | 1  | 13.99   | 13.992  | 2.32    | 0.171   |
| Square                  | 2  | 46.94   | 23.471  | 3.90    | 0.073   |
| X1*X1                   | 1  | 25.51   | 25.510  | 4.24    | 0.079   |
| X2*X2                   | 1  | 21.52   | 21.519  | 3.57    | 0.101   |
| 2-Way Interaction       | 1  | 47.61   | 47.610  | 7.90    | 0.026   |
| X1*X2                   | 1  | 47.61   | 47.610  | 7.90    | 0.026   |
| Error                   | 7  | 42.16   | 6.023   |         |         |
| Lack-of-Fit             | 2  | 27.85   | 13.926  | 4.87    | 0.067   |
| Pure Error              | 5  | 14.31   | 2.862   |         |         |
| Total                   | 12 | 234.62  |         |         |         |

\[ Y_{\text{corn}} = -15.5 - 3.2X_1 + 17.24X_2 + 6.70X_1^2 - 1.460X_2^2 - 6.90X_1X_2 \]

Where are:

- \( Y_{\text{corn}} \) = Tensile Strength
- \( X_1 \) = Glycerin
- \( X_2 \) = Corn Starch

Furthermore, based on ANOVA tensile strength test model, \( P \)-value was 0.067, which was more than \( \text{sig } \alpha = 0.05 \). It can be concluded that the model was significant and can be used for this research. After a significant model, the next step was the optimal parameter determination stage by using the contour of tensile strength plot.

Figure 1. Contour plot of tensile strength.
In figure 1, it can be seen that optimal solution area is in the center of the plot which has baby green colour. The interval code of optimal solution can be seen on the legend. In the figure 2, it can be seen on the graph that the optimal solution in on the top of the graph because optimal solution is set by maximal solution. Moreover in figure 3, optimal solution can be obtained using D-optimaly response, which are D-Optimal response of tensile strength (corn) is obtained from the value of the desibrability function. The result of optimal solution were 0.5 ml glycerin and 4.72 g corn starch with a tensile strength was 17.18 Mpa. In this research still observed only for one plastic property, for future work this research can be continued for observing another plastic properties, such as elongation, modulus young, degradable period, texture improvement, etc. Comparing with the other natural materials can become interesting research, for instance cassava, banana peel. This can be interesting future research, because it can find materials which have better tensile strength, flexibility, and price.

5. Conclusion
Potential of research and development on bioplastic technology is very large, because the biodiversity of agricultural and marine products owned by Indonesia that can be used as biopolymers is very large, including corn. The availability of corn is also abundant, transparent, odourless, tasteless, semipermeable to CO2, resistant to O2, and capable to be degraded in non-toxic residues. Parameter can be considered for bioplastic is tensile strength, after tested in Laboratory, tensile Strength Optimization of Corn was obtained from D-optimaly calculation. D-optimaly response was obtained by the value of the desibrability function. For optimal solution were 0.5 ml glycerin and 4.72 g corn starch with a tensile strength was 17.18 Mpa.
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