Multi Responses Optimization for the Sugar Content and Microbial Impurities of Carrot Syrup

O Isabella and Yurida Ekawati

Industrial Engineering Department, Ma Chung University
1e-mail: yurida.ekawati@machung.ac.id

Abstract. Carrots are one type of agricultural products with large quantities in Indonesia. One of the carrot based products is carrot syrup. To determine the optimal process and composition of the carrot syrup, design of experiment using Taguchi method was carried out. This research have focused to optimize the carrot syrup with multiple quality using multi response Taguchi method based on the average quality losses. The quality dimension used are the sugar content and microbial impurities of the carrot syrup. The two quality dimensions have different responses, larger the better for sugar content and smaller the better for microbial content mold and yeast. The parameters determined to optimize the product quality dimensions are the duration of heating and the amount of sugar. The result of the optimal process and composition of carrot syrup is the duration of heat for 30 minutes and the amount of sugar of 210%.

Keywords: multi responses, Taguchi, carrot syrup

1. Introduction
Diversification is an attempt to make a product or service diverse. Product diversification can increase the value of a product. Diversification of products can be done on carrots, the agricultural products that have a relatively low durability and cannot be stored for a long time. Carrots are one type of agricultural products with large quantities in Indonesia. A previous research had been conducted to find carrot based products preferred by consumers and the attributes of consumer needs for the products[1]. One of the products found in the research was carrot syrup. The product design of carrot syrup had been developed to find the critical parts in producing carrot syrup[2]. The production process of carrot syrup which had already conducted can be used to produce carrot syrup[3]. However, to optimize the production of the syrup an experimental design need to be carried out. Robust design in quality engineering, as proposed by Taguchi, has significantly improved quality and yield in product and manufacturing process design[4]. Taguchi method can be used to optimize food products such as carrot syrup. As part of food products, carrot syrup has to follow the regulation or standard that have been set by the government. The standard allows an experimental design using more than one quality response. Several methods for addressing optimal factor levels for multi response quality characteristics have been proposed[5], [6], [7]. This study attempts to determine the optimization of the production process and composition parameters for optimal carrot syrup in terms of sugar content and microbial impurities. The method proposed by Wu[7] is used to optimize the multiple quality characteristics design for the carrot syrup.
2. Methods
The method for this research used the work of Wu [7] that offers a simple approach to optimize the multiple quality characteristics based on quality loss function.

2.1 Experimental design
The experimental design of Taguchi is conducted by stating the problems of concern, stating the objectives of the experiment, selecting the quality characteristics and measurement systems, selecting the factor which may influence the selected quality characteristics, identifying control factors and noise factors, selecting levels for the factors, and selecting the appropriate orthogonal array (OA) [8].

2.2 Perform the experiment and laboratory test
The experiment was done by making the combination of factor and level as described in OA. In this study, the sugar content and microbial impurities content is measured by laboratory test.

2.3 Data processing
Taguchi gives the following definitions for the average quality loss when \( n \) units of a product are measured [7].

For larger the better characteristic can be defined as:

\[
L(y) = k \cdot \left( \frac{1}{n} \sum_{i=1}^{n} y_i^2 \right)
\]

For nominal the best characteristic can be defined as:

\[
L(y) = k \cdot \mu_0^2 \left( \frac{s^2}{\bar{y}} \right)
\]

And for smaller the better characteristic can be defined as:

\[
L(y) = k \cdot \left( \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_i^2} \right)
\]

Where \( k \) is quality loss coefficient, \( y_i \) is a measurable statistic of quality characteristic, \( \mu_0 \) is the target value for nominal the-best characteristic, \( \bar{y} \) is the sample mean of \( n \) units and \( s^2 = \sum_{i=1}^{n} \frac{(y_i - \bar{y})^2}{(n-1)} \) is the unbiased estimator of process variance \( (\sigma^2) \). According to the concepts of Taguchi’s quality loss function, the proposed optimization approach for multiple quality characteristic is given in the following steps [7]:

Step 1: Compute the total average quality loss, \( Q \), for each experiment combinations based on the additive model.

\[
Q = \left( \sum_{i=1}^{n} y_i \right)
\]

Step 2: Transform the \( Q \) into the Signal-to-noise ratio (SNR), \( \eta \), in decibels by the following equation.

\[
S/N = -10 \log_{10} Q
\]

Step 3: Evaluate the effects of the control factors under consideration on \( \eta \). The optimal factor settings are obtained by selecting the maximum \( \eta \). Calculate he maximum \( \eta \) by the following equation.

\[
\eta = \left( \frac{1}{n} \sum_{i=1}^{n} y_i \right)
\]
3. Result and Discussion
The experiment used Standar Nasional Indonesia (SNI) as a main consideration in determining the factor and level in the experimental design because the product being tested was a food product. This research used SNI 3544:2013 standard for syrup [9]. SNI 3544:2013 establishes the terms, definitions, quality requirements, sampling, test methods, packaging and labeling syrup. Syrup itself is a beverage product made from a mixture of water and sugar with a minimum sugar content of 65% with or without other food and/or food additives permitted in accordance with applicable regulations.

3.1 Experimental design planning
The Taguchi method consists of three main stages: planning stage, conducting stage, and analysis stage [8]. Planning stage in this research began with the identification of quality dimensions to be improved. They were sugar content and microbial impurities content. SNI 3544:2013 standard for syrup contains coliform bacteria, Escherichia coli, Salmonella sp, Staphylococcus aureus, mold and yeast. Based on various kind of microbial impurities, there are two microbial that will be tested on this research, namely mold and yeast. Coliform bacteria and Escherichia coli are not included in the experiment since they are bacteria that usually occur in water. Salmonella sp is a group of bacteria commonly found in foods containing protein such as eggs and meat. So that type of microbial contamination has a small chance to grow in carrot syrup media.

Other types of microbial contamination are staphylococcus aureus microbes. Staphylococcus aureus microbes are microbes that can be contained in carrot syrup due to skin contact. The microbes grow in humans in the skin area, so hygiene process can minimize the carrot syrup contaminated by the microbes. Carrot syrup is the most suitable growth medium for microbial mold and yeast. High sugar content in the syrup will cause the growth of microbe mold and yeast, but that does not mean that the type of microbes come from the sugar content.

The planning stage was continued by selecting the parameters and their levels. Percentage of sugar content and microbial impurities in the carrot syrup were discussed with some experts in food technology. Based on the discussion, there were two control factors used in this experiment that can affect the quality attributes of carrot syrup. These factors were the duration of heating and the amount of sugar. The duration of heating and the amount of sugar affect the sugar content in carrot syrup, so there should be three levels that consider the lower, the middle and the upper level.

The level of the heating duration was determined based on previous research [3]. Based on the research the duration of heating was less than 30 minutes. Therefore, 30 minutes was chosen as the middle level and the difference with the lower and upper level was 10 minutes. The level of amount of sugar was determined based on SNI that stated that the minimum sugar content in the syrup will be at least 65% [9]. Based on the mathematical calculation to get sugar content of 65% the amount of sugar is at least 186%, but based on the preliminary laboratory test the sugar content can be greater or smaller than the calculation. Therefore the lowest level chosen was 200% increased by 5% for each level. The levels of each parameter is shown in Table 1.

The final stage of experimental planning was the determination of an orthogonal array. The orthogonal array was based on the number of factors and levels of each factor. This research used two control factors with three levels each, so the number of experiments to be carried out were nine experiments. The combination of the composition level of the experiment to be performed on carrot syrup can be seen on Table 2.
Table 1. The Level of Each Parameter

| Factors                        | Levels       |
|-------------------------------|--------------|
| Duration of heating (A)       | 1 2 3        |
| Amount of sugar (B)           | 200% 205% 210% |

Table 2. Combination of Experiments

| Experiment | Factors |                        |                        |
|------------|---------|-------------------------|-------------------------|
|            | A (Duration of Heating) | B (Amount of Sugar)    |                         |
| 1          | 20 minutes | 200%                   |                         |
| 2          | 20 minutes | 205%                   |                         |
| 3          | 20 minutes | 210%                   |                         |
| 4          | 30 minutes | 200%                   |                         |
| 5          | 30 minutes | 205%                   |                         |
| 6          | 30 minutes | 210%                   |                         |
| 7          | 40 minutes | 200%                   |                         |
| 8          | 40 minutes | 205%                   |                         |
| 9          | 40 minutes | 210%                   |                         |

3.2 Data processing

The data for the experiment were the sugar content and microbial impurities for mold and yeast of carrot syrup resulted from the combination of factors shown in Table 2. There were 9 combination and 2 replication so that the total samples were 18. The sugar content and microbial impurities were taken based on laboratory test. Table 3 shows the results for percentage of sugar and microbial impurities for mold and yeast on each combination experiment.

Table 3. Percentage of Sugar and Microbial Impurities for Mold and Yeast

| Experiment | Sugar (%) | Microbial Mold (CFU/ml) | Microbial Yeast (CFU/ml) |
|------------|-----------|-------------------------|--------------------------|
|            | 1 2       | 1 2                     | 1 2                      |
| 1          | 60,57 77,89 | 1 0                     | 10 3                     |
| 2          | 65,49 76,75 | 0 0                     | 37 1                     |
| 3          | 74,87 74,76 | 0 0                     | 1 2                      |
| 4          | 60,23 74,6  | 0 0                     | 17 16                    |
| 5          | 67,99 77,68 | 0 0                     | 2 2                      |
| 6          | 73,91 75,69 | 0 0                     | 2 1                      |
| 7          | 74,87 77,07 | 0 0                     | 70 2                     |
| 8          | 75,57 83,1  | 0 0                     | 6 2                      |
| 9          | 80,75 75,4  | 0 0                     | 0 1                      |

The percentage of sugar content and microbial impurities data resulted from laboratory test then transformed into average quality loss for each response based on the quality characteristic. Sugar content used a larger the better characteristic and for microbial content mold and yeast used smaller the better characteristic. The average quality loss for sugar content was computed using equation (1) and the result
can be seen in Table 4. The average quality loss for microbial mold and yeast were computed using equation (3) and can be seen in Table 4.

| Experiment | Sugar   | Microbial Mold | Microbial Yeast |
|------------|---------|----------------|-----------------|
| 1          | 0.0002187 | 0.5            | 54.5            |
| 2          | 0.0002015 | 0              | 685             |
| 3          | 0.0001787 | 0              | 2.5             |
| 4          | 0.0002277 | 0              | 272.5           |
| 5          | 0.0001910 | 0              | 4               |
| 6          | 0.0001788 | 0              | 2.5             |
| 7          | 0.0001734 | 0              | 2452            |
| 8          | 0.0001600 | 0              | 20              |
| 9          | 0.0001646 | 0              | 0.5             |

From the data in Table 4, then the total average quality loss, $Q$, for each experiment was computed using equation (4) and transform the $Q$ into the Signal-to-noise ratio (SNR), $\eta$, in decibels using equation (5). Table 5 shows the quality loss and SNR for the 9 experiments.

| Experiment | Factors | Q            | SNR            |
|------------|---------|--------------|----------------|
| A          | B       |              |                |
| 1          | 1       | 55.0002187   | -17,40364416   |
| 2          | 1       | 685.0002015  | -28,35690699   |
| 3          | 1       | 2,500178658  | -3,979710437   |
| 4          | 2       | 272.5002277  | -24,35366869   |
| 5          | 2       | 4,000191025  | -6,02087311    |
| 6          | 2       | 2,500178806  | -3,979710693   |
| 7          | 3       | 2452.000173  | -33,89520497   |
| 8          | 3       | 20,00015996  | -13,01033469   |
| 9          | 3       | 0.500164629  | 3,008870245    |

From the data in Table 5. the maximum $\eta$ was calculated using equation (6) and the result is presented in Table 6.
Based on all figures above, it can be seen levels with the highest score on each factor. This main effect is done to optimized carrots syrup based on sugar and microbial impurities, so it is found the optimal process and composition of carrot syrup is as follows:

| Factors            | Levels | Composition |
|--------------------|--------|-------------|
| Duration of heating| Level 2 | 30 minutes  |
| Amount of sugar    | Level 3 | 210%        |

Based on Table 7, the optimal composition for carrot syrup in term of sugar content and microbial impurities is the amount of sugar of 210% with duration of heating 30 minutes. The optimal composition is shown as experiment number 6.

4. Conclusion
A research to find the best composition and process of carrot syrup had been done using Taguchi method for multi responses. The quality dimensions for the carrot syrup are determined based on the SNI that states standard composition for syrup. The quality dimensions are sugar content and microbial impurities, with the quality responses for the two quality dimensions are larger the better for sugar content and smaller the better for microbial impurities. The parameters selected to optimize the product quality are the duration of heating and the amount of sugar with each parameter uses three levels. The result of the optimal process and composition of carrot syrup is the duration of heating for 30 minutes and the amount of sugar of 210%.

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