Determination of the best formula to increase potato chips quality with the integration of consumer acceptance and laboratory testing

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Abstract. Consumers’ demand for competitive product quality is a challenge for Small Medium Enterprises (SMEs) producing potato chips. One of the constraints is the inconsistent quality of the production. Thus, it is necessary to determine a formula as a standard for optimization in production. This research aims to determine the best formula in the quality of the production process based on the integration of consumer assessment and laboratory testing. The analytical method for determining the best formulation was the Effectiveness Index (EI) and Multiple Attribute (MA) and it will be compared with the standard quality of potato chips (SNI 01-4031-1996). The research object was the SMEs cluster of the potato chip (9 units) in Batu City. The indicators for consumer acceptance tests include color, taste, aroma, wholeness, and crunchiness, while indicators for laboratory tests include moisture content, fat content, and free fatty acids. The results showed that the best performance of SMEs A and the worst of SMEs C compared to SNI 01-4031-1996 as a basis for improvement in its critical processes. The results of determining the best formula show that the moisture content for SMEs A is still not suitable so that improvements in the drying and frying process are recommended.

1. Introduction

Batu City is one of the tourist destinations in East Java and is geographically located on the highland. Moreover, it is a city with various sources of horticultural products such as apples, oranges, potatoes, carrots, chrysanthemums, and roses [1,2]. The development of superior regional products based on horticultural products has the potential to be increased, considering that the agricultural sector in Batu City also plays an important role in the economy [2]. One of the products is potato chips, a typical food highly favored by tourists and locals. Processed potato products have the potential to be developed due to their high economic value. Moreover, it also refers to the data held by the Central Statistics Agency of Batu City [3] that potato production has increased from 91,377 quintals (2018) to 94,014 quintals (2019). However, the production of potato chips is mostly carried out by household-scale businesses or Small Medium Enterprises (SMEs) [1].

The high competition for potato chips in Batu City triggers SMEs to improve the potato chip products quality continuously. Crispy texture characteristics are one of the most important quality indicators for potato chips. Other indicators are color [3] and flavor [4]. Potato chips as a food product must meet the
food safety standards before being distributed to consumers. In this case, Indonesian National Standard (SNI 01-4031-1996) is a reference standard for SMEs in producing potato chips.

Product quality plays a major role in determining competitiveness [6]. The competitiveness of the agro-industry is carried out through controlling the production process and improving the product quality. Enhancement is committed from production activities to marketing by making improvements to the production process, promotion, and relevant information delivery to the business actors [7].

In the production implementation, SMEs often experience problems related to the production process, thus requiring quality control on the production process to ensure the implementation of planned production activities, reduce the incidence of non-conformities and reduce the decline in the final product quality. The quality control aims to maintain the product quality [8], produce product consistency and uniformity through identification of the factors causing defects in products, improve producer-consumer relationships, increase profits, reduce quality control costs [9], and as an effort to meet consumer demand [8].

The quality problem experienced by SMEs of potato chips is in the form of diversity in the production process between SMEs, which causes inconsistencies in the final product quality in terms of color, taste, wholeness, crispness, and appearance. The evaluation of the production process quality can be performed by integrating consumer acceptance by the sensory attributes testing on consumers and the laboratory testing on the product attributes compared to SNI. The product testing on consumers is carried out through a preference/hedonic test assessing the organoleptic of the product to determine consumer acceptance of the potato chips. The preference test results were then analyzed using the Effectiveness Index (EI) method, which aims to obtain the best alternative of all treatments for the product [10]. The laboratory testing aims to determine the suitability of the initial formula for the existing products of SMEs with SNI (Indonesian National Standard) and then is analyzed using the Multiple Attribute (MA) method to obtain the best alternative based on the weight. The MA method is applied to find the weight value for each attribute, and then a ranking process is carried out to determine the optimal alternative [11].

2. Methods
The research was conducted on the SME’s cluster of potato chips in Batu City. The cluster is formed into 2 clusters based on some attributes: the production capacity per month, the number of labors, the length of operation, the average sales turnover per month, and the ownership of halal certification. The target population was all 30 units of SMEs potato chips in Batu City, while the access population that meets the criteria and is stable in the production process was 9 units. The research used saturated sampling with the samples are 9 units. The analysis method integrated consumer acceptance tests and laboratory testing to obtain the best formula compared to the SNI potato chip quality standard. The organoleptic testing with the following parameters, color, size consistency, appearance and crispness was carried out on 30 respondents (consumers) based on the minimum number of samples according to a normal distribution, and the laboratory testing add the parameters of water content, free fatty acids, and fat content. Analysis of determining the best formula according to the consumer acceptance results was using Effectiveness Index (EI), and the laboratory testing used Multiple Attribute (MA).

Determination of the best formula can be done using the EI method. The following is the EI weighting procedure to determine the best treatment:

a) Parameter grouping, physical and chemical parameters are grouped separately with organoleptic parameters.

b) Each parameter is given a weight of 0-1 in each group.

\[
\text{Weight Value} = \frac{(\text{Total value of each parameter})}{(\text{Total value of all parameters})} \tag{1}
\]

c) The value of effectiveness (VE) is calculated by the formula:

\[
\text{VE} = \frac{(\text{PV-WV})}{(\text{BV-WV})} \tag{2}
\]
Note:
VE: Effectiveness Value
PV: Product Value
WV: The Worst Treatment Value
BV: The Best Treatment Value

d) For the average parameter, the bigger, the better, then the lowest value is the worst value, and the highest value is the best value.
e) Calculation of product value (pv) is obtained by multiplying the effectiveness value (ev) with the weighted value.

\[
PV = EV \times \text{Weight Value} \tag{3}
\]
f) The production values of all parameters in each treatment group were added up. The treatment that had the highest PV was the best treatment in the parameter group.
g) The best treatment was selected based on the treatment that had the highest PV for organoleptic parameters.

The stage of Multiple Attribute (MA) Analysis are:
a) Determine the best treatment/formula using the MA method for the laboratory test parameters.

Following are the steps in doing the Multiple Attribute (MA) method:
b) Determine the ideal value based on the expected value for each parameter (d^k).
c) Calculating density degrees that \(d_i^k = (\min) = 1/(d_i^k)_{\max}\)

If the ideal value \(d_i^k\) is min, then:

\[
d_i^k = \frac{\text{The real value that is close to the ideal (x^*_i)}}{\text{Ideal value of each alternative (x_i^k)}} \tag{4}
\]

If the ideal value \(d_i^k\) is max, then:

\[
d_i^k = \frac{\text{Ideal value of each alternative (x_i^k)}}{\text{The real value that is close to the ideal (x^*_i)}} \tag{5}
\]
d) Calculating density distance
Assuming all parameters are important, the density distance (L_\alpha) is calculated based on the number of parameters (L入住) 

\[
L_\alpha = \frac{1}{L^1} \tag{6}
\]

\[
L_1 = (\lambda, k) = 1 - d_i^k \tag{7}
\]

\[
L_2 = (\lambda, k) = [\sum \lambda_k^2 (1 - d_i^k)]^{1/2} \tag{8}
\]

\[
L_\infty = \max [\lambda_k(1 - d_i^k)] \tag{9}
\]

The best treatment is chosen from the alternative, which has the smallest value \(L_1, L_2, \text{ and } L_\infty\).

3. Results and discussion
According to the analysis of the k-means clustering method, the SMEs cluster potato chip was based on 5 attributes, including production capacity per month, the number of workers, the length of operation, the average sales turnover per month, and the ownership of halal certification. Based on Regulation of
Law No. 20/2008, it was formed into 2 clusters, namely, 1st cluster on a small scale and 2nd cluster on a micro-scale, as shown in table 1.

Table 1 shows 7 SMEs that have more than ten years of operations. The reducing production costs are due to their skills in managing productivity [12] and are related to the length of operation. The maximum business turnover is closely associated with the successful implementation of efficiency in the production process [13]. SMEs B has the highest average sales turnover, and SMEs C is the lowest. Therefore, SME C needs to optimize its productivity. The relatively low turnover requires optimization of production, product marketing, and product pricing, which significantly affects sales turnover [14]. The number of workers does not affect substantially the income of potato chip SMEs in Batu City because each SME has a different supply, demand, and need for labor. However, ideally, an increase in production output is accompanied by an increase in income for business actors [15]. Judging from the ownership of halal certificates on the products produced, only a portion of potato chip SMEs have it. Manufacturers who already had halal certificates on their products were more likely to improve product quality and encourage consumer confidence than producers who do not have halal certificates [16]. The majority of SMEs used raw potatoes with the Granola variety. Granola is the dominant potato variety grown in Indonesia (estimated at 90%) [17]. Differences in potato varieties cause differences in physical and chemical properties that impact the quality of potato chips produced. The potato chip’s quality can be seen through several parameters such as appearance, texture (crispness), color, and nutritional content [18].

Table 1. The profile of clustering potato chips in Batu City.

| No | Variable | 1st Cluster | | 2nd Cluster | | SMEs |
|----|----------|-------------|-----|-------------|-----|-----|
|    |          | A | B | E | I | C | D | F | G | H |
| 1  | The average sales turnover per month (million IDR) | 50 | 70 | 20 | 30 | 4 | 20 | 10 | 20 | 30 |
| 2  | Production capacity per month (kilogram) | 40 | 50 | 60 | 65 | 20 | 20 | 10 | 10 | 20 |
| 3  | The number of workers (person) | 16 | 12 | 15 | 8 | 4 | 8 | 4 | 6 | 10 |
| 4  | The length of operation (year) | 10 | 15 | 15 | 10 | 6 | 11 | 17 | 15 | 7 |
| 5  | The ownership of halal certification | Yes | Yes | Yes | No | Yes | No | No | No | No |

Information the coding of SMEs on Table 1
A = SMEs Ramadaya  E = SMEs Rimbaku  I = SMEs Istana
B = SMEs Gizi Food  F = SMEs Asli
C = SMEs Gajah  G = SMEs Super
D = SMEs Santoso  H = SMEs Sri Rejeki Jaya

In the analysis of determining the best formula for potato chips, a consumer acceptance test was conducted using 30 respondents who have consumed potato chips from 9 SMEs at least in the last 1 month to get an objective assessment. The assessment was carried out with 5 organoleptic attributes, namely color, taste, aroma, appearance, and crispness, with the results shown in table 2.
Table 2. The result of customers’ acceptance of potato chips.

| Brand | Parameter | Color | Taste | Aroma | Appearance | Crispness |
|-------|-----------|-------|-------|-------|------------|-----------|
| A     |           | 3.17  | 3.43  | 3.17  | 3.73       | 3.50      |
| C     |           | 3.87* | 4.23* | 3.67* | 3.97*      | 3.90*     |
| F     |           | 3.17  | 2.87  | 3.17  | 3.07       | 3.27      |
| G     |           | 2.90  | 3.23  | 2.83  | 2.63       | 3.10      |

Based on the preference test, taste is the parameter with the highest value of 4.23 with a scale of 1-5. This condition indicates that taste is an important attribute of potato chips and greatly affects consumer acceptance. Quality chips are chips that have a color that matches the flesh of the fruit, have a good taste, and have a crunchy texture [1]. Potato chips with original taste, crunchy texture, and evenly white-yellow color indicate that the chips are ready to be marketed to consumers [1]. Thus, color is included in the indicator because it is the most important quality parameter for consumer perception [19].

Color is an important attribute of the product acceptance process and is related closely to the changes in aroma and taste [20]. It is also related to the decrease in the sugar content in potatoes which affects the color of potato chips after frying. The low of reducing sugar tends to produce a brighter color of potato chips, while high reducing sugar content causes the browning process [18].

Aroma has a special function in product development because it can increase product value or acceptability [20] and evaluate product damage. The quality indicators for potato chips can be seen through the following characteristics, crispness texture (crisp level) [4], color [4,19], and flavor [5]. The factors affecting the appearance and texture of potato chips are the variety of potatoes used and the initial soaking process that can affect the structural properties of potatoes (volume, density, porosity, moisture content, water activity, changes in texture, sensory properties: color, texture, taste, overall acceptance). The texture of potato chips is the result of a dehydration process due to heat transfer from cooking oil into the ingredients [19].

Based on the results of the acceptance test of preference in Table 2, then the best alternative product decisions are obtained by considering the results of the organoleptic assessment and the level of importance of product quality attributes. It is through the comparison of the values of each product based on the weighting determined by the respondent using the EI analysis and MA. The results of the EI analysis (1st) in SMEs potato chips are shown in Figure 1.

Figure 1. The results of EI analysis (1st) in SMEs potato chips.
Figure 1 shows the color code of the analysis results. The red indicates SMEs have the highest PV (rank 1), the green has the lowest PV (rank 9) while the blue indicates other SMEs that have PV for ranks 2-8. The determination of the best formula value is based on the result of the highest product value (PV), so that product C has the best formula and G is the product with the worst formula compared to the other SMEs. The Effectiveness Index (EI) shows the best alternative results of all treatments used in the products [10]. All parameters (taste, color, aroma, appearance and texture) in product C affect the achievement of the PV because all of them have the highest score favored by respondents. Especially for taste has the highest score as an important attribute of food products. The taste factor is also important in influencing consumer ratings. According to [21], the taste is a factor that consumers can evaluate where consumers will evaluate all the products they consume to find out which products match their taste preferences. According to respondents, product G has a low value on 3 attributes, especially on the appearance which is considered not in accordance with the level of consumer preference, less attractive to consumers with the shape of chips that are not uniform in size. Especially for the appearance or appearance of the product is the first element that consumers pay attention to when choosing a product [22]

The laboratory testing results with attributes of water content, fat content, and free fatty acid (FFA) content compared to the quality standard of potato chips Indonesian National Standard (SNI in Indonesian) 01-4031-1996 with Multiple Attribute (MA) analysis are shown in Figure 2.

Based on Figure 2, it can be seen the use of several colors for different analysis results. The red indicates SMEs have the lowest value of L (rank 1), the green has the highest value of L (rank 9) while the blue indicates other SMEs that have the value of L for ranks 2-8. The determination of the best formula value based on the results of the lowest density distance (L) belongs to SMEs A, and the highest is SMEs F. Product A has the lowest value of L supported by the value of content fat content and free fatty acid according to the maximum standard of SNI. Especially for the content of water, have the higher than of SNI that need the improvement of process to reducing of water in chips. The content of water is one of the most important characteristics of foodstuffs because the water content in foodstuffs can affect the appearance, texture, and taste of these foodstuffs. The low of water affects the durability of foodstuffs and shortens shelf life and facilitates the growth of microorganisms because it is a good medium for their life [23]. For product F, all parameters are in accordance with SNI standards so that they do not get priority repairs with the highest L value.

Based on the EI and MA analysis, there are differences of SMEs as to how to determine the best formula, so it is necessary to do EI second a second EI analysis to get the best optimization formula with the
results are shown in Figure 3. The result of laboratory testing for all attributes in potato chips compared with SNI is shown in Table 3.

![Figure 3. The result of integration EI and MA analysis.](image)

Based on Figure 3, the best formula based on organoleptic assessment and laboratory testing that has a high level of conformity with SNI is product C, while it is a priority target for improvements in the production process that affect the water content that is not in accordance with the maximum limit of SNI.

**Table 3. The result of laboratory testing for all attributes in potato chips compared with SNI.**

| Parameter         | SNI 01-4031-1996 | A        | C        | F        | G        |
|-------------------|------------------|----------|----------|----------|----------|
| Moisture content  | Max. 3% (w/w)    | 4.56     | 1.37     | 1.06     | 3.31     |
|                   | Unqualify        |          | Qualify  | Qualify  | Qualify  |
| FFA (%)           | Max. 1% (w/w)    | 0.16     | 0.16     | 0.16     | 0.31     |
|                   | Qualify          |          | Qualify  | Qualify  | Qualify  |
| Fatty Acid (%)    | -                | 27.76    | 20.02    | 31.83    | 32.78    |

Based on Table 3, the water content parameters in SMEs C, F, and G met the quality requirements, while SMEs A did not meet it because the water content was greater than the quality requirements stated in SNI. The moisture content of potato chips is influenced by the potato variety used and the treatment at the drying stage. The higher the moisture content in the water evaporation of the material. Furthermore, vaporization can reduce the moisture of the material [1]. The texture of potato chips is influenced by the dry matter content and the processing temperature. The higher the temperature, the less oil is absorbed, and the higher the water content evaporated, the crispier the texture of the slices is [5].

The first strategy to improve water content reduction in potato chips is by using the greenhouse cabinet drying method. The greenhouse cabinet is effective in improving the drying performance of potato chips. Some advantages of using a greenhouse cabinet are, increasing labor efficiency and productivity [24]. On the same amount of product, drying with greenhouse cabinet an 83.3% saving in drying time compared to sun-drying [24], the combination of solar heat with LPG energy create energy efficiency, and the use of a drying control system will increase productivity so that allows it to meet consumer demand. The use of greenhouse cabinets can reduce production costs with more optimal quality results [24].

The second improvement strategy is through 2 frying treatments. Increasing the frying time or temperature can reduce the water content of a product [25,26]. The frying stage can also be used to
create flavor, color, texture and enhance the delicacy of potato chips. The higher the temperature, the less oil is absorbed, and the higher the water content evaporated, the crisper the texture of the slices is [5]. The following treatments, first, frying at a temperature of 197 ± 2°C for 4-5 minutes, second, frying at a temperature of 193 ± 2°C for 5-6 minutes. The two proposed improvement strategies were prepared based on the results of laboratory tests. The laboratory tests show that the water content of potato chips did not meet the SNI quality requirements. Therefore, improvement strategies prepared are about to reduce the moisture content of potato chips, such as greenhouse cabinet for drying method and adjusting frying time or temperature. Both treatments were carried out to reduce the water content of potato chips [25,26].

Judging from the FFA parameter, the four SMEs have produced potato chip products that meet the quality requirements of SNI. The quality indicator of potato chips is also influenced by the oil content, closely related to frying. The frying stage causes the chips to have high oil content due to the absorption of oil during the frying process [17]. The amount of oil absorbed by the product is influenced by: the water content of the material, the thickness of the slices of chips, pre-frying treatment [18], and the immersion stage (type of solution and water temperature used).

The quality requirements of potato chips in SNI 01-4031-1996 are related to oil content seen from the content of free fatty acids (FFA), which is calculated as lauric acid. The content of FFA is related to rancidity due to the auto-oxidation process that begins with the formation of free radicals. The increase in FFA content can be triggered by temperature and sunlight. Fat or oil will be easily oxidized when stored at high temperatures and exposed to sunlight which then reduces the potato chips quality because they cause rancidity. The proposed improvement related to the FFA content of potato chips is by improving the type of potato chip packaging for example, using aluminum foil or polyethylene plastic materials. The main types of packaging used for potato chips are polyethylene plastic and aluminum foil. Packaging plays an important role in protecting food from contamination and damage. Not only to ensure that food is still well-packaged, maintain the amount and the shape of the ingredients, as well as the required nutrients, but packaging also plays an important role in improving the sensory quality and color stability of the food [27].

4. Conclusions
Determination of the best formula value is based on the result of the highest product value (PV) in EI analysis. The EI analysis showed the consumer acceptance of the product results so that the best formula is in the formula of SMEs C and the worst formula in SMEs G. The results of laboratory tests with attributes of water content, fat content, and free fatty acid (FFA) content to be compared with the quality standard of potato chips SNI 01-4031-1996. Based on integration EI and MA analysis that the best formula is SMEs A and the worst formula is SMEs I. Parameters of water content in SMEs C, F, and G assigns with the quality requirements, while SMEs A the is greater than the quality requirements in SNI. One of the strategies to improve water content reduction in potato chips is using the greenhouse cabinet drying method. Increasing the frying time or temperature can reduce the water content of a product. Six Sigma DMAIC can be used as quality control analysis for minimizing defects in potato chips production.

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