Comparison of Gayo Arabica coffee taste sensory scoring system between Eckenrode and Fuzzy-Eckenrode methods

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Abstract. Comparison of a decision appraisal system with a multi-criteria approach is currently highly developed, one of which is the Eckenrode and Fuzzy-Eckenrode methods. A method with the addition of valuation logic such as fuzzy is one alternative in making decisions. The purpose of this study is to compare the sensory scoring system of Gayo Arabica coffee taste using the Eckenrode and Fuzzy-Eckenrode methods. The material needed in this study was Gayo Arabica coffee obtained from farmers in Bener Meriah, Aceh Province of Indonesia and specially ordered with the best handling in the form of green beans at a moisture content of 12%. Coffee was roasted at a medium level and brewed using a Delonghi 35.11 semi-automatic machine made in China. Sensory assessment of the taste of Gayo Arabica coffee included Fragrance, Flavor, Acidity, Body, After-taste, Balance, and Sweetness with 15 panelists. The results showed that the Eckenrode and Fuzzy-Eckenroe methods differed slightly from the weighting calculation results for each criterion chosen by the respondents. However, the accuracy of the Fuzzy-Eckenrode method had a better weight value than the usual Eckenrode method in the sensory assessment of the taste of Gayo Arabica coffee. Sequentially the highest degrees of importance according to sensory assessments of Gayo Arabica coffee taste are Flavor, Sweetness, Balance, Fragrance, Acidity, After-taste and Body. Based on the analysis of the sensory assessment criteria of Gayo Arabica coffee taste, it showed that the Flavor criterion is the most important criteria compared to other criteria.

Keywords: Eckenrode, fuzzy, Gayo Arabica coffee, sensory, taste

1. Introduction
Sensory assessment system by adopting a decision-making approach is one method that is still rarely used. Given the decision - making techniques are usually designed to help to analyze a policy that requires certain views before it is decided to be a decision. The decision-making system is indeed well developed, both quantitative and qualitative. In the engineering systems approach, quantitative decision making is a more certain model than one through a qualitative approach that is open and has the opportunity to be further discussed.

Sensory assessment system with a decision-making approach has been used as an alternative in calculating the accumulation of preferences of panelists or respondents both experts and other general public [1, 2]. Some decision-making system approaches which are then used in sensory assessment systems such as Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) [3, 4], Elimination and Choice Expressing Reality (ELECTRE) [5, 6], Simple Additive Weighting (SAW) [6-8], Analytic Hierarchy Process (AHP) [9, 10] and others. Although there are many methods that can be used, in fact, each method has its own philosophy and is not one method that is more correct than
the others [11]. Even an old method or a new method proposed does not mean that the old method is not good or inferior to the new method [12].

**Eckenrode Method**

Around 1965, a scientist named Robert T. Eckenrode from Dunlop and Association, Inc. in the United States initiated one of the multi-criteria decision-making methods known as the Weighting Multiple Criteria (WMC) method. The WMC method was then often referred to as the Eckenrode method and until now continues to be widely used in various decision-making studies. The Eckenrode method is considered to be quite simple and efficient in solving problems for determining the specific importance of a decision [13]. According to Maarif and Tanjung [14], the Eckenrode weighting analysis method is one of the weighting methods used to determine the importance or weight (B) of each criteria (K) and Sub-Criteria (SK) specified in decision making. Determination of the weight is considered very important because it will affect the final total value of each decision choice. The concept used in this weighting method is to change the order to a value where for example 1 for the highest level (value) and 5 for the lowest level (value).

Comparison of the current decision-making system has been widely developed, both the development of one method for itself and the comparison with other methods. Georgiadis [15] for example had made a comparison between the TOPSIS, SAW and WPM (Weighted Product Model) methods in his research on the use of multi-criteria for decision making technology choices that are possible for the United States Department of Defense. Other researchers such as Şenyiğit and Demirel [16] tried to compare the AHP, TOPSIS and SAW methods in making decisions on the use of soft drink packaging based on multi-criteria considerations. One form of comparison of a method is to include a different grading system such as the use of a fuzzy logic grading system. The use of fuzzy logic systems in decision making gives more intermediate values in a certain range of judgments that are not certain to just one number. According to the fuzzy set, an element is defined to have two values at once, namely true and false values simultaneously [17]. The degree of truth value or error value is determined by the weight or degree of membership of each.

Fuzzy logic is a modification of set theory which explains that each member has a degree of continuous value between 0 and 1 [2]. Therefore, the fuzzy set will represent the interpretation for each assessment based on preferences or opinions and probabilities. According to Kusumadewi and Purnomo [18] and Wang [19] stated that the value of 0 means false and value 1 means true, while between the values of true and false there are still values. The fuzzy set has two attributes namely linguistic attributes and numerical attributes. The linguistic attribute is the naming of a group that represents a certain condition or condition by using natural language, such as extremely dislike, dislike, ordinary, like, and extremely like (Figure 1). The numerical attribute is a value (number) that indicates the size of a variable such as 1, 5, 7, 9 and so on.

![Figure 1. Membership function](image)

The membership function is a curve that defines how each point in the input space is mapped into membership values (membership degrees between 0 and 1). According to Wang [19] if $U$ is expressed
as a universal set and A as a set of fuzzy functions in U, so that A can be expressed as an ordered pair as follows:

\[ A = \{(x, \mu_A(x)) | x \in U\} \]  

(1)

Where \( \mu_A(x) \) is membership function with the degree membership value \( x \) with the fuzzy set A:

\[ \mu_A : U \rightarrow [0,1] \]  

(2)

The fuzzy set has several membership functions for the new fuzzy set generated from the basic operations of the fuzzy set:

- Intersection: \( A \cap B = \min (\mu_A[x], \mu_B[y]) \)  

(3)

- Union: \( A \cup B = \max (\mu_A[x], \mu_B[y]) \)  

(4)

- Complement: \( \sim A = 1 - \mu_A[x] \)  

(5)

Membership function is determined by:

\[ \mu(x) = \begin{cases} 
0; & x \leq a \ or \ x \geq c \\
\frac{(b-a)}{(x-a)}; & a \leq x \leq b \\
\frac{(b-x)}{(c-b)}; & b \leq x \leq c 
\end{cases} \]  

(6)

The purpose of this study was to compare the sensory scoring system of Gayo Arabica coffee taste using the Eckenrode and Fuzzy-Eckenrode methods. The Eckenrode method with a certain rating system in a certain nominal number given by the panelists, while the Fuzzy-Eckenrode method is an assessment that has a certain range of numbers.

2. Materials and Method

This research was conducted in the Post-Harvest Technology laboratory of the Faculty of Agriculture, Syiah Kuala University in July 2019. Gayo Arabica coffee was obtained from farmers in Bener Meriah, Aceh Province of Indonesia, specially ordered with the best handling in the form of green beans at a moisture content of 12%. Coffee was roasted at a medium level and brewed using a Delonghi 35.11 semi-automatic machine. Sensory assessment of the taste of Gayo Arabica coffee included Fragrance, Flavor, Acidity, Body, After-taste, Balance, and Sweetness.

Sensory assessment of Gayo Arabica coffee taste was carried out by 15 panelists with identification as follows:

- a. Interested in coffee and used to consuming them everyday
- b. Can provide sensory assessments based on the taste of the coffee tasted
- c. Having knowledge about coffee, especially Gayo Arabica coffee
- d. The sense of taste is in good condition and can give an objective assessment

Assessment of the Eckenrode Method

The initial step in the Eckenrode method was to request an assessment from panelists to rank, in this case ranking from R1 to Rn. Where n rank is \( j = 1, 2, 3, \ldots, n \), then rank \( j = R_j \) for each criterion (criterion i, is denoted by \( K_i \) which has n criteria, \( i = 1, 2, 3, \ldots, n \)) [14, 20]. The calculation system based on the Eckenrode method is as in Table 1.

Based on \( P_{ij} \) and \( R_{n-j} \), the calculation of \( N_i \) is as follows:

\[ N_i = \Gamma_{j=1} P_{ij} \times R_{n-j}, j = 1, 2, 3, \ldots, n. \]  

(7)
Total Score = $\sum_{i=1}^{N_i} N_i$, $i = 1, 2, 3, \ldots, n$. \hfill (8)

Then the calculation of the criteria weights of $B_i$ (namely $B_1$, $B_2$, $B_3$, \ldots, $B_n$), where $i = 1, 2, 3, \ldots, n$, using the formula:

$$B_i = \frac{N_i}{\text{Total Score}}$$ \hfill (9)

Table 1. Calculation of the Eckenrode method criteria weight

| Criteria | Ranking | Score | Weight |
|----------|---------|-------|--------|
| K_1      | $P_{11}$ $P_{12}$ $\ldots$ $P_{in}$ | $N_1$ | $B_1$ |
| K_2      | $P_{21}$ $P_{22}$ $\ldots$ $P_{2n}$ | $N_2$ | $B_2$ |
| \ldots   | $\ldots$ $\ldots$ $\ldots$ $\ldots$ $\ldots$ | $\ldots$ | $\ldots$ |
| K_n      | $P_{n1}$ $P_{n2}$ $\ldots$ $P_{nn}$ | $N_n$ | $B_n$ |

Multiplier Factor $R_{n-j}$ = Multiplier factor of j, which is obtained by reducing the number of criteria or the number of ranks (i.e. n) in the ranking order in that column. For example, there are 5 criteria, the multiplier factor in the 3rd ranking column (if $j = 3$) is $n-j = 5-3 = 2$.

To find out the level of importance of each Sub-Criteria in a criterion, respondents were also asked to rank each Sub-Criteria in a criterion. Then the same procedure also calculated the weight of each Sub-Criteria in a criterion ($B_{in}$ weight of Sub-Criteria i in Criteria i). Thus, the Weighted Weight (BT) was obtained from Sub-Criteria i in Criteria i, namely $B_{T} = B_{ii} \times B_{i}$. Furthermore, to find out the value of each criterion, respondents were asked to rate from each Sub-Criteria on each Criteria [2].

Rating of each Sub-Criteria was calculated based on the geometric mean formula of the results of all panelists multiplied by the Weighted Weight of each Sub-Criteria. Furthermore, for each criterion (from K1 to K5) it was calculated by adding up the results of all the Sub-Criteria values contained in each Criteria. The weighting of importance level assessment based on sensory taste of Gayo Arabica coffee was taken into action by panelists based on the Eckenrode and Fuzzy-Eckenrode methods using the value preferences as in Table 2 and Table 3.

Table 2. Weighting scale comparison between criteria of Eckenrode method

| Scale | Description       | Score |
|-------|-------------------|-------|
| 1     | Strongly unimportant | 1     |
| 2     | Less important    | 2     |
| 3     | Neutral           | 3     |
| 4     | Important         | 4     |
| 5     | Strongly important | 5     |
Table 3. Weighting scale comparison between criteria of Fuzzy-Eckenrode method with triangular fuzzy number (TFN)

| Scale | Description       | TFN Membership Function | TFN Reciprocal |
|-------|-------------------|-------------------------|----------------|
| ^1    | Strongly unimportant | 1,1,2                   | (1/2, 1, 1)    |
| ^2    | Less important     | 1,2,3                   | (1/3, 1/2, 1)  |
| ^3    | Neutral            | 2,3,4                   | (1/4, 1/3, 1/2) |
| ^4    | Important          | 3,4,5,                 | (1/5, 1/3, 1/3) |
| ^5    | Strongly important | 4,5,5                   | (1/5, 1/5, 1/4) |

3. Result and Discussion

To assess the weighting of interests for each criterion according to the Eckenrode and Fuzzy-Eckenrode methods of the Gayo Arabica coffee taste sensory, the panelists were given each coffee sample in one glass for one person. The sensory assessment process of taste which included Fragrance, Flavor, Acidity, Body, After-taste, Balance, and Sweetness were carried out simultaneously with each panelist separated from one another and did not confirm each other. Combining the results of the assessment of each panelist, then it was summarized into one based on the value of the mode (the number that most often appears from the population or sample). The overall assessment results are as shown in Table 4.

Table 4. Assessment of weighting of the criteria according to panelists using the Eckenrode method

| No | Criteria       | Sequence | Score | Weight | Ranking |
|----|----------------|----------|-------|--------|---------|
| 1  | Fragrance      | 2 3 2 1 1 1 0 | 51    | 0.164  | 3       |
| 2  | Flavor         | 5 2 2 0 1 0 0 | 60    | 0.193  | 1       |
| 3  | Acidity        | 0 2 0 2 5 1 0 | 37    | 0.119  | 4       |
| 4  | Body           | 1 0 1 0 1 2 5 | 24    | 0.077  | 6       |
| 5  | After-taste    | 0 0 2 2 2 3 1 | 31    | 0.100  | 5       |
| 6  | Balance        | 2 2 2 3 1 0 0 | 51    | 0.164  | 3       |
| 7  | Sweetness      | 4 1 3 2 0 0 0 | 57    | 0.183  | 2       |

| Score(TCriterias-sequence) | 7 6 5 4 3 2 1 311 | 1 |

In the grading system using the Fuzzy-Eckenrode method, the evaluation of each panelists was broken down into the lower, middle and upper limit values in accordance with the Triangular Fuzzy Number (TFN) membership function. The complete results of the assessment were summarized in Table 5.

The results of this study indicated that the comparison between the Eckenrode method and the Fuzzy-Eckenrode method has some interesting differences to study. First, the weighting of the criteria importance based on the Eckenrode method showed the same value in the Fragrance (0.164) and Balance (0.164) criteria. Although the evaluation of interests according to panelists varies in the order in which they were determined, it still produced the same accumulation of values, so that the weighted values were the same (Table 4). The results of this assessment will be a bit difficult to be carried out in the decision making, where at the same weight value will have the same level of importance or equivalent when it ranked based on the alternative interests.
Second, in the Fuzzy-Eckenrode method, the accumulation of values according to panelists preferences showed huge differences in all the assessment criteria. It meant that none of the results of the calculation on all criteria have the same value. Included in the Fragrance and Balance criteria in the weighting assessment calculation method using the Eckenrode method have the same value, but the Fuzzy-Eckenrode method looked a clear difference between the two (Table 5). Third, the assessment of criteria weighting based on the Fuzzy-Eckenrode method showed that the assessment range between criteria is closer than the assessment range based on the Eckenrode method (Figure 4). However, the weighting of criteria based on the Fuzzy-Eckenrode method showed the value that is not the same between one criterion to another.

Alternative ranking of criteria importance weight in the Eckenrode method in sequences were Flavor, Sweetness, Balance and Fragrance which were equal, Acidity, After-taste and Body. While the Fuzzy-Eckenrode method for alternative ranking of criteria importance yields the same sequence as the usual Eckenrode method, but in the Fuzzy-Eckenrode Method the third rank was Balance and the fourth was Fragrance. This means that the Balance importance criteria were higher compared to the Fragrance criteria.

![Figure 2. Comparison of criteria weights between the Eckenrode and Fuzzy-Eckenrode methods](image-url)

This sensory assessment of Gayo Arabica coffee taste showed that the Flavor criterion was the most important or strongly important criterion according to consumer preferences, which in this study was represented by a number of selected panelists. Flavor criteria were also the product quality attributes that were considered the most important according to the research of Ranitaswari et al. [21]. The next consideration was the Sweetness criterion which ranked second in the importance of the sensory taste chosen. This means that the level of sweetness or having a somewhat sweet taste is considered more preferred by panelists based on the preference level for the flavor of Gayo coffee produced. According to Dairobbi [22] the Sweetness criterion is one of the most important criteria in sensory assessment of Gayo Arabica coffee flavor, moreover sweet taste gives its own sensation from the natural flavor produced.

Furthermore, the taste of the Balance criteria means that all aspects of the Flavor, After-taste, Acidity, and Body produced are balanced, so it is called the Balance. This also means that if one aspect is lacking or exceeds the sample that is tested for sensory taste, the resulting Balance value will be reduced. It can also be explained that in other words, Balance is the absence of one of the dominant tastes.

Fragrance criteria ranked fourth when viewed from the results of weighing the importance of criteria based on the Fuzzy-Eckenrode method. Fragrance Criteria is the aroma of coffee produced, usually can be assessed in two circumstances. First when the coffee has just been ground in a dry fragrance and the second is the aroma of coffee when it is infused (brewed) with hot water so that it releases steam with a particular aroma (wet aroma). Some examples of aroma descriptions are floral,
jasmine, tea rose, fruity, berry, spicy, woody, nutty, sweet, smoky, ashy, burnt, etc. [23-25]. As for other criteria such as Acidity, After-taste and Body, occupying the level of the weight of sensory importance is lower than the alternative criteria of Flavor, Sweetness, Balance and Fragrance.

4. Conclusion
The evaluation of criteria importance weighting based on the sensory assessment of Gayo Arabica coffee taste by using the Eckenrode method and the Fuzzy-Eckenrode method has been able to rank an alternative of the same criteria in a decision making for product acceptance preferences. However, based on comparison of the assessment of the weighting of the importance criteria by the Fuzzy-Eckenrode method the room of distinction is clearer than using the usual Eckenrode method, so that the weighting grading system via the Fuzzy-Eckenrode method is more recommended in making decisions that require high accuracy. This study also concluded that according to panelist preferences, the sensory taste of Gayo Arabica coffee that had the highest weighting importance was successively Flavor, Sweetness, Balance, Fragrance, Acidity, After-taste and Body.

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