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Decision-Making for Product Preferences of Functional Beverages Based on Mangosteen Peel and Red Ginger Using ROC and SAW

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Abstract
Bioflavonoids in mangosteen peel possess antioxidative and anti-inflammatory properties that are beneficial to health, making them a potential raw material for the development of functional beverages. However, the xanthone content in mangosteen peel contributes to a bitter taste, which may reduce consumer acceptance. Therefore, component substitution with other ingredients is necessary to enhance its organoleptic quality, one of which is red ginger, known for its distinctive aroma and additional health benefits. In this study, the Rank Order Centroid (ROC) and Simple Additive Weighting (SAW) methods were implemented in the decision-making process to determine the optimal composition of a functional beverage based on mangosteen peel and red ginger. The evaluation was based on several criteria, including taste, antioxidant activity, aroma, and color. The results indicated that taste had the highest weight, followed by antioxidant activity, aroma, and color. The decision matrix normalization and preference score calculations showed that the optimal composition was 5 grams of mangosteen peel + 10 grams of red ginger + 5 grams of sugar, achieving the highest preference score (1.00). This study confirms that the ROC and SAW methods can effectively assist in data-driven decision-making for developing functional beverages that are more acceptable to consumers.

Keywords: *mangosteen peel, red ginger, functional drink, ROC, SAW.*

Pengambilan Keputusan untuk Preferensi Produk Minuman Fungsional Berbahan Dasar Kulit Buah Manggis dan Jahe Merah Menggunakan ROC dan SAW

Abstrak
Bioflavonoid pada kulit buah manggis memiliki sifat antioksidatif dan anti-inflamasi yang bermanfaat bagi kesehatan, sehingga berpotensi untuk dimanfaatkan sebagai bahan baku dalam pengembangan produk minuman fungsional. Namun, kandungan *xanthone* pada kulit buah manggis menyebabkan rasa pahit yang dapat mengurangi penerimaan konsumen. Oleh karena itu, diperlukan substitusi komponen dengan bahan lain untuk meningkatkan kualitas organoleptik, salah satunya dengan penambahan jahe merah yang memiliki aroma khas dan manfaat kesehatan tambahan. Dalam penelitian ini, metode *Rank Order Centroid* (ROC) dan *Simple Additive Weighting* (SAW) digunakan dalam proses pengambilan keputusan untuk menentukan komposisi terbaik minuman fungsional berbasis kulit buah manggis dan jahe merah. Evaluasi dilakukan berdasarkan beberapa kriteria, yaitu rasa, aktivitas antioksidan, aroma, dan warna. Hasil analisis menunjukkan bahwa rasa memiliki bobot tertinggi, diikuti oleh aktivitas antioksidan, aroma, dan warna. Hasil perhitungan skor preferensi menunjukkan bahwa komposisi terbaik diperoleh pada campuran 5 gram kulit buah manggis + 10 gram jahe merah +

5 gram gula, dengan skor preferensi tertinggi (1,00). Penelitian ini menegaskan bahwa penggunaan metode ROC dan SAW dapat membantu dalam pengambilan keputusan berbasis data untuk pengembangan produk minuman fungsional yang lebih diterima oleh konsumen.

Kata Kunci: *kulit manggis, jahe merah, minuman fungsional, ROC, SAW.*

Introduction

Sensory satisfaction and nutritional adequacy are essential aspects that must be fulfilled by functional food products. In the context of functional beverages, key nutrients often included are probiotics, vitamins, and minerals, along with health benefits such as reducing the risk of certain diseases (Herawati et al., 2012). One promising raw material for the development of functional beverages is mangosteen peel. Mangosteen peel contains xanthones, which exhibit anti-cancer properties (Madury et al., 2012). Fully ripe mangosteen peel also contains polyhydroxy xanthones, which serve as antioxidants, anti-tumor, and antibacterial agents. The antioxidative properties of xanthones are considered superior to vitamins C and E. As xanthones are rarely found in other fruits, mangosteen has earned the nickname "Queen of Fruits" (Yatman, 2012).

However, the high tannin content in mangosteen peel results in a bitter taste (Perwitasari, 2009). Furthermore, xanthones also contribute to the bitter taste and less appealing aroma. Therefore, a partial substitution of mangosteen peel in functional food products is necessary to ensure consumer acceptance. One potential substitute for functional beverage products based on mangosteen peel is red ginger. Besides its widely favored taste and aroma, red ginger is also beneficial for enhancing immunity. These two ingredients can be formulated into a functional beverage in the form of instant powder, which: (1) simplifies consumer use while retaining the product's benefits, and (2) extends the product's shelf life (Sariati et al., 2019).

Previous research by Sariati et al. (2019) revealed that adding red ginger powder as a substitute ingredient in functional beverages based on mangosteen peel significantly influences the sensory properties of aroma and taste. However, varying compositions of red ginger powder yield different antioxidative properties, as measured by IC_{50} values. Consequently, determining the preferred composition for a mangosteen peel and red ginger-based functional beverage that combines favorable sensory properties and antioxidative quality becomes a central focus of this study. One suitable approach for this is the use of Multiple Attribute Decision Making (MADM). A combination of MADM methods, such as Rank Order Centroid (ROC) and Simple Additive Weighting (SAW), can be applied.

The Rank Order Centroid (ROC) method is used to assign weights based on the importance level of each criterion. In general, ROC is expressed as follows: "Criterion 1 is more important than Criterion 2, Criterion 2 is more important than Criterion 3, Criterion 3 is more important than Criterion 4," and so on (Aziz et al., 2023). ROC has previously been implemented as a decision-making method by Irwan et al. (2022) for selecting the best employees for promotion recommendations. Mandarani et al. (2022) also employed ROC for weighting criteria in a decision-making system to determine the best authors using the Evaluation-based on Distance from Average Solution (EDAS) method.

One widely used decision-making method in MADM is Simple Additive Weighting (SAW). The basic concept of SAW is to calculate the weighted sum of performance ratings for each alternative across all criteria. The alternative with the highest weighted sum is considered the most favorable (Frieyadie, 2016). SAW has been used in various fields, including food product evaluations. For instance, Utama and Baroto (2018) applied SAW to analyze the soybean boiling process in tempeh production, focusing on its sensory quality. Similarly, Savitri et al. (2022) utilized SAW to determine the best bread based on sensory profiles and maturity levels. Moreover, Pratama et al. (2024) employed SAW for preference determination in green tea extract products, focusing on sensory characteristics based on brewing process control. Thus, this study aims to make preference decisions for a functional beverage product based on mangosteen peel and red ginger using ROC and SAW methods, with emphasis on sensory characteristics and antioxidative properties.

Method

Preparation of Research Data

The data used in this study were obtained from previous research conducted by the authors (Sariati et al., 2019), which included test results on antioxidative properties and sensory evaluations of functional beverages made from mangosteen peel and red ginger. Sensory evaluation data were collected using the hedonic method, while the antioxidative properties were assessed by measuring antioxidant activity using the DPPH method.

Table 1. Composition combinations in functional beverage research using mangosteen peel and red ginger by Sariati et al. (2019)

Alternative	Composition Combination		
	Mangosteen Peel (g)	Red Ginger (g)	Sugar (g)
J0	5	0	5
J1	5	4	5
J2	5	6	5
J3	5	8	5
J4	5	10	5

This study utilized data from five types of alternative compositions of mangosteen peel and red ginger powder, coded as J0, J1, J2, J3, and J4. The composition combination of each alternative can be seen in Table 1. The sensory evaluation results, which include color, aroma, and taste parameters, along with antioxidant activity test results (measured as IC_{50} values) for each sample (alternative), are presented in Table 2.

Table 2. Sensory evaluation and antioxidant activity test results for each alternative

Alternative	Sensory Evaluation			Antioxidant Activity (IC_{50})
	Color	Aroma	Taste	
J0	2.75	2.65	2.70	1804
J1	2.85	3.25	2.85	1738
J2	3.05	3.25	3.17	2038
J3	3.25	3.40	3.30	1967
J4	3.35	3.41	3.40	1359

Implementation of ROC and SAW for Decision-Making

Before decision-making, the criteria involved in this study (sensory evaluation and antioxidative properties) were weighted using the Rank Order Centroid (ROC) method. The mathematical equation for ROC calculation is as follows:

$$Wk = \frac{1}{k}\sum_{i=1}^{k}\left(\frac{1}{i}\right) \quad (1)$$

where Wk is the final weight for each criterion, k is the total number of criteria, and i is the priority level of each criterion, previously determined by assigning a ranking order. In this study, the priority order of each criterion was obtained through interviews with experts in agro-industrial engineering.

Furthermore, the weight for each criterion and the sensory evaluation scores of the alternatives were processed using the Simple Additive Weighting (SAW) method with the following steps:

1) Defining criteria (Cj) and alternatives (Ai) used in decision-making, where i represents the row count (i = 1, 2, ..., n) and j represents the column count (j = 1, 2, ..., m).
2) Filling performance ratings for each alternative across all criteria. Performance ratings were obtained by calculating the average sensory and antioxidative property scores.
3) Determining weight values (W) for all criteria. Weight values for each criterion were derived from ROC calculations.
4) Creating a decision matrix (X) using the performance ratings of each alternative for all criteria. The configuration of the decision matrix is as follows:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{bmatrix} \quad (2)$$

5) Normalizing the decision matrix by calculating the normalized performance ratings (r_{ij}) depending on the type of criteria: (1) benefit or (2) cost. The equations for each type are as follows:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{\max_{x_{ij}}} \text{ if } j \text{ is } benefit \\ \dfrac{\min_{x_{ij}}}{x_{ij}} \text{ if } j \text{ is } cost \end{cases} \quad (3)$$

6) Calculating the weighted sum to determine the final preference score (Vi) for all alternatives using the following equation:

$$Vi = \sum_{j=1}^{n} W_j \, r_{ij} \quad (4)$$

The alternative with the highest *Vi* score will be selected as the final result of the decision-making process, indicating its position as the best alternative for the functional beverage product based on mangosteen peel and red ginger.

Results and Discussion

The initial step in the decision-making process for the preference of functional beverage products made from mangosteen peel and red ginger was to assign weights using the Rank Order Centroid (ROC) method. The determination of the importance level order among the criteria was conducted through discussions with experts in agro-industrial engineering and food technology. The results of the discussion indicated that the priority order of criteria for the functional beverage product made from mangosteen peel and red ginger was as follows: taste > antioxidant activity > aroma > color. The calculation results indicate that the taste criterion has the highest weight, demonstrating its importance in determining the consumer preference for the functional beverage product. On the other hand, the color criterion has the lowest weight, indicating that it is the least prioritized attribute compared to other criteria in this decision-making process.

Table 3. Calculation of Criterion Weights Using ROC

Criterion	Weight Calculation Using ROC
Taste	$\frac{1+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}}{4}$ = 0.520833
Antioxidant Activity (IC_{50})	$\frac{0+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}}{4}$ = 0.270833
Aroma	$\frac{0+0+\frac{1}{3}+\frac{1}{4}}{4}$ = 0.145833
Color	$\frac{0+0+0+\frac{1}{4}}{4}$ = 0.062500

In this study, the sensory criteria, which include taste, aroma, and color, were categorized as benefits, while antioxidant activity was categorized as a cost. The sensory criteria were considered as benefits because higher values indicate better sensory acceptance by consumers, ultimately increasing the preference for the functional beverage product. Higher sensory scores reflect better consumer satisfaction regarding the taste, aroma, and color aspects of the product. Conversely, antioxidant activity was categorized as a cost because, in the DPPH assay, a lower IC_{50} value indicates stronger antioxidant activity. The lower the IC_{50} value, the higher the ability of antioxidant compounds to neutralize free radicals, signifying better health potential of the product (Wardani et al., 2020). Therefore, in the decision-making process using the ROC and SAW methods, the values of sensory criteria were prioritized for maximization, while the value of antioxidant activity was targeted to be minimized to achieve an optimal formulation.

The weight calculation results for each criterion using the ROC method are presented in Table 3. After completing the weighting process with ROC, the next step was decision-making using the Simple Additive Weighting (SAW) method. The first stage of this process was to construct the decision matrix based on the data in Table 2, followed by normalization of the decision matrix using Equation (3). The normalization results are presented in Table 4.

Table 4. Normalization of the Decision Matrix

Alternative	Sensory Evaluation			Antioxidant Activity (IC_{50})
	Color	Aroma	Taste	
J0	0.82	0.78	0.79	0.75
J1	0.85	0.95	0.84	0.78
J2	0.91	0.95	0.93	0.67
J3	0.97	1.00	0.97	0.69
J4	1.00	1.00	1.00	1.00

The final step was to calculate the final preference score (Vi) for each alternative. The analysis results are presented in Table 5. The decision obtained through the ROC and SAW methods showed that J4 is the best alternative for developing functional beverage products made from mangosteen peel and red ginger, with a preference score of 1.00. This is attributed to the superior characteristics of product J4 (5 grams of mangosteen peel + 10 grams of red ginger + 5 grams of sugar), which had the highest organoleptic scores (indicating the best level of consumer acceptance) and the lowest antioxidant activity score (indicating the strongest antioxidant activity) compared to other product alternatives.

Table 5. The results of the final preference score calculation (Vi)

Alternative	Sensory Criterion Weight			Antioxidant Activity (IC_{50}) Weight	Final Preference Score (Vi)
	Color	Aroma	Taste		
	0.062500	**0.145833**	**0.520833**	**0.270833**	
J0	0.82	0.78	0.79	0.75	0.78
J1	0.85	0.95	0.84	0.78	0.84
J2	0.91	0.95	0.93	0.67	0.86
J3	0.97	1.00	0.97	0.69	0.90
J4	1.00	1.00	1.00	1.00	1.00

Conclusion and Recommendations

This study demonstrated that the ROC and SAW methods successfully identified the best alternative for functional beverage products based on mangosteen peel and red ginger. The results of the criteria weighting indicate that taste is the most important criterion, followed by antioxidant activity, aroma, and color. The ROC method assigned a weight of 0.520833 to taste, 0.270833 to antioxidant activity, 0.145833 to aroma, and 0.062500 to color. Based on the analysis of five composition alternatives, the J4 alternative (5 grams of mangosteen peel + 10 grams of red ginger + 5 grams of sugar) achieved the highest preference score (1.00), indicating the best organoleptic acceptance and the strongest antioxidant activity. These findings suggest that J4 is the optimal composition for developing functional beverage products based on mangosteen peel and red ginger, offering both health benefits and consumer preferences.

For future studies, clinical trials are recommended to confirm the health benefits and safety of regular consumption of this product. Stability testing during storage should also be conducted to ensure that organoleptic quality and antioxidant properties remain intact over time. Additionally, involving more respondents from various demographic segments could provide a broader understanding of consumer preferences. Future research could also explore the sensitivity analysis between SAW and other Multiple Attribute Decision-Making (MADM) methods, such as the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), to determine the most suitable MADM method for solving the problem (Suyanti and Roestam, 2018).

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