Decision Making on The Organoleptic Quality of Salted Egg Products using Analytical Hierarchy Process and Simple Additive Weighting

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Abstract

Chicken and duck eggs are highly nutritious food products that are popular among the Indonesian community. However, their perishable nature leads to a decline in quality if not further processed. The salting process is a simple preservation method that can also enhance the flavor of salted egg products. To produce salted egg products with high organoleptic quality preference, a combination of Analytical Hierarchy Process (AHP) and Simple Additive Weighting (SAW) is implemented as a quality decision-making method based on: (1) the experts viewpoints on the importance level of organoleptic criteria, and (2) the scores of organoleptic tests for the criteria of texture, taste, and appearance. In this study, chicken and duck eggs were processed into salted eggs using a salting mixture made of a blend of scouring ash and table salt with a mass ratio of 5:4 and 5:6, resulting in product combinations coded as CE-5/4, CE-5/6, DE-5/4, and DE-5/6. Data processing results on the importance level from the experts viewpoints using the AHP method resulted that the criteria for texture, taste, and aroma had final priority weights of 0.244, 0.617, and 0.139, respectively. Final decision-making using the SAW method indicated that the highest to lowest final preference scores were obtained by products CE-5/4, DE-5/4, DE-5/6, and CE-5/6, with the final preference scores of 0.979, 0.963, 0.931, and 0.906, respectively. The results demonstrated that AHP and SAW were successfully implemented to assist in making decisions regarding the quality of salted egg products based on their organoleptic characteristics.

Keywords: salted egg, organoleptic, decision-making, AHP, SAW

1. INTRODUCTION

Eggs are an alternative source of animal protein besides livestock meat, milk, and fish. Eggs are favored for their delicious taste, ease of digestion, and high nutritional content [1]. Some types of eggs that are popular and loved by the Indonesian community are chicken eggs and duck eggs. Chicken eggs are a highly nutritious food containing 12.8% protein and 11.8% fat, with a weight of about 50-70 grams per egg [2]. On the other hand, duck eggs weigh approximately 60-75 grams each and are rich in nutrients, including fat, protein, minerals, vitamin B6, vitamin A, vitamin E, and vitamin B12 [3]. Additionally, duck eggs have higher fat and protein content compared to other poultry eggs [3].

The downside of eggs is their perishable nature, which makes them susceptible to physical, chemical damage, or microbial activity. The longer the storage time, the more the quality and freshness of the eggs decrease. If eggs are stored at room temperature, their freshness can only be preserved for approximately 10-14 days. Beyond this period, indications of spoilage will emerge, including: (1) a reduction in egg weight caused by water evaporation through the shell pores, and (2) alterations in chemical composition and dilution of the egg content [4]. Therefore, egg preservation technology is essential to maintain their quality. One straightforward method that can be employed is the salting technique, which entails immersing the eggs in a solution (comprising water, scrubbing ash, red brick powder) mixed with a concentrated salt solution [1]. The mechanism of the egg salting process occurs due to the ionization of table salt (NaCl) mixed in the medium, which then diffuses into the eggs through the shell pores. The egg salting process is easy to perform and economical [6]. In addition to prolonging the storage duration, the salting procedure also improves the taste of the egg products [1].

Previously, research has been conducted on making salted eggs from various types of poultry eggs. Ariawan and Hafid [7] made salted egg products from duck eggs, broiler chicken eggs, native chicken eggs, and Muscovy duck eggs, and analyzed their effects on the organoleptic quality of the salted egg products produced. The results showed that the use of different types of eggs had a significant impact on the overall acceptance of salted eggs and had different acceptance levels (scores) for each characteristic of salted eggs, specifically: (1) albumen and yolk color, (2) aroma, (3) albumen and yolk texture, (4) taste, (5) saltiness level, and (6) firmness. However, the study did not apply a decision-making method to determine the best salted egg product.

Previously, multiple criteria decision-making methods, such as Simple Additive Weighting (SAW), had been applied to determine the best quality food products based on their physicochemical and organoleptic characteristics. Utama and Baroto [8] implemented the SAW method to evaluate the organoleptic quality of tempeh at different boiling times. The organoleptic criteria used to evaluate the products are color, taste, texture, aroma, and shape. The research results indicated that tempeh boiled for 2 hours has a higher preference score compared to tempeh boiled for 3 hours, with scores of 0.982 and 0.694, respectively. Furthermore, Savitri et al. [9] used the SAW method to create a decision support system for selecting bread based on maturity level, volume, and organoleptic criteria. The research results showed that the ranking of bread quality, from best to worst, is as follows: torn bread, small bread rolls, round bread, pizza bread, folded bread, and sliced bread. However, in this study, the weights were determined in advance without applying any specific weighting method.

The advantage of the Simple Additive Weighting (SAW) method compared to other decision-making methods lies in its ability to provide a more accurate assessment because it is based on predetermined criteria values and preference weights. Additionally, SAW can select the best alternative from a number of available alternatives due to the ranking process by calculating the preference scores [10]. Therefore, this research aimed to produce salted egg products by combining factors: (1) type of egg, (2) salt concentration, and (3) salting treatment, and to analyze their effects on the resulting organoleptic quality of the products.

This research aimed to implement a decision-making method to determine the best alternative salted egg product based on its organoleptic quality. The decision-making method implemented is a combination of Analytical Hierarchy Process (AHP) and Simple Additive Weighting (SAW). In this study, AHP was used as the weighting method for criteria that would be further utilized in SAW calculations, involving relevant experts. The advantages of the AHP method are: (1) it considers the importance levels between criteria, thus enabling each expert to evaluate the criteria based on their objectives; and (2) AHP assessments are not based on consensus, but rather combine different evaluations by the experts [11]. The involvement of AHP as a weighting method in this study is an advantage compared to previous research [9] that only used SAW as a decision-making method, thus making the criteria weighting in this study more reliable. This research can also serve as an additional reference and provide ideas for future studies or activities related to assessing the quality of food industry products using multiple criteria decision-making methods.

2. RESEARCH METHOD

This research consists of several phases as illustrated in Figure 1. The production of salted egg products was conducted in parallel with expert assessments of the importance level of criteria used in the organoleptic assessment. The determination of preference scores for salted egg products can be carried out once the data from the organoleptic assessment and criteria importance levels have been obtained.

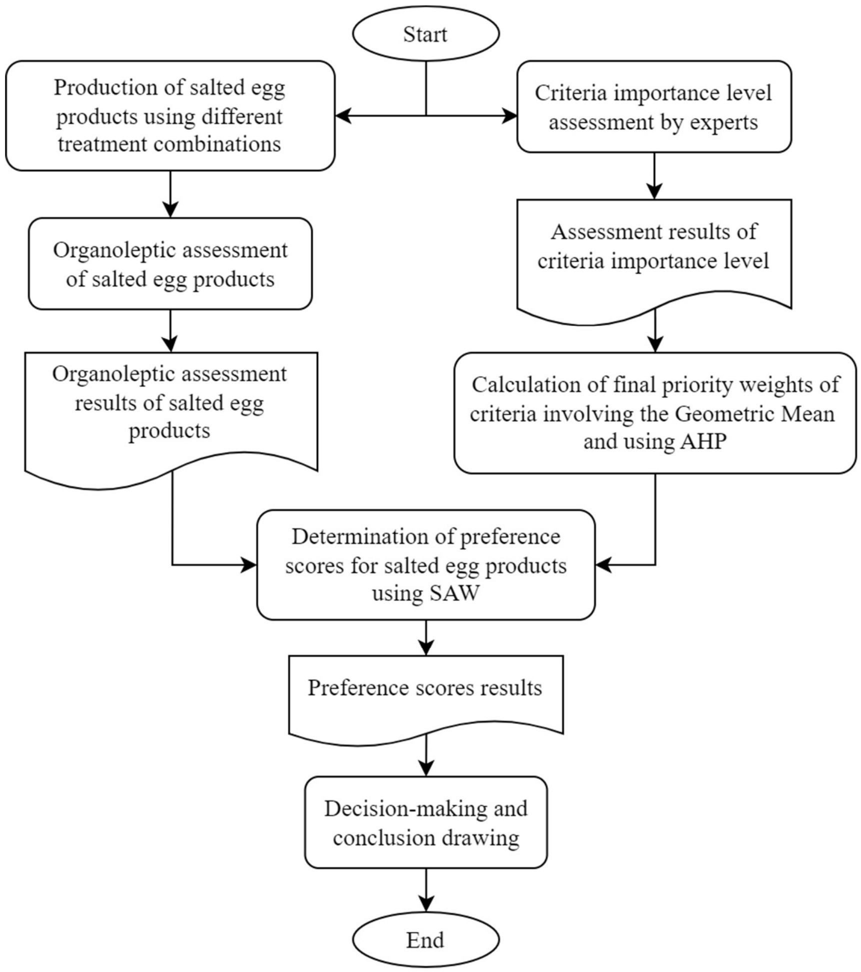

Figure 1. The flowchart of research method

2.1 Equipment and Materials

The equipment used for the salted egg production process includes medium-sized plastic containers, a mortar and pestle, a stove, and a pot. The materials used are chicken eggs and duck eggs (obtained from the local market), scouring ash, table salt, and clean water.

2.2 Salted Egg Production

The chicken and duck eggs obtained from the local market were washed with running clean water. Separately, the salting mixture is made by mixing scouring ash and table salt with mass ratios of 5:4 and 5:6. This mixture was then moistened with water until it forms a slurry and subsequently applied to the surface of the eggs. The eggs coated with the salting mixture were left to sit for 10 days at room temperature in open plastic containers. After the salting period, the coating was cleaned off the eggs, and the eggs were further boiled in water using the pot and stove until fully cooked.

The cooked salted eggs were then peeled and presented to 10 untrained panelists for an organoleptic test, assessing the organoleptic criteria of texture, taste, and appearance for all products. The organoleptic test used a 9-point hedonic scale, where the scale ranges from extremely dislike (1), very dislike (2), dislike (3), slightly dislike (4), neutral (5), slightly like (6), like (7), very like (8), to extremely like (9). The data obtained from the panelists were processed using descriptive statistics, and the results were displayed as mean ± standard error. In this study, the codes of egg product samples for each treatment combination can be seen in Table 1.

Table 1. The egg product samples for each treatment combination

Material	**Scouring Ash to Table Salt Ratio of 5:4**	**Scouring Ash to Table Salt Ratio of 5:6**
Chicken Egg	CE-5/4	CE-5/6
Duck Egg	DE-5/4	DE-5/6

2.3 Decision-making using Analytical Hierarchy Process and Simple Additive Weighting

The initial stage in decision-making procedure is the determination of the final priority weights of criteria using the Analytical Hierarchy Process (AHP). In this study, five experts, all of whom are academics in the fields of agro-industry, were involved in determining the importance level of criteria. Data collection from the experts was conducted through interviews and discussions. The steps of implementing the AHP method for this research are as follows: [12][13][14][15]

1) Constructing a hierarchy of the problems to be solved.
2) Establishing priorities for each element engaged in the hierarchy, which constituted each criterion used in the sensory evaluation of salted eggs. The prioritization of each element (criterion) is conducted by the experts involved in this research using comparative judgment, which is done by providing assessments regarding the relative importance level between two criteria. The magnitude of the importance level values that can be assigned by the experts can be seen in Table 2.

Table 2. Comparative judgement

The Importance Level between Criteria	**Details**
1	Both criteria are equally important
3	One criterion is slightly more important than the other
5	One criterion is more important than the other
7	One criterion is significantly more important than the other
9	One criterion is absolutely more important than the other
2, 4, 6, 8	Values between two adjacent levels of importance
Reciprocal	If criterion A has an importance level of *x* towards criterion B, then the importance level of criterion B towards criterion A is represented as *1/x*

3) As data were obtained from multiple experts, a geometric mean calculation was conducted on all the data obtained from the experts, including their reciprocal values, resulting in a pairwise comparison matrix. The geometric mean calculation was performed using the following equation:

$$GM = (z_1 * z_2 * z_3 * \dots * z_n)^{(\frac{1}{n})} \quad (1)$$

where GM represents the geometric mean, n is the number of experts, and z is the assessment result of the weight by the 1st, 2nd, 3rd, until the n^{th} expert.

4) Performing normalization on the pairwise comparison matrix, which consists of two main steps. The initial step involves summing the columns in the pairwise comparison matrix using the following equation:

$$a = \sum_{i=0}^{i=n} X_{ij} \qquad (2)$$

where a represents the total sum of each column (from row 0 to row n), n is the number of rows, and x_{ij} is the value contained within the cell. The next step involves dividing the value of each column by the total sum of each column, using the following equation:

$$b = \frac{X_{ij}}{a} \qquad (3)$$

where b represents the normalized result in each cell (*normalized* x_{ij}), a is the total sum of each column, and x_{ij} is the value contained within the cell.

5) Calculating final priority weights using the following equation:

$$PW = \frac{\sum_{j=0}^{j=n} normalized\ X_{ij}}{n} \qquad (4)$$

where PW represents the final priority weight, and n is the number of criteria used. In this equation, the normalized x_{ij} values are summed from column 0 to column n in the same row.

6) Calculating the maximum eigenvalue (λmax) using the following equation:

$$\lambda max = \frac{\sum \lambda}{n} \qquad (5)$$

where λ represents the eigenvalue and n is the number of criteria used.

7) Calculating the consistency index (CI) using the following equation:

$$CI = \frac{\lambda max - n}{n - 1} \qquad (6)$$

where CI represents the consistency index, λmax is the maximum eigenvalue, and n is the number of criteria used.

8) Determining the random index (*RI*) based on the guidelines in the AHP calculation. In this study, the number of criteria used is 3, thus the value of *RI* used is 0.58.

9) Calculating the consistency ratio (CR) using the following equation:

$$CR = \frac{CI}{RI} \qquad (7)$$

where CI is the consistency index and RI is the random index. If the value of $CR \leq 0.1$, it is considered consistent, and the final priority weights (*PW*) obtained from the calculation can be used for further data processing in the next step of making the final decision.

The next step is the processing of organoleptic data along with the final priority weights (*PW*) obtained from the AHP calculation using the Simple Additive Weighting (SAW) method. The implementation steps of the SAW method are as follows: [16]

1) Determining the criteria (C_i) and alternatives (A_j) used, where i represents the number of rows (i = 1, 2, 3, ..., m) and j represents the number of columns (j = 1, 2, 3, ..., n). In this study, the involved alternatives are all the egg products listed in Table 1.
2) Calculating the performance rating for each alternative on all criteria, obtained from the average calculation of organoleptic scores for each salted egg product in terms of taste, texture, and appearance criteria.
3) Determining the weight values (W_j) for each criterion involved. In this study, the weight values have been obtained from the AHP calculation (calculated as *PW*) conducted in the previous stage.

4) Creating a decision matrix involving the performance rating values for each alternative on all criteria.
5) Normalizing the decision matrix by calculating the normalized performance rating (r_{ij}) based on the type of criteria used, either benefit or cost, using the following equation:

$$r_{ij} = \begin{cases} \frac{x_{ij}}{\max x_{ij}}, & if\ the\ criterion\ is\ benefit \\ \frac{\min x_{ij}}{x_{ij}}, & if\ the\ criterion\ is\ cost \end{cases} \quad (7)$$

All criteria used in this study are categorized as benefits, thus the calculation of *max* x_{ij} is conducted for each criterion.
6) Calculating preference scores (Vi) for all involved alternatives using the following equation:

$$Vi = \sum_{j=1}^{j=n} W_j \cdot r_{ij} \quad (7)$$

The alternative with the highest preference score (Vi) is considered the product with the best quality based on the decision-making method's data processing.

The major phases of this research are illustrated as flowchart in Figure 1.

3. RESULTS AND DISCUSSION

The illustration of the salted egg product samples from this research is presented in Figure 2. Additionally, the average sensory evaluation scores for taste, texture, and appearance criteria of the salted egg products are presented in Figure 3. The data processing results indicated that the average acceptance scores for texture in the products CE-5/4, CE-5/6, DE-5/4, and DE-5/6 were 7.1±0.23, 7.0±0.21, 7.4±0.22, and 7.7±0.21, respectively. The panelists' level of acceptance for texture for all products ranged around a score of 7 (like). Generally, salted duck egg products had slightly higher average scores for texture compared to salted chicken egg products. In salted egg products, the organoleptic texture score is greatly influenced by the degree of salting. Grainy texture in salted eggs is caused by protein coagulation due to the penetration of salt into the egg, resulting in a sandy texture in the yolk [17]. The slightly higher acceptance score for the texture of salted duck egg products in this study was probably attributed to the better salting level of salted duck egg products compared to salted chicken egg products.

Figure 2. Salted duck egg (left) and salted chicken egg (right) product samples

The results showed that the average taste acceptance scores for the products CE-5/4, CE-5/6, DE-5/4, and DE-5/6 were 7.2±0.25, 6.4±0.34, 6.9±0.41, and 6.4±0.34, respectively. The level of taste acceptance by the panelists for all resulting products ranged from scores 6-7 (slightly like-like). In general, when the salt-to-ash mass ratio in the salting mixture is increased from 5:4 to 5:6, there was a slight decrease in the organoleptic taste acceptance scores for all products, both salted chicken eggs and salted duck eggs. This occurs due to an increase in saltiness in the resulting products, observed both in salted chicken eggs and salted duck eggs, when the salt-to-ash mass ratio in the salting mixture is increased.

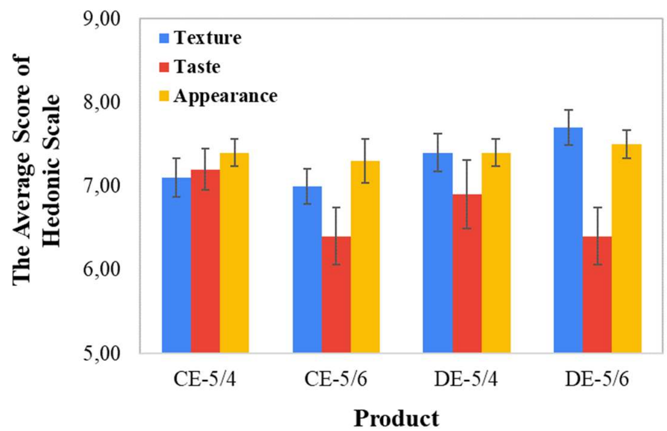

Figure 3. Organoleptic test results for salted egg product samples

The results obtained were consistent with the feedback given by the panelists, who mentioned that the saltiness level of salted chicken eggs and salted duck eggs made with a 5:6 ash-to-salt ratio is higher compared to the products made using a 5:4 ash-to-salt ratio. Furthermore, the findings of this study were also consistent with the previous study conducted by Rukmiasih et al. [4], which indicated an increase in salt content (NaCl) in salted eggs immersed in a solution with higher salt concentration. In the process of making salted eggs, there is a diffusion of salt ions (Na^+ and Cl^-) into the eggs, thus an increase in salt concentration will result in a greater number of salt ions diffusing into the eggs, leading to an increase in the saltiness of the product.

The average appearance acceptance scores for the products CE-5/4, CE-5/6, DE-5/4, and DE-5/6 were 7.4±0.16, 7.3±0.26, 7.4±0.16, and 7.5±0.17, respectively. Thus, in this study, the level of appearance acceptance by the panelists for all resulting products ranged around a score of 7 (like). Although the results displayed in Figure 2 show a very clear difference in yolk color appearance between salted chicken egg products and salted duck egg products, however, the difference in appearance acceptance scores for all products was not substantial.

Table 3. The level of importance between criteria according to experts

Criterion		The Level of Importance of Criterion A to B (According to Experts)					Geometric Mean
A	B	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	
Texture	Taste	0.143	0.200	0.200	4.000	1.000	0.470
Texture	Appearance	1.000	0.333	1.000	7.000	3.000	1.476
Taste	Appearance	7.000	5.000	5.000	3.000	9.000	5.431

The findings of this study indicated that the color of the yolk in salted duck eggs appears more orangish compared to salted chicken eggs. Before undergoing the salting process, the yolk of duck eggs has a basic yellow color. After salting process, the color of the duck egg yolk changed to orange. This color change is caused by the decrease in water content inside the salted egg due to the presence of salt, resulting in an increased color intensity in the duck egg yolk. Additionally, the increase in color concentration is also caused by the release of oil content in the salted duck egg yolk due to the damage of lipoproteins caused by the presence of diffused salt into the duck egg [18][19]. However, this color change was not as noticeable in salted chicken eggs, requiring further research and analysis.

Table 4. Pairwise comparison matrix along with the total sum of columns (a)

Criterion (A)	**Criterion (B)**		
	Texture	**Taste**	**Appearance**
Texture	1.000	0.470	1.476
Taste	2.129	1.000	5.431
Appearance	0.678	0.184	1.000
Total Sum of Column (*a*)	**3.807**	**1.654**	**7.907**

The data obtained from interviews with experts and sensory evaluation results for each criterion (texture, taste, and appearance) were further processed using a combination of AHP and SAW methods. The initial step was to determine the weights of criteria based on the level of importance among criteria using AHP. Subsequently, geometric mean calculations were performed on all values provided by the experts. The values provided by each expert regarding the level of importance among the involved criteria and the results of geometric means calculated using equation (1) can be seen in Table 3. Furthermore, the pairwise comparison matrix generated using the AHP method, along with the calculated total sum of columns (a) using equation (2), are presented in Table 4.

Table 5. Normalized pairwise comparison matrix along with the total sum of rows ($\sum X_{ij}$ *normalized*)

Normalized Criterion (A)	**Normalized Criterion (B)**			**Total Sum of Row (*b*)**	**Final Priority Weight (*PW*)**
	Texture	**Taste**	**Appearance**		
Texture	0.263	0.284	0.187	0.733	0.244
Taste	0.559	0.605	0.687	1.851	0.617
Appearance	0.178	0.111	0.126	0.416	0.139

Furthermore, the normalization of the pairwise comparison matrix into a normalized pairwise comparison matrix along with the *normalized* $\sum x_{ij}$ (*b*) calculated using equation (3) and the final priority weight (*PW*) calculated using equation (4) were done, which the results can be seen in Table 5. The calculation results of final priority weights indicated that the criteria of texture, taste, and appearance had weights of 0.244, 0.617, and 0.139, respectively. The values of λmax, *CI*, and *CR* calculated using equation (5), (6), and (7) were 3.047, 0.023, and 0.040, respectively. These results indicated that the calculation of criterion weights using AHP has been categorized as consistent because the *CR* value is < 0.1. Given the consistency of the calculation results, the criterion weights can be utilized for subsequent processing steps, which is constructing the SAW decision matrix and presented in Table 6.

Table 6. The SAW decision matrix and calculation of $max\ x_{ij}$ values

Products	**Criterion**		
	Texture	**Taste**	**Appearance**
CE-5/4	7.1	7.2	7.4
CE-5/6	7	6.4	7.3
DE-5/4	7.4	6.9	7.4
DE-5/6	7.7	6.4	7.5
max x_{ij}	**7.7**	**7.2**	**7.5**

The data involved in the SAW decision matrix were the sensory evaluation scores for all criteria for all products. Subsequently, the sensory evaluation scores for each criterion (texture, taste, and appearance) in the SAW decision matrix were normalized by calculating the r_{ij} for each cell in the matrix using equation (8). This was done by initially calculating the $max\ x_{ij}$ value of each column. Furthermore, the data in the normalized SAW decision matrix along with the criterion weights (W_j) previously calculated from the AHP process and the calculation results of preference score (V_i) using equation (9) can be seen in Table 7. The results showed that the ranking of preference scores from highest to lowest were obtained by the products CE-5/4, DE-5/4, DE-5/6, and CE-5/6, respectively, with values of 0.979, 0.963, 0.931, and 0.906. In this study, DE-5/4 excelled in texture acceptance scores but had lower taste acceptance scores compared to CE-5/4. However, the higher weight assigned to the taste criterion gave CE-5/4 an advantage in the final preference score (V_i) calculations using the SAW method.

Table 7. The normalized SAW decision matrix and preference score calculation (V_i)

Products	**Criterion and Weight**			**Preference Score (*Vi*)**	**Ranking**
	Texture (0.244)	**Taste (0.617)**	**Appearance (0.139)**		
CE-5/4	0.922	1.000	0.987	0.979	1
CE-5/6	0.909	0.889	0.973	0.906	4
DE-5/4	0.961	0.958	0.987	0.963	2
DE-5/6	1.000	0.889	1.000	0.931	3

4. CONCLUSION

In this study, the combination of Analytical Hierarchy Process (AHP) and Simple Additive Weighting (SAW) methods was successfully implemented to determine the best alternative salted egg products, which were consist of salted duck egg and salted chicken egg products with different ash-to-salt mass ratios, based on their organoleptic qualities. The results of the expert interview data processing, which provided importance levels between criteria using the AHP method, indicated that texture, taste, and aroma criteria had final priority weights of 0.244, 0.617, and 0.139, respectively. The calculated CR value was 0.040, indicating that the weight calculation using AHP was consistent since $CR < 0.1$. Subsequently, the quality decision-making using the SAW method showed that the preference scores from highest to lowest were obtained by products CE-5/4, DE-5/4, DE-5/6, and CE-5/6, with scores of 0.979, 0.963, 0.931, and 0.906, respectively.

In future research, standardizing the freshness level of the egg raw materials used will be necessary. Additionally, increasing the number of untrained panelists involved in the study is recommended. Further research could also compare the results between (1) the method of making salted eggs using the ash-salt mixture (using variations in combination of ash and salt) and (2) the method of making salted eggs by soaking the eggs in a salt solution, especially in terms of the organoleptic or physicochemical characteristics of the products. Future research should also consider comparing the performance of different combinations of multiple criteria decision-making methods. This comparison could provide insights into the strengths and weaknesses of each method. Additionally, understanding these differences could help in selecting the most appropriate method for specific decision-making scenarios.

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