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Evaluating Students' Bread Preferences in UiTM Perlis: An Application of the Fuzzy Analytical Hierarchy Process

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ABSTRACT

Nowadays, the food industry has expanded significantly, attracting many investors to invest in this business. Among these, the popularity of bread has been increasing, and many brands are available in the market. Bread has become a popular alternative food, especially among students, as it is convenient to store and carry. With numerous bread brands available, students have more options to choose from, give a challenge for bread manufacturers to compete with one another. This study aims to evaluate the factors influencing students' bread selection and determine the most preferred brand among UiTM Perlis students. It considers four criteria which are price, taste, packaging, and brand, while the alternatives bread brands are Gardenia, Massimo, Mighty White, and High Five. A multi criteria decision making method, the Fuzzy Analytical Hierarchy Process (FAHP), is applied to rank the preferred bread among UiTM Perlis students. The FAHP methodology involves data collection, consistency ratio measurement, and FAHP calculations. This approach is able to handle the subjective judgments of consumers. The results indicate that brand is the most influential factor, while the factor of price takes the lowest. Gardenia has become as the most preferred brand, followed by Mighty White, with High Five being the least favoured. This study provides valuable view of the students' bread preferences, helping industry players better understand consumer behaviour in the bread market while also improving their business and marketing strategies.

1. INTRODUCTION

Bread has been a preferred food in human civilization for centuries, serving as a primary source of food across various country. According to Skořepa and Pícha (2016), Mesopotamians and Egyptians eat bread for their daily meal. Traditionally, bread is made by mixing the grain flour with water. However, the industry of bread has evolved into variety of types and flavour to serve different consumer preferences worldwide. In Malaysia, the popularity of bread was started during the era of foreign trade and colonization.

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The British and Dutch as major colonial powers introduced the technique of making bread and the corresponding ingredients. Over the time, bread became an alternatives food of the Malaysian diet, influenced by the country's multicultural society. Chinese immigrants also played a role in promoting bread consumption, contributing to the emergence of various bread recipes that cater to different ethnic preferences. A multiracial and multicultural society in Malaysia has contributed to the diversification of bread production over the years. This development has provided consumers with a wider variety of choices.

The increasing demand for bread in Malaysia has been driven by industrial advancements after the independence. The expansion of commercial bakeries and large scale of bread production has made bread more available and affordable to the general public. With the growth of the bread industry, various brands have appeared and contribute to a huge number of breads. Started from traditional loaf bread, now the various types of bread with different flavours and shapes can easily found in the market. In the modern era, many artificial ingredients have been developed, which may affect the production of the bread industry. The high glycaemic index of bread can contribute to increased blood glucose levels, potentially leading to weight gain (Kourkouta et al., 2017). However, this occurs if consumers take bread in large quantities. The diverse selection of bread continues to attract consumers, particularly students who rely on it as a quick and convenient food option. As bread companies compete for market dominance, understanding consumer preferences becomes important. At UiTM Perlis for example, students are supplied with various bread brands through campus cafeterias and local markets. Vendors must ensure they stock preferred brands to minimize wastage and maximize sales since they are given the limited shelf life of bread. Hence, identifying the factors influencing students' bread selection and determining the most preferred brand can help vendors and manufacturers to improve their products.

In this study, Fuzzy Analytical Hierarchy Process (FAHP) is employed to identify the key criteria influencing bread selection and rank them to determine the preferred brand among students at UiTM Perlis. The study focuses on four criteria which are price, taste, packaging, and brand, followed with four major bread brands known as Gardenia, Massimo, Mighty White, and High Five. The data is collected from four student representatives, including Association and Club leaders, Student Representative Council members, and college committee members. The results of this study are anticipated to offer valuable insights for various stakeholders. As for example, the university's cafeterias can use the results to optimize their bread selection while bread manufacturers can enhance their products to meet the student preferences. Additionally, this research offers students an opportunity to understand and apply FAHP as a decision-making tool in evaluating consumer preferences. By implementing the FAHP method, this study may contribute to a better understanding of bread preferences among students, ensuring that vendors and manufacturers comply to consumer demands effectively while enhancing overall market strategies.

2. LITERATURE REVIEW

In this section, some theories behind the fuzzy numbers and FAHP is briefly introduced. Additionally, a review of previous studies on the topic and the hierarchical framework, including the criteria and alternatives considered in the study.

2.1 Fuzzy number

The idea of fuzzy set theory was introduced by Zadeh (1965). In this theory, values between zero and one are used to show how much something belongs to a set. Fuzzy sets are useful for describing uncertain or vague information in a meaningful way. From this idea, fuzzy numbers were developed to represent uncertain numerical values. One common type is the triangular fuzzy number, written as (l, m, u), where l is the lowest possible value, m is the most likely value, and u is the highest possible value.

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Definition 1: (Zadeh, 1965) A triangular fuzzy number (TFN) of $\tilde{A} = (l, m, u)$ has a membership function of $\mu_{\tilde{A}}$ provided by

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x-l}{m-l}, & l \le x \le m, \\ \dfrac{u-x}{u-m}, & m \le x \le u, \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

where l and u stand for the fuzzy number's lower and upper bounds, respectively, while m is the median value. Fig. 1 illustrates the TFN in its standard form.

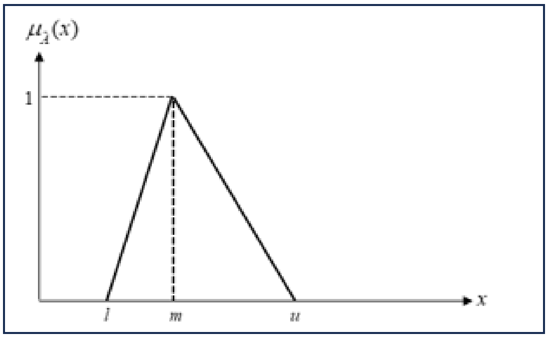

Fig. 1. Representation of a TFN (l, m, u)

2.2 Fuzzy analytical hierarchical process

In the 1970s, Thomas Saaty (Saaty, 1980) introduced the Analytic Hierarchy Process (AHP), a method that able to help in making decisions involving multiple criteria. AHP breaks down complex decisions into a hierarchy of goals, criteria, and options. Decision-makers then compare these elements in pairs to determine their importance, which helps rank the options. Until now, AHP has been widely used in various fields such as in business, healthcare, and government for solving many complicated problems. An extension of AHP that incorporates fuzzy logic is known as a Fuzzy Analytic Hierarchy Process (FAHP) which has been firstly proposed by Chang et al. in 1996 (Chang, 1996).

Unlike traditional AHP, FAHP uses a fuzzy triangular scale to handle uncertainties in subjective judgments. This adaptation is particularly useful in situations where decision-makers face ambiguity or imprecise data. In applying the FAHP method, data is collected through a questionnaire that facilitates pairwise comparisons of all boundaries and categories for analysis and ranking. This data is gathered from subject-matter experts who have the necessary qualifications to provide relevant insights, using a judgmental sampling technique. As noted by Saaty and Ozdemir (2015), FAHP primarily relies on expert opinions rather than a strict statistical approach. Therefore, the validity and consistency of judgments in AHP depend on the expertise of the participants in the specific field.

In FAHP, fuzzy number is often represented in reciprocal form of TFN, particularly when inverting a fuzzy pairwise comparison. Normally, the reciprocal fuzzy number is defined as

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Definition 2: (Chandran, 2005) A triangular fuzzy number (TFN) of $\tilde{A} = (l, m, u)$, which $0 < l < m < u$. The reciprocal of $\tilde{A}$ denoted as $\tilde{A}^{-1}$, is approximated by

$$\tilde{A}^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) \quad (2)$$

Over the years, the FAHP has been widely applied in various fields to solve complex decision-making problems involving multiple criteria. Halim et al. (2014) used FAHP to prioritize the essential criteria by ranking design attributes in Product Line Architecture (PLA). A year then, Brajkovic et al. (2015) used FAHP to evaluate the criteria weights based on students' online behaviours alongside with the Fuzzy TOPSIS. Besides that, FAHP has been employed in evaluating the in-flight service quality (Li et al., 2017) and also in selecting the passenger’s aircraft types (Dožić et al., 2018). Additionally, Calabrese et al. (2019) utilized the FAHP to identify key sustainability issues, emphasizing the need for businesses to integrate sustainability into their strategies to mitigate environmental and societal impacts. Most recently, in 2023 and 2024, Idris et al. (2023) used FAHP in selecting the effective ways to prevent the COVID-19 spread, while Aziz et al. (2024) applied the FAHP in obtaining the ranking of factors to select the online shopping platform in Malaysia.

On the other hand, there are a few studies conducted on the criteria consumers consider when choosing a bread brand. In 2013, Nair (2013) highlighted numerous parameters for selecting bread. The study found that 'freshness' and 'quality' were ranked the highest, followed by 'taste,' 'softness,' and 'date of manufacturing,' while 'price' and 'appearance' ranked the lowest. Other criteria listed in this study are ‘variety’, ‘availability’ and ‘brand name’. Furthermore, Gava et al. (2016) investigated additional criteria such as ‘shelf life,’ ‘familiarity,’ and ‘weight control,’ alongside the usual factors of price, shelf life, taste, freshness, familiarity, and weight control in evaluating the factors influencing bread choices. While, Eglite and Kunkulberga (2017) state in their study that the characteristic in choosing the bread is ‘external appearances’, ‘producers’, ‘packaging design’, ‘expiry date’, ‘buying the same bread’, and ‘price’.

With various factors influencing consumer preferences in bread selection, it is also important to examine the most popular bread brands in Malaysia. Among the many established brands, the most well-known are Gardenia, Massimo, Mighty White, and High Five (Muhammad Fikri et al., 2022). As of now, no study has been conducted to evaluate the most popular bread brands in Malaysia using AHP. However, two studies have explored a somewhat similar scope using AHP. Soja and Melani (2021) examined the priority criteria and sub-criteria in selecting a bread marketing strategy at King's Bakery, while Shukriah et al. (2024) evaluated consumer perspectives on the marketing mix features of peanut bread products in Indonesia.

The following Fig. 2 illustrates the hierarchical framework used in this study which initiated based on the literature reviews. The hierarchical framework shows that, there are four key criteria of evaluation consists of price, taste, packaging, and brand that influence consumer choices. These criteria serve as the basis for evaluating the available options. Meanwhile, the second level presents the four bread brands considered which are Gardenia, Massimo, Mighty White and High Five. Each brand is assessed based on all four criteria, ensuring a comprehensive evaluation. The decision-making process relies on pairwise comparisons, where brands are evaluated against each other for each criterion. The FAHP method is used to systematically quantify subjective preferences, reducing bias and improving accuracy. This approach also helps rank the brands and determine the most preferred option based on consumer preferences.

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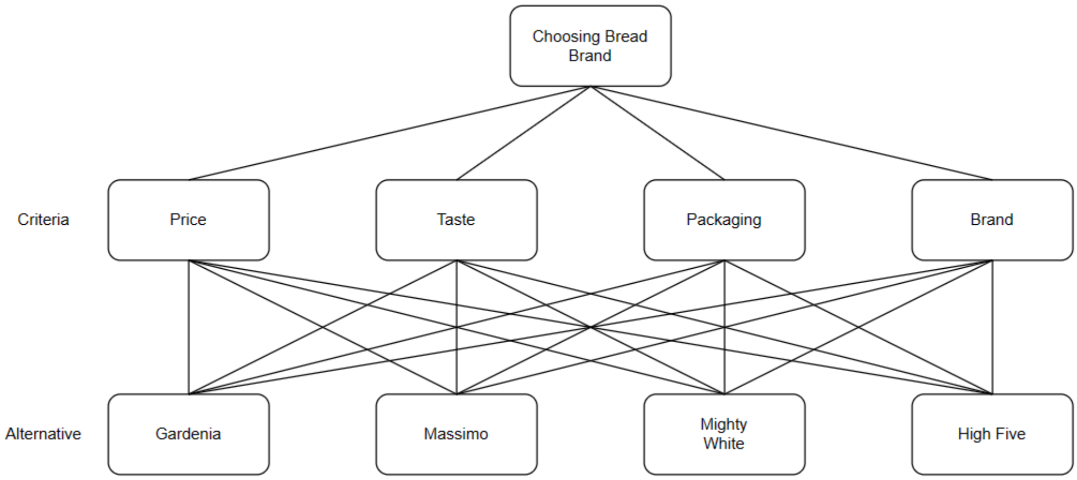

Fig. 2. Hierarchical decision model of the bread preferences

2.3 Criteria for the analysis

This section provides a brief overview of the criteria involved in this study.

2.3.1 Price

Price plays an important role in selecting a product to buy. Sometimes, the price reflects the quality of the product. Customers' perception of a product can often depend on its price. Albari and Indah (2020) discovered that the price of a product contributes to shaping its image.

2.3.2 Taste

Nordin and Teo (2024) identified taste as a key factor influencing adults' purchase intention for packaged food in Klang Valley. This factor is often related to the ingredients of the product. A good taste has a positive impact on the product and can also indicate its quality. The taste of packaged food may vary over time.

2.3.3 Packaging

Packaging is crucial when a company wants to sell its product. Good packaging represents the reputation and image of the company's product. Dutta and Sharma (2023) mentioned that quality and good packaging reflect the authenticity of the product. Moreover, it also helps employees promote the product.

2.3.4 Brand

The image of a brand can influence consumers to purchase a product. A strong brand is important, and manufacturers need to maintain its image to ensure its relevance for many years. Albari and Indah (2020) mentioned that manufacturers must consistently improve product quality and implement effective marketing strategies to sustain the brand.

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3. METHODOLOGY

The methodology of this study is structured into three phases: data collection, consistency testing and weight calculation. Each phase comprises a series of steps, detailed in the subsequent sections.

3.1 Data collection method

The data used in this study consists of primary data which collected through a questionnaire. The questionnaire is constructed based on the previous study of FAHP (Harputlugil, 2018). In this study, four respondents consist of student committee and student clubs of UiTM Perlis are selected to complete the questionnaire. The respondents have some experience in organizing events for fellow students. Typically, the events they organized involve providing bread for breakfast for participants. Additionally, these students also are well-acquainted with the preferred bread brands among their peers.

3.2 Consistency test

Prior to calculating the weight for both the criteria and the alternative, it is necessary to conduct a consistency test to verify that the decision-maker's response is coherent. Inconsistency in the decision maker's answer examples include declaring A is more important than B while yet saying B is more significant than C. Despite this, the respondent afterwards said that C is more significant than A (Peng et al., 2021). This may be prevented if the consistency test is performed on all decision-makers. There are several steps in calculating the consistency ratio and the step is as follows:

Step 1: The first step is to make a pair-wise comparison matrix of the decision maker. The general form of pairwise comparison matrix is given as follows:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{3}$$

where A is positive and symmetric matrix, since $a_{ji} = \frac{1}{a_{ij}}$ and $a_{ii} = 1$ for every $i, j = 1,2,3,\ldots,n$. In other words, if the essential preferences a_{ij} is located in the upper triangle of the matrix, then the reciprocal value $a_{ji} = \frac{1}{a_{ij}}$ must be at the lower triangle or vice versa (Bozanic, et al., 2013).

Step 2: After the pair-wise comparison matrix is formed, the total for each criteria column is calculated, and the normalised matrix is found by dividing each cell by the total number of the respective column.

Step 3: The weight for each criterion is then determined by averaging the sum of each criterion.

Step 4: To find the weighted sum value, the first step is to multiply the original value of each cell in the judgement matrix by the normalised value that is found. Then total each of the criteria to get the weighted sum value.

Step 5: The ratio of the weighted criteria is found by dividing the weighted sum value by the weight criteria.

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Step 6: After the ratio of the weighted criteria is found, the consistency index (CI) is calculated using Equation (4).

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \tag{4}$$

where $\lambda_{\max}$ is the largest eigenvalue of the comparison matrix, obtained by

$$\lambda_{\max} = \frac{\sum \overline{w}_i}{n} \tag{5}$$

which n is the number of alternatives.

Step 7: The consistency ratio can afterwards be calculated using Equation (6).

$$\mathrm{CR} = \frac{\text{Consistency index (CI)}}{\text{Random consistency index (RI)}} \tag{6}$$

The greater the order of the matrix, the bigger the number in RI. The value in RI can be referred in the Table 1 according to the Kaganski et al. (2018).

Table 1. Random Consistency Index Matrix (RI)

Mean random consistency index										
n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

If the consistency ratio (CR) is less than 0.1, then the decision maker respond is consistent and acceptable (Afolayan et al., 2020). However, if the value of CR is greater than 0.1, it indicates a level of inconsistency that is too high, suggesting that the judgments may need to be revised or reconsidered to improve consistency (Saaty, 1980).

3.3 Weight calculation for criteria and alternatives

In this process, the ranking for both criteria and alternatives are determined using Buckley's approach (Ayhan, 2013). The steps are as follows:

Step 1: The criteria and alternative are compared by the decision maker using the linguistic term as shown in Table 1. The linguistic term is using the Saaty Scale (Saaty, 1980) and its corresponding fuzzy triangular number (Ayhan, 2013). The Saaty Scale is a fundamental tool used in the AHP and FAHP to compare the relative importance of different criteria or alternatives. This scale assigns numerical values ranging from 1 to 9, where 1 represents equal importance, while 9 signifies absolute importance of one criterion over another. Additionally, intermediate values (2, 4, 6, and 8) allow for better distinctions between levels of importance.

The linguistic term and the corresponding fuzzy triangular number are used in the construction of the pair wise comparison matrix. If the decision maker said that criteria 1 is fairly important compared to criteria 2, the fuzzy triangular scale are (4,5,6). On the other hand, the pair wise comparison will take the reciprocal of the triangular scale which are $\left(\frac{1}{6},\frac{1}{5},\frac{1}{4}\right)$. The reciprocal values are used to maintain consistency in pairwise comparisons. This ensures logical coherence in the decision-making process.

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In the FAHP approach, the Saaty Scale is extended using Triangular Fuzzy Numbers (TFNs) to handle uncertainty and imprecision in decision-making. Each scale value is represented as a fuzzy number in the form of (*l*, *m*, *u*), where *l* (lower bound), *m* (middle value), and *u* (upper bound) define the range of possible judgments. For instance, a weakly important comparison (Saaty Scale = 3) is expressed as (2,3,4) in fuzzy terms, reflecting a more flexible assessment rather than a fixed numerical value.

By incorporating Triangular Fuzzy Numbers into the Saaty Scale in Table 2, FAHP allows decision-makers to handle subjective judgments more effectively, capturing the uncertainty in human perceptions.

Table 2. Linguistic term and corresponding fuzzy triangular number

Saaty Scale	Linguistic Variable	Triangular Fuzzy Number	Reciprocal of the Triangular Fuzzy Number
1	Equally Important (Eq. Imp.)	(1,1,1)	(1,1,1)
3	Weakly Important (W. Imp.)	(2,3,4)	(1/4,1/3,1/2)
5	Fairly Important (F. Imp.)	(4,5,6)	(1/6,1/5,1/4)
7	Strongly Important (S. Imp.)	(6,7,8)	(1/8,1/7,1/6)
9	Absolutely Important (A. Imp.)	(9,9,9)	(1/9,1/9,1/9)
2	The Intermittent Value Between Two Adjacent Scales	(1,2,3)	(1/3,1/2,1)
4		(3,4,5)	(1/5,1/4,1/3)
6		(5,6,7)	(1/7,1/6,1/5)
8		(7,8,9)	(1/9,1/8,1/7)

The pair-wise comparison matrices that are obtained are then put in the comparison matrices according to the pair. The general comparison matrix is shown in Equation (7). The representation in each column indicates the k^{th} decision with the preference of the first criteria over the second criteria. The next element in the column is followed by the preference of the first criteria over the second criteria. The same can be said for the next row of the first column, which indicates the pair-wise comparison matrix of the preference of the second criteria over the first criteria.

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & \cdots & \cdots & \tilde{d}_{2m}^k \\ \cdots & \cdots & \cdots & \vdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & \tilde{d}_{nm}^k \end{bmatrix} \tag{7}$$

Step 2: Since the decision maker preference is used for the calculation, if there exist more than one decision maker, the preference of the decision maker is averaged by:

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{k} \tilde{d}_{ij}^k}{k} \tag{8}$$

where k represents the number of experts and $\tilde{d}_{ij}^k = (l_{ij}^k, m_{ij}^k, u_{ij}^k)$. From the average value, the pairwise comparison is updated as shown in Equation (9).

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$$\tilde{A} = \begin{bmatrix} \tilde{d}_{11} & \cdots & \tilde{d}_{1n} \\ \cdots & \ddots & \cdots \\ \tilde{d}_{n1} & \cdots & \tilde{d}_{nm} \end{bmatrix} \tag{9}$$

Step 3: The next step is to calculate the geometric mean of fuzzy comparison value for each of the criteria using the formula in the Equation (10).

$$\tilde{r}_i = \left(\tilde{d}_{i1} \times \tilde{d}_{i2} \times \ldots \times \tilde{d}_{in}\right)^{\frac{1}{n}} \tag{10}$$

where n is the number of factors. Subsequently, the vector summation of the geometric mean and its reciprocal are determined by means of the following formulas.

$$\sum_{i=1}^{n} \tilde{r}_i = (\sum l_{\tilde{r}_i}, \sum m_{\tilde{r}_i}, \sum u_{\tilde{r}_i})$$

$$\left(\sum_{i=1}^{n} \tilde{r}_i\right)^{-1} = \left(\frac{1}{\sum u_{\tilde{r}_i}}, \frac{1}{\sum m_{\tilde{r}_i}}, \frac{1}{\sum l_{\tilde{r}_i}}\right) \tag{11}$$

which $\sum_{i=1}^{n} \tilde{r}_i$ and $\left(\sum_{i=1}^{n} \tilde{r}_i\right)^{-1}$ represent the vector summation and reciprocal, respectively.

Step 4: The fuzzy weight of each criterion is calculated using Equation (12).

$$\begin{aligned} \tilde{W}_1 &= \tilde{r}_i \times \left(\tilde{r}_1 + \tilde{r}_2 + \cdots + \tilde{r}_n\right)^{-1} \\ \tilde{W}_1 &= lw_i + lm + uw_i \end{aligned} \tag{12}$$

This equation is calculated by first finding the vector summation of each criteria geometric mean. The reciprocal of the vector summation is then found before putting it in the Equation (12).

Step 5: The next step the defuzzification method. The number can be de-fuzzified by using the Centre of Area (COA) method using Equation (13).

$$COA = M_1 = \frac{lw_i + lm + uw_i}{3} \tag{13}$$

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If $\sum M_1 > 0$, then it is normalized. Otherwise, it is not considered as a fuzzy number. Hence it needs to be de-fuzzified by using

$$N_1 = \frac{M_1}{\sum M_1} \tag{14}$$

The criteria with the highest weight are ranked first. As for the ranking of the alternative with respect to each criterion, an additional calculation step needs to be done. Equation (15) show the formula to obtain the ranking of the alternative with respect to each criterion.

$$R = \sum N_{criteria} \times N_{alternative-criteria} \tag{15}$$

4. RESULT AND DISCUSSION

The results are presented in the following order. First, the consistency ratio is checked for both the criteria and alternatives based on input from all respondents. Once the consistency ratio meets the required conditions, the weights are determined to establish the ranking of both criteria and alternatives.

4.1 Criteria consistency ratio

The consistency ratio for the criteria is tested for each expert by converting their questionnaire responses into a pair-wise comparison matrix. For instance, the pair-wise comparison matrix for Expert 1 is presented in this paper as follows:

Table 3. Expert 1 pair-wise comparison matrix

Criteria	Price	Taste	Packaging	Brand
Price	1	2	3	3
Taste	0.5	1	3	3
Packaging	0.33	0.33	1	3
Brand	0.33	0.33	0.33	1
Total column	2.1666667	3.6666667	7.333333333	10

Similar matrices were constructed for the other three experts. However, only the matrix for Expert 1 is presented as an example. After constructing the pair-wise comparison matrix, a normalized matrix for each expert is formed based on the normalized values for each criterion. This is achieved by dividing each criterion's value by the respective total value in the column for that criterion. The normalized matrix for the Expert 1 is shown in the following Table 4.

Table 4. Expert 1 normalized matrix

Criteria	Price	Taste	Packaging	Brand
Price	0.4615	0.5455	0.4091	0.3
Taste	0.2308	0.2727	0.4091	0.3
Packaging	0.1538	0.0909	0.1364	0.3
Brand	0.1538	0.0909	0.0455	0.1

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After normalizing the matrix, the weight of each criterion is calculated by averaging the sum of each criterion. The weights for all criteria of Expert 1 are presented in the following Table 5.

Table 5. Expert 1 normalized matrix

Criteria	Weight
Price	0.429
Taste	0.3031
Packaging	0.1703
Brand	0.0976

Next, each value in the normalized matrix is multiplied by the previously computed weight of its associated criterion. The resulting values are then summed to obtain the weighted sum value.

Table 6. Expert 1 weighted sum value

Criteria	Price	Taste	Packaging	Brand	Weighted Sum Value
Price	0.429	0.6063	0.5108	0.2927	1.8388
Taste	0.2145	0.3031	0.5108	0.2927	1.3212
Packaging	0.143	0.101	0.1703	0.2927	0.7069
Brand	0.143	0.101	0.0568	0.0976	0.3984

Subsequently, the ratio of the weighted criteria is calculated based on the weighted sum value. The calculation is implemented by dividing the weighted sum value of each criterion with the respective weight of each criterion.

Table 7. Expert 1 ratio of weighted criteria

Criteria	Ratio of Weighted Criteria
Price	4.2861
Taste	4.3581
Packaging	4.1519
Brand	4.0836

Hence, the consistency index (CI) and consistency ratio (CR) for Expert 1 are obtained by using Equation (2) and (3).

Table 8. Expert 1 consistency index

Lambda Max	4.2199
Consistency Index	0.0733
Ratio Index (RI)	0.89
Consistency Ratio (CR)	0.0824

Based on the CR, the results are deemed consistent since the value is less than 0.1. The same processes are executed for all experts and presented in the following Table 9.

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Table 9. Criteria consistency ratio

Expert	Consistency Ratio
Expert 1	0.0824
Expert 2	0.036
Expert 3	0.0723
Expert 4	0.0593

The CR is important for AHP and FAHP to make sure that the experts' answers make sense and acceptable. Based on the results shown in the Table 9, Expert 1 has a CR of 0.0824 (8.24%), Expert 2 has 0.0360 (3.60%), Expert 3 has 0.0723 (7.23%), and Expert 4 has 0.0593 (5.93%). Notably, Expert 2 has the highest level of consistency with a CR of only 3.60%, suggesting well-structured and reliable comparisons. Meanwhile, Expert 1 has the highest CR at 8.24%, but it still falls within the acceptable range. In overall, all the CR values are below 0.10 which indicates that the judgments made by these experts are consistent and valid for further analysis.

4.2 Alternative-criteria consistency ratio

In addition to the criteria pairwise comparison consistency test, consistency tests for alternatives with respect to each criterion pairwise comparison are also conducted. Hence, the second pairwise comparison is the pairwise comparison between each alternative and each criterion. The consistency tests performed are the consistency tests of alternative vs criterion pricing, alternative vs criteria test, alternative vs criteria packing, and alternative vs criteria variety. The procedures used to generate the consistency ratio for the criterion are used to compute the consistency ratio for each alternative criteria for each expert. The consistency test results are presented in the Table 10.

Table 10. Consistency ratio of alternative with respect to criteria

Expert Consistency	Expert 1	Expert 2	Expert 3	Expert 4
Alternative-Price	0.0646	0.0663	0.0925	0.0701
Alternative-Taste	0.0229	0.0232	0.0683	0.0937
Alternative-Packaging	0.0493	0.0319	0.0305	0.0174
Alternative-Brand	0.0692	0.0924	0.0649	0.0468

Table 10 shows the consistency exhibited by the experts for each alternative in relation to each criterion. When evaluating the consistency test of alternatives based on the price criteria, it is worth noting that Expert 1 achieved a consistency score of 0.0646, while Expert 2 obtained a slightly higher score of 0.0662. Expert 3 and Expert 4 both have consistency values of 0.0925 and 0.0701, respectively. When it comes to the consistency test for the alternative in relation to the taste criteria, all experts have consistency values ranging from 0.02300 to 0.0937, which is below the interval of 0.1.

The consistency tests for the alternative with respect to criteria packaging and the alternative with respect to criteria brand both show consistent results, falling within the ranges of 0.0174 to 0.0493 and 0.0468 to 0.0924, respectively. Based on the consistency ratio being less than 0.1, it can be inferred that the pairwise comparison of alternatives by all four experts, in relation to each criterion, is consistent.

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Therefore, the next step involves aggregating expert judgments to derive the final weights for the criteria. This will be proceed using the geometric mean method, which helps combine individual expert opinions into a single, more representative set of priority weights. Once the aggregation is completed, the final ranking of criteria and alternatives can be determined, providing valuable insights for decision making.

4.3 Weight of criteria and alternative

At this phase, the calculation of FAHP is performed to obtain the weight for each criterion and alternative. The weight is determined by first calculating the fuzzy geometric mean for each respective calculation.

4.3.1 Weight of criteria

Determining the weight of criteria involves calculating the average contribution matrix. The process begins by converting the values in the pairwise comparison matrix of all experts to the fuzzy numbers based on the Saaty scale as shown in Table 2. The average contribution is then determined by calculating the mean of the fuzzy numbers provided by each expert. This information is summarized in the average contribution matrix, as shown in Table 11.

Table 11. Averaged contribution matrices for criteria

Criteria	Price	Taste	Criteria	Brand
Price	(1,1,1)	(0.14,0.45,0.54)	(1.61,1.88,2.16)	(0.62,0.90,1.20)
Taste	(2.75,3.50,4.25)	(1,1,1)	(2.63,3.17,3.75)	(2.31,2.82,3.34)
Packaging	(3.78,4.54,5.29)	(1.07,1.59,2.10)	(1,1,1)	(0.68,0.98,1.33)
Brand	(3.81,4.58,5.38)	(3.80,3.60,4.13)	(1.81,2.58,3.38)	(1,1,1)

Next, based on the averaged contribution matrices in the Table 11, the geometric mean for each criterion is calculated using the Equation (6) and presented as follows.

Table 12. Geometric mean of fuzzy comparison value

Criteria	RI		
Price	0.7986	0.9356	1.0892
Taste	2.0215	2.3651	2.7002
Packaging	1.2864	1.629	1.9629
Brand	2.1481	2.5548	2.9412
Total	6.2547	7.4845	8.6935
Reciprocal	0.1599	0.1336	0.115
Reciprocal increasing	0.115	0.1336	0.1599

Table 12 above presents the Relative Importance (RI) values for the four decision-making criteria: price, taste, packaging and brand. Each criterion is assigned a fuzzy RI value, represented by three bounds: lower (l), middle (m) and upper (u) or usually represented as (l, m, u) These values indicate the varying degrees of importance given to each criterion in the decision-making process. From the RI values, brand has the highest importance, with values of (2.1481, 2.5548, 2.9412) across the three fuzzy bounds. This confirms that brand perception is a dominant factor in purchasing decisions. Taste follows closely, with

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values of (2.0215, 2.3651, 2.7002), showing that consumers also prioritize the sensory experience of the product. Packaging holds moderate importance, with RI values of (1.2864, 1.6290, 1.9629), while price has the lowest influence, with values of (0.7986, 0.9356, 1.0892). The total sum of the RI values for all criteria is (6.2547, 7.4845, 8.6935). To normalize these values, reciprocal values are calculated, which are (0.1599, 0.1336, 0.1150) for each respective fuzzy bound. These reciprocals are then used to adjust the RI values proportionally, ensuring that the final fuzzy weight distribution is consistent. Additionally, the reciprocal increasing values (0.1150, 0.1336, 0.1599) are applied in the defuzzification process to refine the ranking of the criteria.

From that, the relative fuzzy weight for each criterion is calculated by using the Equation (7), and presented as follows in Table 13.

Table 13. Relative fuzzy weight for criteria

Criteria		**Weight**	
Price	0.0919	0.125	0.1741
Taste	0.2325	0.3159	0.4317
Packaging	0.1479	0.2177	0.3138
Brand	0.2471	0.3413	0.4702

Next, the relative fuzzy weight for each criterion is defuzzified using the COA formula of Equation (8). As for the example, the COA for the criteria 'price' is shown, as follows.

$$COA(Gardenia) = \frac{(0.0919 + 0.1250 + 0.1741)}{3} = 0.1303$$

Table 14 presents the averaged defuzzified value for each criterion. Furthermore, the normalized value for each criterion needs to be determined since the total of the average defuzzified is more than 1. The calculation is using the Equation (9).

Table 14. Averaged and normalized fuzzy relative weight for criteria

Criteria	**Average Defuzzified**	**Normalized**
Price	0.1303	0.1303/1.0365 = 0.1257
Taste	0.3267	0.3267/1.0365 = 0.3152
Packaging	0.2265	0.2265/1.0365 = 0.2185
Brand	0.3529	0.3529/1.0365 = 0.3405
Total	1.0365	1

The total of the normalized values sums up to 1, which confirms that the weights for each criterion have been successfully obtained. The analysis of decision-making criteria using the FAHP method reveals that 'brand' holds the highest importance in consumer preference when selecting bread. With an average defuzzified weight of 0.3529 and a normalized weight of 0.3405, it is evident that consumers perceive brand reputation as a key factor influencing their purchasing decisions. This indicates that well-established brands have a strong impact on consumer trust and perception. Following closely, 'taste' is the second most important criterion, with a defuzzified weight of 0.3267 and a normalized weight of 0.3153. This suggests that consumers value the sensory experience of the product, emphasizing that a good taste enhances

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satisfaction and loyalty. 'Packaging' ranks third, with a defuzzified weight of 0.2265 and a normalized weight of 0.2185. While not as critical as brand or taste, packaging still plays a significant role in attracting customers, preserving product quality, and influencing purchase decisions. Lastly, 'price' is the least influential factor, with a defuzzified weight of 0.1303 and a normalized weight of 0.1257. This finding suggests that consumers are willing to prioritize quality aspects such as brand reputation and taste over cost when selecting bread.

4.3.2 Weight of alternative-criteria

In addition to assessing the importance of the criteria, the evaluation also involves calculating the relative importance of each option with respect to each of the four criteria. The process for calculating these weights is identical to the procedure used to determine the weight of each criterion. The following Table 15 summarized the overall weight for each criterion.

Table 15. Weight of Alternative with Respect to Each Criteria

Alternative	Price	Taste	Packaging	Brand
Gardenia	0.3513	0.3913	0.2534	0.2718
Massimo	0.1471	0.2269	0.2267	0.1926
Mighty white	0.289	0.2343	0.3655	0.2781
High five	0.2125	0.1475	0.1543	0.2575

4.4 Ranking result

The procedure of obtaining the ranking of alternatives is performed by considering both the weights of the criteria and the aggregated results of the alternatives under each criterion. Table 16 presents the aggregated results for each alternative with respect to the criteria.

Table 16. Aggregated result for each alternative with respect to each criterion

Criteria	Weight	Scores of Alternatives with Respect to Criteria			
		Gardenia	Massimo	Mighty White	High Five
Price	0.1257	0.3513	0.1471	0.289	0.2125
Taste	0.3153	0.3913	0.2269	0.2269	0.1475
Packaging	0.2185	0.2535	0.2267	0.3655	0.1543
Brand	0.3405	0.2718	0.1926	0.2781	0.2575
	Total	0.3155	0.2051	0.2824	0.1946

The Table 16 presents the weighted scores of four bread brands Gardenia, Massimo, Mighty White and High Five based on the four key criteria which are price, taste, packaging and brand. Each criterion has a specific weight, indicating its relative importance in the decision-making process. As obtained previously, 'brand' has the highest weight, followed by 'taste', 'packaging' and 'price'. Meanwhile, looking at the alternative scores which is the bread brands, Gardenia performs the best overall, with the highest scores in taste (0.3913) and price (0.3513), making it a strong choice for consumers. Mighty White stands out in packaging (0.3655) but falls behind in other categories. Massimo and High Five have lower overall scores, with High Five scoring the lowest in taste (0.1475) and packaging (0.1543), suggesting weaker consumer preference. Hence, the ranking results for both criteria and alternatives are determined based on their

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respective weights, which obtained after utilizing the Equation (10). The example calculation is given for the Gardenia, which provides the highest ranking, as follows.

$$R(Gardenia) = (0.1257\times 0.3513) + (0.3153\times 0.3913) + (0.2185\times 0.2535) + (0.3405\times 0.2718)$$
$$= 0.3155$$

The overall results are presented in Table 17.

Table 17. Rank of each criteria and alternatives

Criteria	Scores	Rank	Alternative	Scores	Rank
Price	0.1255	4	**Gardenia**	0.3155	1
Taste	0.3152	2	**Massimo**	0.2051	3
Packaging	0.2185	3	**Mighty White**	0.2824	2
Brand	0.3405	1	**High Five**	0.1946	4

Given that ‘brand’ and ‘taste’ are the most influential criteria, the higher-ranked alternatives are likely perceived as stronger in these areas. Gardenia, holding the top position, likely benefits from a well-established and positive brand image combined with a favourable taste profile. Consumers likely associate Gardenia with quality and a satisfying sensory experience. It can also be said that even though ‘price’ has the lowest scores, Gardenia still excels in this aspect. Mighty White, ranked second, probably performs well in both ‘brand’ and ‘taste’, though perhaps not as strongly as Gardenia. It may have a slightly less prominent brand presence or a taste that is considered good but not exceptional compared to the market leader. It is also worth noting that since ‘packaging’ holds a low rank, these criteria would not be a factor for Mighty White. Massimo, ranking third, may face challenges in either brand perception or taste appeal. Consumers might be less familiar with the Massimo brand or find its taste less appealing than Gardenia or Mighty White. Alternatively, Massimo could be stronger in one area (e.g., taste) but weaker in the other (e.g., brand), resulting in a lower overall ranking. High Five, at the bottom of the ranking, likely struggles in both brand and taste. It may have a less recognizable brand identity and a taste profile that does not resonate as well with consumers. Also, it is worth noting that since both ‘price’ and ‘packaging’ holds a low rank, High Five excels at neither of these criteria. This clearly shows that in order for High Five to improve, the company should find a new branding that will allow them to compete with Gardenia and Mighty White. The ranking of alternatives appears to be heavily influenced by brand perception and taste appeal, with packaging and price playing secondary roles. To improve their position, lower-ranked alternatives should focus on strengthening their brand image and enhancing their taste profile to better align with consumer preferences. A more detailed investigation, perhaps involving consumer surveys or sensory evaluations, would be needed to confirm these hypotheses and identify specific areas for improvement.

5. CONCLUSION

Bread is an alternative food frequently consumed by students. With many brands available in the market, understanding the factors that influence their choices is important. This study applied the FAHP method to evaluate and rank these factors which involves subjective judgments. The result shows that the criteria brand is the most preferred factor for student to make a selection of bread, followed by taste, packaging, and price. A good brand not only produces a positive perception of the product but also convincing consumers of its quality and reliability.

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Among the four bread brands observed Gardenia appeared as the most preferred alternative. This brand has built its own standard in the market and successfully winning the consumer trust. However, this result does not deny the quality of its competitors because each brand possesses its own strengths in many aspects. The findings show that bread manufacturers need to pay attention to improving their brand reputation. They must maintain customer trust and loyalty to their products. Investing in marketing and promotion can help consistently secure customer preference. There are several recommendations that can enhance the results of future research. Future studies could expand the scope by including additional factors such as texture, bread durability, ingredients, halal certification, and other elements that may influence consumer preferences. Furthermore, applying alternative models or techniques, such as fuzzy ELECTRE, could provide different perspectives on consumer choices. Additionally, future researchers may consider combining FAHP with other models, such as Fuzzy TOPSIS. This hybrid method could potentially enhance the results and make the findings more convincing.

By considering these improvements, future research can provide a better understanding of consumer preferences. The findings may benefit both consumers and manufacturers in making decisions regarding bread selection and product development.

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7. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

8. AUTHORS' CONTRIBUTIONS

Khairu Azlan Abd Aziz: Supervision, conceptualisation, development of methodology, and formal analysis; **Wan Suhana Wan Daud**: Data interpretation, manuscript writing, and final editing.; **Mohd Fazril Izhar Mohd Idris**: Conceptualisation, methodology development, and formal analysis; **Nur Aqilah Kamal Azman**: Literature review, data collection, simulation of results, and validation; **Rizauddin Saian**: Language editing and contribution to the interpretation of results.

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