

QFD and Fuzzy AHP for Formulating Product Concept of Probiotic Beverages for Diabetic

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Abstract

In Indonesia, the number of diabetics is increasing. In term of age, people suffered diabetes at the age of 20-79 years old in the past, but now young people also suffer it. Some of the attempts to contain uncontrollable effects of diabetes are to implement healthy lifestyle and to control type or amount of consumed foods. One type of product to ease the risks of Type 2 Diabetes Mellitus is dairy product, and its derivatives. One example of the product is probiotic. This research is intended to design yoghurt product for diabetic consumption, using quality function deployment (QFD) and fuzzy Analytical hierarchy process (fuzzy AHP) methods. This research shows that the technical responses, that serve the priority to develop probiotic product for diabetics, are the use of low-calorie sugar and skimmed milk, and the addition of high-fiber ingredients.

Keywords: Diabetes, Fuzzy AHP, Probiotic, QFD

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1. Introduction

The change of dietary habit and the lack of physical activities have been the causes of the growing risks of non-contagious diseases. These risks are even becoming the main causes of global decease [1]. In Indonesia, the number of diabetics has been increasing. In the early days, diabetes was suffered by people at the age of 20-79, but at present time, it is also suffered by people at early age. According to International Diabetes Federation (IDF), Indonesia has been ranked 7th in the world as country with the highest diabetes prevalence, after China, India, The USA, Brazil, Russia and Mexico [2].

Various risks may occur in case of diabetics do not get proper treatment. Diabetics should be extra careful while consuming certain foods, especially foods which have high glycemic index. Glycemic index is a measurement which shows the effects of the food in increasing sugar concentration in blood [3]. According to American Diabetes Association (ADA) [4], diabetics should be extra careful in choosing food and implementing healthy lifestyle. This statement is also supported by Lee; et al [5] stated that medical recommendation for patients with Type 1 and Type 2 Diabetes includes nutrition, physical activities and medication. Diabetics need to control their dietary habit properly, in order to maintain glycemic level in blood, by consuming high-fiber foods, low-carbohydrate foods and low-fat foods, as well as foods containing probiotic [6].

Probiotic is a food supplement, which contains microbe that is useful in developing the balance of intestine microbe. The use of probiotic in various conditions has been investigated. Research [7] reveals that probiotic products, such as yoghurt, shall reduce HDL level of patients with Type 2 Diabetes Mellitus. Some studies have also found the role of probiotic in preventing the growth of Diabetes Mellitus. According to [8], yoghurt consumption in a certain period of time shall lower the risks of Type 2 Diabetes Mellitus. Some studies [9] also show that the risks of Diabetes Mellitus decrease as a result of applying dietary habit by consuming low-fat dairy products. Therefore probiotic is believed as one of products to reduce the risks of Diabetes Mellitus.

One of problems that arise is how to design probiotic products intended to help diabetics. There are numerous methods to formulate the products. One of the methods is QFD [10, 11]. According to [12], House of Quality (HoQ) matrix in QFD is a tool which is able to

formulate the priority of technical aspects to be considered. To improve the accuracy level in choosing the technical aspects priority, QFD method is integrated with some other methods. Research [13] reveals that the integration of QFD method with fuzzy AHP shall be able to formulate the efficient strategy for logistic outsourcing. Study [14] has successfully implemented fuzzy AHP, linear programming and QFD in formulating the efficient and effective strategy. The other study [15, 16] show the integration of fuzzy method with other methods gives some advantages to create decision more optimal. Therefore this research is intended to design yoghurt product for diabetics, by applying QFD and fuzzy AHP methods. This approach is an solution alternative to formulate yoghurt product with consider some aspects which closely related with consumer preferences.

2. Research Method

This research is performed in some stages. The first stage is preliminary identification, followed by data collecting and data processing, and the second stage is analysis and result interpretation. The first stage of problem identification is performed by observing foods and beverages products available in market, which are promoted as beneficial for diabetics.

2.1. Data Collection

This stage is performed by collecting data of preliminary survey and main survey. Preliminary survey is conducted to collect voice of consumer. Voice of consumer is the key factor to recognize the attributes of product quality and packaging quality. These attribute will be useful for determining product parameters in design phase. The number of samples is determined by using proportion method, since the overall dimension and number of population are unknown. Number of samples is determined with the following calculation [17].

$$n = \frac{(Z_{\alpha/2})^2 \cdot p \cdot q}{E^2} \quad (1)$$

Note :

- n = number of samples
- E = error
- Z $\alpha/2$ = critical number in significance level $\alpha/2$
- α = significance level
- p = proportion of acceptable variant
- q = proportion of unacceptable variant = (1-p)

Based on the sample calculation with confidence level of 95% and error not more than 10%, the minimum number of samples is:

$$\begin{aligned} n &= \frac{(1,96)^2 \cdot 0,5 \cdot 0,5}{0,1^2} \\ &= 96 \text{ respondents} \end{aligned}$$

2.2. Analysis and Data Interpretation

The stage of analysis and data interpretation is conducted by analyzing the level of importance of product attributes, determining the technical response attributes and matrix of relation between product and technical response attributes. The integration with fuzzy AHP method is done in technical response stage. The data used for analysis with AHP is the result of questionnaire in the form of pairwise comparison. Pairwise comparison scale is shown in Table 1.

The following are some stages in Fuzzy AHP method [18]:

1. Analyzing the problem
2. Determining the scale of pairwise comparison for the applied criteria using triangular fuzzy number (Figure 1 and Tabel 1).

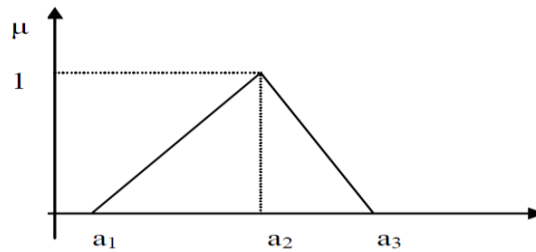


Figure 1. Triangular Fuzzy Number [19]

Table 1. Level of Importance with Pairwise Comparison [20]

Level of importance (Score)	Level of importance Triangular Fuzzy Number (TFN)	Definition
1	(1,1,3)	2 elements are equally important
3	(1,3,5)	Moderately more important than the other element.
5	(3,5,7)	Strongly more important than the other element.
7	(5,7,9)	Very strongly more important than the other element.
9	(7,9,9)	Extremely more important than the other element (the most important)

3. Collecting evaluation results from various experts. By assuming that evaluator assesses core attribute m and expert k conducts pairwise comparison using fuzzy scale. The importance of C_i relative to C_j is shown by the following fuzzy matrix:

$$S_k = \begin{bmatrix} \tilde{b}_{11k} & \tilde{b}_{12k} & \dots & \tilde{b}_{1mk} \\ \tilde{b}_{21k} & \tilde{b}_{22k} & \dots & \tilde{b}_{2mk} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{b}_{m1k} & \tilde{b}_{m2k} & \dots & \tilde{b}_{mmk} \end{bmatrix} \quad i = 1, 2, \dots, m, \quad j = 1, 2, \dots, m, \quad k = 1, 2, \dots, S, \quad (2)$$

\tilde{b}_{ijk} represents preference of fuzzy C_i to C_j , which is assessed by panelist k. Furthermore, the expert's decision is aggregated with the following equation:

$$b_{ij} = (L_{ij}, M_{ij}, U_{ij}) \tilde{b}_{ji} = \tilde{b}^{-1}_{ij} = \left(\frac{1}{U_{ij}}, \frac{1}{M_{ij}}, \frac{1}{L_{ij}} \right) \quad (3)$$

$$L_{ij} = \min_k (\tilde{b}_{ijk}), \quad M_{ij} = \text{median}_k (\tilde{b}_{ijk}), \quad U_{ij} = \max_k (\tilde{b}_{ijk}) \quad (4)$$

$$b_{ij} = \left(\frac{L_{ij} + M_{ij} + U_{ij}}{3} \right) \quad (5)$$

\tilde{b}_{ij} shows fuzzy aggregation value and b_{ij} shows defuzzified crisp value by implementing Centre of Area scheme.

4. Maximum eigenvalue is corresponding to eigenvector and is calculated to estimate criteria weights m:

$$A = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1m} \\ b_{21} & b_{22} & \dots & b_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \dots & b_{mm} \end{bmatrix} \quad (6)$$

$$AW = \lambda_{\max} W \quad (7)$$

A is $m \times m$ matrix between attribute m, λ_{\max} is maximum eigenvalue from matrix A, and W is the corresponding eigenvector. In this research, eigenvector is considered as a technical response (importance weight).

5. Defining Consistency Index (CI) and Consistency Ratio (CR) with the following formulation

$$CI = \frac{\lambda_{maks} - n}{n - 1} \tag{8}$$

$$CR = \frac{CI}{RI} \tag{9}$$

CI is Consistency Index and RI is Random Index that corresponds to the number of applied criteria. Evaluation is considered consistent if $CR \leq 0,1$.

6. Weighing with Fuzzy

a. Determining the fuzzy synthetic value (Si) priority, with the following formulation:

$$Si = \sum_{j=1}^m M_i^j \times \frac{1}{\sum_{i=1}^n \sum_{j=1}^m M_i^j} \tag{10}$$

$\sum M_{ij} m_j = 1$ is summation line in pairwise matrix, whereas $\sum i j m_j = 1 \sum n i = 1$ is the summary result of column in pairwise comparison matrix.

b. Defining the vector value (V) and ordinate of defuzzification value (d')

If the value of each fuzzy matrix,

$M2 \geq M1$ ($M2 = (l_2, m_2, u_2)$ and $M1 = (l_1, m_1, u_1)$)

therefore the vector value is formulated as follows:

$V(M2 \geq M1) = \sup[\min(\mu_{M1}(x), \min(\mu_{M2}(y)))]$

or equivalent with Figure 2.

$$v(M_2 \geq M_1) = \begin{cases} 1 & \text{if } m_2 \leq m_1 \\ 0 & \text{if } l_1 \leq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{lainnya} \end{cases} \tag{11}$$

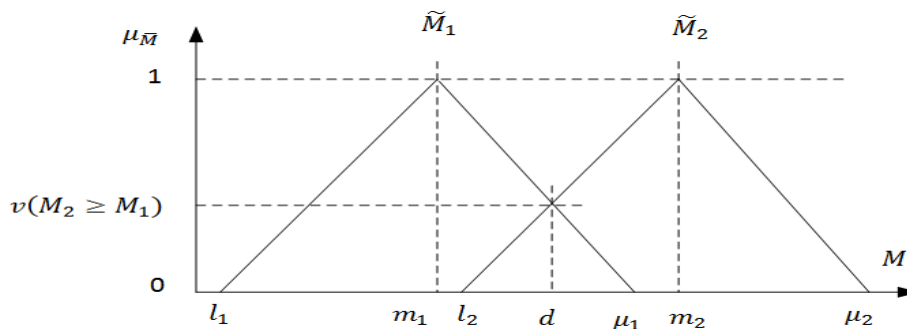


Figure 2. Interaction between M1 and M2 [21]

If the value of fuzzy is greater than k, M_i , ($i=1,2,,k$) then the vector value is defined as follows:

$$V(M \geq M1, M2, \dots, Mk) = V(M \geq M1) \text{ and } V(M \geq M2) \text{ and } V(M \geq Mk) = \min V(M \geq M_i) \tag{12}$$

$$\text{by assuming that } d'(A_i) = \min V(S_i \geq S_k) \tag{13}$$

For $k = 1,2,\dots, n; k \neq i$, vector value is defined as follows:

$$W' = (d'(A1), d'(A2), \dots, d'(An))T \quad (14)$$

where $A_i = 1, 2, \dots, n$ is fuzzy vector (W)

C. Normalization of weight vector value fuzzy (W). After normalization of equation (14), then normalized weight vector value is defined with the following formulation:

$$W (d(A1), d(A2), \dots, d(An),)T \quad (15)$$

3. Results and Discussion

3.1. Preliminary Identification

Preliminary data, which is required in developing a product, is gained by recognizing consumer needs. This preliminary data is obtained by performing preliminary research addressed to 30 respondents, who suffer diabetes, in a supermarket in Malang. The next stage is defining the importance level and the expectation to product attributes. This survey is given to 100 respondents, who suffer diabetes specifically Type 2 Diabetes Mellitus.

3.2. Analysis and Interpretation

The early stage of analysis with QFD method is by defining consumer needs or consumer requirements (*Whats*). This stage is important to interpretate consumer needs in order to outline the product design [22].

Analysis on the consumer importance level is intended to define the priority of consumer needs from the highest to the lowest level. The scale used for consumer needs is based on Likert method, with score of 1 (very unimportant) to 5 (very important). The calculation results of consumer importance from the highest to the lowest score are shown in Table 2.

Table 2. Consumer Importance Level

Voice of Consumer	Importance Level
Low fat	4.78
Low calorie	4.66
High fiber	4.58
Vitamin D fortification	4.54
Not too sour	4.26
Attractive colour	3.98
Aftertaste	3.87
Various flavours	3.80
Aroma	3.46

3.3. Planning Matrix Analysis

This stage defines the commercial contribution made by attributes, which is a part of HoQ calculation. This matrix is used to find contribution value as a reference for defining the priority. The calculation results are shown in Table 3.

Table 3. Planning Matrix for Defining Priority of Consumer Voice

Voice of Consumer	Importance weight	Current Point	Plan	Improvement Ratio	Sales Point	Absolute Weight	Consumer Need Weight	Rank
Not too sour	4.26	4.36	5.00	1.15	1.5	7.33	9.29	6
Various flavours	3.80	4.02	5.00	1.24	1.5	7.09	8.99	7
Aroma	3.46	3.67	5.00	1.36	1.5	7.07	8.96	8
Attractive colour	3.98	3.86	4.00	1.04	1.5	6.19	7.84	9
Aftertaste	3.87	3.72	5.00	1.34	1.5	7.80	9.89	5
Low fat	4.78	3.25	5.00	1.54	1.5	11.03	13.98	2
Low calorie	4.66	3.27	5.00	1.53	1.5	10.69	13.55	3
High fiber	4.58	3.09	5.00	1.62	1.5	11.12	14.09	1
Vitamin D fortification	4.54	3.22	5.00	1.55	1.5	10.57	13.40	4

Table 3 shows that the information regarding Consumer Need Weight has been obtained. Table 3 indicates that high fiber attribute is the attribute that requires improvements from the standpoint of sales. The improvement priority can also be recognized from the improvement ratio value. In addition to high fiber attribute, other attributes to be improved subsequently are low fat and low calorie. The next priority is also Vitamin D fortification.

3.4. Technical Respons Design

Consumer importance in QFD or Voice of Consumer is later interpreted in Technical Response, which is technical parameter relevant to consumer importance. The outcomes of interview to panelists of experts are 10 technical responses to be considered in designing probiotic product for diabetics. Calculation shows Consistency Index of 0.091. $CR \leq 10\%$ indicates that the matrix of evaluation results is consistent [18].

3.5. Weighing with Fuzzy AHP

a. Fuzzy pairwise comparison matrix

Table 4. TFN Transformation of the Results of Pairwise Comparison Matrix

	T1	T2	T3	T4	...	T10										
T1	1	1	3	1	1	3	1	1	3	1	1	3	...	1/7	1/5	1/3
T2	1	1	3	1	1	3	1	3	5	1	1	3	...	1/7	1/5	1/3
T3	1	1	3	1/5	1/3	1	1	1	3	1	1	3	...	1/9	1/7	1/5
T4	1	1	3	1	1	3	1	1	3	1	1	3	...	1/5	1/3	1
T5	1/5	1/3	1	1	1	3	1/5	1/3	1	1	1	3	...	1/9	1/7	1/5
T6	1	1	3	1	3	5	1	1	3	1/5	1/3	1	...	1/5	1/3	1
T7	1	1	3	1	1	3	1	1	3	1	3	5	...	1/7	1/5	1/3
T8	3	5	7	5	7	9	3	5	7	5	7	9	...	1	1	3
T9	5	7	9	5	7	9	5	7	9	3	5	7	...	1	1	3
T10	3	5	7	3	5	7	5	7	9	1	3	5	...	1	1	3

b. Defining upper, medium and lower limit values of each triangular fuzzy number with Centre of Area method.

Table 5. Lower, Medium and Upper Values of TFN

	L	M	U
T1	0.54394	0.66589	1.55185
T2	0.45159	0.57687	1.32115
T3	0.45159	0.57687	1.32115
T4	0.47893	0.62788	1.55185
T5	0.31647	0.44002	0.95020
T6	0.34417	0.49532	1.17462
T7	0.74322	1.05241	2.41020
T8	2.14113	3.13559	5.51977
T9	2.37144	3.35386	5.80430
T10	1.91836	2.97944	5.33713

c. Determining the matrix of Synthetic Extent Fuzzy using pairwise comparison matrix for each technical response.

Table 6. Matrix of Synthetic Extent Fuzzy

<i>S_i</i>	L	M	U
S1	0.05573	0.19862	0.10250
S2	0.04626	0.16899	0.08721
S3	0.04626	0.16899	0.08721
S4	0.04907	0.19121	0.09868
S5	0.03242	0.12275	0.06335
S6	0.03526	0.14486	0.07476
S7	0.07614	0.30249	0.15611
S8	0.21936	0.77649	0.40073
S9	0.24295	0.82922	0.42794
S10	0.19654	0.73611	0.37989

- d. Comparing probability level between synthetic extent fuzzy and its minimum value.

Table 7. Matrix of Probability Among Synthetic Extent Fuzzy

S_i	$S1 \geq$	$S2 \geq$	$S3 \geq$	$S4 \geq$	$S5 \geq$	$S6 \geq$	$S7 \geq$	$S8 \geq$	$S9 \geq$	$S10 \geq$
S1		0.515	0.515	0.853	0.091	0.261	1	1	1	1
S2	1		1	1	0.27	0.541	1	1	1	1
S3	1	1		1	0.27	0.541	1	1	1	1
S4	1	0.632	0.632		0.173	0.357	1	1	1	1
S5	1	1	1	1		1	1	1	1	1
S6	1	1	1	1	0.56		1	1	1	1
S7	0.202	0.077	0.077	0.168	0	0		1	1	1
S8	0	0	0	0	0	0	0		1	1
S9	0	0	0	0	0	0	0	0.75		0.595
S10	0	0	0	0	0	0	0	1	1	
Minimum	0	0	0	0	0	0	0	0.75	1	0.595

- e. Calculating the technical response weight vector and the normalization of technical response weight vector. The normalization of technical response weight vector is presented in Table 8. The analysis results show that there are 3 technical responses that are expected to meet the consumer needs. The results are useful for producers in determining the priority level of each technical response formulated.

Tabel 8. The Normalization of Technical Response Weight Vector

	(T1)	(T2)	(T3)	(T4)	(T5)	(T6)	(T7)	(T8)	(T9)	(T10)
W	0	0	0	0	0	0	0	0.32	0.43	0.25

According to Table 8, there are 3 technical responses considered as the most important compared to the other 7 technical responses. The prioritized technical responses are: the substitution of sugar with low-calorie natural sweetener ingredient (0.47), the use of skimmed milk (0.32) and the addition of high-fiber ingredient (0.25). Based on the analysis result, it is expected that probiotik producers can incorporate those 3 technical responses into their product development. The drawback factor of this research is there is no development of product prototype that can be used for product testing such as ; physical test, chemical test and organoleptic test. Other than that, the use of more specific ingredients has not been written in detail.

4. Conclusion

QFD and Fuzzy AHP methods has been applied to identify what consumer needs are and also to analyze technical responses. Based on the results of this research, high-fiber ingredient is the most important attribute out of 9 other attributes, which will influence consumer's consideration in choosing yoghurt products for diabetic. There are 10 technical responses resulted from this research. Based on the weight vector calculation, there are 3 technical responses considered as the most important ones. The highest priority is the substitution of sugar with low-calorie natural sweetener (0.426). The priority is followed by other technical responses, which are the use of skimmed milk (0.32) and the addition of high-fiber ingredients (0.254). Thus, the integration of QFD and Fuzzy AHP is to be one of the best alternatives method for the development of probiotic beverages for diabetic.

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