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Implementation of Fuzzy Logic on Adding Sodium Bicarbonate and Carboxy Methyl Cellulose (CMC) Concentrations to the Texture of Wet Noodles

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Abstract

The purpose of this study was to identify appropriate concentrations of sodium bicarbonate and CMC in order to produce wet noodles with textures preferred by consumers. The steps used in this study are to conduct a literature study to obtain data in the form of input variables, namely sodium bicarbonate and Carboxy Methyl Cellulose (CMC), and output, namely texture. The input variables are fuzzified, and then the fuzzy rules and inference are determined by Mamdani and defuzzification methods. Data processing using the Mamdani method is carried out with the help of the Matlab application. The result of this study is the formulation of sample 1 with the addition of 0.6% sodium bicarbonate and 0.2% CMC and sample 2 with the addition of 0.6% sodium bicarbonate and 0% CMC, which are recommended to consumers because they produce the preferred texture of wet noodles.

Keywords: wet noodles, mamdani, texture, fuzzy logic.

INTRODUCTION

Of the many staple foods in Indonesia, noodles are staple foods that people like to consume because, in addition to tasting good, noodles are also easy to process with various menu variants such as fried noodles, noodle soup, chicken noodles, noodles, and tek-tek noodles and the price is affordable. Noodles were originally introduced to Indonesia in the early 7th to 9th centuries by Chinese traders. At first, the sales and consumption of noodles were smaller than they are now. Still, along with the times until the era of globalization, noodle consumption has increased rapidly and has become one of the main needs of people in Indonesia. One of the noodle products that is often consumed, especially by families in Indonesia, is wet noodles (Oktiarni, Ratnawati, & Anggraini, 2012).

Wet noodles are noodles that are processed by boiling before being marketed, with a moisture content of up to 52%, and are known in Indonesia as yellow noodles or meatball noodles (Kurniawan, Estiasih, & Nugrahini, 2015). Wet noodles are made from wheat flour and additional CMC and Sodium Bicarbonate (Parengkuan, Hariyadi, Paat, & Tumbel, 2022). According to research conducted by (Mulyadi, Wijana, Dewi, & Putri, 2014), Carboxy Methyl Cellulose, or CMC, is a food additive that functions as a stabilizer. The addition of CMC to the noodle dough serves to control the transfer of water when the noodle dough is cooked so that the texture of the noodle dough is not easily destroyed. In addition, CMC serves to prevent gel rupture due to temperature changes so that the texture of the noodles remains consistent during the storage process (Awaliya and Setiyoko 2023). With the addition of CMC to the noodle dough, the dough becomes more concentrated (Tinambunan, Rusmarilin, & Nurminah, 2014).

Meanwhile, according to (A. R. Nasution, Suhaidi, & Limbong, 2018), Sodium Bicarbonate (NaHCO3) works by producing gas that is useful during the carbonation process. The advantages of using sodium bicarbonate as a food additive include low prices and the fact that it does not affect taste. In noodle products, the addition of sodium bicarbonate can increase the chewiness of the noodles due to alkaline conditions that will make the gluten proteins in the flour bind to each other so that the texture of the noodles becomes chewier (Hutahaean, Sumartini, Haryanti, & Zai, 2022).

The addition of Carboxy Methyl Cellulose (CMC) and Sodium Bicarbonate (NaHCO3) to the wet noodle batter affects the texture of the noodles. So, it is necessary to use the Fuzzy Logic method that is able to determine the concentration of Carboxy Methyl Cellulose (CMC) and Sodium Bicarbonate (NaHCO3) in wet noodles (Nurfina, Sumartini, & Situmorang, 2022). In computer science, Fuzzy Logic is a method used to process information that is vague or uncertain. The use of fuzzy logic allows a variable to have a level of membership in a set where the variable can be described as being close to the user's desired characteristics (Cahyani, Dewatama, & Kamajaya, 2023). Meanwhile, according to (Tarigan, 2013), by using fuzzy logic, the operational laws of a system, which are usually in the form of mathematical equations, can be expressed in the form of written language.

The implementation of fuzzy logic allows for a more accurate representation of situations by allowing partial membership in defined sets (Arman & Karfindo, 2017). In cases related to product sensory quality, product results from optimal processing will be validated by fuzzy logic through sensory attributes such as taste, aroma, and texture (Vivek, Subbarao, Routray, Kamini, & Dash, 2020). Therefore, in this case, fuzzy logic methods are used to determine the formulation of carboxymethyl cellulose (CMC) and sodium bicarbonate (NaHCO3), which produces the texture of wet noodles that consumers prefer. The use of fuzzy logic methods can also determine suitable formulations from the use of Carboxy Methyl Cellulose (CMC) and Sodium Bicarbonate (NaHCO3) as food additives to produce output in the form of suitable formulations or according to preferences consumers on the texture of wet noodles.

METHODS

This research method uses a literature study with scientific journal sources related to the research title, namely the implementation of fuzzy logic on the concentration of sodium carbonate and carboxy methyl cellulose (CMC) on the texture of wet noodles.

The data used came from the results of the sensory test practicum of wet noodle processing using the hedonic test method. Hedonic uji is carried out to determine the difference in sensory quality of a group of products and determine the level of product liking by providing an assessment on a certain scale (Tarwendah, 2017). The research conducted this time has a rating scale from 1 to 9, namely with the definition of a rating scale of 1 indicates very or very dislike, a rating scale of 2 indicates very dislike, a rating scale 3 indicates dislike, rating scale 4 somewhat dislikes, ordinary rating scale 5, rating scale 6 somewhat likes, rating scale 7 likes, rating scale 8 very likes and rating scale 9 is very very like.

Data analysis aims to produce a consumer-preferred wet noodle texture with sodium carbonate and Carboxy Methyl Cellulose (CMC) added by applying fuzzy logic with the help of the FIS (Fuzzy Inference System) program in the Matlab application with stages:

1. Define fuzzy sets and fuzzy inputs. The variables that become fuzzy inputs are sodium bicarbonate and CMC, with sodium bicarbonate variable categories of 0% and 0.6% and CMC variable categories of 0% and 0.2%. Next, the degree of commensuracy

between the fuzzy input data and the specified fuzzy set for each variable of the fuzzy rule is determined. The degree of membership used is a triangular function. The triangles are used at the highest membership degree value, forming a maximum value based on the parameters they want to know through fuzzy (Santosa, Hidayat, & Siskandar, 2022).

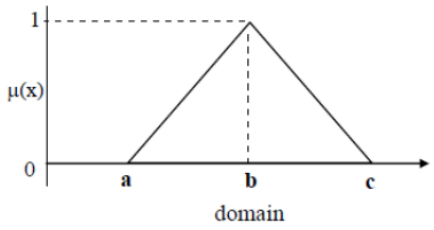


Figure 1. Degrees of Membership Triangle

2. Apply fuzzy operators and fuzzy rules that have been created. The rules for the concentration of sodium bicarbonate and CMC to the texture of wet noodles are as follows:
   - If the concentration of sodium bicarbonate is 0.6% and CMC is 0.2%, then the texture of wet noodles LIKE (S)
   - If the concentration of sodium bicarbonate is 0.6% and CMC is 0%, then the texture is LIKE (S)
   - If the concentration of sodium bicarbonate is 0% and CMC is 0%, then the texture is ORDINARY (B)
3. Applying the implication function, the results obtained from the operator rule are combined to produce fuzzy inference output. The Mamdani method uses the MIN or minimum implicit function, where this implication function will truncate the fuzzy output set (Sari, 2018). In addition to using the MIN implication function, inter-rule MAX composition produces inter-rule compositions in IF and THEN (D. Nasution, 2018).
4. Composes all outputs, combining membership graphs from the results of implication calculations. The variable that becomes the output is the texture of wet noodles with variable categories, namely dislike, like, and ordinary.
5. Defuzzification: This stage uses the centroid method by looking at the results of high consistency, total significance and sensitivity to the width of the fuzzy area (Al-Jabbar 2024). The centroid method compares fuzzy operators' moment and area results (Santosa et al., 2022). The defuzzified input will produce the rules created, and the output is a fuzzy domain set.

RESULTS AND DISCUSSION

Data on the use of sodium bicarbonate and CMC in wet noodles are listed in Table 1.

Table 1. Sodium Bicarbonate and CMC Concentration Data on Wet Noodles

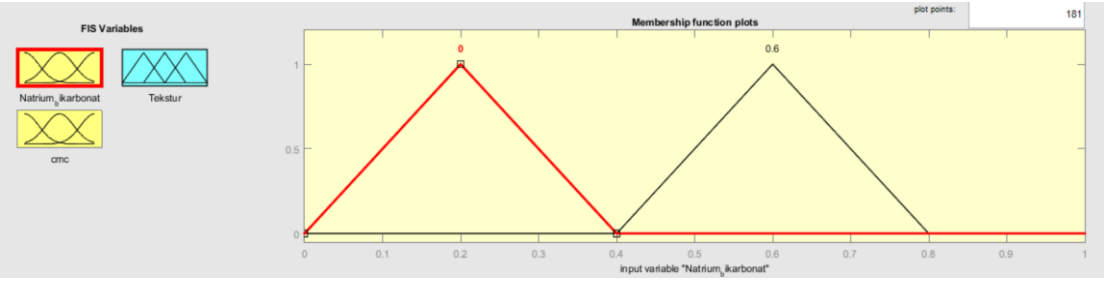
Sample No.	Sodium Bicarbonate (%)	CMC (%)
1	0.6	0.2
2.	0.6	0
3.	0	0

According to (V. M. Nasution & Prakarsa, 2020), fuzzy logic is one type of logic that involves the value of fuzziness between right and wrong. Fuzzy logic is a method for mapping input space into an output space (Irawan & Herviana, 2018). Fuzzy logic has membership degrees with a range of 0 to 1 (H. Nasution, 2020). Because fuzzy logic is developed based on human language or natural language, it can connect machine language with human language, which is emphasized through the meaning of language. This method allows several degrees of truth to be processed through decision variables. There is flexibility in accommodating all desired conditions and requirements by including input variables and fuzzy rules, one of which is a fuzzy analysis of the texture of noodle products. The stages of the fuzzy system are as follows:

1. The Input Fuzzy
   first stage is to define input and output variables. The variables that become fuzzy inputs in this case are sodium bicarbonate and CMC. In comparison, the variable that becomes the fuzzy output is the texture of the wet noodles. The reason for choosing sodium bicarbonate and CMC as variables is that they play a role in the formation of gluten, which can increase elasticity.

Figure 2. Fuzzy Inputs and Outputs

2. Fuzzification
   Fuzzification is the stage that defines the membership level and the process of translating each existing input and output. At this stage, each degree value of membership will be calculated against each set of fuzzy (Shaum et al., 2023). Texture parameters are classified into 3 levels of members: like, ordinary, and dislike.
   For input membership levels, sodium bicarbonate is defined with 2 membership levels, namely 0% and 6%. Similarly, CMC is defined by 2 membership levels, namely 0% and 2%. As for the output membership level, it is defined by 3 membership levels, namely dislike, ordinary, and like.
   The fuzzy input variable for the addition of sodium bicarbonate has two sets, which include the addition of sodium bicarbonate as much as 0% with parameters [0.0.2, 0.4] and 0.6% with parameters [0.4, 0.6, 0.8]. Each fuzzy set has different parameters, which will affect the output produced.



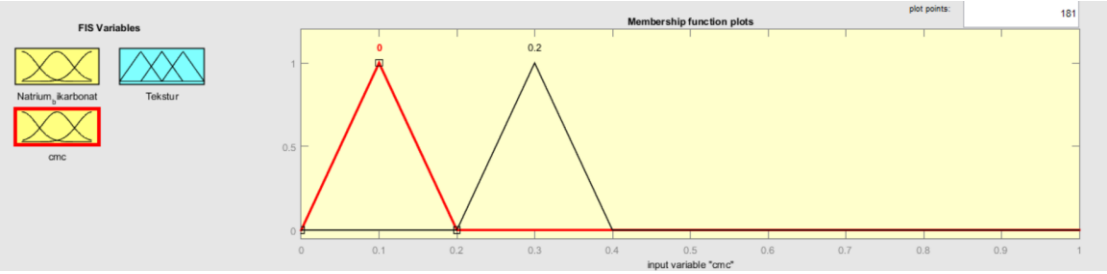
Graph 1. Sodium Bicarbonate Membership Rate Graph

From the graph above, the calculation results are as follows.

$$\mu\, Natrium\ Bikarbonat = \begin{cases} 0 & \times < 0{,}4 \\ \dfrac{x-a}{b-a} & 0{,}4 \le \times < 0{,}6 \\ 1 & \times = 0{,}6 \\ \dfrac{c-x}{c-b} & 0{,}6 < \times \le 0{,}8 \\ 0 & X > 0{,}8 \end{cases}$$

Figure 3. Calculation Results of Sodium Bicarbonate Membership Level

The fuzzy input variable for CMC addition has two sets, which include the addition of sodium bicarbonate as much as 0% with parameters [0.0.1, 0.2] and 0.2% with parameters [0.2, 0.3, 0.4]. Each fuzzy set has different parameters, which will affect the output produced.



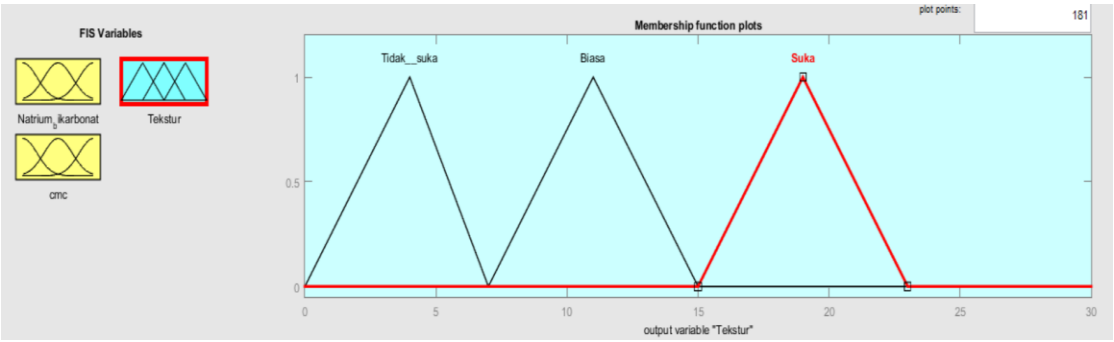
Graph 2. CMC Membership Level Graph

From the graph above, the calculation results are as follows.

$$\mu\, CMC = \begin{cases} 0 & \times < 1 \\ \dfrac{x-a}{b-a} & 0 \le \times < 0{,}2 \\ 1 & \times = 0{,}2 \\ \dfrac{c-x}{c-b} & 0{,}2 < \times \le 0{,}4 \\ 0 & X > 0{,}4 \end{cases}$$

Figure 4. CMC Membership Level Calculation Results

The fuzzy output variable of texture has three sets: dislike with parameters [0 4 7], ordinary with parameters [7 11 15], and likes with parameters [15 19 23].



Graph 3. Noodle Texture Membership Level Graph

From the graph above, the calculation results are as follows.

$$\mu\ dislike = \begin{cases} 0 \times < 0 \\ 0 \times = 1 \\ \frac{x-a}{c-b}\ 0 \leq \times < \sim 4 \\ 1 \times = \sim 4 \\ \frac{c-x}{c-b} \sim < \times \leq 7 \\ 0 \times > 7 \end{cases} \quad \mu\ usual = \begin{cases} \frac{x-a}{b-a} & 0 \times < 7 \\ & 7 \leq \times < 13 \\ & 1 \times = 13 \\ \frac{c-x}{c-b} & 13 < \times \leq 15 \\ & 0\,X > 15 \end{cases}$$

$$\mu\ like = \begin{cases} \frac{x-a}{b-a} & 0 \times < 15 \\ & 15 \leq \times < 19 \\ & 1 \times = 19 \\ \frac{c-x}{c-b} & 19 < \times \leq 23 \\ & 0\,X > 23 \end{cases}$$

Figure 5. Noodle Texture Membership Level Calculation Results

Based on the variables and texture memberships that have been analyzed, the level of 'dislike' can be indicated by an x value greater than seven. As for the 'ordinary' level, it can be indicated by x values greater than fifteen. Then, the degree of 'like' can be indicated by an x value greater than twenty-three.

3. Fuzzy Rule Formation and Inference Using the Mamdani Method

Table 2. The Fuzzy Rules

Sample No	Variable		Categories Textures
	Sodium Bicarbonate (%)	CMC (%)	
1	0.6	0.2	Like(s)
2.	0.6	0	Like(s)
3.	0	0	Ordinary (B)

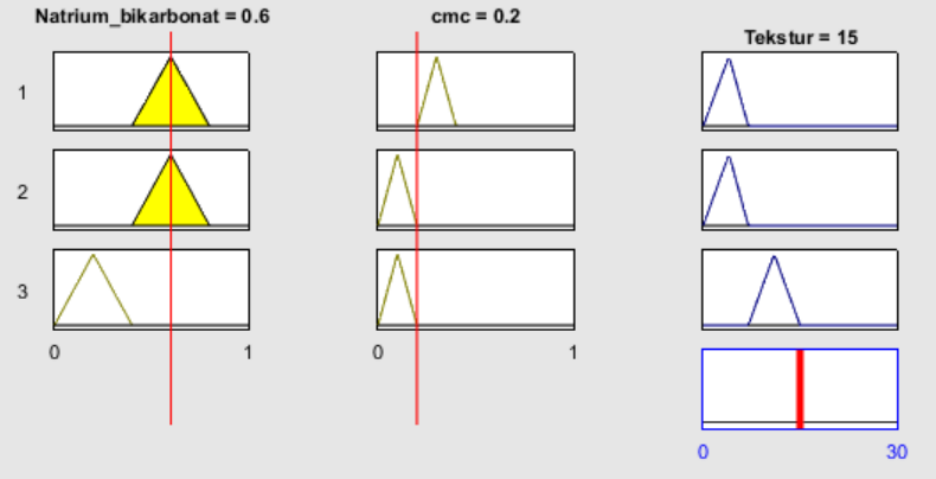
The next stage is the formation of fuzzy rules from each of the variables that have been compiled. Based on the existing data table, several rules are obtained, as follows: sodium bicarbonate concentrations of 0.6%, 0.6%, and 0%. Then, the CMC concentration is divided into 0.2%, 0%, and 0%. As for the texture category, noodles are defined as (S) and ordinary (B).

Based on the instrument rules that have been made, the rules used in the sample are:

1. IF sodium bicarbonate is 0.6% AND cmc is 0.2%, THEN texture is like (S).
2. IF sodium bicarbonate is 0.6% AND cmc is 0%, THEN texture is like(S).
3. IF sodium bicarbonate is 0% AND cmc is 0%, THEN texture is regular (B).

4. Defuzzification

Defuzzification is an activity that changes the fuzzy set produced from the fuzzy rule instrument into a number in the fuzzy set domain. A commonly used method in defuzzification is the centroid. The results of defuzzification show that the texture is in the range of LIKE Decisions [15], so the results obtained are in accordance with the rules so that they can be set.



Graph 4. Membership Degrees

5. Computer Applications for Fuzzy Stage Affirmation

Input raw data from sodium bicarbonate and cmc concentration variables, which are then grouped into fixed values and converted into fuzzy sets. The applied fuzzy rule is selected and removed to get the corresponding result on the value of the variable that has been entered. The fuzzy value of the variable is generated using the Mamdani method. The defuzzification process returns the fuzzy output value to a fixed value (Nisa, Abdy, & Zaki, 2020).

This study examines how to determine consumer-friendly wet noodles with sodium bicarbonate and cmc concentrations with fuzzy logic using a fuzzy inference system (FIS) in a matrix-based computer programming application, namely Matlab. Here are the steps for implementing the fuzzy logic:

1. The first step of implementing fuzzy logic is the determination of inputs and outputs. In this study, two input variables were determined, namely the concentration of sodium bicarbonate added and the concentration of cmc added to wet noodles. The texture of wet noodles determines the output variable in this study.
2. The next step is the assignment of set parameters from input and output variables. The set of input variables in the form of the concentration of adding sodium bicarbonate to wet noodles is determined with parameters expressed in intervals as follows: sodium bicarbonate 0% = [0, 0.2, 0.4] and sodium bicarbonate = [0.2, 0.4, 0.8]. The set of input variables in the form of the concentration of adding CMC to wet noodles is determined with parameters expressed in CMC intervals as follows: CMC 0% = [0, 0.1, 0.2] and CMC 0.2% = [0.2, 0.3, 0.4]. Then, for the set of output variables in the form of noodle texture with three memberships including dislike, ordinary, and like, each set with parameters expressed in the following intervals: dislike = [0.0, 4, 7], ordinary = [7, 11, 15], and like = [15, 19, 23].
3. In the third step, fuzzification is performed by defining the membership levels of inputs and outputs. The concentration of sodium bicarbonate is divided into 3 samples, namely sample 1 with a concentration (of 0.6), sample 2 with a concentration (of 0.6), and sample 3 with a concentration (of 0). Similarly, the content of the CMC concentration is divided into 3 samples, namely sample 1 with a concentration (0.6), sample 2 with a concentration (0), and sample 3 with a concentration (0). As for the texture of noodles, it is defined into 3 levels of members, namely Like (S), Ordinary (B), and Dislike (TS).
4. The next step is to determine the fuzzy rules. A fuzzy rule is a statement that plays a role in determining how variables determine the output of noodle textures.
5. Defuzzification is the last step used in the process, where, at this stage, the degree of membership for each sample is determined. The samples used are sodium bicarbonate

and cmc, so the concentration calculation of each sample will be carried out. After we enter the sodium bicarbonate and cmc concentration values from the first sample into the input box, we will get the degree of membership to appear in the texture column.

CONCLUSION

After taking steps in determining the formula for the concentration of sodium bicarbonate and CMC in making wet noodles, it was concluded that the formulation of sample 1 with a concentration of sodium bicarbonate 0.6% and CMC 0.2% and sample 2 with the addition of sodium bicarbonate 0.6% and CMC 0% are the most recommended formulas because they have a texture preferred by consumers. This selection model is needed so that the public, especially wet noodle producers, can identify the appropriate amount of sodium bicarbonate and CMC concentrations in order to produce noodles with textures that consumers like.

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