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Evaluating the Quality Grade of Cookies through Crispness and Baking Temperature Analysis Using a Fuzzy Inference System

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Cookies are one of the most popular processed food products due to their distinctive taste, long shelf life, and variety of textures ranging from soft to crisp. Physical properties such as crispiness play an important role in determining consumer preferences and acceptance. These characteristics are influenced by several factors, one of which is the baking temperature that determines the quality of soft cookies. Advances in computing technology have enabled objective food quality analysis through artificial intelligence approaches. This study aims to evaluate the suitability of cookies based on crispiness and baking temperature parameters using the Fuzzy Inference System (FIS) method. The research was conducted using a fuzzy system designed with input variables of temperature and crispiness, and output variables of product quality categorized as poor, moderate, and good. Each variable was represented in the form of a triangular membership function. The results showed that fuzzy logic was able to effectively integrate parameters, making it a smart and objective quality assessment method.

Keywords: cookies, fuzzy logic, crisp.

INTRODUCTION

Cookies are one of the most popular bakery products due to their delicious taste, long shelf life, and various textures ranging from soft to crispy. Physical properties such as crispness and fragility greatly influence consumer preference and acceptance of cookies. Factors that can affect the characteristics of crispness and fragility include flour composition, moisture content, and baking conditions, which are the main determinants of these textural attributes. These properties are influenced by ingredient formulation and the baking process, which determine the physical structure of the product, thereby directly affecting its sensory quality and consumer preference (Anggraeni *et al.,* 2018).

Efforts to improve the quality of cookies have been widely carried out through raw material modification. For instance, the use of composite flour made from *sago baruk* and mung beans has been shown to produce significant differences in hardness and acceptability, indicating that mechanical characteristics such as hardness, crispness, and fragility are among the most important parameters in determining product quality (Lasaji *et al.,* 2023).

The advancement of computational technology now allows food quality analysis to be conducted quantitatively and systematically through artificial intelligence approaches. The Fuzzy Logic system is capable of processing linguistic data such as “less crisp,” “moderately crisp,” and “crisp” using mathematical reasoning that mimics human thought processes. The *Fuzzy Inference System* (FIS) has proven effective in controlling temperature and humidity during food drying processes, resulting in higher energy efficiency and more consistent product quality compared to conventional methods (Tampubolon *et al.,* 2024).

Although numerous studies have optimized cookie formulations and texture characteristics, the application of fuzzy logic to systematically assess cookie palatability based on crispness and fragility remains limited. Therefore, this study aims to evaluate the level of cookie palatability using a Fuzzy Inference *System* approach, with input variables consisting of crispness and fragility, and an output variable representing quality level (poor, medium, and good). This approach is expected to serve as an innovation that bridges subjective sensory evaluation with computational modeling, resulting in a more intelligent and objective quality assessment system in the bakery industry.

METHODS

The method applied in the writing of this journal is the Study Literature Review (SLR), which is conducted by examining several journals relevant to the research topic and analyzing the data using a fuzzy logic control system combined with a fuzzy inference system (FIS). The selection of the Mamdani method is based on its ability to utilize linguistic rules in its process, supported by a structured fuzzy algorithm that can be analyzed mathematically, thereby facilitating understanding (Nasyuha 2019; Sinaga Y 2023). The SLR approach is used to identify, review, evaluate, and interpret various studies that have been conducted within a particular research area, based on research questions relevant to the phenomenon being examined (Anjani et al., 2019). The Study Literature Review, also known as a literature study, is considered a highly relevant method for this research because many references are available, such as articles, scientific journals, proceedings, and other scholarly works that provide useful data and information for the testing conducted in this study.

The use of the Study Literature Review aims to provide a comprehensive understanding of the researched topic through journal databases using relevant keywords such as cookies, crispness, and temperature from an exclusion-based perspective that employs two input variables and one significant output variable (Hayati et al., 2025). This study uses 18 verified references that provide data related to these variables to obtain objective results. The data analysis follows several fuzzy logic stages, including fuzzification, fuzzy rules, fuzzy inference, defuzzification, and fuzzy system testing. Each stage is described as follows:

1. Fuzzification of Values
   Converting crisp values into membership degrees.
2. Rule Formation
   Formulating IF–THEN rules based on the variables.
3. Fuzzy Inference
   Processing the rules and determining the fuzzy output.
4. Aggregation & Defuzzification
   Combining the rule results and converting them into a crisp value.

Based on the results of the Study Literature Review, fuzzy variables are defined as variables discussed within the fuzzy system whose values are represented by fuzzy ranges/sets rather than fixed single values (Saatchi et al., 2024). The input variables used to evaluate cookie quality are baking temperature and crispness, with the output variable being cookie quality. The selection of these variables refers to previous studies showing that temperature and crispness have direct effects on the quality of baked products. Therefore, temperature and crispness are set as input variables because both are process parameters that can be controlled or adjusted, while the final quality of the cookies is used as the output variable because it reflects the end result of the baking process.

The variables Temperature (low, medium, high), Crispness (not crisp, slight crisp, crisp), and Quality (poor, moderate, good) are converted into numerical fuzzy data. These data are represented as triplet values (a, b, c), which form triangular membership functions to represent the degree of membership of each category (Singh V et al., 2025). The determination of numerical ranges and parameters for each variable is based on a comprehensive Study Literature Review of previous research to ensure that the values used are relevant, aligned with real-world conditions, and supported by credible empirical evidence.

In addition to the Study Literature Review, validation was also conducted to ensure the credibility and replicability of the developed model. This was achieved by comparing the defuzzified crisp quality values with expert judgment (ground truth), using an independent test dataset separate from the data used to define the membership functions and fuzzy rules.

In the fuzzy logic method, fuzzy logic is an appropriate approach to map the input space to the output space. After the rule execution process is performed on the input data, a final output is generated in the form of a result that must be satisfied.

LITERATURE STUDY METHOD

This literature review serves as a basis for determining the optimal baking temperature and crispness level in the cookie baking process, considering the final product quality as the desired outcome. Several studies have shown that baking temperature significantly affects the crispness of cookies (Panghal et al., 2018). To determine the optimal baking temperature and the best crispness level for producing high-quality cookies, it is essential to maintain consistent control over the baking temperature. The integration of temperature and crispness data into a fuzzy logic system can assist in identifying the most appropriate combination of parameters. This approach enhances the accuracy of the optimization process and contributes to producing cookies with stable and standardized final quality.

RESULTS AND DISCUSSION

Table 1 Literature study data for the variables of temperature, crispiness, and quality of soft cookies

Variable	Fuzzy Parameter	Range Set	a	b	c
Temperature (℃)	Low	80-120	80	100	120
	Medium	110-150	110	130	150
	High	140-180	140	160	180
Crispiness	Not Crisp	0-4	0	0	4
	Slight Crisp	1-9	1	5	9
	Crisp	6-10	6	10	10
Quality	Poor	0-30	0	15	30
	Moderate	30-60	30	45	60
	Good	60-100	60	80	100

Case Study

The case study used had a maximum temperature criterion of 160 and a crispiness criterion of slightly crisp 8, resulting in an assessment. After obtaining the case study, the next step was to complete the Fuzzy Inference System (FIS) stage as follows.

Determining Input and Output Variables

Fuzzy variables can be defined as variables that will be discussed in a fuzzy system and whose values are represented by a fuzzy range/set, rather than a single definite value (Saatchi et al., 2024). In this case, there are two fuzzy variables as inputs, namely temperature and crispness, and there is one fuzzy variable as output, namely cookie quality. The selection of these variables refers to previous research results which show that temperature and crispness have a direct effect on the quality of baked products (Panghal et al., 2018). Therefore, temperature and crispness are set as input variables, because both are process parameters that can be controlled or changed, while the final quality of cookies is used as the output variable because it reflects the final result of the baking process.

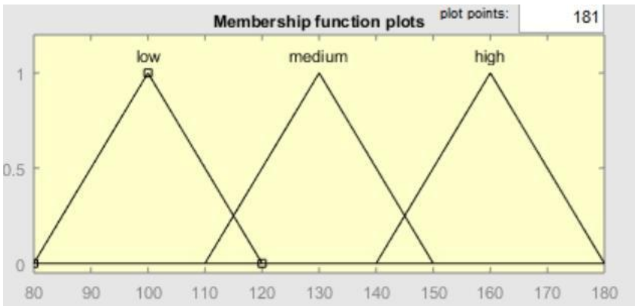

Figure 1. Temperature Input

This figure illustrates the output variable quality within the range of 0-100, which is categorized into three parameters: Low, Medium, and High.

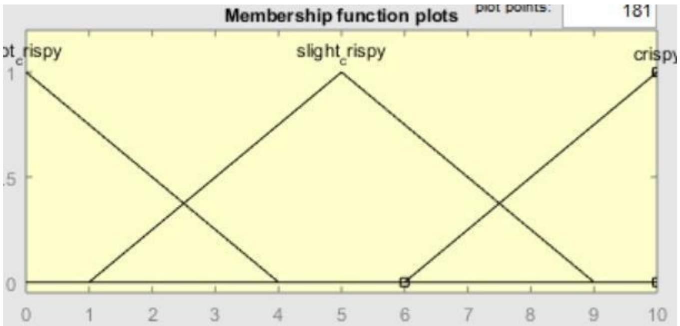

Figure 2. Crispiness Input

This figure illustrates the input variable crispness within the range of 0-10, which is categorized into three parameters: Not Crisp, Slight Crisp, and Crisp.

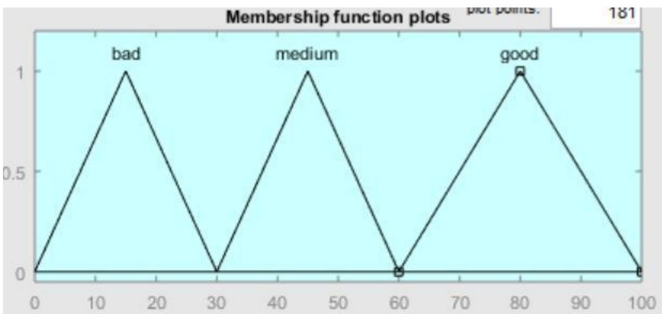

Figure 3. Output Quality

This figure illustrates the output variable quality within the range of 0-100, which is categorized into three parameters: Poor, Moderate, and Good.

Building Fuzzy Membership Sets

The process of building fuzzy membership sets begins with understanding that fuzzy logic is based on the concept of value ambiguity or uncertainty. In this system, a value can possess both truth and falsity simultaneously, which is expressed through the degree of membership. This degree of membership indicates the extent to which a value belongs to a set, ranging from 0 to 1. A value of 0 indicates that an element does not belong to the set, while a value of 1 indicates that the element is fully a member of the set (Setia B & Ramadan A, 2019). The evaluation of soft cookie samples was based on the variables Temperature (℃), Crispiness, and Quality. The Temperature (℃) variable includes the parameters “low”, “medium”, and “high”. The Crispiness variable includes the parameters “not crisp”, “slight crisp”, and “crisp”. The Quality variable includes the parameters “poor”, “moderate”, and “good”. These parameters were then converted into fuzzy numerical data in the form of triplet values (three values: a, b, c), which form a triangular fuzzy membership function. This process is used to describe the degree of membership of each value within a particular category (Singh V et al., 2025).

Temperature Input Membership Set

The first input used in evaluating soft cookies is the crispness input. The parameters of the crispness variable are “low”, “medium”, and “high” These three parameters are converted into fuzzy numerical data in the form of triplet values (a, b, c) to determine the midpoint by forming a triangular shape in the MATLAB application.

$$\mu_{\text{Low}}(x) = \begin{cases} 0, & x < 80 \\ \dfrac{x-80}{100-80}, & 80 \le x < 100 \\ 1, & x = 100 \\ \dfrac{120-x}{120-100}, & 100 < x \le 120 \\ 0, & x > 120 \end{cases}$$

In this study, the membership function of the input variable “temperature” is divided into three sets, namely “low” with a central value of 100°C, “medium” with a central value of 130°C, and “high” with a central value of 160°C. The temperature range used is 110–150°C.

$$\mu_{\text{Medium}}(x) = \begin{cases} 0, & x < 110 \\ \dfrac{x-110}{130-110}, & 110 \le x < 130 \\ 1, & x = 130 \\ \dfrac{150-x}{150-130}, & 130 < x \le 150 \\ 0, & x > 150 \end{cases}$$

In this study, the membership function of the input variable "temperature" is divided into three sets, namely "low" with a central value of 160°C, "medium" with a central value of 180°C, and "high" with a central value of 210°C. The temperature range used is 140–180°C.

$$\mu_{\text{High}}(x) = \begin{cases} 0, & x < 140 \\ \dfrac{x - 140}{160 - 140}, & 140 \leq x < 160 \\ 1, & x = 160 \\ \dfrac{180 - x}{180 - 160}, & 160 < x \leq 180 \\ 0, & x > 180 \end{cases}$$

Crispiness Input Membership Set

The second input in the evaluation of soft cookies is the crispiness input. The parameters of the crispiness variable are "not crisp", "slight crisp", and "crisp". These three parameters are converted into fuzzy numerical data in the form of triplet values (three values: a, b, c) to obtain the initial, middle, and final points by forming a triangle in the MATLAB application.

$$\mu_{\text{not\_crispy}} = \begin{cases} x < 0 & x < a \\ x = 0 & x = a \\ 0 < x \leq 4 & a < x \leq c \\ x > 4 & x > c \end{cases}$$

In the not crisp parameter, there are three points that can form the formula for the crispiness variable. The not crisp parameter is in the range of 0–4, with the initial point being 0, the middle point (which becomes the peak) being 0, and the final point being 4.

$$\mu_{\text{slightly\_crispy}} = \begin{cases} x < 1 & 0, \\ 1 \leq x < 5 & \dfrac{x - a}{b - a} \\ x = 5 & 1, \\ 5 < x \leq 9 & \dfrac{c - x}{c - b} \\ x > 9 & 0, \end{cases}$$

In the slight crisp parameter, there are three points that can form the formula for the crispiness variable. The slight crisp parameter is in the range of 1–9, with the initial point being 1, the middle point (which becomes the peak) being 5, and the final point being 9.

$$\mu_{\text{crispy}} = \begin{cases} x < 6 & x < a \\ 6 \leq x < 10 & a \leq x < b \\ x = 10 & x = b \\ x > 10 & x > b \end{cases}$$

In the crisp parameter, there are three points that can form the formula for the crispiness variable. The crisp parameter is in the range of 6–10, with the initial point being 6, the middle point (which becomes the peak) being 10, and the final point being 10.

Output Membership Set

In this test, the output used is “quality,” which consists of three fuzzy parameters: “poor”, “moderate”, and “good”. These three parameters are processed to obtain the midpoint by forming a triangular shape in the MATLAB application, starting from the “poor” parameter with a midpoint of 15, followed by the “moderate” parameter with a midpoint of 45, and the “good” parameter with a midpoint of 80.

$$\mu \text{ bad} \begin{cases} X \leq 0 \text{ atau } X \geq 30 & 0, \\ 0 \leq x \leq 15 & \frac{x-a}{b-a} \\ 15 \leq x \leq 30 & \frac{c-x}{c-b} \end{cases}$$

The membership function of the “bad” parameter indicates that the product quality is categorized as poor within the range of 0–30, with the membership degree increasing from 0 at value 0 to a maximum (μ=1) at value 15, and then decreasing back to 0 at value 30. This means that the closer the value is to 15, the more the product quality is considered “bad,” while values below 0 or above 30 are not included in the “bad” category.

$$\mu \text{ medium} \begin{cases} X \leq 30 \text{ atau } X \geq 60 & 0, \\ 30 \leq x \leq 45 & \frac{x-a}{b-a} \\ 45 \leq x \leq 60 & \frac{c-x}{c-b} \end{cases}$$

The membership function of the “medium” parameter indicates that the product quality is categorized as moderate within the range of 30–60, with the membership degree increasing from 0 at value 30 to a maximum (μ=1) at value 45, and then decreasing back to 0 at value 60. This means that the closer the value is to 45, the more the product quality is considered “medium,” while values below 30 or above 60 are not included in the “medium” category.

$$\mu \text{ good} \begin{cases} X \leq 60 \text{ atau } X \geq 100 & 0, \\ 60 \leq x \leq 80 & \frac{x-a}{b-a} \\ 80 \leq x \leq 100 & \frac{c-x}{c-b} \end{cases}$$

The membership function of the “good” parameter indicates that the product quality is considered good within the range of 60–100, with the membership degree gradually increasing from 0 at value 60 to a peak membership of 1 at value 80, and then decreasing back to 0 at value 100. This means that the closer the value is to 80, the more the product quality is categorized as “good”, while values below 60 or above 100 are no longer included in the “good” category.

Baking Temperature Input (High: 160)

The variable that has a significant effect on the X value of the baking temperature input is the height parameter (160).

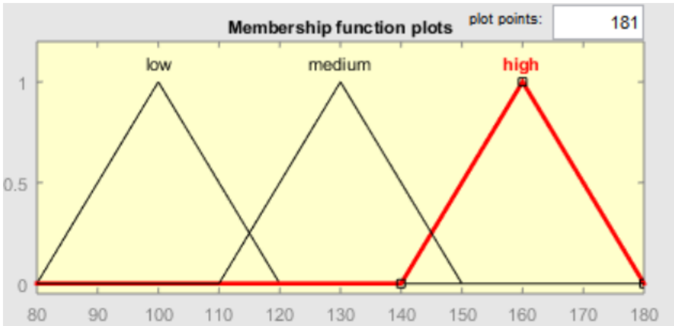

Figure 4. Baking Temperature Input

$$\mu\ \text{high} \quad \begin{cases} x < 140 \\ 140 \leq x < 160 \\ x = 160 \\ 160 < x \leq 180 \\ x > 180 \end{cases}$$

$$\frac{c\ -\ x}{c\ -\ b} = \frac{180 - 160}{180 - 160} = \frac{20}{20} = \ 1$$

In Figure 4, it is related to the right side, so the formula is used to calculate the right side. According to Sari (2012), fuzzy numbers are considered normal if the membership function value is equal to 1. The results show that the membership degree is 1, meaning that the fuzzy number is normal and the input size is strong at high baking temperatures, so the quality will be good.

Crispiness Input (Slight Crisp: 8)

The variable that has a significant effect on the crispness input value X is the slight crisp parameter (8).

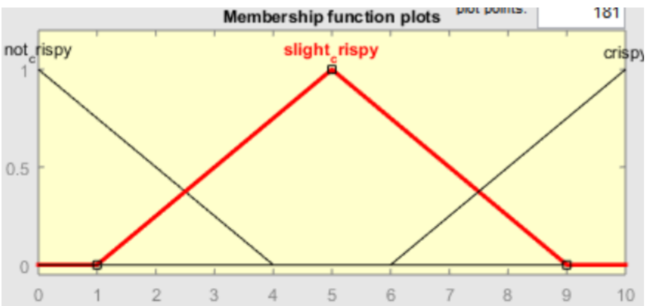

Figure 4. Crispiness Input

$$\mu_{\text{slightly\_crispy}} = \begin{cases} x < 0 & 0, \\ x = 0 & \dfrac{x-a}{b-a} \\ & 1, \\ 0 < x \leq 4 & \dfrac{c-x}{c-b} \\ x > 4 & 0, \end{cases}$$

$$\frac{c - x}{c - b} = \frac{9 - 8}{9 - 5} = \frac{1}{4} = 0,25$$

In Figure 5, concerning the right side, the formula is used to calculate the right side. The results show that the membership degree of 0.25 is still below 1, which means that the fuzzy number has moderate membership or only half of the category is fulfilled.

Determining Fuzzy Operators

The next step involves determining the fuzzy operator. This stage is used to define the quality of the cookies. The rule format employed is IF-THEN.

1. If (kerenyahan is not_crispy) and (suhu is low) then (mutu is bad) (1)
2. If (kerenyahan is not_crispy) and (suhu is medium) then (mutu is bad) (1)
3. If (kerenyahan is not_crispy) and (suhu is high) then (mutu is medium) (1)
4. If (kerenyahan is slight_crispy) and (suhu is low) then (mutu is bad) (1)
5. If (kerenyahan is slight_crispy) and (suhu is medium) then (mutu is medium) (1)
6. If (kerenyahan is slight_crispy) and (suhu is high) then (mutu is good) (1)
7. If (kerenyahan is crispy) and (suhu is low) then (mutu is medium) (1)
8. If (kerenyahan is crispy) and (suhu is medium) then (mutu is good) (1)
9. If (kerenyahan is crispy) and (suhu is high) then (mutu is good) (1)

Figure 6. Fuzzy Rules Base

A fuzzy set defined by a membership function is called a consequence. During the implication process, the consequence is modified based on its antecedent, resulting in a new fuzzy set. In each rule, the minimum operator is used to determine the predicate α (Putri and Saputro, 2021).

The basis of the fuzzy rule in this test is “AND,” which requires a relationship between the two input variables used. To achieve a “good” quality, several input variations are needed, such as “slight crisp” texture with “high” temperature, or “crisp” texture with “medium” or “high” temperature. When the implication function uses the “AND” operator, the minimum value is applied. Conversely, if the implication function uses the “OR” operator, the maximum value is applied (Yunan and Ali, 2020).

Next, the minimum value between two membership degrees—1 and 0.25—is determined. The fuzzification of variables is carried out using membership functions, followed by fuzzy rule evaluation using the “AND” operator in the “IF” part. Subsequently, the fuzzy rule consequence is defined through a linear equation in the “THEN” part. Finally, defuzzification is performed using the weighted average method to obtain the final output value (Sitinjak et al., 2024).

$$(\alpha) = min\ (1 : 0,25)$$
$$(\alpha) = 0,25$$

Determine the Implication Function

To obtain the values of X1 and X2, use the same formula as for the output data, i.e., use the right and left sides.

Equations on the left side:

$$\alpha = \frac{X1-a}{b-a}$$

$$0,25 = \frac{X1-60}{80-60}$$

$$5 = X1 - 60$$

$$X1 = 65$$

Equations on the right side:

$$\alpha = \frac{c-X2}{c-b}$$

$$0,25 = \frac{100-X2}{100-80}$$

$$5 = 100 - X2$$

$$X1 = 95$$

From the above calculations, the implied values of X1 (70) and X2 (95) are obtained

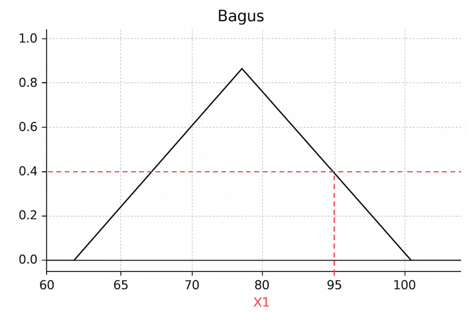

Figure 6. Evaluate the implications of X1 and X2

The data value arrangement will become the new formula, which is the final stage. In this formula, it is divided into three parts (a, x1) (x1, x2) (x2, c), as follows:

$$f(x,a,b,c)\ \begin{cases} x < 60 \\ 60 \leq x \leq 80 \\ 80 \leq x\ 95 \\ 95 < x \leq 100 \\ x > 100 \end{cases}$$

With a value of,

$$0$$

$$\frac{x-60}{80-60}$$

$$0,25$$

$$\frac{100-x}{100-80}$$

$$0$$

Defuzzifikasi

Defuzzification is the process of converting the fuzzy inference output represented as a fuzzy set into a precise (crisp) value that can be used for decision-making. The input of this process is a fuzzy set derived from the composition of fuzzy rules, while the output is a single numerical value within the domain of that fuzzy set. In other words, when a fuzzy set is defined over a certain range, defuzzification determines a specific crisp value that best represents it (Haerani, 2014). In this study, the centroid or center of area (CoA) method is applied, as it provides a more representative result by taking into account the entire area of the aggregated membership function. The defuzzified value is calculated using the following equation:

$$z^* = \frac{\int z\,\mu(z)\,dz}{\int \mu(z)\,dz}$$

The output membership function used in this study is the Good set, represented by a triangular shape with parameters a = 60, b = 80, and c = 100. Based on the inference results, the maximum membership degree (h) is 0.25. Consequently, the membership function is clipped at the height of h = 0.25, resulting in two boundary points:

$$z_1 = a + h(b-a) = 60 + 0{,}25(80-60) = 65$$

$$z_2 = c - h(c-b) = 100 - 0{,}25(100-80) = 95$$

The clipped membership function can therefore be expressed as follows:

$$\mu(z) = \begin{cases} \dfrac{z-60}{20}, & 60 \leq z \leq 65 \\ 0{,}25, & 65 \leq z \leq 95 \\ \dfrac{100-z}{20}, & 95 \leq z \leq 100 \end{cases}$$

The next step is to calculate the area of the implication result. In this stage, the output variable becomes essential because the computed area value is used in the defuzzification process to determine the final crisp value. Each output variable is represented as a membership function graph, where the shaded region illustrates the portion clipped according to its membership degree. To obtain the crisp value, an integral calculation is performed over three sections of the function. Based on the triangular shape of the Good function, the total area is divided into three parts: A1, A2, and A3, which are computed as follows:

$$\text{A1} = \frac{(65-60)\ x\ 0{,}25}{2} = 0{,}625$$

$$\text{A2} = (95 - 65)\ \text{x}\ 0{,}25 = 7{,}5$$

$$\text{A3} = \frac{(100-95)\ x\ 0.25}{2} = 0{,}625$$

Total Area (Denominator): A total = A1 + A2 + A3 = 8.75

To determine the crisp value, the moment of each area section is calculated through integration.

Calculation Moment 1

The moment for the rising interval is obtained by integration, which yields a

$$\int_{60}^{65} z\frac{z-60}{20}\,dz$$

numerical value of M1 = 39,58

Calculation Moment 2

For the plateau interval, since μ(z) remains constant, the moment is expressed as a simple linear function.

$$\int_{65}^{95} z(0{,}25)\,dz$$

The evaluated result gives M2 = 600

Calculation Moment 3

For the descending interval, the moment is again determined through integration:

$$\int_{95}^{100} z\frac{100-z}{20}\,dz$$

resulting in M3 = 60,42

Total Moment Area (*Numerator*): M*total* = M1 + M2 + M3 = 39,58 + 600 + 60,42= 700

Thus, the defuzzified value is obtained as:

$$z^* = \frac{N}{D} = \frac{700}{8{,}75} = 80$$

A crisp value of 80 indicates that the fuzzy system output lies at the peak of the Good membership set. This suggests that the evaluated product falls within the "Good" quality category, corresponding to the range of 60–100. Hence, the centroid defuzzification method produces a result consistent with the fuzzy inference output, accurately reflecting the optimal quality level of the evaluated parameter.

Discussion on Area Calculation / Visualization.

After the defuzzification process, the next step involves calculating the area within the case study. At this stage, the output variable becomes the primary focus, representing the determined value. To obtain the area, appropriate planar geometric formulas are applied based on the results of the implication function (as illustrated in the implication function diagram), as follows:

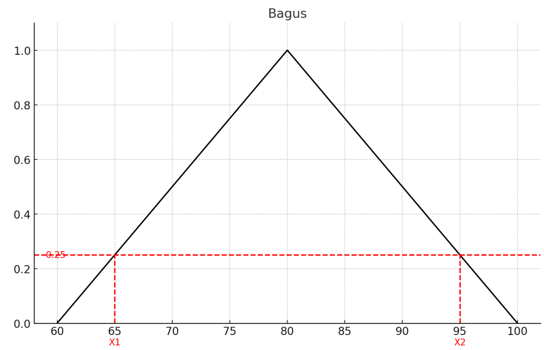

Figure 7. Model of the Implication between X_1 and X_2.

$$A1 = \frac{(65 - 60) \times 0.25}{2} = \frac{5 \times 0.25}{2} = 0.625$$

$$A2 = (95 - 65) \times 0.25 = 30 \times 0.25 = 7.5$$

$$A3 = \frac{(100 - 95) \times 0.25}{2} = 0.625$$

In other words, the area under the truncated (at membership value 0.25) triangular membership function is partitioned into three regions: a rising flank A1, a plateau region A2, and a falling flank A3. Each region's area is computed using basic geometry: for the flanks the triangle area formula (base × height / 2), and for the plateau region the rectangle/trapezoid equivalent (Base x height). The sum of these area parts gives the total area which is then used in the defuzzification step (for instance in a centroid method) to compute the crisp output value.

CONCLUSION

This study demonstrates that the application of a Fuzzy Inference System (FIS) using the Mamdani method is effective for evaluating cookie quality based on the variables of baking temperature and crispness. The fuzzy approach successfully translates linguistic variables such as "not crisp," "slight crisp," and "crisp" into quantitative assessments that represent product quality levels (poor, moderate, and good). Based on the case study, high baking temperature (160°C) combined with a slight crisp texture (crispness level 8) produced the highest membership value for the "good" quality category, indicating optimal baking conditions. Moreover, the defuzzification stage applying the centroid approach generated a well-represented crisp output value by accounting for the entire area under the combined membership function. This outcome indicates that the fuzzy logic model can act as an intelligent and reliable tool for decision-making in food quality assessment, providing evaluations that are more objective, efficient, and consistent than conventional sensory testing methods. Future studies are recommended to integrate additional parameters such as moisture content, baking time, or ingredient ratio to further enhance the accuracy and applicability of the fuzzy-based quality evaluation system in the cookies/ Bakery industry.

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