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Tempe Manufacturer's Feasibility System for its Ingredients and Production Process using the K-Nearest Neighbor (KNN) Method

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***Abstract*— Technological developments have caused changes in almost all sectors of human life, including the economy. Technology can be applied to the tempe producing industry by maintaining the quality of the tempe. So an expert system is needed that can help determine the quality of the tempe produced. Using the K-Nearest Neighbor (KNN) algorithm with the application of the Case Based Reasoning (CBR) method in the material feasibility system and tempe production process to determine the percentage value based on predetermined symptoms. The system can provide percentage results of eligibility based on the assessment carried out. System testing uses functional and non-functional methods. Based on the system testing results on 5 respondents, the results of non-functional testing on the usability aspect obtained a score percentage of 82.67%, the ease of use aspect 85.33%, the ease of learning aspect 78.67%, and the satisfaction aspect 73.67%. From these four aspects, an average score of 80% was obtained, which means the system runs well and is suitable for use.**

***Index Terms*— Case Based Reasoning (CBR), Tempe, K-Nearest Neighbor (KNN)**

I. INTRODUCTION

Tempe is a food product that has high nutritional value and is widely consumed as a source of vegetable protein in various countries, especially in Asia. However, the quality of tempe really depends on the suitability of the raw materials and the production process (K. A. C. I. Dewi, 2022). Low quality such as a rotten or rancid aroma, unusual color, dark mold, too hard soybeans, and tempe that rots quickly can have a negative impact on consumer health and potential economic losses for producers. Alim Tempe Producer is an MSME that was founded in 1995. Located at Dipan RT 75 / RW 45, Wates, Kulon Progo. This MSME was founded by Mr Sutrisno. The passage of 28 years is not a short time to embrace Tempe Alim customers. Quality that binds Tempe Alim customers. Mr. Sutrisno and his employees really care about the quality of the tempe they produce.
Based on observations and interviews with Muhammad Alim Muhtar as the son of Mr. Sutrisno, Tempe Alim UMKM determines the quality of tempe based on experience and is done manually. In this context, it is important to have an effective and accurate way to assess the suitability of raw materials and tempe production processes. One method that can be used is K-Nearest Neighbors (KNN) by implementing the Case Base Reasoning (CBR) method. The KNN algorithm can assist tempe producers in making informed decisions to ensure the quality of their products by evaluating the appropriateness of materials and tempe production

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techniques. The program utilizes the Case Base Reasoning (CBR) method to assess the compatibility of tempe ingredients and production methods. This allows tempe producers to efficiently determine if the raw materials and manufacturing processes they employ adhere to the required criteria. And consequently, enhance consumer trust in the tempe items manufactured. Case Based Reasoning (CBR) is a cognitive process that involves utilizing previously employed solutions for similar situations as a basis for solving new problems and as a point of reference for decision makers (J. Ahn et al., 2020; Lata & Kumar, 2022). The K-Nearest Neighbor algorithm is a method used to determine the shortest distance between each instance in a database and measure the similarity in size between each source case in the database and the target case (I. B. Y. Semara Putra and S. Wibisono, 2020).

The production of soybean tempe involves a series of steps, namely soaking, grinding, washing, boiling, cooling, adding packaging yeast, and fermentation (R. Ahsanunnisa, 1970; S. L. Suknia and T. P. D. Rahmani, 2020). Figure 1 depicts the method of producing soybean tempe.

Figure 1. Tempe production process

A feasibility system for assessing tempe quality in general, where tempe quality data consists of 3 qualities, including: 1) Super Quality 2) Pure Quality 3) Good Quality. The aim of this research is that it is hoped that the Tempe Producer Suitability Assessment System for Tempe Production Materials and Processes will create more consistent quality standards in tempe production and can be a useful guide for new producers who wish to enter the tempe industry with a better understanding of the quality of raw materials and processes (Lata & Kumar, 2023). optimal production (A. R. Radiati, 2017; N. P. Astuti, 2009).

II. RESEARCH METHODS

In designing and building the Material Feasibility System and Tempe Production Process, several methods were used:

A. Data Collection Methods

The data collection technique in this research is to conduct a literature study to look for library sources related to aspects of the research, followed by interviews to add information or complete information from journals. At this stage the author asked several questions to the son of the owner of this MSME, namely Muhammad Alim Muhtar, so that by conducting interviews the author was able to obtain various kinds of information needed in the research. Next, observations were carried out by directly observing the tempe production process at the Tempe Alim production house which is located at Dipan RT 75 / RW 45, Wates, Kulon Progo. Observations are carried out to obtain data that cannot be obtained through interviews.

B. System Development Methods

System Development Life Cycle (SDLC) is the process of creating and processing systems as well as the models and methodologies used to develop a system (Y. Permana and P. Romadlon, 2019).

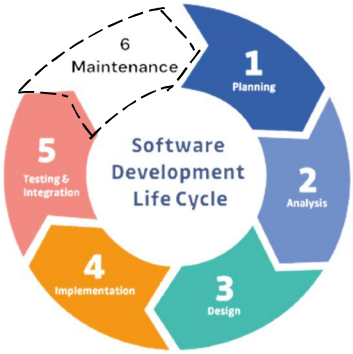

Figure 2. SDLC method stages

The System Development Life Cycle (SDLC) is a pattern taken to develop a software system which consists of six stages, but only five stages were used in this research, namely:

i. Planning: At this stage, identification and finding priorities for the tempe feasibility system to be developed, targets achieved and implementation time figures for creating the tempe feasibility system are carried out.

ii. Analysis: At this stage, an analysis is carried out on the quality of tempe, symptoms in the tempe production process and materials as well as the design needed to build a system for the suitability of tempe materials and production using the K-Nearest Neighbor (KNN) method.

iii. Design: Design or designing in the form of system process flows, database tables and designing interfaces and system modules. In this stage, database tables are created using diagrams such as flowcharts and UML (Unified Modeling Language). What needs to be there is to describe the material suitability system and tempe production process, data concept model, physical model and conformity testing focusing on requirements and implementation.

iv. Implementation: This stage can also be called software development. At this stage, we design a system using the PHP programming language with the Laravel framework. Data storage uses a MySQL database and the user interface uses HTML and CSS.

v. Testing: The testing stage is the process of executing all parts of the software with the aim of finding errors. Testing of this program was carried out using Functional techniques. Functional testing is carried out by observing execution results through test data and checking the functionality of the system being created. Non-functional testing was carried out by surveying several Tempe Production MSMEs by distributing questionnaires to measure the feasibility of the system.

C. K-Nearest Neighbor (KNN)

K-Nearest Neighbor (KNN) is a supervised technique that classifies new query instances based on the majority of class labels in KNN (M. M. Hasmawati and Jumadil Nangi, 2017). The K-Nearest Neighbor (KNN) algorithm is a technique used to classify new objects by considering their (K) closest neighbors. KNN is a supervised learning technique that classifies the results of querying new instances based on the majority of categories in KNN. The most often occurring class will be identified as the classification result class (S. P. Dewi and E. Rahayu, 2022).

The K-Nearest Neighbor algorithm is a method used to determine the closest distance between each example in the database and the target case, as well as the degree of similarity in size between each source case in the database and the target case. The similarity function in this scenario is defined as follows (Liao, T. Z., 1998):

$$S(p,c) = \frac{s1*w1+s2*w2+\cdots+sn*wn}{w1+w2+\cdots+wn} \qquad (1)$$

Information :

s = similarity

w = weight

Typically, similarity is measured on a scale ranging from 0 to 1. According to Semara Putra and Wibisono (2020), a value of 0 indicates that the two examples are completely dissimilar, while a value of 1 indicates that the two situations are completely alike.

The objective of the KNN algorithm is to categorize novel entities by considering their qualities and utilizing training data (M. M. Hasmawati and Jumadil Nangi, 2017). By utilizing the K-Nearest Neighbor technique, product sales can be streamlined by obtaining new items based on the data that is most similar to the new data.

The K-nearest neighbors (KNN) technique use neighborhood classification to predict the values of new test samples. The calculation of near or far neighbors is often based on the Euclidean distance.

D. Case Based Reasoning (CBR)

Case-based Reasoning (CBR) is a process of considering a past case, which will be reused and adapted to a new case (I. B. Y. Semara Putra and S. Wibisono, 2020). Figure 3 displays the CBR cycle

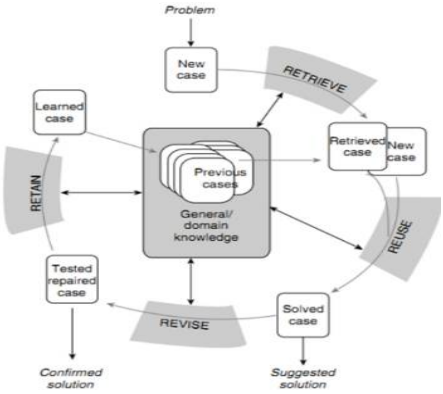

Figure 3. Case Based Reasoning (CBR) cycle

The subsequent text provides a detailed account of the many phases comprising the CBR cycle: 1) Retrieve: Identify the stages involved in locating cases stored in the case base that exhibit similarities with new instances. During this step, the process of discovering initial similarities, tracing, recovery, and implementation takes place. 2) Reuse: The phase in which one applies information, facts, data, and explanations derived from the case to address the situation at hand. 3) Revise: The Revise stage involves monitoring and updating completion proposals. 4) Preserve; Stages save the outcomes of prior stages, allowing them to be utilized for problem-solving purposes as necessary.

III. Results and Discussion

A. Research Data

The research data utilized consists of three categories of tempe quality: 1) good tempe quality, 2) pure tempe quality, and 3) super tempe quality. These categories serve as the research subjects, along with the inherent symptoms associated with each tempe quality. To elucidate the methodology employed in this study and the insights gleaned from expert interviews. Information is acquired in the form of knowledge and rules, which the system utilizes to make decisions based on the predefined categories outlined in Table 1.

TABLE 1. REPRESENTATION TABLE

Quality Id	Quality Name	Symptom Id	Symptom Name
S01	Good	G01	Moldy soybeans affect the quality of the tempe produced
		G03	The water used for washing is cloudy
		G04	The water used in the process of making tempe is colorless (clear)
		G05	The water used in the process of making tempe smells
		G06	The water used in the process of making tempe is odorless
		G07	The water used in the process of making tempe has a taste
		G10	Soaking soybeans is done for less than 24 hours
		G12	Yeast clumps together
		G13	Yeast changes color
		G15	Temperature too hot
		G17	Temperature too cold
		G19	Fermentation time is more than 3 days
S02	Pure	G01	Moldy soybeans affect the quality of the tempe produced
		G02	The soybeans showed no signs of rot
		G04	The water used in the process of making tempe is colorless (clear)
		G06	The water used in the process of making tempe is odorless
		G08	The water used in the process of making tempe has no taste
		G10	Soaking soybeans is done for less than 24 hours
		G11	The yeast used is in good condition

		G17	The temperature is too cold
		G19	Fermentation time is more than 3 days
		G20	Separating the soybeans from the skin using a machine
S03	Super	G02	The soybeans showed no signs of rot
		G04	The water used in the process of making tempe is colorless (clear)
		G06	The water used in the process of making tempe is odorless
		G08	The water used in the process of making tempe has no taste
		G09	Soaking the soybeans is done for 24 hours
		G11	The yeast used is in good condition
		G16	Normal room temperature
		G18	Fermentation time is less or equal to 3 days
		G20	Separating the soybeans from the skin using a machine
		G21	Manual separation of soybeans from skin

B. Symptom Input

The process of assigning a weight to each symptom depending on the user's response is referred to as the symptom selection stage. If the response is negative, the weight assigned is zero. However, if the response is affirmative, the weight assigned is determined by the weight of each symptom, as indicated in Table 2.

TABLE II. USER INPUT TABLE

Symptom Id	Symptom	Expert Weights	Input Results
G01	Moldy soybeans affect the quality of the tempe produced	3	Yes
G02	The soybeans showed no signs of rot	5	Yes
G03	The water used for washing is cloudy	3	No
G04	The water used in the process of making tempe is colorless (clear)	5	Yes
G05	The water used in the process of making tempe smells	3	No
G06	The water used in the process of making tempe is odorless	5	Yes
G07	The water used in the process of making tempe has a taste	3	No
G08	The water used in the process of making tempe has no taste	5	Yes
G09	Soaking the soybeans is done for 24 hours	3	Yes
G10	Soaking soybeans is done for less than 24 hours	3	Yes
G11	The yeast used is in good condition	5	Yes
G12	Yeast clumps together	1	Yes
G13	Yeast changes color	1	Yes
G14	Expired yeast	5	No
G15	Temperature too hot	3	Yes
G16	Normal room temperature	3	Yes
G17	Temperature too cold	3	Yes
G18	Fermentation time is less or equal to 3 days	5	No
G19	Fermentation time is more than 3 days	5	Yes
G20	Separating the soybeans from the skin using a machine	5	No
G21	Manual separation of soybeans from skin	5	Yes

C. Retrieve Process

The retrieval process is a phase that involves comparing new examples to an existing knowledge base in order to identify similarities. The similarity search is conducted by comparing the symptoms provided by the user with the symptoms stored in the knowledge base. The weighting in the K-Nearest Neighbor (KNN) retrieval method is computed during the retrieval stage. During the initial stage of the diagnosis procedure, the user will enter all the symptoms they are now experiencing without the need for many questions. Furthermore, the user activates the process button to access the diagnostic information results. Subsequently, this system will analyze the weighting by systematically comparing each symptom in the knowledge base. The system will calculate the weight similarity processing stage using the following formula.:

$$Similarity\ (Problem, Case) = \frac{s1 * w1 + s2 * w2 + \cdots sn * wn}{w1 + w2 + \cdots wn} \quad (2)$$

Information :

S = Similarity (similarity value), in similarity, if there is similarity in cases, it will have a value of 1, whereas if it is not similar, it will have a value of 0.

W = weight (given weight).

Calculation of Good Tempe Quality Cases can be seen in Table 3:

TABLE III. GOOD TEMPE QUALITY SCHEME

Symptoms of Good Tempe (S01)	Weight	User input	Weight
Moldy soybeans affect the quality of the tempe produced	3	Moldy soybeans affect the quality of the tempe produced	3
The water used for washing is cloudy	3	The soybeans showed no signs of rot	5
The water used in the process of making tempe is colorless (clear)	5	The water used in the process of making tempe is colorless (clear)	5
The water used in the process of making tempe smells	3	The water used in the process of making tempe is odorless	5
The water used in the process of making tempe is odorless	5	The water used in the process of making tempe is tasteless	5
The water used in the process of making tempe has a taste	3	Soaking the soybeans is done for 24 hours	3
Soaking soybeans is done for less than 24 hours	3	Soaking soybeans is done for less than 24 hours	3
The yeast clumps together	1	The yeast used is in good condition	5
Yeast changes color	1	The yeast clumps together	1
Temperature too hot	3	Yeast changes color	1
The temperature is too cold	3	Temperature too hot	3
Fermentation time is more than 3 days	4	Normal room temperature	3
		The temperature is too cold	3
		Fermentation time is more than 3 days	4
		Repeated separation of soybeans from the skin manually	5

Similarity (S01,X):

$$= \frac{(s1*w1)+(s2*w2)+(s3*w3)+(s4*w4)+(s5*w5)+(s6*w6)+(s7*w7)+(s8*w8)+(s9+w9)+(s10*w10)+(s11*w11)+(s12*w12)}{w1+w2+w3+w4+w5+w6+w7+w8+w9+w10+w11+w12}$$

$$= \frac{(1*3)+(0*3)+(1*5)+(0*3)+(1*5)+(0*3)+(1*3)+(1*1)+(1*1)+(1*3)+(1*3)+(1*4)}{3+3+5+3+5+3+3+1+1+3+3+4}$$

$$= \frac{28}{37} = 0{,}75676$$

$$= 75{,}68\%$$

Calculation of Pure Tempe Quality Cases can be seen in Table 4:

TABLE IV. PURE TEMPE QUALITY SCHEME

Symptoms of Pure Tempe (S02)	Weight	User input	Weight
Moldy soybeans affect the quality of the tempe produced	3	Moldy soybeans affect the quality of the tempe produced	3
The soybeans showed no signs of rot	5	The soybeans showed no signs of rot	5
The water used in the process of making tempe is colorless (clear)	5	The water used in the process of making tempe is colorless (clear)	5
The water used in the process of making tempe is odorless	5	The water used in the process of making tempe is odorless	5
The water used in the process of making tempe has no taste	5	The water used in the process of making tempe has no taste	5
Soaking soybeans is done for less than 24 hours	3	Soaking soybeans is done for less than 24 hours	3
The yeast used is in good condition	5	Soaking soybeans is done for less than 24 hours	3
The temperature is too cold	3	The yeast used is in good condition	5
Fermentation time is more than 3 days	4	The yeast clumps together	1
Separating the soybeans from the skin using a machine	5	Yeast changes color	1
		Temperature too hot	3
		Normal room temperature	3
		The temperature is too cold	3
		Fermentation time is more than 3 days	4
		Repeated separation of soybeans from the skin manually	5

Similarity (x,S02):

$$= \frac{(s1*w1)+(s2*w2)+(s3*w3)+(s4*w4)+(s5*w5)+(s6*w6)+(s7*w7)+(s8*w8)+(s9+w9)+(s10*w10)}{w1+w2+w3+w4+w5+w6+w7+w8+w9+w10}$$

$$= \frac{(1*3)+(1*5)+(1*5)+(1*5)+(1*5)+(1*3)+(1*5)+(1*3)+(1*4)+(0*5)}{3+5+5+5+5+3+5+3+4+5}$$

$$= \frac{38}{43} = 0{,}88372$$

$$= 88{,}37\%$$

Calculation of Super Tempe Quality Cases can be seen in Table 5:

TABLE V. SUPER TEMPE QUALITY SCHEME

Symptoms of Super Tempe (S03)	Weight	User input	Weight
The soybeans showed no signs of rot	5	Moldy soybeans affect the quality of the tempe produced	3
The water used in the process of making tempe is colorless (clear)	5	The soybeans showed no signs of rot	5
The water used in the process of making tempe is odorless	5	The water used in the process of making tempe is colorless (clear)	5
The water used in the process of making tempe has no taste	5	The water used in the process of making tempe is odorless	5
Soaking the soybeans is done for 24 hours	3	The water used in the process of making tempe is tasteless	5
The yeast used is in good condition	5	Soaking the soybeans is done for 24 hours	3
Normal room temperature	3	Soaking soybeans is done for less than 24 hours	3
Fermentation time is less or equal to 3 days	4	The yeast used is in good condition	5
Separating the soybeans from the skin using a machine	5	The yeast clumps together	1
Repeated separation of soybeans from the skin manually	5	Yeast changes color	1
		Temperature too hot	3
		Normal room temperature	3
		The temperature is too cold	3
		Fermentation time is more than 3 days	4
		Repeated separation of soybeans from the skin manually	5

Similarity (x,S03):

$$= \frac{(s1*w1)+(s2*w2)+(s3*w3)+(s4*w4)+(s5*w5)+(s6*w6)+(s7*w7)+(s8*w8)+(s9+w9)+(s10*w10)}{w1+w2+w3+w4+w5+w6+w7+w8+w9+w10}$$

$$= \frac{(1*5)+(1*5)+(1*5)+(1*5)+(1*3)+(1*5)+(1*3)+(0*4)+(0*5)+(1*5)}{5+5+5+5+3+5+3+4+5+5}$$

$$= \frac{36}{42} = 0{,}85714$$

$$= 85{,}71\%$$

The results of the tempe quality feasibility analysis using manual calculations using the KNN algorithm by implementing the CBR method can be seen in table 6 below:

TABLE VI. RECOMMENDATION RESULTS

No	Solution Code	Solution Name	Weight/Value
1	S01	Good Quality	75,68%
2	S02	Pure Quality	88,37%
3	S03	Super Quality	85,71%

Figure 4. Diagram of Recommendation Results

Based on the recommendation results from the symptoms that have been input by the user, the percentage of tempe quality feasibility with the highest feasibility value is 88.37% with the pure tempe quality type.

D. System Feasibility Testing

System feasibility testing uses non-functional methods. This test describes how good the system is against the development process, standards and time. Non-functional testing is carried out by conducting a survey by distributing questionnaires to 5 respondents who will assess the feasibility system and tempe production process. To determine the feasibility level of the material feasibility system and the tempe production process, use the following formula:

$$Y = \frac{x}{Ideal\ score} \text{ x } 100\% \qquad (3)$$

$$X = \sum(N\ x\ R)$$

Ideal Score = highest Linkert value x number of respondents

Information:

Y = percentage value sought

X = the sum of the values multiplied by the value of each answer by the respondent

N = value of each answer

R = number of respondents

The percentage results are utilized to determine the viability of the examined features. This scale focuses on the spectrum of percentage values. The upper limit of the expected value is 100% while the lower limit is 0%. Table 9 displays the distribution of the various categories of eligible quality range [6].

TABLE IX. ELIGIBILITY CATEGORIES

Category	Score
Very good	81%-100%
Good	61%-80%
Pretty good	41%-60%
Not good	21%-40%
Very Not Good	<20%

By determining the average value for each criterion and weighting depending on importance, the results of research on the quality of the material suitability system and the tempe production process were obtained from 5 tempe producer respondents. Data from the answers of 5 respondents can be seen in table 10 below:

TABEL X. QUESTIONNAIRE ANSWERS

Scale (N)	Question Items											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	1	0	1	3	4	0
4	5	3	5	3	4	4	4	5	3	2	1	3
5	0	2	0	2	1	1	0	0	1	0	0	2

From the table of results of respondents' answers which can be seen in table 10, 4 aspects were then calculated to assess the feasibility of the system, including aspects of usability, ease of use, ease of learning and satisfaction. The average value is obtained from the calculation results of finding the percentage value based on the assessment criteria contained in the questionnaire using the following formula:

$$P = \frac{\text{Total Aspect Value}}{\text{Number of Questions}} \times 100\% \qquad (4)$$

After calculating the 4 aspects using non-functional methods, the values will be summarized which are displayed in the form of table 11.

TABLE XI. RECAPITULATION RESULTS

Aspect	Average Percentage	Eligibility Category
Utility	82,67%	Very good
Ease of Use	85,33%	Very good
Ease of Learning	78,67%	Good
Satisfaction	73,33%	Good

The results of the recapitulation of system testing calculations can be seen in graphical form in Figure 5 below:

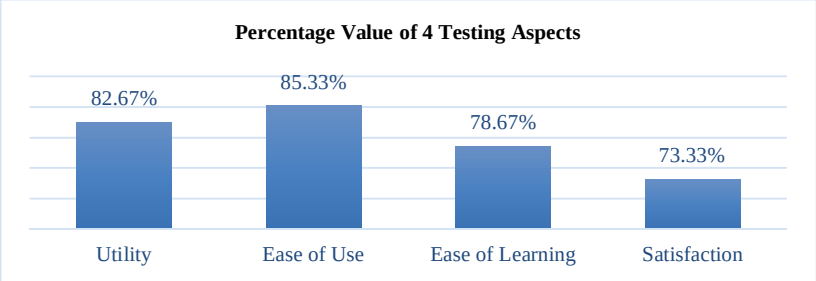

Figure 5. Graph of Recapitulation Results

From the calculation results above, it can be concluded that the system testing uses non-functional methods using 4 assessment aspects, namely the usability aspect with a value of 82.67%, the ease of use aspect with a value of 85.33%, the ease of learning aspect with a value of 78.67%, and satisfaction with a value of 73.33%. From these results, the average is sought to see the overall system feasibility value and the results obtained are 80%, therefore this system has good system feasibility and is suitable for use.

IV. CONCLUSION

From the system that has been built, namely the material feasibility system and tempe production process, the following conclusions can be drawn: Material feasibility system and tempe production process for assessing the suitability of tempe quality with 3 types of quality used. The results obtained from testing the feasibility of the system using non-functional methods from four aspects, namely the usability aspect got a score of 82.67%, the ease of use aspect got a score of 85.33%, the ease of learning aspect got a score of 78.67%, and the satisfaction aspect got a score 73.33%. The results of the four aspects assessed received an average score of 80%, which shows that this system can run well and is suitable for use.

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