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Determining The Quality and Production of Fresh Vegetables Using Simple Multi - Attributes Rating Technique (SMART) - Fuzzy Tsukamoto

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ABSTRACT

Vegetables are one of the most important needs in Indonesia. This is due to the increasing need for healthy food to meet daily needs. With the need for vegetables, the quality and production process are still hampered because it is done manually. Therefore created a system that can help someone determine the quality and production of the right vegetables. This system uses the SMART method and fuzzy Tsukamoto with the criteria and variables of vegetables used to get good quality and production. The SMART and fuzzy Tsukamoto method used a dataset of 20 vegetable commodities. In this study, 4 criteria and 3 variables were used, namely height, soil pH, temperature and age of harvest for quality determination. The production uses the variables of demand, supply and production.

1. Introduction (*Heading 1*)

Vegetable products in Indonesia have potential in leading export commodities. However, vegetable products in Indonesia are still unable to compete. The underlying factor is because vegetables from Indonesia have not been able to guarantee the supply and quality of vegetable crops. Meanwhile, consumers want the level of quality and supply of vegetables as needed. In this case, the demand and decrease in vegetable supply and quality are the most important factors in determining future vegetable production. The system developed later uses a decision making system with fuzzy logic.

According to [1] in their research, developing a decision-making system using two methods, namely SMART and Fuzzy Tsukamoto. In this study, the input included in the SMART method is in the form of four criterias to produce a value for Determining the quality of charcoal from a predetermined criterion and the Fuzzy Tsukamoto method, the input using two variables and the output is in the form of a production variable based on the fuzzy inference rule as the basis for determining the amount of production to be made.

Other research on Tsukamoto was conducted by [2] in his research on Decision Making Systems in Determining the Quality of Fresh Food Imports with the SMART Method. In his research using 4 criteria as input from his research using the SMART method to produce a calculation in the form of the final result of determining the quality of the intake of fresh plant-based food.

The need for vegetables that is the main requirement for healthy food consumption, so to determine the quality and quantity of production, the SMART and Fuzzy Tsukamoto are proposed to overcome the uncertainty. Thus, the objectives of this study are applying the SMART and fuzzy Tsukamoto method to predict the quality and quantity of vegetable production and Measure the level of accuracy Tsukamoto's SMART and fuzzy methods to predict quality and vegetable production in order to give the right results.

2. Literature Study

This chapter will discuss the basic theory used in research to determine the quality of vegetables and vegetable production as well as a review of previous literature relevant to SMART and fuzzy Tsukamoto.

a. Theoritical Basis

1. Understanding the SMART Method

SMART (Simple Multi Attribute Rating Technique) is a multi-criteria decision making method by taking into account quantitative and qualitative matters. In this multi-criteria decision making, basically each alternative consists of a number of criteria that have values and each criterion has a weight which explains how important it is when compared to others. In this case the weighting is used to assess each alternative to obtain the best alternative. [3].

The steps for the SMART method are as follows.

1. Identify the criteria that will be used to solve problems in decision making.
2. Give weight to each criterion based on the most important priority of an alternative.
3. Calculating the normalization of each criterion where the weighted value of the criteria obtained will be divided by the total result of each criterion weight.
4. Provide a criterion value for each alternative, where the value can be in the form of qualitative or quantitative data, if the criteria value is in qualitative form then it needs to be converted to quantitative data by making the criteria value parameter.
5. Determine the utility value by converting the value of a criterion into a standard data criterion value. In this case the utility value is based on the nature of the criteria itself. To determine the final value of each, it can be done by multiplying the value obtained from the normalization of the standard data criteria value with the normalized value of the criteria weight. Then add up the values of these multiplications.

$$u(a_i) = \sum_{j=1}^{m} w_j u_i(a_i), \tag{1}$$

where

u (ai) : total value of alternatives

w (j) : results from the normalization of the criteria weights

ui (ai) : result of determining utility value

2. FUZZY Tsukamoto

The Fuzzy Tsukamoto method applies monotonous reasoning in every rule. Where each consequent in the IF-Then form must be represented by a fuzzy set with a monotonous membership function as a fuzzification process. Then using the weighted average defuzzification to produce the inference result of each rule is given firmly (crisp) based on the α-predicate. According to four stages to get the output of this method, namely:

- *Fuzzyfication*, is a process for changing or converting input values in the form of crisp values into fuzzy sets. And determine the degree of membership in the fuzzy set.
- Forming IF-Then Rules, is a process to form a rule and then implied using the IF – THEN form stored in the fuzzy membership base.
- Inference engine, is the process of converting fuzzy input into fuzzy output using a predefined fuzzification method. At this stage, the MIN method is used and the alpha-

predicate value is obtained for each rule. The resulting value will be used to calculate the output of each rule (z value).

- *Defuzzification*, In the final stage, this is to convert the resulting fuzzy values from the inference engine into a crisp. Then by using the method of the average Weight Average the final result is obtained.

3. Membership Function

The membership function is a curve to show the mapping of input data points into membership values with value intervals from 0 to 1 [4]. To get the membership value you can use the function approach. Some of the functional approaches used include the triangular curve membership graph, the linear curve membership graph, the shoulder curve membership graph, the trapezoid curve membership graph, the bell curve membership chart, the S-curve membership chart. In this study, the curve graph used is the linear curve membership graph.

In the linear curve membership graph, for input mapping to the degree of membership it is described as a straight line. To overcome a concept that is less clear this form is a good and simplest choice. There are two states of a linear fuzzy set, namely an ascending linear representation and a downward linear representation. The representation of linear descending and linear ascending curves can be seen in Fig 1, the representation of the triangle curve can be seen in Fig 2, and the representation of the deep shoulder curves in the concept of fuzzy logic can be seen in Fig 3.

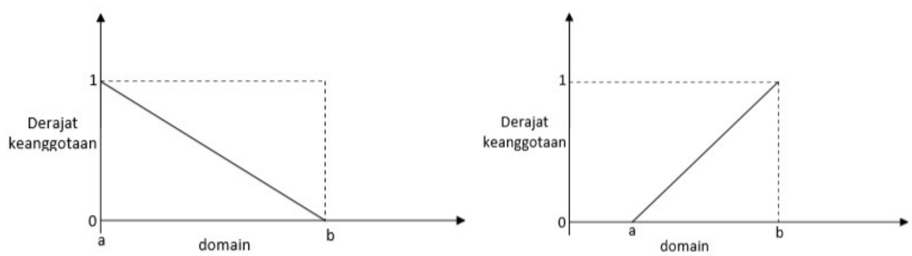

Fig 1. The representation of linear ascending and ascending linear curves [5]

With the equations in the representation of the initial, middle, and final shoulder curves can be seen in equation 2 and 3.

$$B(x,a,b) = \frac{b-x}{b-a}; \quad a \tag{2}$$

$$B(x,a,b) = \frac{x-a}{b-a}; \quad c \tag{3}$$

where

μ [X]	: fuzzy value
x	: number for which the value is sought *fuzzy* his
a	: the smallest range of criteria
b	: the largest range of criteria

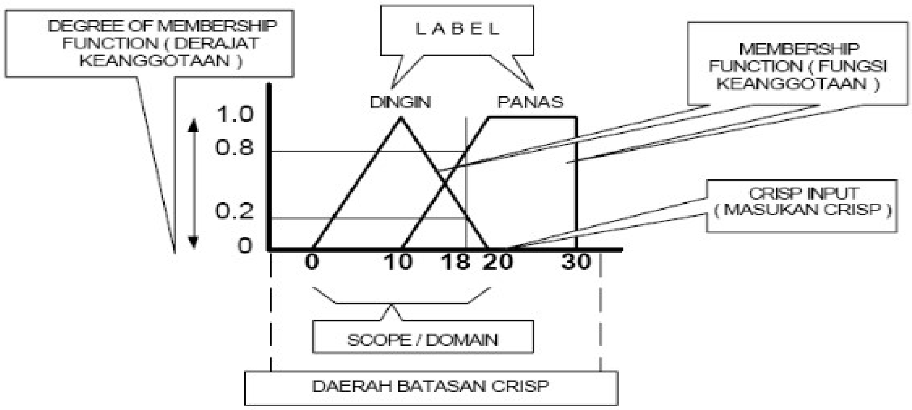

Fig 2. Shoulder curve representation in fuzzy logic concept [4]

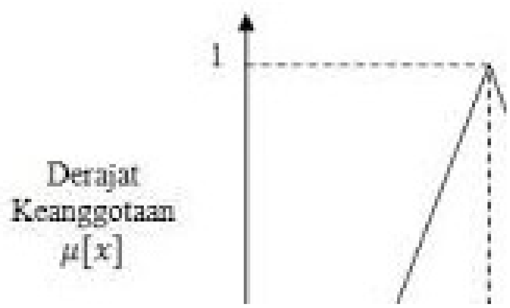

Fig 3. Triangle curve representation [4]

This section describes the background of the study that supported with information from existing literatures, underlines the issues and states the research objectives

b. **Relevant Research**

According to [1] develop a decision support system for determining the quality and production of charcoal using the SMART method and the fuzzy tsukamoto. There are 5 criteria used in this study, namely the length of charcoal, the diameter of the charcoal, the cracking of the charcoal, and the humidity to determine the quality of the charcoal, while the production has a variable demand, supply and production. While the output of this research is the quality and production of charcoal that will be produced.

On research [2] entitled decision support system in determining the quality of fresh food using the SMART method. This study used 4 criteria in the form of duration from post-harvest, physical condition, color, and pesticide residues to design applications that are used to determine the quality of plant-based fresh food intake accurately and accurately. This system can still be developed by combining with other methods to obtain more accurate results.

According to [6] in his research entitled application of employee work performance using the SMART method. In his research using 6 criteria to determine employee performance such as integrity, cooperation, creativity, customer service, professionalism and goal orientation. This system is effective for calculating employee performance. The results of the system testing have a trial score of 93.33%.

c. **Confusion Matrix**

*Confusion matrix*is a method for calculating the performance of a method used. In the confusion matrix, there are 2 dimensions that show true positive values, true negative values, false positive values, and false negative values.

Table 1. Confusion Matrix

Data		*Prediction Outcome*	
		P	N
Actual Value	P	*True Positives (TP)*	*False Negatives (FN)*
	N	*False Positives (FP)*	*True Negatives (TN)*
Total			

A model can be measured by calculating the following:

1. *True Positive* (TP) is a positive label which is predicted to be positive.
2. *False Positive* (FP) is a negative label which is predicted to be positive.
3. *True Negative* (TN) is a negative label which is predicted to be negative.
4. *False Negative* (FN) is a positive label which is predicted to be negative.

d. **Mean Square Error**

Mean Square Error(MSE) is a measure used in this study to measure the accuracy of the forecasting results. As the name implies, MSE has a percentage (fraction) unit. The word "mean" itself is used when there is a lot of data to be compared with the real data. The following is the formula for MSE in equation 4:

$$MSE = \sum (Actual - Forecast)\ 2 / n \quad (4)$$

From equation II.4, it can be interpreted that ∑ (Actual - Forecast) 2 is the result of the reduction between the squared actual and forecast values, then the results are added. And n is the number of periods used for calculation.

3. Methodology

a. Research Unit

In making this research the authors conducted research at the Department of Food Crops and Horticulture, South Sumatra Province, located on Jalan Kapten P. Tendean No. 1058, Palembang 30129. The Office of Food Crops and Horticulture in the Province of South Sumatra is a Regional Apparatus Organization engaged in the Food Crops and Horticulture Sub-sector Agriculture. Headed by a Head of Service in charge of 4 Sectors (Food Crops, Horticulture, Agricultural Infrastructure and Facilities, and Processing, Product Marketing and Agricultural Extension) and 4 UPTDs.

b. Data

Vegetable demand and supply data were obtained from the Food Consumption Database dataset. And the criteria and vegetable production data were obtained from interviews with the head of the Horticultural Sector Office.

Table 2. SMART Criteria and Subcriteria

Name Criteria	**Subcriteria**
Altitude Place	Plateau
	Lowland
Soil ph	Acid
	Neutral
	Wet

Vol. 2, No. 1, January 2021, pp. 29-39

Temperature	High
	Normal
	Low
Harvest Age	According to the season
	Out of season

Table 3. Fuzzy Tsukamoto variable

Variable	**Linguistics**
Demand	Ride
	Down
Inventory	Lots
	a little
Production	Increased
	Less

From research at the South Sumatra Agricultural Service, the criteria for calculating the quality of vegetables consisted of altitude, soil pH,temperature, and age of harvest, and each criterion has its own sub-criteria.Based on the results of this study, it can be concluded that to determine the quality of vegetables, a plant's needs must be fulfilled so that the plants can produce high-quality and marketable plants.

Apart from the results of the interviews, this study also uses secondary data obtained from the food consumption database site to determine the amount of production to be made. The data consists of 3 variables in the form of 2 input variables, the demand variable is obtained from the number of consumer requests and the inventory variable obtained from the database, while the production variable is used for output. The data will be used as a reference in making membership curves and membership functions. Below is the membership curve and the membership function for each variable.

A. Demand

In the demand variable is divided into 2 sets, namely up and down. The demand curve can be seen in Fig 4.

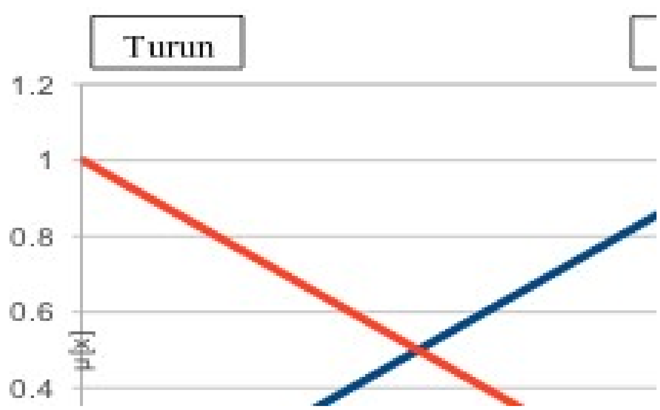

Fig 4. Demand Membership Curve

Based on the membership curve above, a membership function is obtained with an up and down linguistic value which can be seen in equations 5 and 6 [4].

$$\mu(PmtNaik) = \begin{cases} 1; \\ \left(\frac{x-100}{29900}\right); & 10 \end{cases} \quad (5)$$

$$\mu(PmtTurun) = \begin{cases} 0; \\ \left(\frac{30000-x}{29900}\right); & 10 \end{cases} \quad (6)$$

Where

μ [Y] : fuzzy value

y : the number for which the fuzzy value is sought

B. Inventory

Inventory variables are divided into 2 sets, namely lots and a little. The inventory variable curve can be seen in Fig 5.

Fig 5. Inventory Variable Membership Curve

Based on the membership curve above, we get a membership function with many and a few linguistic values which can be seen in the following equation [4].

$$\mu(PsdSedikit) = \begin{cases} \left(\frac{3000-y}{2990}\right); & 1 \end{cases} \quad (7)$$

$$\mu(PsdBanyak) = \begin{cases} \left(\frac{y-10}{2990}\right); \end{cases} \quad (8)$$

Where

μ [Y] : fuzzy value

y : the number for which the fuzzy value is sought

C. Production

Production variables are divided into 2 sets, namely increasing and decreasing. The production variable curve can be seen in Fig 6 below.

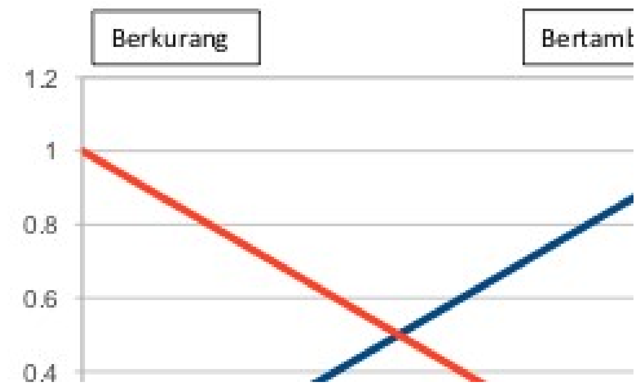

Fig 6. Production Variable Membership Curve

Based on the membership curve above, the membership function of the linguistic value increases and decreases which can be seen in the following equation [4].

$$\mu(PsdBerkurang) = \begin{cases} 1 \\ \left(\frac{60000-z}{59990}\right); \end{cases} \quad (9)$$

$$\mu(PsdBertambah) = \begin{cases} \left(\frac{z-10}{59990}\right); \end{cases} \quad (10)$$

where

μ [Y] : fuzzy value

y : the number for which the fuzzy value is sought

The temporary variables are then processed using the MIN method to obtain the alpha-predicate value of each rule. The resulting value will be used to calculate the output of each rule (z value). To get the output in the form of the amount of vegetable production, the defuzzification converts the fuzzy value from the inference engine into a crisp. Then the final value obtained by using the Average Weight Average method.

c. Research Stages

This research will be carried out in stages as shown in Fig 7.

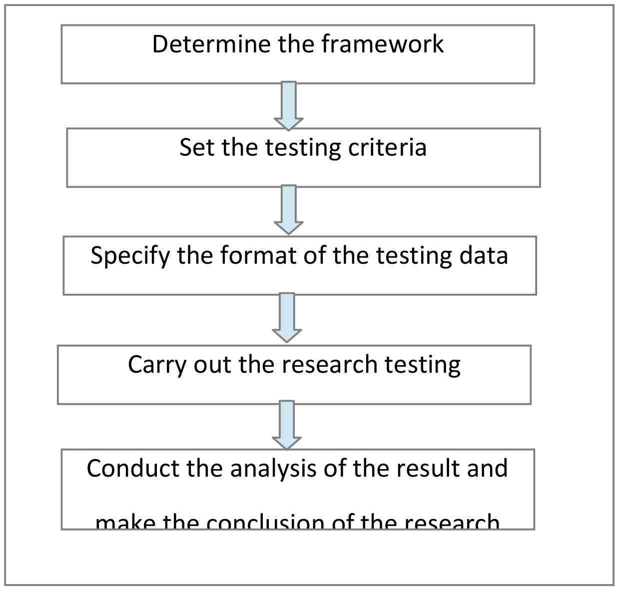

Fig 7. Research Stages Diagram

4. Result and Discussion

1. SMART Test Results

In testing, determining the quality of vegetables was carried out using 20 vegetable commodities. Based on the results of calculations based on the SMART method, the quality results of the vegetables were obtained. The following is a table of the results of the quality of vegetables in Table 4.

Table 4. Comparison of Research Results with System Results

	Commodity Vegetables	**Input Value**				**System Results**	**Result Research**
		Altitude Place	**Soil Ph**	**Tempe rature**	**Harvest Age**	**Quality**	**Quality**
1.	Shallot	405	6.25	28.5	82	A1	A1
2	Garlic	1100	7	20	105	A1	A1
3	Spring onion	700	6.5	21	75	AA	AA
4	Spinach	625	6.5	26	30	A1	A1
5	Green Chili	500	6.15	23	105	AA	AA
6	Red chili pepper	625	6.15	22.5	105	AA	A1
7	Cayenne pepper	500	6.5	27	120	AA	AA
8	Mushroom	625	6	25.5	60	AA	AA
9	Long beans	400	6	26	90	A1	A1
10	Cabbage	1500	6.5	20	60	A1	A1
11	Cucumber	500	6.5	20.5	75	AA	AA
12	Eggplant	600	5.5	26	120	AA	A1
13	Tomato	625	6	24.5	90	AA	AA

Sriwijaya Journal of Informatic and Applications
Vol. 2, No. 1, January 2021, pp. 29-39

14	Carrot	1000	6	23	90	A1	A1
15	Chinese cabbage	625	6.25	17.5	47	AA	A1
16	Mustard greens	625	6.25	17.5	47	AA	AA
17	Petai	405	5.75	17.5	1095	AA	AA
18	Chayote	1000	5.75	24.5	90	AA	AA
19	Jengkol	500	5.75	17.5	3095	AA	AA
20	Kale	625	6	26	25	AA	AA

Based on table 5., the SMART method test results were obtained by using vegetables commodity data. To analyze the test results to predict the quality of vegetables using confusion matrix can be seen in the Analysis of test results.

Table 5. Vegetable Quality Testing Results

Confusion Matrix		Predicted Classes		
		AA	A1	A2
Actual Classes	AA	11	0	0
	A1	2	6	0
	A2	1	0	0

2. Fuzzy Tsukamoto Test Results

The test results on the Tsukamoto fuzzy are carried out by using a confusion matrix to calculate the accuracy value, for data using 20 vegetable commodities. Furthermore, analysis of the results of the system will be carried out with the results of the research. The analysis results can be seen in Table 6.

Table 6. Table System Results with Research Results

Number	Commodity	System Results	Research result	Information
1	Shallot	95242,221	95242,221	Correct
2	Garlic	108 498,832	108 498,832	Correct
3	Spring onion	545917,210	545917,210	Correct
4	Spinach	118604,442	118604,442	Correct
5	Green Chili	225527,996	225527,996	Correct
6	Red chili pepper	69462,663	69462,663	Correct
7	Cayenne pepper	67711,328	67711,328	Correct
8	Mushroom	49303,646	49303,646	Correct
9	Long beans	146405,609	146405,609	Correct
10	Cabbage	356475,221	356475,221	Correct
11	Cucumber	125930,082	125930,082	Correct
12	Eggplant	100319,728	100319,728	Correct
13	Tomato	80965,436	80965,436	Correct
14	Carrot	224030,012	224030,012	Correct

15	Chinese cabbage	311580,144	311580,144	Correct
16	Mustard greens	146405,609	146405,609	Correct
17	Petai	84658,469	84658,469	Correct
18	Chayote	156820,920	156820,920	Correct
19	Jengkol	82251,249	82251,249	Correct
20	Kale	72885,959	72885,959	Correct

To find out the accuracy of this method, the Mean Square Error test is used to get the error level of the method which can be seen in Table 6.

Table 6. Tsukamoto Fuzzy Test Table

The amount of data	Correct Diagnosis Results	Incorrect Diagnosis Results
20 data	20 Data	0 Data

3. Conclusion

In this study, two tests were carried out, the first test was carried out on the SMART method using the Confusion Matrix. In the results of the experiments carried out, the accuracy value of the SMART method is 85%. Then the second test was carried out on the Tsukamoto fuzzy method using the Mean Square Error (MSE). In the results of experiments conducted using the Tsukamoto fuzzy method, the Mean Square Error value can be obtained in accordance with equation 4 as MSE = 0.

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