

Determining The Amount of Tempeh Production Based on Demand and Inventory Data Using Fuzzy Logic Method (Case Study: “Murni” Soybean Tempe Msmes Madiun)

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Abstract

Tempeh is a typical Indonesian food that is consumed by almost all people. In the industrial world, companies are required to increase productivity because many competitors are increasingly competitive. The increase in raw material prices makes companies reluctant to buy materials in large quantities, so companies tend to maintain stock or supply of materials in order to meet increasing demand. This research aims to estimate the amount of tempe production using the Mamdani fuzzy logic approach with consideration factors in the form of supply and consumer demand. The research method uses literature reviews, testing with Matlab, and manual calculations to analyze demand and supply of tempeh in the industry. The test results using Matlab and manual calculations on tempe demand and supply obtained data that is in accordance with existing history, where if there is a demand for 6006 units of tempeh with a raw material supply of 6945, then it is predicted that the company will produce 6569 units of tempeh. It is hoped that this research can help the tempe industry in preparing production plans.

Keywords: demand, fuzzy logic, inventory, mamdani, tempeh production

INTRODUCTION

Tempeh is a typical Indonesian food that is consumed by almost all levels of society. Apart from its cheap price, tempeh has been recognized as a nutritious food and has become a popular food among the public (Darmawan *et al.* 2022). The tempe making industry can be found in almost every city in Indonesia, but most of it is still limited to a home industry scale. The popularity of tempeh as a nutritious and affordable food has made it a daily consumption for Indonesian people so that demand often increases (Nugroho *et al.* 2023).

In the industrial world, companies are required to increase productivity because many competitors are increasingly competitive. However, the challenges do not only stop at competition between business actors. Limited supply of raw materials is also a big problem that many industries have to face (Putri 2019). An increase in the price of raw materials, especially soybeans, can increase production costs and cause losses for tempeh craftsmen. When raw material prices rise sharply, companies are usually reluctant to buy materials in large quantities (Musyarrofah *et al.* 2024). Therefore, they tend to maintain stock or supply of materials to continue to meet increasing demand. Production activities need to be regulated in such a way that the number of products produced can meet

demand, thereby helping the company achieve greater profits in conditions of tight competition (Sufarnap dan Sudarto 2019).

Tempeh craftsmen often rely on experience and intuition in determining production quantities. This method, although effective for some craftsmen, does not always provide optimal and consistent results. The use of fuzzy logic could be one solution (Nurmuslimah 2017). Fuzzy logic is a logic system that can resolve uncertainty more flexibly, where fuzzy logic allows truth values to be between 0 and 1. This approach is what makes fuzzy logic able to model complex systems that contain uncertainty (Setia 2019). One of its advantages is the ability to map input to output without ignoring factors that can influence it. Factors that play a role in determining production quantities using fuzzy logic include the amount of demand and the amount of inventory (Upuy dan Hiariey 2023). By applying the Mamdani fuzzy logic method, craftsmen can carry out more accurate and systematic calculations. In this way, craftsmen can predict the most appropriate production quantities, minimize the risk of excess or underproduction, and increase production efficiency (Sufarnap dan Sudarto 2019).

The purpose of writing this scientific paper is to estimate the amount of tempeh production using a fuzzy logic approach by considering several factors, namely supply and consumer demand. Thus, this paper is expected to help tempeh craftsmen in the production planning process.

METHODS

In this research, data collection using a literature review. Literature review is a systematic process of collecting, analyzing, and synthesizing information from various sources to gain a better understanding of a specific topic (Cahyono *et al.* 2019). Through literature review, researchers can collect and study various information and references relevant to the research topic. The literature reviewed comes from scientific journals, books, research reports, and other related sources, discussing Fuzzy Logic and raw material inventory management (Amelia *et al.* 2023).

Besides, this research used data analysis using MATLAB (Matrix Laboratory). This application is used as a platform to design fuzzy control systems. The use of MATLAB in matrix calculation solutions is used to simplify calculations that were initially done traditionally and took a considerable amount of time, which can now be solved by using MATLAB software (Fatwa *et al.* 2022). With the existing data, the system will be processed using the Mamdani type fuzzy inference system method, because mamdani method is more flexible, more intuitive, and better at presenting output results in statistical form (Sianipar A 2020). Fuzzy Mamdani consists of 3 main stages: fuzzification, rule evaluation, and defuzzification (Mada *et al.* 2022). The process begins with fuzzification, which converts crisp input into fuzzy input. Next, rules are applied to fuzzy input, and each rule is evaluated based on the results of fuzzification, which produces fuzzy output through the Rule Evaluation stage. The final stage is defuzzification, where fuzzy output is converted back to crisp output.

Tempeh sales data spanning a year served as the basis for this study. Following data collection, a data plot is made to identify the kind of sales that occurred over a given time frame. The 2015 sales figures for "MURNI" soybean tempe MSMEs Madiun are shown in table 1 (Indrawati 2016).

Table 1 Statistical data on tempe demand, inventory, and production quantity

Month	Sales Data (unit)	Amount of Soybeans (Kg)	Production quantity
January	6.006	6.945	6.035
February	5.454	6.175	5.486
March	6.238	7.260	6.278
April	6.887	6.675	6.905
May	7.089	6.700	7.164
June	7.249	6.075	7.338

July	6.771	7.260	6.849
August	6.680	6.675	6.699
September	6.645	6.300	6.722
October	6.957	6.850	7.013
November	6.499	6.250	6.575
December	7.658	6.600	7.727

RESULTS AND DISCUSSION

In order to decide the amount of tempeh production, we need historical data from the last few months or years (Putri 2019). From the literature we've reviewed, the least amount of tempeh produced was 5454 units in February 2020, and the most amount of tempeh produced was 7727 units in December 2020, these data can be seen in Table 1. Until now, the company has been able to produce 8000 units of tempeh per month (Indrawati 2016). With all of this data, it will be difficult to make decisions, so the effective way to decide how much to produce tempeh based on data is using the fuzzy logic method (Intarakumthornchai and Kesvarakul 2020).

Historical data is essential in tempeh production decision making because it helps understand past demand and supply patterns (Saatchi 2024). By looking at past production and demand data, companies can predict future demand trends. For example, if there is an increase in demand in certain months, this data allows for more appropriate production planning, thereby avoiding excess or shortage of stock that can lead to losses or missed profit opportunities. Fuzzy logic is suitable for this scenario because it is able to handle uncertainty and variation in tempeh production, which often cannot be explained by traditional methods that tend to be rigid. This approach provides flexibility by using non-absolute values, allowing companies to consider various factors such as demand and supply simultaneously in making optimal decisions. Traditional methods are less effective because they are unable to accommodate data uncertainty and complexity efficiently, especially when external factors, such as fluctuations in raw material prices, affect production.

The Fuzzy logic method is one of the most powerful mathematical methods for representing uncertainty in all fields (Aurelia *et al.* 2024). As the basic concept of fuzzy systems, fuzzy logic calculates an input variable based on its fuzzy value. Fuzzy in fuzzy set theory, expressed in degrees of membership and degrees of truth, simultaneously states partly true and partly false (Triawan 2019). Fuzzy methods are simple to understand because the process uses etymological strategies and has fuzzy algorithms that can be dissected numerically (Friska and Ahmad 2024). This time, we will use fuzzy logic with the Mamdani method. The Mamdani method is often referred to as the Min-Max method (Sari and Rani 2021).

Data Preparation

In this literature review, the variables are divided into two variables, input and output. Variables input are demand and inventory. Variable output is production amount. Each of the input and output was given a domain or range, for demand its [5454-7658], inventory [6075-7260], and production amount [5486-7727]. Each of the variables has three names of fuzzy sets, for input demand and inventory are few, moderate, and many, while for variable output are reduce, still, and increase.

The formation of fuzzy sets from these inputs and outputs allows fuzzy systems to obtain uncertainty and accuracy in data, as well as to make more consistent conclusions and decision-making. The determination of the variables input, output, value, and range used in this study is shown in Table 2.

Table 2 Variable input, output, value, and range of membership

Function	Variable Name	Fuzzy Set	Notes
Input	Demand	[5454 - 7658]	Number of product requests per month (units)
	Inventory	[6075 - 7260]	Amount of product inventory per month (units)
Output	Total Production	[5486 - 7727]	Production capacity company (unit)

Table 3 Input, Output, and Domain

Function	Variable Name	Name Set Fuzzy	Fuzzy Set	Domain (unit)
Input	Demand	Few		[5400 - 6166]
		Moderate	[5454 - 7658]	[5784 - 7316]
		Many		[6934 - 7700]
Input	Inventory	Few		[6000 - 6433]
		Moderate	[6075 - 7260]	[6217 - 7083]
		Many		[6867 - 7300]
Output	Total Production	Reduce		[5400 - 6200]
		Still	[5486 - 7727]	[6200 - 7000]
		Increase		[7000 - 7800]

Fuzzification

Fuzzification is performed by taking the input-output variable values and determining their degree of membership in all fuzzy sets using each respective membership function (Rumalowak *et al.* 2023). Following the fuzzy set that has been made, Matlab is used to progress the data by inputting the variables and range. In manual calculations, input and output values can be calculated using geometric shapes. Geometric shapes in fuzzy logic can be triangular, trapezoidal, generalized bell, gaussian, and others (Sani 2019). The membership function of the fuzzy variable is created based on the demand variable values listed in Table 2. The membership function for input variable demand can be seen in Figure 1.

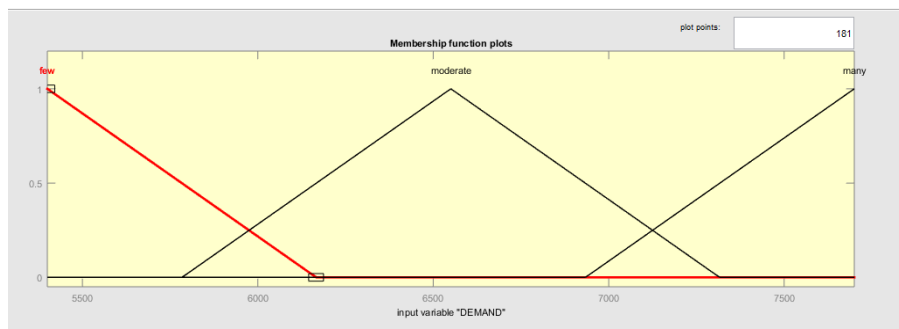


Figure 1 Fuzzy membership function for the input variable demand

The demand membership function is as follows:

$$\mu_{Demand\ Few}(x) = \begin{cases} 0; & x \geq 6166 \\ \frac{6166 - x}{6166 - 5400}; & 5400 \leq x \leq 6166 \\ 1; & x = 5400 \end{cases}$$

$$\mu_{Demand\ Moderate}(x) = \begin{cases} 0; & x \leq 5784 \cup x \geq 7316 \\ \frac{x - 5784}{6550 - 5784}; & 5784 \leq x \leq 6550 \\ \frac{7316 - x}{7316 - 6550}; & 6550 \leq x \leq 7316 \\ 1; & x = 6550 \end{cases}$$

$$\mu_{Demand\ Many}(x) = \begin{cases} 0; & x \leq 6934 \\ \frac{7700 - x}{7700 - 6934}; & 6934 \leq x \leq 7700 \\ 1; & x = 7700 \end{cases}$$

The membership function of the fuzzy variable is created based on the inventory variable values listed in Table 2. The membership function for input variable demand can be seen in Figure 2.

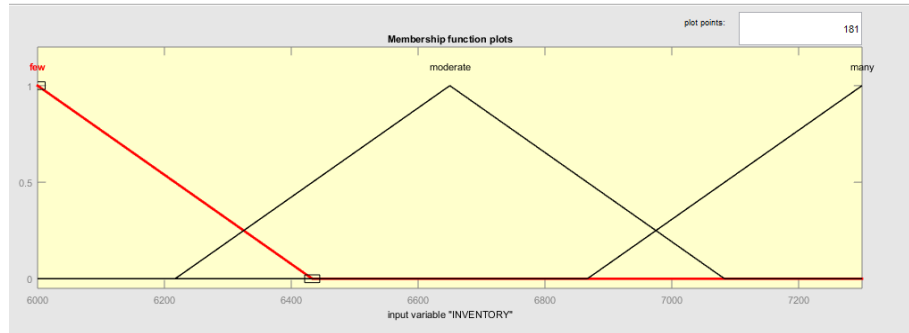


Figure 2 Fuzzy membership function for the input variable inventory

The demand membership function is as follows:

$$\mu_{Inventory\ Few}(y) = \begin{cases} 0; & x \geq 6433 \\ \frac{6433 - x}{6433 - 6000}; & 6000 \leq x \leq 6433 \\ 1; & x = 6000 \end{cases}$$

$$\mu_{Inventory\ Moderate}(y) = \begin{cases} 0; & x \leq 6217 \cup x \geq 7083 \\ \frac{x - 6217}{6650 - 6217}; & 6217 \leq x \leq 6650 \\ \frac{7083 - x}{7083 - 6650}; & 6650 \leq x \leq 7083 \\ 1; & x = 6650 \end{cases}$$

$$\mu_{Inventory\ Many}(y) = \begin{cases} 0; & x \leq 6867 \\ \frac{7300 - x}{7300 - 6867}; & 6867 \leq x \leq 7300 \\ 1; & x = 7300 \end{cases}$$

The membership function of the fuzzy variable is created based on the Total Production variable values listed in Table 2. The membership function for input variable demand can be seen in Figure 3.

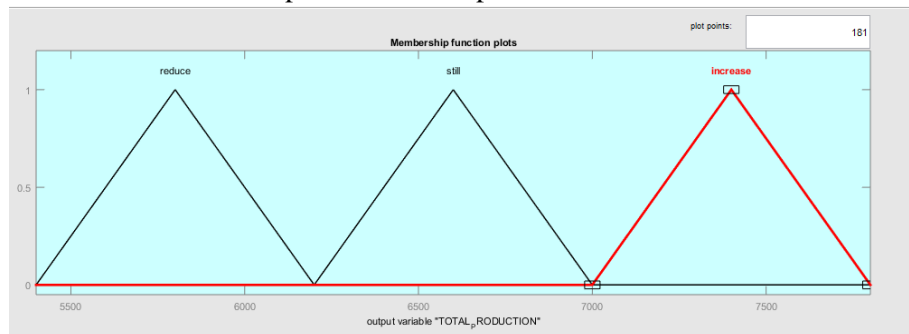


Figure 3 Fuzzy membership level for the output variable production

The demand membership function is as follows:

$$\mu_{T. Production Reduce}(z) = \begin{cases} 0; & x \leq 5400 \cup x \geq 6200 \\ \frac{x-5800}{5800-5400}; & 5400 \leq x \leq 5800 \\ \frac{6200-x}{6200-5800}; & 5800 \leq x \leq 6200 \\ 1; & x = 5800 \end{cases}$$

$$\mu_{T. Production Still}(z) = \begin{cases} 0; & x \leq 6200 \cup x \geq 7000 \\ \frac{x-6600}{6600-6200}; & 6200 \leq x \leq 6600 \\ \frac{7000-x}{7000-6600}; & 6600 \leq x \leq 7000 \\ 1; & x = 6600 \end{cases}$$

$$\mu_{T. Production Increase}(z) = \begin{cases} 0; & x \leq 7000 \cup x \geq 7800 \\ \frac{x-7400}{7400-7000}; & 7000 \leq x \leq 7400 \\ \frac{6200-x}{6200-5800}; & 7400 \leq x \leq 7800 \\ 1; & x = 7400 \end{cases}$$

Based on the data received (January supply and demand data), the current demand is at 6006 units and the inventory is 6945 units. To determine the optimal amount of production, the fuzzy system performs a membership level analysis of the two variables.

- Demand (6006 units)

$$f(x: a, b, c) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0, & c \leq x \end{cases}$$

$$\mu_{T_Few} = \frac{c1-x}{c1-b1} = \frac{6166-6006}{6166-5400} = \frac{160}{766} = 0,21$$

$$\mu_{T_Moderate} = \frac{x-a2}{b2-a2} = \frac{6006-5784}{6550-5784} = \frac{222}{766} = 0,29$$

For the demand variable of 6006 units, the system shows that this value has a "few" characteristic with a membership degree of 0.21 and a "moderate" characteristic with a degree of 0.29. This demand does not have a "many" characteristic at all, indicated by a membership degree of 0.

- Inventory (6945 units)

$$f(x: a, b, c) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0, & c \leq x \end{cases}$$

$$\mu_{T_Moderate} = \frac{c1-x}{c1-b1} = \frac{7083-6945}{7083-6650} = \frac{138}{433} = 0,32$$

$$\mu_{T_Many} = \frac{x-a2}{b2-a2} = \frac{6945-6867}{7300-6867} = \frac{78}{433} = 0,18$$

For the inventory of 6945 units, the analysis shows that this value does not have a "few" characteristic, but has a fairly dominant "moderate" characteristic with a membership degree of 0.32 and a "many" characteristic with a degree of 0.18.

$$\text{Fuzzy Set Few (Demand)} \mu p_{few[6006]} = 0,21$$

$$\text{Fuzzy Set Moderate (Demand)} \mu p_{moderate[6006]} = 0,29$$

$$\text{Fuzzy Set Many (Demand)} \mu p_{many[6006]} = 0$$

$$\text{Fuzzy Set Few (Inventory)} \mu p_{few[6945]} = 0$$

$$\text{Fuzzy Set Moderate (Inventory)} \mu p_{moderate[6945]} = 0,32$$

$$\text{Fuzzy Set Many (Inventory)} \mu p_{many[6945]} = 0,18$$

Rule Determination

The definition of fuzzy rules and variables is done based on expert discussions with the company. The fuzzy rules that will be used can be seen in Table 4.

Table 4 Rule Determination

Rule	Demand	Inventory	Production
1	Few	Few	Reduce
2	Moderate	Few	Reduce
3	Many	Few	Still
4	Few	Moderate	Reduce
5	Moderate	Moderate	Still
6	Many	Moderate	Increase
7	Few	Many	Still
8	Moderate	Many	Increase
9	Many	Many	Increase

The sentences were exchanged through the And logical connector, creating all the possible combinations of system control rules (The rule base formulation is the process of developing fuzzy implication rules that define the relationships between input and output variables (Wardani *et al.* 2017). This rule base is created by combining the fuzzy sets and the rule list used by the company. In the Mamdani method, each rule in the form of an implication with antecedents in a conjunctive (AND) structure has a membership value in the form of a minimum (min) function (Surbakti *et al.* 2020). The implication function applied is the minimum value between the two implications involved. This minimum value is often referred to as the α -predicate. Below is the rule base formulation for a demand of 6006 units and an inventory of 6945 units:

- [R1] IF Demand is Few AND Inventory is Few THEN T. Production is Reduce
 $\alpha_1 = \min (\mu_{\text{Demand Few}} (6006) \cap \mu_{\text{Inventory Few}} (6945)) = \min (0,21;0) = 0$
- [R2] IF Demand is Moderate AND Inventory is Few THEN T. Production is Reduce
 $\alpha_2 = \min (\mu_{\text{Demand Moderate}} (6006) \cap \mu_{\text{Inventory Few}} (6945)) = \min (0,29;0) = 0$
- [R3] IF Demand is Many AND Inventory is Few THEN T. Production is Still
 $\alpha_3 = \min (\mu_{\text{Demand Many}} (6006) \cap \mu_{\text{Inventory Few}} (6945)) = \min (0;0) = 0$
- [R4] IF Demand is Few AND Inventory is Moderate THEN T. Production is Reduce
 $\alpha_4 = \min (\mu_{\text{Demand Few}} (6006) \cap \mu_{\text{Inventory Moderate}} (6945)) = \min (0,21;0,32) = 0,21$
- [R5] IF Demand is Moderate AND Inventory is Moderate THEN T. Production is Still
 $\alpha_5 = \min (\mu_{\text{Demand Moderate}} (6006) \cap \mu_{\text{Inventory Moderate}} (6945)) = \min (0,29;0,32) = 0,29$
- [R6] IF Demand is Many AND Inventory is Moderate THEN T. Production is Increase
 $\alpha_6 = \min (\mu_{\text{Demand Many}} (6006) \cap \mu_{\text{Inventory Moderate}} (6945)) = \min (0;0,32) = 0$
- [R7] IF Demand is Few AND Inventory is Many THEN T. Production is Still
 $\alpha_7 = \min (\mu_{\text{Demand Few}} (6006) \cap \mu_{\text{Inventory Many}} (6945)) = \min (0,21;0,18) = 0,18$
- [R8] IF Demand is Moderate AND Inventory is Many THEN T. Production is Increase

$$\alpha_8 = \min (\mu_{\text{Demand Moderate}} (6006) \cap \mu_{\text{Inventory Many}} (6945)) = \min (0,29;0,18) = 0,18$$

9. [R9] IF Demand is Many AND Inventory is Many THEN T. Production is Increase

$$\alpha_9 = \min (\mu_{\text{Demand Many}} (6006) \cap \mu_{\text{Inventory Many}} (6945)) = \min (0;18) = 0$$

Fuzzy Inference System (FIS), also known as fuzzy inference engine, is a system that can perform reasoning using similar principles to how humans perform reasoning using their instincts (Surbakti and Sunaga 2018). These rules form a fuzzy decision-making system that considers two inputs (Demand and Supply) to determine the output (Production Quantity). It was done by analyzing the data on the boundaries of each fuzzy set for each variable (Nisa *et al.* 2020). Nine fuzzy rules were used in this system, with the arrangement of the rules IF demand IS... AND supply IS... THEN production IS. Each condition has three possible decisions :

- Reduce : Reduce production
- Still : Maintain production level
- Increase: Increase production

To determine the area of the implication obtained after applying the fuzzy operator and aligning it with the output, the membership degree value can be used:

- Reduced rule

$$0,21 = \frac{x - 5400}{5800 - 5400} \rightarrow 84 = x - 5400 \rightarrow x = 5484$$

$$0,21 = \frac{6200 - x}{6200 - 5800} \rightarrow 84 = 6200 - x \rightarrow x = 6116$$

- Still rule

$$0,32 = \frac{x - 6200}{6600 - 6200} \rightarrow 128 = x - 6200 \rightarrow x = 6328$$

$$0,32 = \frac{7000 - x}{7000 - 6600} \rightarrow 128 = 7000 - x \rightarrow x = 6872$$

- Increased rule

$$0,18 = \frac{x - 7000}{7400 - 7000} \rightarrow 72 = x - 7000 \rightarrow x = 7072$$

$$0,18 = \frac{7800 - x}{7800 - 7400} \rightarrow 72 = 7800 - x \rightarrow x = 7728$$

We can simplify the composition function of the implication area as follows:

$$\mu_{SF[Z]} = \begin{cases} 0, & x \leq 6000 \text{ or } x \geq 7800 \\ \frac{x - 5400}{5800 - 5400}, & 5400 \leq x \leq 5484 \\ 0,21, & 5484 \leq x \leq 6116 \\ \frac{6200 - x}{6200 - 5800}, & 6116 \leq x \leq 6200 \\ \frac{x - 6200}{6600 - 6200}, & 6200 \leq x \leq 6328 \\ 0,32, & 6328 \leq x \leq 6872 \\ \frac{7000 - x}{7000 - 6600}, & 6872 \leq x \leq 7000 \\ \frac{x - 7000}{7400 - 7000}, & 7000 \leq x \leq 7072 \\ 0,18, & 7072 \leq x \leq 7728 \\ \frac{7800 - x}{7800 - 7400}, & 7728 \leq x \leq 7800 \end{cases}$$

Defuzzification

The next step is to perform Defuzzification. Defuzzification is achieved by calculating the moment and area of the implication result (Priyo 2017). Below is the calculation of the area from the composition result.

- $A1 = \frac{(5484-5400) \times 0,21}{2} = 8,82$
- $A2 = (6116 - 5484) \times 0,21 = 132,72$
- $A3 = \frac{(6200-6116) \times 0,21}{2} = 8,82$
- $A4 = \frac{(6328-6200) \times 0,32}{2} = 20,48$
- $A5 = (6872 - 6328) \times 0,32 = 174,08$
- $A6 = \frac{(7000-6872) \times 0,32}{2} = 20,48$
- $A7 = \frac{(7072-7000) \times 0,18}{2} = 6,48$
- $A8 = (7728 - 7072) \times 0,18 = 118,08$
- $A9 = \frac{(7800-7728) \times 0,18}{2} = 6,48$

After determining the boundaries of the composition area, the next step is to simplify its composition function.

$$\mu_{SF[z]} = \left\{ \begin{array}{ll} 0, & x \leq 6000 \text{ atau } x \geq 7800 \\ 0.0025x - 13.5, & 5400 \leq x \leq 5484 \\ 0.21, & 5484 \leq x \leq 6116 \\ 15.5 - 0.0025x, & 6116 \leq x \leq 6200 \\ 0.0025x - 15.5, & 6200 \leq x \leq 6328 \\ 0.32, & 6328 \leq x \leq 6872 \\ 17.5 - 0.0025x, & 6872 \leq x \leq 7000 \\ 0.0025x - 17.5, & 7000 \leq x \leq 7072 \\ 0.18, & 7072 \leq x \leq 7728 \\ 19.5 - 0.0025x, & 7728 \leq x \leq 7800 \end{array} \right.$$

The defuzzification method used is the centroid or central of area method, utilizing the equation of the composition function above. This composition function is employed to calculate the moments.

- $M1 = \int_{5400}^{5484} (0,0025z - 13,5)z \, dz = \int_{6000}^{6063} (0,0025z^2 - 13,5z) \, dz = 48121.92$
- $M2 = \int_{5484}^{6116} (0,21)z \, dz = 769776$
- $M3 = \int_{6116}^{6200} (15,5 - 0,0025z)z \, dz = 54190.08$
- $M4 = \int_{6200}^{6328} (0,0025z - 15,5)z \, dz = 128723.626$
- $M5 = \int_{6328}^{6872} (0,32)z \, dz = 1148928$
- $M6 = \int_{6872}^{7000} (17,5 - 0,0025z)z \, dz = 141612.373$
- $M7 = \int_{7000}^{7072} (0,0025z - 17,5)z \, dz = 45671.04$
- $M8 = \int_{7072}^{7728} (0,18)z \, dz = 873792$
- $M9 = \int_{7746}^{7800} (26 - 0,0033z)z \, dz = 50232.96$

The final step is to perform calculations using the α -predicate values and Z values obtained in the previous process (Nurdini S 2021), there are 9 rules in total:

$$\begin{aligned} z^* &= \frac{(M1 + M2 + M3 + M4 + M5 + M6 + M7 + M8 + M9)}{(A1 + A2 + A3 + A4 + A5 + A6 + A7 + A8 + A9)} \\ &= \frac{(48121.92 + 769776 + 54190.08 + 128723.626 + 1148928 + 141612.373 + 45671.04 + 873792 + 50232.96)}{(8,82 + 132,72 + 8,82 + 20,48 + 174,08 + 20,48 + 6,48 + 118,08 + 6,48)} \\ &= \frac{3261056.999}{496.44} = 6568.88446 \end{aligned}$$

After carrying out the defuzzification process using the Center of Area (COA) method, which divides the calculation area into nine parts and considers various production rules (decreasing, constant,

and increasing) (Ismail *et al.* 2022), the result of the defuzzification process for the tempe demand variable, amounting to 6,006 units, and the soybean inventory variable, amounting to 6,945 units, the system produces a recommended production amount of 6,569 units. This recommendation makes sense considering the medium-low demand and medium-high inventory levels. The recommended production numbers are within the acceptable range of 5,400 to 7,800 units, and represent a good balance between the need to meet demand while considering the amount of inventory on hand. The view rules result on Matlab can be seen in Figure 4.

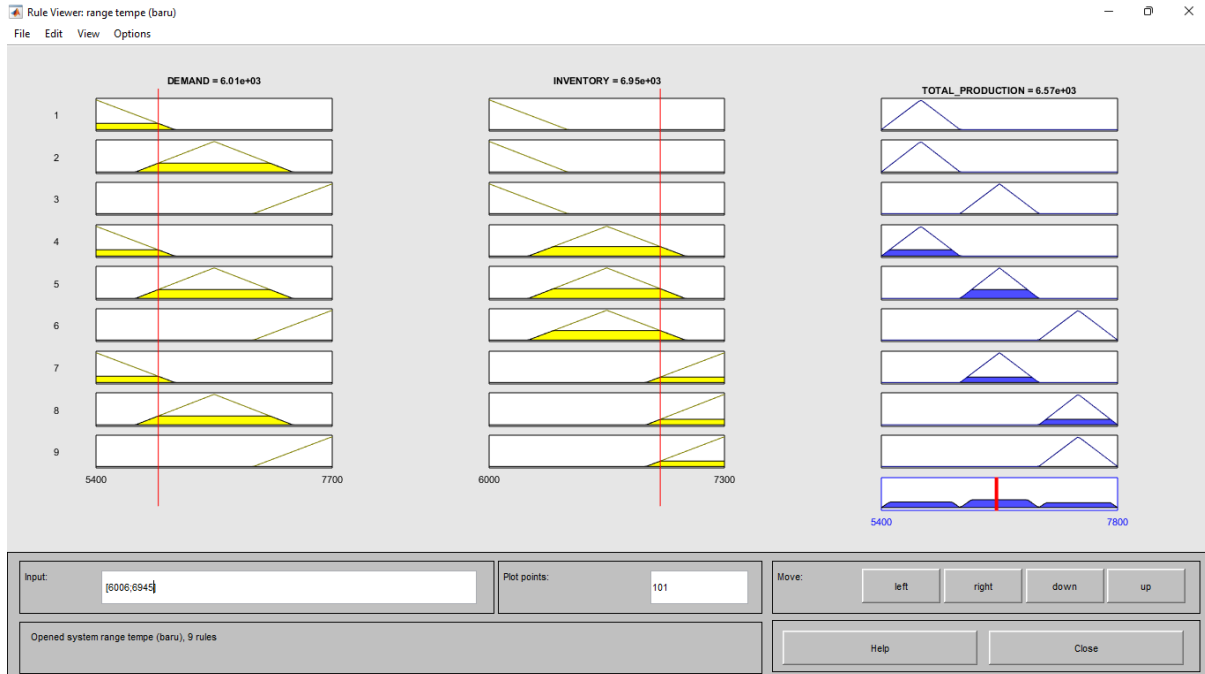


Figure 4 Tempeh production with centroid defuzzification

To find out the description of each demand, supply, and production amount, to ensure that the calculations performed are correct, testing was carried out also using Matlab Toolbox R2009. This testing method was done by contributing to the input column in the rule viewer. The contribution given later affects the results. In Matlab, the results of the defuzzification calculations can also be visualized using a surface plot, as shown in the following image below.

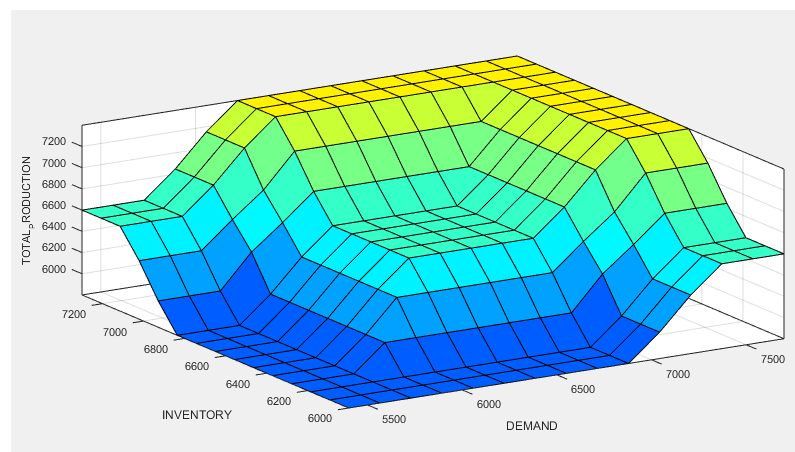


Figure 5 Tempeh production with surface

In figure 5, it shows a 3D surface plot illustrating the relationship between inventory, demand, and total production in a tempe production system. The x-axis represents inventory levels, the y-axis represents demand, and the z-axis shows the resulting total production based on the fuzzy logic model used (Trejo *et al.* 2022). This serves as an important tool for an in-depth analysis of the results, with its interpretation relying on the graph's shape (Morales *et al.* 2015).

System Analysis

This system is examined so that the application of theory to the program is consistent with the real situations in the field. As a result, the results will be similar whether calculated manually or with a computer program. This application is expected to provide a solution or a new method for calculating Tempe manufacturing quantities (Nurmuslimah 2017).

Table 5 Comparison of production quantities

Month	Sales Data (unit)	Amount of Soybeans (Kg)	Production Quantity	Production Quantity with System	Accuracy
January	6.006	6.945	6.035	6.569	100%
February	5.454	6.175	5.486	5.796	100%
March	6.238	7.260	6.278	7.394	100%
April	6.887	6.675	6.905	6.595	95%
May	7.089	6.700	7.164	6.925	97%
June	7.249	6.075	7.338	6.436	88%
July	6.771	7.260	6.849	7.394	100%
August	6.680	6.675	6.699	6.595	98%
September	6.645	6.300	6.722	6.116	91%
October	6.957	6.850	7.013	6.655	95%
November	6.499	6.250	6.575	5.936	90%
December	7.658	6.600	7.727	7.394	96%

$$Accuracy = \frac{Production\ Quantity\ with\ System}{Production\ quantity} \times 100\%$$

The production system has a high accuracy rate, with most months exceeding 90%. June had the lowest accuracy (88%), suggesting a considerable gap between actual and calculated production. Overall, the system accurately estimates the amount of production each month, with an average accuracy of 90% or higher. This level of accuracy implies that the system is quite reliable at estimating production, albeit there are some minor variances in some months.

CONCLUSION

To determine the amount of tempeh production, historical data from the past few months or years is needed. According to the literature, the lowest production of tempeh was 5,454 units in February 2020, and the highest was 7,727 units in December 2020. Currently, the company can produce up to 8,000 units per month. The fuzzy logic method is used to facilitate decision-making related to production quantity. Fuzzy logic, specifically the Mamdani method, enables the calculation of input based on the membership values of input and output variables. The inputs are demand (5,454-7,658 units) and inventory (6,075-7,260 units), while the output is the production amount (5,486-7,727 units). The fuzzy system analysis shows that a demand of 6,006 units and an inventory of 6,945 units result in a production recommendation of 6,569 units. Simulation results indicate that this system has an accuracy rate of over 90%, although there are some differences in certain months.

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