Journal of Applied Science, Technology & Humanities
Volume 1, Issue 3, June, 2024, Pages 265-279

ISSN 3032-5765 (Online)
DOI: https://doi.org/10.62535/ws0haa49

Mamdani's Fuzzy Logic-Based Tapioca Optimal Production Amount Prediction System

Tiara Safitrah[1*]
[1*]Computer Engineering Technology, College of Vocational Studies, IPB University
tiarasafitrah@apps.ipb.ac.id

Divo Wibowo Adi[2], Irfan Tigranaufal Nugraha[3], Antonio Banggas Gregory Sinaga[4], Zaki Rafi Athallah[5], Mohammad Akbar Alfa Dirk Steyer[6], Sesar Husen Santosa[7], Muhammad Danang Mukti Darmawan[8], Nanda Octavia[9]
[2345689]Computer Engineering Technology, College of Vocational Studies, IPB University
[2]dipooodivo@apps.ipb.ac.id, [3]tigranaufalirfan@apps.ipb.ac.id, [4]sinagaantonio@apps.ipb.ac.id, [5]zakirafi17athallah@apps.ipb.ac.id, [6]steyerakbar@apps.ipb.ac.id, [8]danangmukti@apps.ipb.ac.id, [9]naocaviananda@apps.ipb.ac.id
[7]Industrial Management, College of Vocational Studies, IPB University
[7]sesarhusensantosa@apps.ipb.ac.id

Abstract

This research focuses on the imbalance between supply and demand in the tapioca industry, especially on the scale of Small and Medium Industries (SMI). Such challenges involve price fluctuations and lack of efficiency in determining the optimal production amount. Using fuzzy logic as an artificial intelligence method, this research aims to develop a system for predicting the optimal amount of tapioca production that can increase efficiency, reduce waste of raw materials and energy, and stabilize prices. The data used in this study was obtained through interviews with resource persons who are involved in the field of tapioca SMI. Furthermore, the data was processed using the Mamdani Fuzzy Inference System method. The results showed that in the case of production when demand is 400 kg and cassava availability is 2000 kg, the optimal production amount of tapioca is 630 kg. This value is also consistent when proven using the Matlab R2015a application. This shows that the model can be relied upon in determining the decision on the amount of tapioca production by considering demand factors and raw material availability.

Keywords: Demand**,** Cassava Availability, Fuzzy, Optimal Production, Tapioca.

INTRODUCTION

Manihot esculenta Cranzt or known as cassava, is a plant that has a high carbohydrate content and has various potential uses, ranging from food, feed, industry, to energy needs. Although cassava has become a commonly cultivated plant in Indonesia, the need for this plant is still not fully met. In 2016, national cassava production reached 20.26 million tons (FAO et al., 2018). In the same year, Indonesia imported 12,530 tons of cassava with a value of around US$ 2.2 million. The importation of cassava mainly aims to meet the needs of starch, both in the food industry and non-food industry (Li et al., 2016). The increase in cassava production and imports in Indonesia in 2016 is a concern, especially because the character that directly affects the starch content of a genotype is the weight of tubers (Subekti et al., 2018).

After rice, corn, soybeans, peanuts, and green beans, cassava has now followed to become one of the main food crop commodities in Indonesia (Novaldi et al., 2022). This plant has an important role as a source of foodstuffs, animal feed, and industrial raw materials, both in the early stages and in the final stages of production. In addition to functioning as a food ingredient, cassava can also be used as raw material in industry and as feed for livestock (Suryani, 2020).

One of the superior products from cassava that produces significant added value is tapioca flour. The development of tapioca production in Negaratengah Village, Cineam District, Tasikmalaya Regency has a positive impact on industry players and the region as a whole. Tapioca flour agro-industry entrepreneurs managed to achieve an added value of Rp 662 per kilogram, with total production reaching 700 kilograms in each production process (Herdiyandi et al., 2016). The same research was also conducted in Bojongasih Village, with the achievement of an added value of Rp 5,589 per kilogram of raw materials. This reflects the economic potential that can be obtained through the development of the tapioca industry at the local level (Nopiani et al., 2019).

Indonesia itself is one of the largest tapioca flour producing countries in the world. According to BPS data in 2020, Indonesia produced 27.4 million tons of tapioca flour, making it an important commodity with high demand in the domestic and international markets (BPS, 2020). Domestic consumption of tapioca flour in 2021 reached 14.3 million tons, while exports reached 13.1 million tons in the same year (BPS, 2021). However, behind its great potential, the tapioca industry in Indonesia still faces several problems. This problem can hinder the progress of the industry and result in losses for stakeholders, such as farmers, entrepreneurs, and consumers.

One of the challenges is the imbalance between supply and demand. Agricultural production tends to fluctuate because it is influenced by seasonal changes, weather, climate, and natural factors such as floods and water shortages (Surmaini & Faqih, 2016). Pest and disease attacks can also affect agricultural production. Food commodity prices can change drastically if the supply of agricultural products changes due to inelastic demand. The harvest season causes an increase in supply and a decrease in prices, while the dry season causes a decrease in supply and an increase in prices (Kusnadi, 2022). In addition, inefficiency in determining the amount of production is a serious problem. Farmers and entrepreneurs often find it difficult to determine the optimal amount of production, which can lead to losses due to overproduction or underproduction. BPS data shows that the price of tapioca flour experienced significant fluctuations reaching IDR 8,000 per kilogram in 2020 and dropped dramatically to IDR 3,000 per kilogram in 2021 (BPS, 2021).

In the tapioca industry sector, especially on the scale of Small and Medium Industries (SMI), there are often challenges of inefficiencies in the production process (Hidayat et al., 2022). This arises from several factors, such as activities that do not add value to the final product, causing waste of time, energy, and resources (Fattahillah et al., 2020). In addition, lack of knowledge about optimal production processes and limited infrastructure, such as storage warehouses and production equipment, contribute to such inefficiencies (Ginanjar, 2018).

The impact of inefficiencies in the tapioca production process can be felt in decreasing the productivity of tapioca SMIs, which have difficulty in producing optimal products within the specified time. The waste of raw materials, energy, and time also has an impact on increasing production costs, thereby reducing the potential profits that can be achieved (Sholihah & Jaelani, 2023). As a potential solution, this research proposes a system of predicting the optimal amount of tapioca production based on fuzzy logic. Fuzzy logic is an artificial intelligence method used to address vague or partial truths, such as market demand and raw material availability (Kharisma et al., 2023). This system is expected to increase production efficiency, minimize losses, and stabilize tapioca prices by improving the balance between supply and demand.

Nugget production capacity research states that one of the variables that affect the determination of optimal production capacity is demand. The problem that occurs is that when companies have high demand, production capacity cannot meet that demand. This condition requires a model to determine the optimal production capacity based on the market (Santosa et al., 2020). Previous research has also developed a system of predicting the amount of rice production based on the amount of supply and demand using fuzzy logic. This system has proven effective in supporting companies in decision making, with a truth rate of 98.41902%. In addition, this system also facilitates warehouse admins in determining the optimal amount of rice production according to demand and availability (Indra, 2016).

In addition, the prediction system is also expected to improve the quality of products produced by tapioca SMIs. By minimizing production defects, this industry can produce higher quality tapioca flour products so as to increase competitiveness in domestic and international markets. The implementation of the prediction system is also expected to expand market access for tapioca SMIs. By having an accurate prediction of the amount of production required, SMIs can be more effective in marketing their products to a wider market. This can open up new opportunities and increase the competitiveness of tapioca products.

METHODS

Research Location and Time

The research was conducted in one of the tapioca Small and Medium Industries (SMI) located on Jl. Taman Kenari Housing No.7 Block D5, RT.03/RW.01, Cimahpar, North Bogor. This location was chosen because the SMIs is a representation of the industrial environment relevant to the object of research with a research period carried out from February 11th until March 2024.

Data Collection

The data collection method applied in this research is direct interviews with tapioca Small and Medium Industries (SMI) stakeholders. The data collected includes factors that affect the amount of tapioca production in the field. To support the data collection process, reference sources such as literature books and research journals related to tapioca industry and production are also used.

Based on the results of interviews that have been conducted, 2 variables were obtained that affect the amount of tapioca production, namely market demand and cassava availability. The two variables are then described in the fuzzy set model as inputs that affect the output of the development of the model of the optimal amount of production of tapioca. The process for determining tapioca production quantity data uses mamdani's fuzzy logic which can be illustrated on the following flowchart:

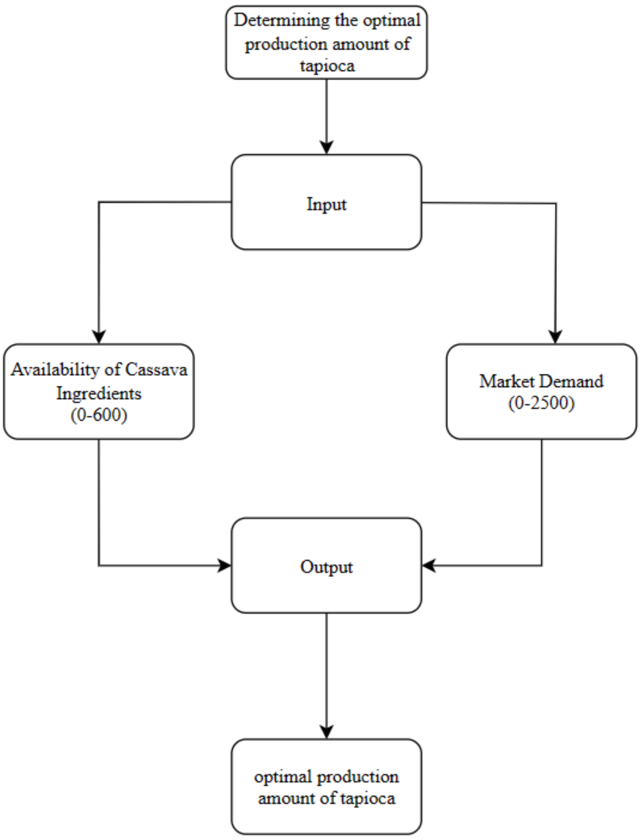

Figure 1. Flowchart Determines Optimal Production Amount of Tapioca

Based on the flowchart above, in determining the optimal amount of tapioca production, two inputs are used, namely cassava availability and market demand, both of which use kilograms. With the output of the optimal production amount of tapioca consisting of three parameters namely Low, Medium, and High. In determining the optimal amount of tapioca production, data analysis will be carried out using the fuzzy mamdani principle and proving the results using the Matlab application.

Data Analysis

This research uses the Mamdani Fuzzy Inference System (FIS) method in analyzing tapioca demand data and cassava availability to obtain optimal production data. Data that has been collected through interviews will be processed and converted into a format that can be used in FIS.

Fuzzy rules are made based on the knowledge and experience of resource persons in the tapioca industry. In this research, SMIs engaged in the tapioca industry became a source for determining rules. This rule specifies the relationship between the input variable (tapioca demand and cassava availability) and the output variable (optimal production amount). The fuzzy output is then converted into numerical values through the process of defuzzification.

The results of the analysis are then evaluated based on accuracy and suitability with the actual data. It is hoped that the results of this research can help companies or partners in determining optimal tapioca flour production decisions, so as to increase efficiency and profits in the tapioca industry, especially in Small and Medium Industries (SMI).

a. Fuzzy Membership Function

A set refers to a set of objects that have the same characteristics (Darwanto et al., 2020). A fuzzy membership *set* is a set in which there are elements that have varying degrees of membership. By using fuzzy sets, one can operate in the context of uncertain and ambiguous situations, as well as be able to solve problems that arise unexpectedly or problems related to information limitations. Fuzzy membership sets have values ranging from 0 to 1. If x has a fuzzy membership value $\mu A(x) = 0$, it means x does not belong to the set A. Conversely, if x has a fuzzy membership value $\mu A(x) = 1$, then x is considered to be a full member in the set A (Davvaz et al., 2021).

b. Fuzzy Relations

Fuzzy relations are mathematical relationships between two fuzzy sets that describe the extent to which the elements of one set are connected or related to the elements of the other set. The y-axis characteristic of the Cartesian chart represents the degree of fuzzy membership, which has a range of values between 0 and 1. Each variable value describes the x-axis, where the fuzzy relationship U = {x} to V = {y} on the Cartesian diagram is expressed as U×V (Santosa & Hidayat, 2019).

c. Fuzzy Rule Based System

Rule Based System is a rule-based system that can help to classify a problem using known characteristics. The combination of Fuzzy Logic with Rule Based System can be called Fuzzy Rule-Based System which serves to describe the relationship between input parameters and output parameters that aim to get the desired results (Hartanto, 2017).

Rule Based Systems are created to solve a problem with rules made based on experts. This rule has a condition (if) and an action (then). The rules will later be added to a simulation. With multiple matching of a pattern and rules from the applier. Nantinya akan dicocokan dengan pengaturan yang ada dan menentukan aturan yang berhubungan. Rule-based will be easy to use and understand, but rule-based itself does not create new rules or be modified with existing rules because rule-based itself is not designed to be able to learn (Pangkatodi et al., 2016). Unlike monotonous reasoning, if the system has several rules, inference can be obtained from a collection of rules (Kartika et al., 2018).

d. Decision Making Unit

Fuzzy decisions involve making decisions in complex and uncertain environments, where information is evaluated using fuzzy membership sets and fuzzy system modeling (Blanco-Mesa et al., 2017). In making decisions, fuzzy rules can be used, by simulating using human logic based on minimum values by using "AND" or by using "OR" for maximum values (Mamdani, 1976).

e. Defuzzification Process

Defuzzification, is the final step in fuzzy logic systems, which converts each inference engine result from a fuzzy set to a real number (Sutikno, 2018). Deffuzification can also be defined as the process of changing a fuzzy quantity expressed in the form of a fuzzy set of outputs using a membership function, so that it again acquires a clear form (Shuhaila et al., 2024). There are five methods of calculation model in defuzzification, namely COA (Center of Area), Bisector, MOM (Mean of Maximum), LOM (Largest of Maximum), and SOM (Smallest of Maximum) (Haerani, 2014).

The input of the defuzzification process is a fuzzy set resulting from some composition of rules, or fuzzy rules, while the output is a number in the domain of the fuzzy set. Thus, if the fuzzy set is given in a certain range, then a certain crisp value can be taken as output (Simanjuntak et al., 2018). In this research using one method, namely COA (Center of Area).

$$x_{COA} = \frac{\sum_{i=1}^{n} X_i \cdot \mu_i(x_i)}{\sum_{i=1}^{n} \mu_i(x_i)}$$

RESULTS AND DISCUSSION

Fuzzy Membership Function

The membership set or membership function in the prediction system of the optimal amount of tapioca production consists of 2 sets, namely cassava demand and availability.

a. Demand

The determination of the membership set model or membership function demand is designed using the Trapezoidal Membership Function model. Based on the demand data obtained through interviews, the parameters of the demand variables are divided into 3, namely Low, Medium and High whose range is divided between 0-600 kg. Demand conditions when within low parameters range from 100 kg to 350 kg, with peak points being between 200 kg to 250 kg. Further, the values of the medium parameters range from 300 kg to 450 kg, and the peak point is between 350 kg to 400 kg. The height parameter has a value range from 400 kg to 600 kg, with the peak point being between 500 kg to 600 kg. The values of tapioca demand parameters can be seen in Table 1.

Table 1. Demand Parameters

Parameter	Parameter Value
Low	100, 200, 250, 350
Medium	300, 350, 400, 450
High	400, 500, 600

Referring the set and membership value of the demand using the Trapezoidal Membership Function, the membership set value $\mu x(a, b, c, d)$ is obtained for each existing parameter. The demand membership set model (in kilograms) based on the above parameters can be described as follows:

$$\mu_x(\text{demand})\begin{cases} \mu_{low}(x) = \begin{cases} \dfrac{x-100}{200-100} & 100 < x < 200 \\ 1 & 200 \le x \le 25 \\ \dfrac{350-x}{350-250} & 250 < x < 350 \\ 0 & x \le 100 \cup x \ge 350 \end{cases} \\ \mu_{medium}(x) = \begin{cases} \dfrac{x-300}{350-300} & 300 < x < 350 \\ 1 & 350 \le x \le 400 \\ \dfrac{450-x}{450-400} & 400 < x < 450 \\ 0 & x \le 100 \cup x \ge 450 \end{cases} \\ \mu_{high}(x) = \begin{cases} \dfrac{x-400}{500-400} & 400 < x < 500 \\ 1 & 500 \le x \le 600 \\ 0 & x \le 400 \cup x > 600 \end{cases} \end{cases}$$

Based on the parameter data and their values, a graph of the membership function of the demand input variable can be drawn. Valuation of market demand for tapioca production is important because it directly affects the level of production and sustainability of tapioca production. A graph of the demand membership set can be seen in Figure 2.

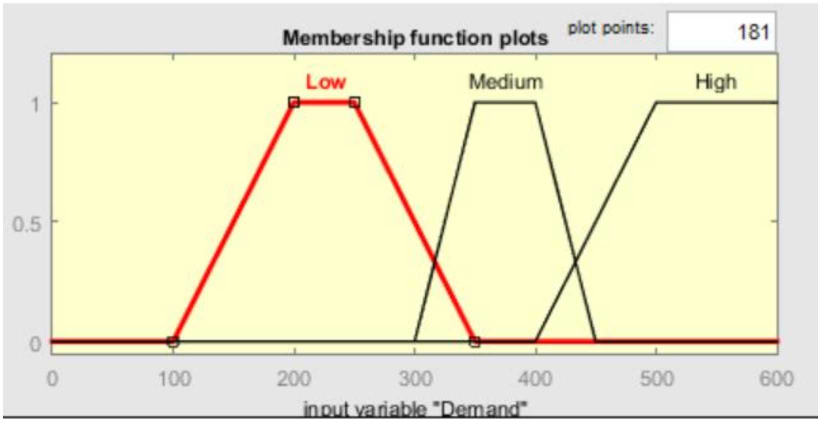

Figure 2. Demand Membership Set graph

b. Cassava Availability

The determination of the membership set model or membership function of cassava availability is also designed using the Trapezoidal Membership Function model. Based on cassava availability data obtained through interviews, the variable parameters of cassava availability are divided into 3, namely Low, Medium and High whose range is divided between 0-2500 kg. Cassava availability conditions when in low parameters range from 0 kg to 1000 kg, with the peak point or degree of membership equal to 1 being between 400 kg to 600 kg. Furthermore, the value of the medium parameter ranges from 800 kg to 2000 kg, and its peak point or degree of membership equal to 1 is between 1200 kg to 1600 kg. The height parameter has a value range from 1700 kg to 2500 kg, with the peak point or degree of membership equal to 1 being between 2100 kg to 2500 kg. The values of the tapioca demand parameter can be seen in Table 2.

Table 2. Cassava Availability Parameters

Parameter	**Parameter Value**
Low	0, 400, 600, 1000
Medium	800, 1200, 1600, 2000
High	1700, 2100, 2500, 2500

Referring to the set and membership value of cassava availability using the Trapezoidal Membership Function, the value of the membership set $\mu x(a, b, c, d)$ is obtained for each existing parameter. The cassava availability membership set model (in kilograms) based on the above parameters can be described as follows:

$$\mu_x(\text{cassava availability}) \begin{cases} \mu_{low}(x) = \begin{cases} \dfrac{x-0}{400-0} & 0 < x < 400 \\ 1 & 400 \le x \le 600 \\ \dfrac{1000-x}{1000-600} & 600 < x < 1000 \\ 0 & x \le 0 \cup x \ge 1000 \end{cases} \\ \mu_{medium}(x) = \begin{cases} \dfrac{x-800}{1200-800} & 800 < x < 1200 \\ 1 & 1200 \le x \le 1600 \\ \dfrac{2000-x}{2000-1600} & 1600 < x < 2000 \\ 0 & x \le 800 \cup x \ge 2000 \end{cases} \\ \mu_{high}(x) = \begin{cases} \dfrac{x-1700}{2100-1700} & 1700 < x < 2100 \\ 1 & 2100 \le x \le 2500 \\ 0 & x \le 500 \cup x \ge 2500 \end{cases} \end{cases}$$

Based on the parameter data and its value, a graph of the membership function of the cassava availability input variable can be drawn. Valuation of the cassava availability for tapioca production is important because as the main raw material, the availability of cassava will ensure a smooth manufacturing process and meet market demand. A graph of cassava availability membership sets can be seen in Figure 3.

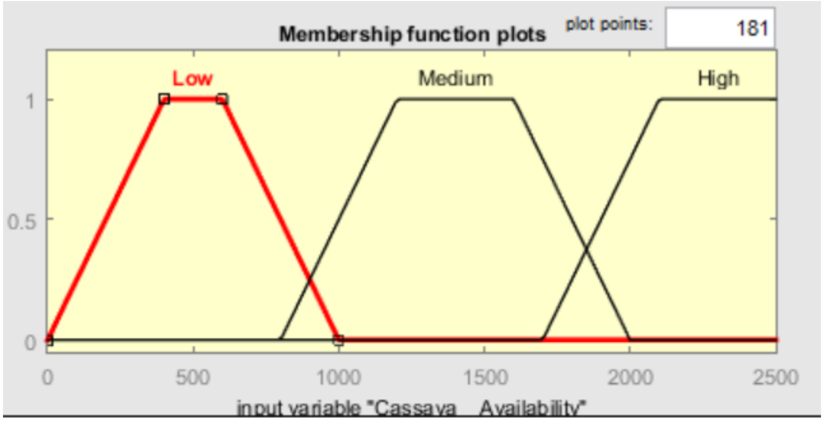

Figure 3. Cassava Availability Membership Set Graph

c. Optimal Production Amount

The optimal production amount membership set model is formed from the cassava demand and availability set model that has been built. The membership function of the optimal production amount uses the Tringular Membership Function model. Based on production amount data, the production amount parameters are divided into 3, namely Low, Medium and High whose range ranges from 0-700 kg. The condition of the amount of production when in low parameters ranges from 0 kg to 300 kg, with the peak point or degree of membership equal to 1 being at a value of 150 kg. Furthermore, the value of the medium parameter ranges from 250 kg to 550 kg, and the peak point or degree of membership equal to 1 is at 400 kg. The height parameter has a value range from 500 kg to 700 kg, with the peak point or degree of membership equal to 1 being at 700 kg. The parameter values of the optimal production amount of tapioca can be seen in Table 3.

Table 3. Tapioca Optimal Production Amount Parameters

Parameter	Parameter Value
Low	0, 150, 300
Medium	250, 400, 550
High	500, 700, 700

Based on the results of modeling the membership set of the production amount, a graph of the membership function of the optimal production amount of tapioca is obtained. The production amount membership function is used to determine the results of input variables that affect the valuation of production amount parameters for optimal results. A graph of the membership set of the optimal production amount of tapioca can be seen in Figure 4.

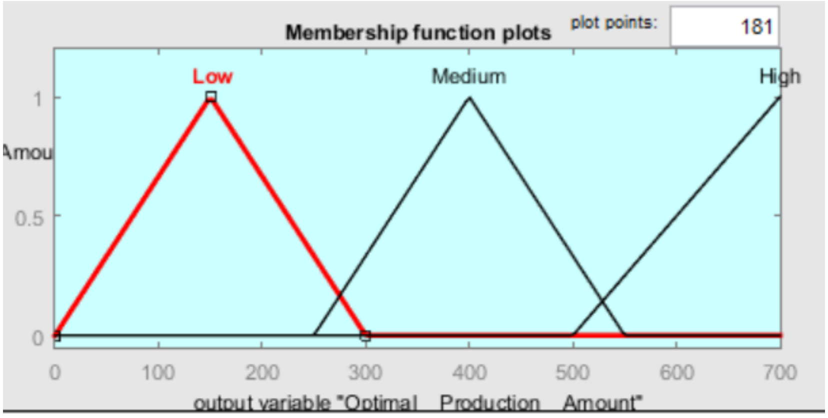

Figure 4. Optimal Production Amount Membership Set Graph

Membership Degrees

By referring to the parameter values of the input variables of the number of demands and availability of cassava, the formulation of the membership set model is carried out $\mu_{x(a,b,c,d)}$. This model is designed to represent the membership level of the input variables of the number of demands and availability of cassava with parameters a, b, c and d.

a. Demand

In this research, a value of 400 kg was given for the demand input variable, so that the degree of membership for that value can be determined when the value is entered into the fuzzy set graph. A graph of a demand set of 400 kg is shown in Figure 5.

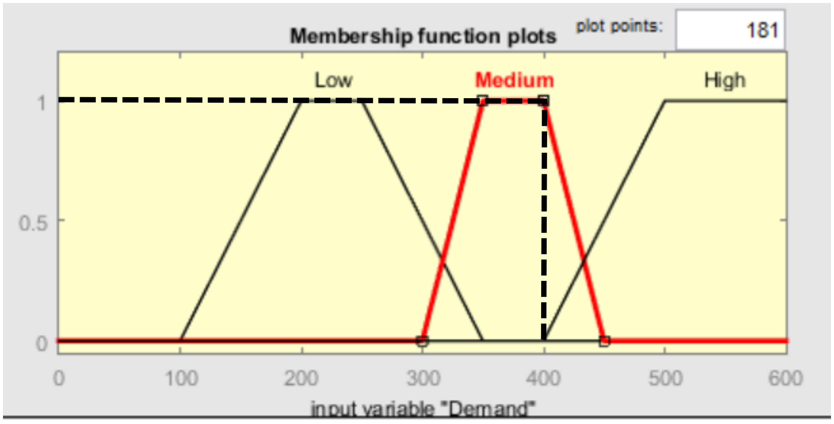

Figure 5. Demand Set Graph for 400 kg

Based on the graph above, the results of the demand valuation of 400 kg are in medium and high parameters. Referring to the graph above, it can be determined the membership degree value of the demand input variable using the membership set that was created earlier. The result of the 400 kg demand membership degree are $\mu_{demand\_medium(400)} = 1$ and $\mu_{demand\_high(400)} = 0$. This membership degree value is obtained because 400 kg is included in the range of values whose membership degree is equal to 1 in the medium parameter and is included in the range of values whose membership degree is equal to 0 in the height parameter $350 \leq x \leq 400x \leq 400$.

b. Cassava Availability

In the research, a value of 2000 kg was given for the cassava availability input variable, so that the degree of membership for the value can be determined when the value is entered into the fuzzy set graph. A graph of cassava availability set for 2000 kg is shown in Figure 6.

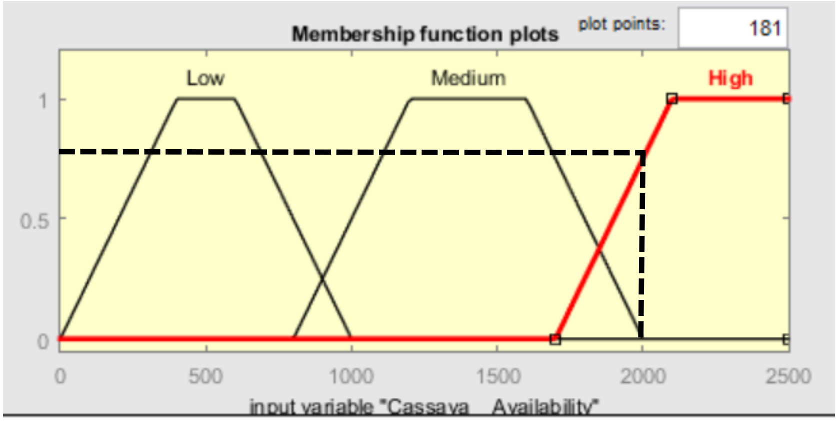

Figure 6. Cassava Availability Set Graph for 2000 kg

Based on the graph above, the results of the cassava availability valuation of 2000 kg are in medium and high parameters. Referring to the graph above, it can be determined the membership degree value of the demand input variable using the membership set that was created earlier. The result of the 400 kg demand membership degree is $\mu_{\text{cassava availability\_medium}(2000)} = 0$ and $\mu_{\text{cassava availability\_high}(2000)} = 0.75$. This membership degree value is obtained because 2000 kg is included in the range of values whose membership degree is equal to 0 in the medium parameter and is included in the range of values $x \geq 20001700 < x < 2100$ whose membership degree is obtained by the following formula:

$$\mu_{\text{cassava availability\_high}(2000)} = \frac{x - 1700}{2100 - 1700}$$
$$= \frac{2000 - 1700}{2100 - 1700}$$
$$= \frac{300}{400}$$
$$= 0{,}75$$

Fuzzy Rule Based System

In forming an optimal production amount prediction system based on fuzzy logic, the principle of the If-Then-Else rule is used. The formed rules are determined based on the membership set of the demand input variables and cassava availability. Since the input variables demand and availability of cassava each have 3 parameters, there are 9 possibilities for the optimal production rate of tapioca. Every possible result contained in the fuzzy rule is obtained through interviews with Tapioca Production SMI actors. The fuzzy rules of a simulation-based tapioca optimal production amount prediction system using the Matlab application are shown in Figure 7.

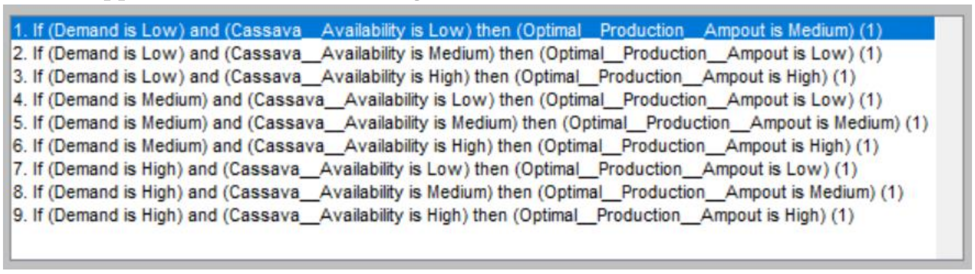
1. If (Demand is Low) and (Cassava__Availability is Low) then (Optimal__Production__Ampout is Medium) (1)
2. If (Demand is Low) and (Cassava__Availability is Medium) then (Optimal__Production__Ampout is Low) (1)
3. If (Demand is Low) and (Cassava__Availability is High) then (Optimal__Production__Ampout is High) (1)
4. If (Demand is Medium) and (Cassava__Availability is Low) then (Optimal__Production__Ampout is Low) (1)
5. If (Demand is Medium) and (Cassava__Availability is Medium) then (Optimal__Production__Ampout is Medium) (1)
6. If (Demand is Medium) and (Cassava__Availability is High) then (Optimal__Production__Ampout is High) (1)
7. If (Demand is High) and (Cassava__Availability is Low) then (Optimal__Production__Ampout is Low) (1)
8. If (Demand is High) and (Cassava__Availability is Medium) then (Optimal__Production__Ampout is Medium) (1)
9. If (Demand is High) and (Cassava__Availability is High) then (Optimal__Production__Ampout is High) (1)

Figure 7. Fuzzy Rules for Optimal Production Amount in Matlab Application

Fuzzy Operator Value Determination

Based on the results of interviews that have been conducted, the fuzzy operator used in fuzzy rule based is an AND operator. The AND operator indicates that the value of the selected parameter will be compared using the minimum value with the aggregation used which is the maximum value. Based on the predetermined membership degree, the fuzzy operator value will be obtained as follows:

a. Demand Medium and Cassava Availability Medium

$\alpha_1 = \min\ (\mu_{\text{demand\_medium}}[400] \cap \min\ \mu_{\text{cassava Availability\_medium}}[2000])$

$= min\ (1; 0)$

$= 0$

b. Demand Medium and Cassava Availability High

$\alpha_2 = \min\ (\mu_{\text{demand\_medium}}[400] \cap \min\ \mu_{\text{cassava availability\_high}}[2000])$

$= min(1; 0\ 75)$

$= 0\ 75$

c. Demand High and Cassava Availability Medium

$\alpha_3 = \min\ (\mu_{\text{demand\_high}}[400] \cap \min\ \mu_{\text{cassava availability\_medium}}[2000])$

$= min\ (0; 0)$

$= 0$

d. Demand High and Cassava Availability High

$\alpha_4 = \min\ (\mu_{\text{demand\_high}}[400] \cap \min\ \mu_{\text{cassava availability\_high}}[2000])$

$= min\ (0; 0{,}75)$

$= 0$

The results of the calculation of the operator value that have been carried out show that the operator value to be used is 0.75. The value of this operator indicates that the condition of the selected rule is *If Demand is Medium and Cassava Availability is High then Optimal Production Amount is High* (Rule 6).

Fuzzy Set Area.

The determination of the fuzzy area is obtained through a predetermined operator value of 0.75. The value is in rule 6, where when demand is in moderate parameters and cassava availability is high, tapioca's optimal production amount is in high parameters. Next, to formulate the area of the fuzzy area, it is necessary to determine the value of x purpose function. The result of calculating the x value of the goal function is as follows:

$$\alpha = \frac{\text{x} - 500}{700 - 500}$$

$$0{,}75 = \frac{\text{x} - 500}{700 - 500}$$

$$0{,}75 = \frac{\text{x} - 500}{200}$$

$$150 = \text{x} - 500$$

$$x = 650$$

The x value of the goal function that has been obtained shows 2 fuzzy set areas that are limitations in producing optimal production amount. The limit values (Zn) include Z1=500, Z2=650 and Z3=700. The formulation of fuzzy set area is shown in Figure 8.

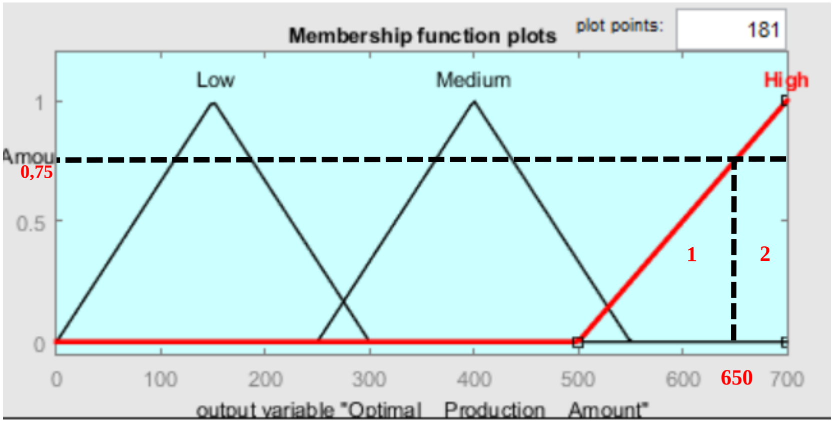

Figure 8. Fuzzy Set Area

Based on the formulation of the area above, the results of the calculation of the area of the fuzzy area are as follows.

$$\begin{aligned} LD_1 &= \frac{150 \times 0.75}{2} \\ &= \frac{112{,}5}{2} \\ &= 56{,}25 \end{aligned}$$

$$\begin{aligned} LD_2 &= 50 \times 0.75 \\ &= 37{,}5 \end{aligned}$$

Determining Moment

In the fuzzy model of the system predicting the optimal production amount of tapioca, with variable input demand of 400 kg and availability of production amount of 2000 kg, the amount of production that occurs is within high parameters. Based on these conditions, the function of the fuzzy membership set of the optimal amount of production selected is as follows:

$$F_{x(a,b,c)} = \begin{cases} 0 & x \le 500 \cup x > 700 \\ \dfrac{x - 500}{700 - 500} & 500 < x < 650 \\ 0{,}75 & 650 \le x \le 700 \end{cases}$$

Based on the fuzzy set of optimal production amount above, the moment of each predetermined area can be determined. The calculation of the moment is carried out referring to the fuzzy set function contained in the model in each region. The moment values for each region of the fuzzy membership set are as follows:

$$\begin{aligned} M_1 &= \int_{500}^{650} (0\ 005x - 2\ 5)x\, dx \\ &= \int_{500}^{650} (0\ 005x^2 - 2\ 5x)\, dx \\ &= 33750 \end{aligned}$$

$$\begin{aligned} M_2 &= \int_{650}^{700} (0\ 75)x\, dx \\ &= \int_{650}^{700} (0\ 75x)\, dx \\ &= 25312\ 5 \end{aligned}$$

Defuzzification

Based on the area and moment that has been determined, the optimal number of tapioca predictions can be calculated through the defuzzification process based on the Center of Area (COA) method. The following is the result of the calculation of defuzzification:

$$Z^* = \frac{\sum \text{Moment}}{\sum \text{Area}}$$

$$= \frac{M_1 + M_2}{LD_1 + LD_2}$$

$$= \frac{33750 + 25312\ 5}{56\ 25 + 37\ 5}$$

$$= \frac{59062\ 5}{93\ 75}$$

$$= 630$$

The defuzzification results obtained by comparing the total moment and total area showed a figure of 630 kg as the output of the optimal production amount of tapioca with input demand of 400 kg and cassava availability of 2000 kg. The calculated defuzzification results are then checked using Matlab software. The results on Matlab show a figure of 632 kg as seen in Figure 9. Although there is a small difference between the defuzzification results obtained and the Matlab results, the level of accuracy is still considered high considering the error factors that may occur.

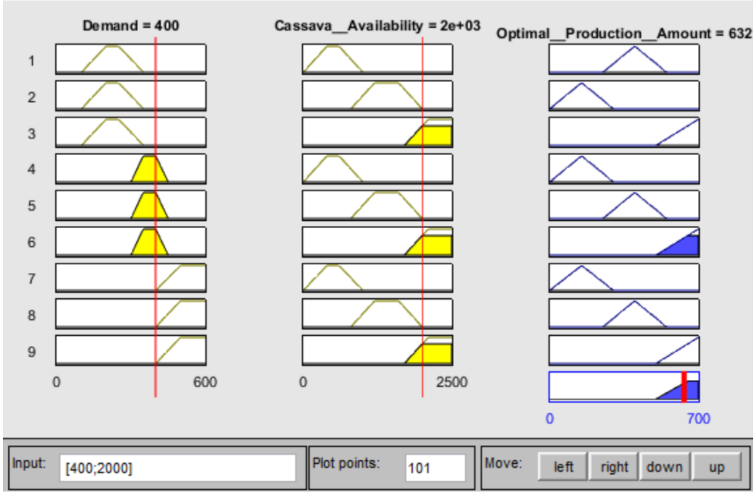

Figure 9. Fuzzy Model of Tapioca Optimal Production Amount Prediction System Using Matlab

The development of a fuzzy model of the optimal amount of tapioca production can be used to help Tapioca SMIs determine the optimal production amount based on market demand and the availability of cassava raw materials owned. The development of a tapioca optimal production amount model using Matlab R2015a software can reduce the risk of production inefficiencies and losses and improve the balance between supply and demand.

CONCLUSION

Successfully developed a fuzzy logic approach model to predict the optimal amount of tapioca production based on cassava demand input and availability variables. By using fuzzy logic, the model can provide output that matches the conditions of market demand and the availability of raw materials.

Simulations using the Matlab R2015a application have proven the consistency of output values obtained through the fuzzy inference system method. This shows that the model can reliably determine the decision on the amount of tapioca production by considering demand factors and raw material availability. The development of this model can also reduce the risk of production inefficiencies and losses and improve the balance between supply and demand.

ACKNOWLEDGMENT

The author would like to thank College of Vocational Studies IPB University, specifically the Computer Engineering Technology Study Program, lecturers and teaching assistants who have facilitated and provided guidance and guidance in making this journal article. The author also wants to express his gratitude to Mr. Agus as a resource person from SMI Tapioca who has provided data and information to support the writing of this article. Not to forget, thank you to family and friends who always provide moral support and enthusiasm in this writing process. Hopefully this journal article can make a positive and useful contribution to readers.

REFERENCES

Badan Pusat Statistik (BPS). (2020). *Statistik Industri Pengolahan Singkong dan Tepung Tapioka 2020*. Jakarta: BPS.

Badan Pusat Statistik (BPS). (2021). *Statistik Industri Pengolahan Singkong dan Tepung Tapioka 2021*. Jakarta: BPS.

Badan Pusat Statistik (BPS). (2021). *Harga Konsumen Bahan Makanan Pokok Nasional per Provinsi*. Jakarta: BPS.

Blanco-Mesa, F., Merigó, J. M., & Gil-Lafuente, A. M. (2017). Fuzzy Decision Making: A Bibliometric-Based review. *Journal of Intelligent and Fuzzy Systems*, *32*, 2033–2050. https://doi.org/10.3233/JIFS-161640

Darwanto, Dinata, K. B., & Junaidi. (2020). *Teori Himpunan* (P. B. Nugroho (ed.); 1st ed.). Universitas Muhammadiyah Kotabumi.

Davvaz, B., Mukhlash, I., & Soleha, S. (2021). Himpunan Fuzzy dan Rough Sets. *Limits: Journal of Mathematics and Its Applications*, *18*(1), 79. https://doi.org/10.12962/limits.v18i1.7705

FAO, IFAD, UNICEF, WFP, & WHO. (2018). The State of Food Security and Nutrition in the World. In *Food and Agriculture Organization of the United Nations,*. www.fao.org/publications%0Ahttp://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1152267/

Fattahillah, G., Merdeka, P., & Nurkertamanda, D. (2020). Identifikasi 9 Waste Beserta Usulan Rekomendasi Perbaikan pada Proses Produksi Side Link dengan Pendekatan Lean Manufacturing pada Divisi Infrastruktur Perhubungan PT PINDAD (Persero). *Industrual Engineering Online Journal*, *12*(3). https://ejournal3.undip.ac.id/index.php/ieoj/article/view/40323

Ginanjar, R. A. (2018). Analisis Efisiensi Industri Pengolahan Tepung Tapioka (Studi pada Desa Rembangkepuh Kecamatan Ngadiluwih Kabupaten Kediri). *Jurnal Ilmiah Mahasiswa FEB, 6*(2). https://jimfeb.ub.ac.id/index.php/jimfeb/article/view/4842

Haerani, E. (2014). Analisa Kendali Logika Fuzzy dengan Metode Defuzzifikasi COA (Center of Area), Bisektor, MOM (Mean of Maximum), LOM (Largest of Maximum), dan SOM (Smallest of Maximum). *SITEKIN: Jurnal Sains, Teknologi Dan Industri*, *10*(2), 245–253. http://dx.doi.org/10.24014/sitekin.v10i2.543

Hartanto, S. (2017). Implementasi Fuzzy Rule Based System untuk Klasifikasi Buah Mangga. *Techsi*, *9*(2), 103–122. https://doi.org/10.29103/techsi.v9i2.217

Herdiyandi, Rusman, Y., & Yusuf, M. N. (2016). Analisis Nilai Tambah Agroindustri Tpung Tapioka di Desa Negaratengah Kecamatan Cineam Kabupaten Tasikmalaya (Studi Kasus pada Seorang Pengusaha Agroindustri Tepung Tapioka di Desa Negaratengah Kecamatan Cineam Kabupaten Tasikmalaya). *Jurnal Ilmiah Mahasiswa Agroinfo Galuh*, *2*(2), 81–86. https://doi.org/10.25157/jimag.v2i2.62

Hidayat, A. P., Santosa, S. H., & Siskandar, R. (2022). Penentuan Jumlah Kebutuhan Bahan Baku Berdasarkan Distribusi Barang Ideal di IKM Tepung Tapioka Kabupaten Bogor. *Jurnal INTECH Teknik Industri Universitas Serang Raya*, *8*(1), 23–28. https://doi.org/10.30656/intech.v8i1.4400

Indra. (2016). Penerapan Logika Fuzzy untuk Menentukan Jumlah Produksi Beras Berdasarkan Data Persediaan dan Jumlah Permintaan (Studi Kasus UD Siregar Wonomulyo). *JTRISTE*, *3*(2), 87–98. https://jurnal.kharisma.ac.id/jtriste/article/download/66/60/

Kartika, D., Sovia, R., & Sandawa, H. M. (2018). Penerapan Metode Fuzzy Mamdani untuk Memprediksi Angka Penjualan Token Berdasarkan Persediaan dan Jumlah Permintaan pada PT. PLN (Persero) Padang Berbasis Web. *KomTekInfo*, *5*(1), 81–95. https://doi.org/https://doi.org/10.35134/komtekinfo.v5i1.8

Kharisma, L. P. I., Yahya, S. R., Sepriano, Handayanto, R. T., Herlawati, Gunawan, I. M. A. O., Handika, I. P. S., Hatta, H. R., & Syamsil, A. (2023). *Metode SPK Favorit di Masa Depan (Teori dan Contoh)* (A. Juansa & Efrita (eds.); 1st ed.).

Kusnadi, N. A. (2022). Pengaruh Fluktuasi kharga komoditas pangan terhadap inflasi di Provinsi Jawa Timur. *Jurnal Ilmiah Mahasiswa FEB*, *6*(2), 1–19. https://jimfeb.ub.ac.id/index.php/jimfeb/article/view/5128/4504

Li, Y. Z., Zhao, J. Y., Wu, S. M., Fan, X. W., Luo, X. L., & Chen, B. S. (2016). Characters Related to Higher Starch Accumulation in Cassava Storage Roots. *Scientific Reports*, *6*(September 2015), 1–17. https://doi.org/10.1038/srep19823

Mamdani, E. H. (1976). Advances in The Linguistic Synthesis of Fuzzy Controllers. *International Journal of Man-Machine Studies*, *8*(6), 669–678. https://doi.org/10.1016/S0020-7373(76)80028-4

Nopiani, S. W., Noor, T. I., & Sudrajat. (2019). Analisis Nilai Tambah Agroindustri Tepung Tapioka (Studi Kasus pada Agroindustri Tepung Tapioka "Madur" di Desa Bojongasih Kecamatan Bojongasih Kabupaten Tasikmalaya). *Jurnal Ilmiah Mahasiswa Agroinfo Galuh*, *6*(2), 377–386. http://dx.doi.org/10.25157/jimag.v6i2.2496

Novaldi, A. A., Miranda, C., & Nurhayati, A. D. (2022). Teknik Budi Daya dan Karakteristik Ubi Kayu (Manihot esculenta Crantz) di Desa Leuwisadeng, Kecamatan Leuwisadeng, Kabupaten Bogor, Jawa Barat. *Jurnal Pusat Inovasi Masyarakat (PIM)*, *4*(1), 8–16. https://doi.org/10.29244/pim.v4i1.38142

Pangkatodi, E., Liliana, & Budhi, G. S. (2016). Implementasi Rule Base System dan Fuzzy Logic Artifical Intelligence pada Game Kartu Capsa. *Jurnal Infra*, *4*(1), 1–7.

Santosa, S. H., & Hidayat, A. P. (2019). Model Penentuan Jumlah Pesanan Pada Aktifitas Supply Chain Telur Ayam Menggunakan Fuzzy Logic. *Jurnal Ilmiah Teknik Industri*, *18*(2), 224–235. https://doi.org/10.23917/jiti.v18i2.8486

Santosa, S. H., Sulaeman, S., Hidayat, A. P., & Ardani, I. (2020). Fuzzy Logic Approach to Determine the Optimum Nugget Production Capacity. *Jurnal Ilmiah Teknik Industri*, *19*(1), 70–83. https://doi.org/10.23917/jiti.v19i1.10295

Sholihah, E., & Jaelani. (2023). Penerapan MFCA dengan Lean Tools. *JRIME : JURNAL RISET MANAJEMEN DAN EKONOMI*, *1*(2), 249–277. https://doi.org/10.54066/jrime-itb.v1i2.649

Shuhaila, D., Maulidan, M. H., Satrio, M. A., Wijayanyo, A. D., Darmawan, M. D. M., Nurfadillah, F., & Octavia, N. (2024). Application of Fuzzy Logic to Predict Rice Production Quantity in Bogor Regency. *Journal of Applied Science, Technology & Humanities*, *1*(2). http://dx.doi.org/10.62535/cbrrmp50

Simanjuntak, P., Suharyanto, C., & Khairiyah, R. (2018). Fuzzy Sugeno untuk Menentukan Penilaian Kompetensi Karyawan PT. Schneider Batam. *Information System Development (ISD)*, *3*(2), 97–103. https://doi.org/https://doi.org/10.31227/osf.io%2F7dph8

Subekti, I., Khumaida, N., Ardie, S. W., & Syukur, D. M. (2018). Evaluasi Hasil dan Kandungan Pati Mutan Ubi Kayu Hasil Iradiasi Sinar Gamma Generasi M1V4. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *46*(1), 64. https://doi.org/10.24831/jai.v46i1.17610

Surmaini, E., & Faqih, A. (2016). Extreme Climate Events and their Impacts on Food Crop in Indonesia. *Jurnal Sumberdaya Lahan*, *10*(2), 115–128. https://epublikasi.pertanian.go.id/berkala/jsl/article/download/3357/3390/4303

Suryani, R. (2020). Outlook Ubi Kayu: Komoditas Pertanian Subsektor Tanaman Pangan. In *Pusat Data dan Sistem Informasi Pertanian Sekretariat Jenderal Kementerian Pertanian*.

Sutikno. (2018). Perbandingan Metode Defuzzifikasi Sistem Kendali Logika Fuzzy Model Mamdani pada Motor Dc. *Jurnal Masyarakat Informatika*, *2*(3), 27–38.