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Implementation of Fuzzy Inference System to Determine Production of Bakpia Using Tsukamoto Method

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Abstract - *The marketing process is closely related to several integrated activities, including determining the target market, using promotional items, placing items correctly. On the other hand, cases of selling products that are of no quality or have expired for safe use are therefore referred to as expired products. This incident has a bad impact on the community as consumers because they are the aggrieved parties, and sellers and producers will receive complaints about their products that are not of good quality, which is likely to reduce sales turnover in the future.*

The Yogyakarta Portrait Company is a company that produces bak pia, which has an expiration date. Bakpia Potret's quality targets are good quality materials, timely delivery, efficient costs and good service with a fast response. Therefore, to manage the amount of Production based on Demand will use the Fuzzy Tsukamoto Method so that the accumulation of production can be as small as possible and can be avoided. The Fuzzy Tsukamoto method is a method that has tolerance for data and is very flexible. In the Tsukamoto method, each rule is represented by a fuzzy set with a monotonic membership function called fuzzification.

The results of the calculation in the study show the correlation between Production and Demand is 0.99. This shows the amount of Production is affected or a very strong relationship with Demand. The correlation value is 0.99 > 0 (positive), meaning that the greater the demand for, the greater the number of productions. The form of the rule or rules that are made can show the actual conditions so that it can be used as a decision-making tool in terms of producing goods, namely bak pia at the Bakpia Portrait Jogjakarta enterprise.

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Keywords – *Expired, demand, production, fuzzy Tsukamoto.*

I. INTRODUCTION

In the era of globalization, competition in business is increasing sharply (Glandon *et al.*, 2019, Yang *et al.*, 2021). The ease of obtaining information through various media has resulted in the business being demanded to be more competitive (Fichter & Tiemann, 2020, Callarisa *et al*., 2012, Fransiska *et al.*, 2012). Companies are not only required to maintain the performance that has been achieved but also has to improve the existing service level in meeting consumer demand and winning the competition. Determination of the amount of production holds an important factor for the production process is closely related to several integrated activities. Determine the target market, sales results data, and previous production. To obtain optimal profit, one of them is in determining the amount of production. Likewise, what must be applied to the Bakpia Potret Djokja enterprise, the determination of the amount of production must be precise so that it will optimize production costs.

Research using expert systems has been carried out/ De Pilli (2021) implemented a fuzzy logic system for the pizza production processing optimization. The result indicated that the induction process showed the scanty influence of gluten on sensory properties, and oven temperature and hydration level offset the poor quality of the flour. Other works on the application of fuzzy logic in business have also been reported by Kozarević & Puška (2018) and Petropoulos *et al*. (2017). The used fuzzy logic for measuring practices and performances of supply chain and for classifying wine quality, accordingly

Bakpia is a typical food of Yogyakarta, which of course, has a limited expired time for consumption. There are many cases where the sale of products are expired products impact consumer health. This incident has a bad impact on the community as consumers because they are the aggrieved parties, and sellers and producers will receive complaints about their products that are poor quality which may in the future reduce their sales turnover. Even though physically they look fine, in fact every product which has expired is dangerous for long terms consumed. To minimize expired products, companies must be able to control products so that production can be optimally absorbed by the community. So far, the Bakpia Potret enterprise determines the amount of production based on the store's demand, but it doesn't calculate the correct amount of product to meet the store's needs. So that when the products are not sold out, the remains are thrown away. This has an impact on the company in the form of material losses. The purpose of this research is to propose the right production strategy to Bakpia Potret Djokja enterprise in determining the amount of production. The Tsukamoto method is used as a method that will calculate how many items will be produced so that there is no excess supply that risks from expired.

II. MATERIALS & METHODS

A. Data Collection

Firstly, data regarding demand, production, and supply of Bakpia Potret are collected online within 7 weeks. Table 1 present the data collection of production and selling average in a week

TABLE 1.
Production and selling average in a week

No	Production and selling average (per week)	Total
1	Minimum demand	15000
2	Maximal demand	21000
3	Production capacity	22000
4	Minimum production	18000
5	Minimum supply	1500
6	Maximal supply	2500

The company's production process uses 4 (four) rules as follows:

[R$_1$] IF demand DOWN And Supply MORE THEN Production REDUCE

[R$_2$] IF demand DOWN And Supply LESS THEN Production REDUCE

[R$_3$] IF demand UP And Supply MORE THEN Production INCREASE

[R$_4$] IF demand UP And Supply less THEN Production INCREASE

B. Member Function and Calculation

There are three fuzzy variables to be modelled, namely as follows:

a) Demand: there are 2 fuzzy sets, UP and DOWN

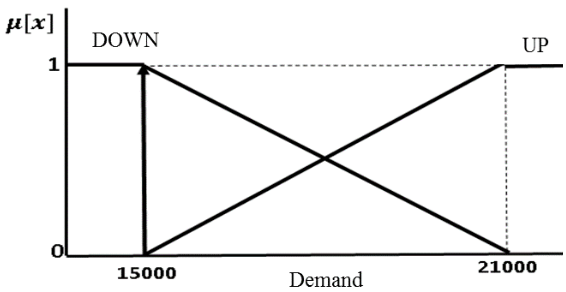

Fig 1. The function of demand per week

$$\mu_{Demand,DOWN}[x] = \begin{cases} 1, & x \leq 15000 \\ \dfrac{21000 - x}{21000 - 15000}, & 15000 \leq x \leq 21000, \\ 0, & x \geq 21000 \end{cases}$$

$$\mu_{PDemand,UP}[x] = \begin{cases} 0, & x \leq 15000, \\ \frac{x-15000}{21000-15000}, & \\ 1, & x \geq 21000 \end{cases}$$

$15000 \leq x \leq 21000$

Value of the function:

$$\mu_{Demand,DOWN}[15000] = \frac{21000-15000}{21000-15000} = 1$$

$$\mu_{Demand,UP}[15000] = \frac{15000-15000}{21000-15000} = 0$$

b) Supply: there are 2 fuzzy sets, LESS and MORE

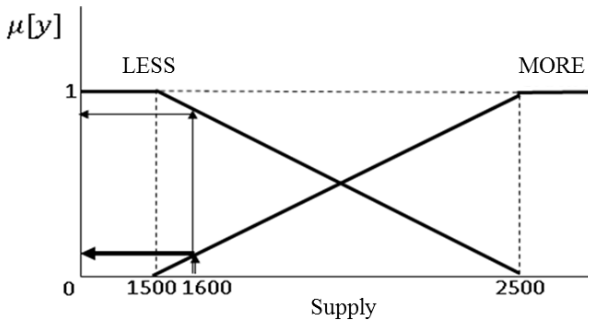

Fig. 2. The function of supply per week

$$\mu_{Supply,LESS}[y] = \begin{cases} 1, y \leq 1500 \\ \dfrac{2500 - y}{2500 - 1500}, 1500 \leq y \leq 2500 \\ 0, y \geq 2500 \end{cases}$$

$$\mu_{Supply,MORE}[y] = \begin{cases} 0, y \leq 1500 \\ \dfrac{y - 1500}{2500 - 1500}, 1500 \leq y \leq 2500 \\ 1, y \geq 2500 \end{cases}$$

Value of a function:

$$\mu_{Supply,LESS}[1600] = \frac{2500-1600}{2500-1500} = 0.9$$

$$\mu_{Supply,MORE}[1600] = \frac{1600-1500}{2500-1500} = 0.1$$

c) Production: consists of 2 fuzzy sets, REDUCE and INCREASE

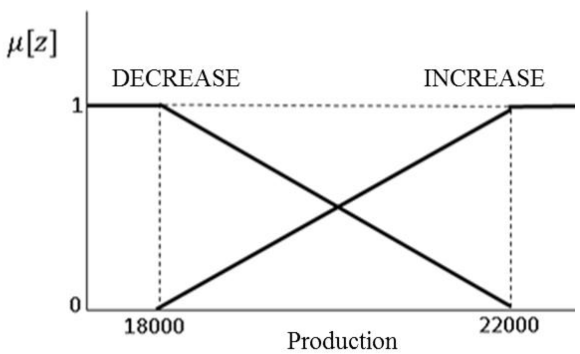

Fig. 3. The function of production per week

$$\mu_{Production\ REDUCE}[z] = \begin{cases} 1, z \leq 18000 \\ \dfrac{22000 - z}{22000 - 18000}, 18000 \leq z \leq 22000 \\ 0, z \geq 22000 \end{cases}$$

$$\mu_{Production\ INCREASE}[z] = \begin{cases} 0, z \leq 18000 \\ \dfrac{z - 18000}{22000 - 18000}, 18000 \leq z \leq 22000 \\ 1, z \geq 22000 \end{cases}$$

C. Tsukamoto Method Inference System

The z value is searched for each rule by using the MIN function in the implication function application. Because it uses the AND operator on every rule (rules). Then the final result is obtained using the weighted average.

[R$_1$] IF demand DOWN And Supply MORE THEN Production REDUCE

$$\begin{aligned} \alpha - predicate_1 &= \mu_{demand\ DOWN \cap Supply\ MORE} \\ &= \min(\mu_{demand\ DOWN}, \mu_{Supply\ MORE}) \\ &= minimum(1 ; 0.1\ ) \\ &= 0.1 \end{aligned}$$

See fuzzy set Production DECREASE

$\frac{22000-z}{22000-18000} = 0.1$, Thus $22000 - z = 0.1\ (4000)$

$$z_1 = 22000 - 400$$

$$= 21600$$

[R$_2$] IF demand DOWN And Supply LESS THEN Production REDUCE

$$\begin{aligned} \alpha - predicate_2 &= \mu_{Demand\ DOWN \cap Supply\ LESS} \\ &= \min(\mu_{Demand\ DOWN}, \mu_{Supply\ LESS}) \\ &= minimum(1\ ;\ 0.9\ ) \\ &= 0.9 \end{aligned}$$

See Fuzzy set Production REDUCE

$\frac{22000-z}{22000-18000} = 0.9$, thus $22000 - z = 0.9\ (4000)$

$$z_2 = 22000 - 3600$$

$$= 18400$$

[R$_3$] IF demand UP And Supply MORE THEN Production INCREASE

$$\begin{aligned} \alpha - predicate_3 &= \mu_{Demand\ UP \cap Supply\ MORE} \\ &= \min(\mu_{Demand\ UP}, \mu_{Supply\ MORE}) \\ &= minimum(\ 0 ; 0.1\ \ ) \\ &= 0 \end{aligned}$$

See fuzzy set Production INCREASE

$\frac{z-18000}{22000-18000} = 0$, thus $z - 18000 = 0$

$$z_3 = 18000 + 0$$

$$= 18000$$

[R$_4$] IF demand UP And Supply LESS THEN Production INCREASE

$$\begin{aligned} \alpha - predicate_4 &= \mu_{Demand\ UP \cap Supply\ LESS} \\ &= \min(\mu_{Demand\ UP}, \mu_{Supply\ LESS}) \\ &= minimum(0\ ;\ 0.9\ ) \\ &= 0 \end{aligned}$$

See fuzzy set Production INCREASE

$\frac{z-18000}{22000-18000} = 0$, thus $z - 18000 = 0.(4000)$

$$z_4 = 18000 + 0$$

$$= 18000$$

III. RESULTS & DISCUSSION

The weighted average to find the value of z, which is the number of goods that must be produced:

$$\begin{aligned} z &= \frac{\alpha - predicate_1 * z_1 + \alpha - predicate_2 * z_2 + \alpha - predicate_3 * z_3 + \alpha - predicate_4 * z_4}{\alpha - predicate_1 + \alpha - predicate_2 + \alpha - predicate_3 + \alpha - predicate_4} \\ &= \frac{0.1 * 21600 + 0.9 * 18400 + 0 * 18000 + 0 * 18000}{0.1 + 0.9 + 0 + 0} \\ &= \frac{2160 + 16560 + 0 + 0}{1} \\ &= \frac{18720}{1} \\ &= 18720 \end{aligned}$$

So, with an order of 15000 and an inventory of 1600, the company must produce 18720 units. In the following table, the application from Tsukamoto will be shown for various orders with an existing inventory of 1600, for 6 weeks minimum inventory of 1500, maximum inventory of 2500, maximum request of 21000, minimum request of 15000, and production capability of 22000 using the same membership rules and functions.

From the calculation, the following results are obtained, as shown in Fig 4. The number of production of goods is always more than the number of requests. The increase in demand turns out to be an increase in the number of production

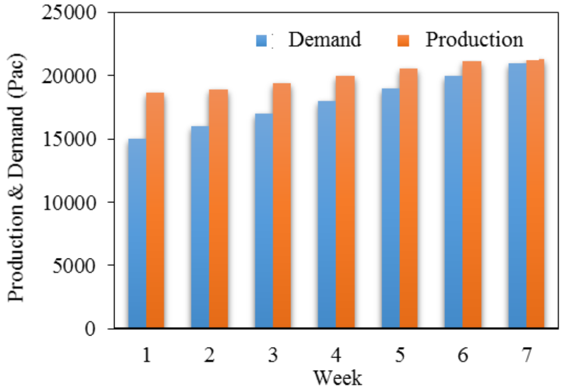

Fig. 4. Production and Demand

Meanwhile, from Fig 5, it can be figured out that: (1) If the increase in demand increases continuously with a constant difference from the previous one, it will approach the maximum production and will tend to approach the same point, (2) Changes in the Demand variable are followed by changes in the Production variable regularly in the same direction. This indicates a correlation between the two variables, and (3)The correlation coefficient of the two variables can be calculated by determining the X variable for Demand and Y for the amount of Production as given in Table 3.

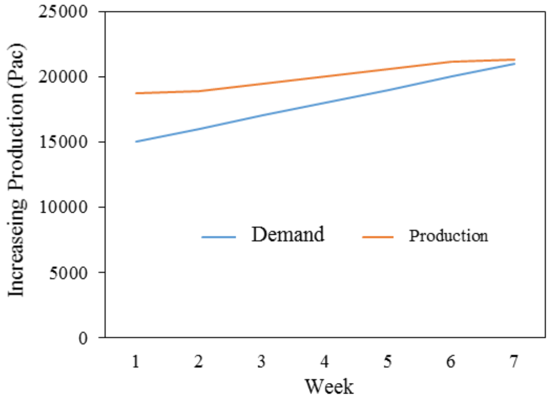

Fig. 5. Production Increase

TABLE 2.
Relation of Demand and Production Quantity

n	X	Y	X^2	Y^2	XY
1	15000	18720	225000 000	350438 400	28080000 0
2	16000	18889	256000 000	356794 321	30222400 0
3	17000	19444	289000 000	378069 136	33054800 0
4	18000	20000	324000 000	400000 000	36000000 0
5	19000	20555	361000 000	422508 025	39054500 0
6	20000	21109	400000 000	445589 881	42218000 0
7	21000	21280	441000 000	452838 400	44688000 0
Σ	126000	139997	229600 0000	280623 8163	25331770 00

From Table 3, correlation coefficient *r* becomes:

$$r = \frac{7.2533177000 - 126000.\ 139997}{\sqrt{7.2296000000 - 126000^2}.\sqrt{7.2806238163 - 139997^2}}$$

$$= \frac{177322390000 - 17639622000}{\sqrt{16072000000 - 15876000000}.\ \sqrt{19643667141 - 19599160009}}$$

$$= \frac{92617000}{\sqrt{196000000}.\sqrt{44507132}}$$

$$= \frac{93037000}{14000\ .\ 6671{,}36657}$$

$$= \frac{93037000}{93399133}$$

$$= 0.99$$

IV. CONCLUSIONS

It can be concluded that:

1 There is a very significant correlation between the Demand variable and the Production variable.

2 The results of the study show a correlation value of 0.99 or close to 1 (one), meaning that the relationship between the Demand variable and the Production variable is very strong, or the amount of Production is influenced by the amount of Demand.

3 The correlation value is 0.99 > 0 (positive), meaning that the greater the demand for, the greater the number of productions.

4 The form of the rule or the rules made can show the actual conditions so that it can be used as a decision-making tool in terms of producing goods, namely bak pia at the Bakpia Portret Jogjakarta enterprise

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