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Implementation of Fuzzy Logic on the Feasibility of Duck Egg Quality

Khairunnissa Zahran Ansyafa[1*]
[1]Computer Engineering Technology, College of Vocational Studies, IPB University
zahransyf1802ansyafa@apps.ipb.ac.id

Dhiya Rizqi Bagus Wibowo[2], Edmund Banyu Kauripan[3], Nabil Arif A'isy[4], Muhamad Fadhil[5], Inna Novianty[6], Nanda Octavia[7], Ivan De NeroI[8]
[2345678]Computer Engineering Technology, College of Vocational Studies, IPB University
dhiyarizqi@apps.ipb.ac.id , edmundbanyu@apps.ipb.ac.id , nabilarifaisy@apps.ipb.ac.id , muhamadfadhil@apps.ipb.ac.id , innanovianty@apps.ipb.ac.id , naocavianda@apps.ipb.ac.id , ivandenerolivan@apps.ipb.ac.id

Abstract

Eggs are a staple food, with chicken eggs being the most common choice. However, duck eggs are gaining popularity due to their nutritional value. Ducks, a local poultry breed, are seeing increased interest, leading to a growth in the national duck population. Duck eggs themselves are one source of animal protein that is rich in nutrients and easily digested. Duck eggs have a very high protein content, which is 13.1 grams per 100 grams. The purpose of building a decision support system for duck egg selection is to help people choose quality duck eggs for consumption. Data collection techniques in this study use literature studies and include direct calculations and using MATLAB software to develop a Fuzzy logic system in determining the feasibility of duck egg quality. The results showed that in the example case for a duck egg that weighs 5.5 grams and then the thickness of the shell is 7.5 mm and the viscosity of the egg contents is given a number of 7, then the egg is still said to be suitable for consumption. This contributes to improving food quality in Indonesia by classifying the feasibility of eggs for public consumption.

Keywords : Duck Egg , Feasibility, Fuzzy Logic Concept

INTRODUCTION

Ducks are domestic birds that produce eggs and meat. The increasing public interest in duck farming is reflected in the growth of the duck population nationally which continues to increase. This increase in interest is due to the advantages of ducks as poultry, including their greater resistance to disease and smaller risks in livestock production (Herawati &; Setiyowati, 2020). In Indonesia, ducks are poultry that are commonly kept by the lower middle class in rural areas because they have many advantages and relatively easy maintenance. According to Hardjosworo, ducks or ducks are the first livestock to be cultivated as a source of income, the benefits obtained are also diverse, one of which is that the eggs produced by these ducks can be used for direct consumption or sold. In addition, ducks can also be sold at a fairly higher selling price than poultry such as chickens that are usually raised or raised by the community (Putra et al., 2018).

Eggs contain many nutrients that are needed by the human body and are one of the highly nutritious animal foods (Dharmawibawa, 2022) such as amino acids that are easily digested (Worang et al., 2022) Because eggs contain a complete composition of essential amino acids, eggs are used as a benchmark in determining the protein quality of various food ingredients (Purwati D, Djaelani MA, 2015) In everyday life eggs are one of the foods that are often consumed, although most people tend to consume only chicken eggs. Each egg contains different amounts of protein, fat, calories, vitamins, and minerals (Basuki et al., 2016)

Duck eggs themselves are one source of animal protein that is very nutritious and easily digested. Duck eggs have a very high protein content, which is 13.1 grams per 100 grams compared to chicken eggs which are 12.8 grams (Nuruzzakiah, Hafnati Rahmatan, 2016). Because of its chemical content and especially its nutritional value, eggs are a highly recommended food product for child growth, the health of pregnant and lactating women, and the elderly. Duck eggs are rich in minerals, vitamin B6, pantothenic acid, vitamin A, vitamin E, and vitamin B12.(Agus Wantoro, n.d.).

In fact, duck eggs have several advantages compared to chicken eggs, mainly due to their higher content of nutrients such as protein, vitamins, and minerals. According to nutritional data from the United States Department of Agriculture, one raw duck egg contains about 9 grams of protein, which is equivalent to about 18 percent of the average person's daily protein needs. Protein is an important component for our body, it is needed in sufficient quantities every day because it acts as the main ingredient in the formation of various body tissues. (Sonia & Khodijah, 2017)

The price of duck eggs is more expensive than chicken eggs. This can happen due to the size and preference of the community itself towards duck eggs rather than chicken eggs. Based on BPS data in 2021, it shows that duck egg commodities experienced an increased average growth and duck egg prices experienced the highest increase of 0.73% from the price of Rp. 3,297/grain to Rp. 3,321/grain (Fanta et al., 2023)

Visually assessing the quality of duck eggs to distinguish normal and non-normal is still a considerable challenge. Therefore, many farmers and the public are more likely to judge duck eggs only in terms of physical appearance, such as by looking at the outer shell of the egg or shaking it to determine that it is still feasible and good. This case is commonly referred to as normal and abnormal. According to Saifullah (2017) to determine the quality of eggs based on their good content or not, it can be done by soaking eggs to see whether the eggs are heavy or light, as well as through manual visual observation (Saifullah et al., 2017). According to Faraditha (2016) that egg quality criteria are determined based on the quality of egg yolks that have a round shape with a bright yellow color without blood stains or spots and do not contain embryos or fetuses for consumption. Another study conducted by (Sela & Ihsan, 2017) in determining the quality of eggs, namely by analyzing eggshell texture. Similarly, research conducted by Ruslianto (2013), classifies the quality of eggs from previous studies to have almost the same shape (Rismawati & Mulya, 2018)

Egg quality can be interpreted as a set of characteristics owned by eggs so that they can influence consumer decisions (Ayu Rahayu, 2020). The lack of information obtained by the community causes them to be less careful about the selection of good eggs and the habits of people who choose them because the color factor of the eggshell or the contents do not shake, therefore a decision support system (SPK) for the selection of quality duck eggs using fuzzy logic is needed.

Fuzzy logic methodology is a highly relevant approach in system management and problem solving that ranges from simple to complex. Fuzzy logic can be widely applied covering various fields, from disease diagnosis systems in medicine to marketing system modeling, operations research in economics, water quality control, and even earthquake event prediction (Irawan & Herviana, 2019).

Fuzzy logic was introduced in 1965 by Professor Lutfi A. Zadeh of the University of California at Berkeley in computer science. He discovered that conventional logic that contains only absolute truth and error cannot fully describe human thinking. Alternatively, he developed the concept of fuzzy logic that could better represent complex circumstances and represent human thought. The main difference between firm logic and fuzzy logic is in the way the members of elements in a set are determined. In strict logic, an element can have only true (1) or false (0) values, whereas in fuzzy logic, element membership can vary in the range from 0 to 1. One of the reasons for using fuzzy logic is because the concept is easier to understand, because it uses natural language that has been known by humans. (Nisa et al., 2020).

Fuzzy logic is a useful approach to modeling complex situations because the development of mathematical models is difficult. The output value can be used to input other algorithms (Nanang Nggufron , Rochmad, 2020). This logic has similarities with the way of thinking of a human being that

has been widely applied in various real situations including for production optimization using fuzzy linear programming. In addition, this logic can be applied in solving traveling salesman problems using the help of the matlab application (Fitriana, 2014)

From the description above, the author feels interested in developing a system by applying "Implementation of Fuzzy Logic on the Feasibility of Duck Egg Quality". The system is a system to help the selection of duck eggs so that their quality and feasibility are safe as seen from the eggshell, egg white, and yolk.

METHOD

This type of research is descriptive research with a qualitative approach. The method used in this study is fuzzy logic using the fuzzy mamdani method. The Fuzzy Mamdani method is one approach in decision support that has advantages in intuitive aspects, acceptable to various parties, and applicable in the field of statistics. In addition, this method also produces output that is closer to the real state, flexible and has tolerance from existing data compared to other forecasting methods, this approach is much more efficient in using numbers (Muntahanah et al., 2021). The advantage of Fuzzy Mamdani is that it is more intuitive and acceptable to many parties. Determination of analysis based on the fuzzy approach is more efficient in the approach in the numerical approach (Maryam et al., 2021) The use of fuzzy mamdani logic is used to determine the feasibility of the quality of a duck egg, which aims to allow people to distinguish the quality of good duck eggs from poor quality duck eggs. Here are some steps in determining the quality of egg feasibility by applying Fuzzy Logic using the Fuzzy Mamdani Method:

1. Literature Study

   Literature study is a method to collect data by understanding and studying theories relevant to research from various literature sources (Adlini et al., 2022) This literature study involves the study and analysis of various books, journals, theses, theses, articles, and reports from related institutions related to the research topic being conducted. (Susandi & Sukisno, 2018). We collected some of these literatures, to determine the quality standards of a duck egg to determine whether the egg is of decent or unfit quality.

2. Interview

   Not only learning from the literature, determining the quality of duck eggs is also done by conducting interviews with experts who are experts in their fields. Interviews are one of the techniques used to collect data, conducted face-to-face and direct questions and answers between data collectors and resource persons (Trivaika & Senubekti, 2022) We conducted an interview with a lecturer Program Studi Teknologi dan Manajemen Ternak namely Mr. Danang Priambodo, SPt, Msi. He gave us knowledge about duck egg production, and what variables make duck eggs feasible or not.

3. Fuzzification

   Fuzzification is the process of converting a clear set into a not-so-definite set that has the criterion that all members on a firm set must contain in a fuzzy set (Nisa et al., 2020). This stage is a stage that refers to techniques for converting data obtained from observations, into fuzzy variables that can be processed. The stage to test the system that has been made by checking the actual data obtained from the results of duck egg suitability parameters.(Lahay et al., 2023)

4. Fuzzy Rules

   The rule used in fuzzy sets is the if-then rule. Fuzzy propositions are divided into two types, namely atomic fuzzy propositions and complex fuzzy propositions. Atomic fuzzy propositions are simple propositions where x is the linguistic variable and A is the fuzzy set of x. A complex fuzzy proposition is a composite of atomic fuzzy propositions connected by "or", "and", and "not" operators. (Nisa et al., 2020)

5. Defuzzyfication

Defuzzyfication is a process of modifying the fuzzy output generated from each rule in the system to obtain a value that can be used as a benchmark for comparison based on certain memberships (Neonbeni et al., 2023)

The following is a flowchart image of the process of determining the eligibility of duck eggs:

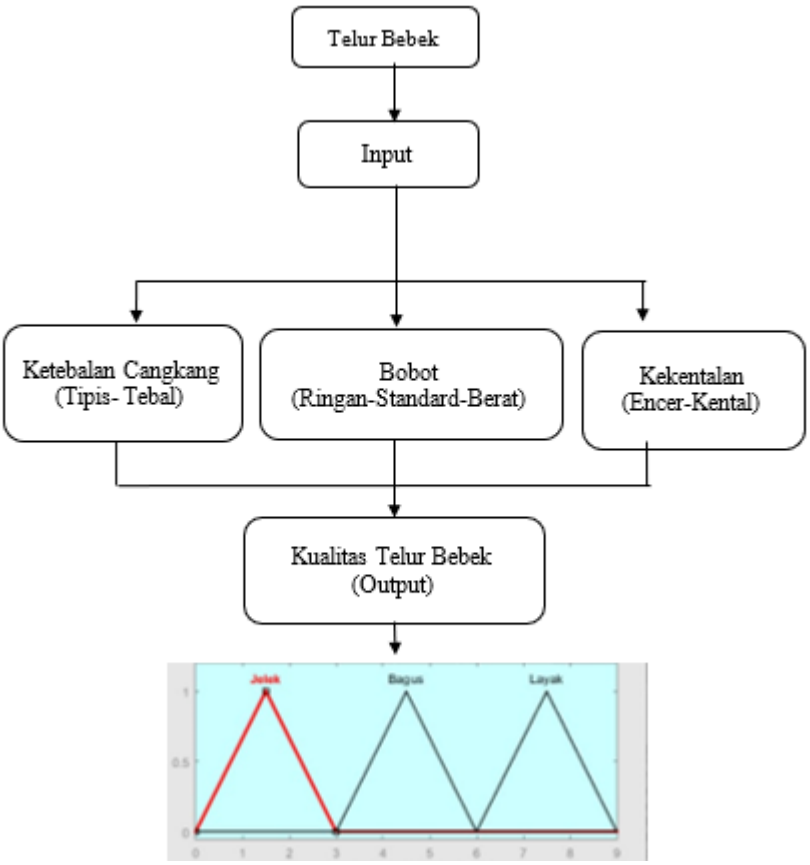

Figure 1. Flowchart for the process of determining the quality of duck egg feasibility

From the plot image above, to get the results of a quality duck egg, we need duck eggs as input or objects to be tested. Now from the duck eggs, 3 factors are selected that cause whether or not an egg is suitable for consumption, or the good or bad quality of the duck egg. These factors can be seen from the thickness of the shell, the weight of the egg and also the viscosity of the contents of the egg. Where, for the viscosity of the contents of this duck egg, we can see from the shape of the yolk and white of the egg. In this experiment, we have several rules that will determine the feasibility of the quality of a duck egg, which are as follows:

1. Standard Weight, Thick Shell and Lumpy Egg (Feasible Egg)
2. Standard Weights, Thick Shells, and Watery Eggs (Eggs May Be Feasible)
3. Standard Weights, Thin Shells, and Lumpy Eggs (Eggs May Be Feasible)
4. Standard Weights, Thin Shells, and Watery Eggs (Not Feasible Eggs)
5. Heavy Weight, Thick Shell, and Lumpy Eggs (Feasible Eggs)
6. Heavy Weight, Thick Shell, and Watery Eggs (Not Feasible Eggs)
7. Heavy Weight, Thin Shell, and Lumpy Eggs (Not Feasible Eggs)
8. Heavy Weight, Thin Shell, and Watery Eggs (Not Feasible Eggs)
9. Light Weight, Thick Shell, and Lumpy Eggs (Eggs May Be Feasible)
10. Light Weight, Thick Shell, and Watery Eggs (Not Feasible Eggs)
11. Light Weight, Thin Shell, and Lumpy Eggs (Not Feasible Eggs)
12. Light Weight, Thin Shell, and Watery Eggs (Not Feasible Eggs)

In this study, we get 12 rules that will determine the feasibility of duck egg quality. These rules are obtained from interviews with experts and also literature studies by reading literature in the form of journals, so that these rules are obtained.

RESULTS AND DISCUSSION

The following are the results of data obtained during an interview with an expert in his field who is a lecturer in the Livestock Technology and Management Study Program of IPB University Vocational School, namely Mr. Danang Priambodo, SPt, MSi. There are 3 input variables that are used to determine the quality of good duck eggs, namely, the weight of the egg, the thickness of the eggshell, and the level of viscosity of the contents of the egg. And for the output itself is to determine the quality of duck eggs. In determining the quality of duck egg feasibility will go through several stages and also use Matlab software. This stage begins with determining the degree of membership, making rules until the final stage, namely defuzzyfication.

Membership Function in Determining the Quality of Eligibility of Duck Eggs

The following Membership Function graph is the result of data obtained during an interview with one of the lecturers from the Department of Technology and Livestock Management, namely **Danang Priambodo, SPt, MSi.** There are three input variables used, namely egg weight, shell thickness, and egg viscosity. At the time of the interview with experts or experts in the quality knowledge of duck egg feasibility, it was also said that the parameters or indices given can vary, so they can be taken from several reference sources as a determination of the data needed. That way we take some from reference sources from one of the journals, namely:Identifikasi Karakteristik Biologis Telur Bebek (Anas Domesticus) Dalam Usaha Penetasan karya (Sumaryani & Permatasari, 2020). Then for the output variable is the quality of duck egg feasibility and here is the explanation.

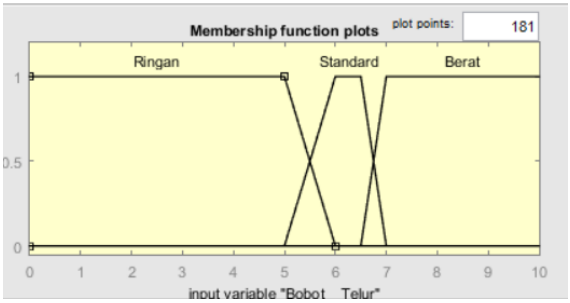

Figure 2. Variable input graph Bobot_Telur

In the graph above is a membership function of one of the input variables, namely Duck Egg Weight. This duck egg weight variability is made with the Trapezoidal type and has a range between **0-10** grams. It can be known that the value of the Light Weight parameter is 0-6 grams with a peak point of 0-5.9 grams. The value of the Standard Weight parameter is 5.9 – 7 grams with a peak point of 5.9 – 6.5 grams. And for the value of the Weight parameter is 6.5 – 10 grams.

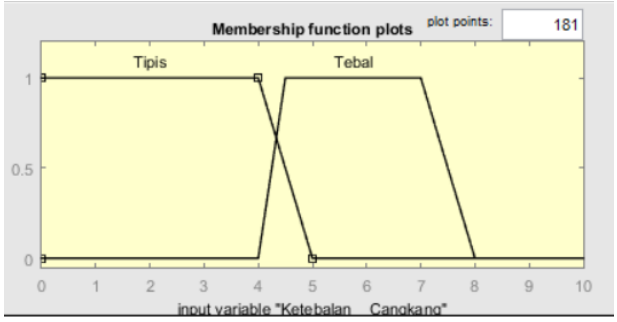

Figure 3. Variable input graph Ketebalan_Cangkang

In the graph above is a membership function of one of the input variables, namely Duck Eggshell Thickness. This variable is made with the Trapezoidal type and has a range of 0 - 8 mm. It can be known that the value of the Shell Thin parameter is 0 - 5 mm and the peak point is 0- 4.5 mm. And for the value of the Shell Thickness parameter is 4 - 8mm with the peak value of 4.5-7.8 mm.

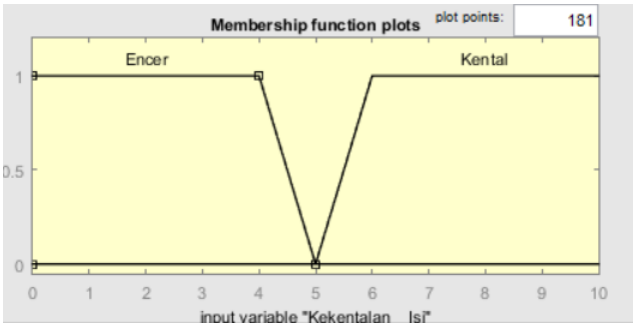

Figure 4. Variable input graph Kekentalan_Isi Egg

In the graph above is a membership function of one of the input variables, namely the Viscosity of the Duck Egg Contents. This variable is created with the Trapezoidal type and has a range of 0-10. It can be seen that the value of the Egg Content Dilute parameter is 0-5 and the peak point is 0-4. And for the parameter value of the Thick Egg Content is 5-10 with the peak value of 5-10.

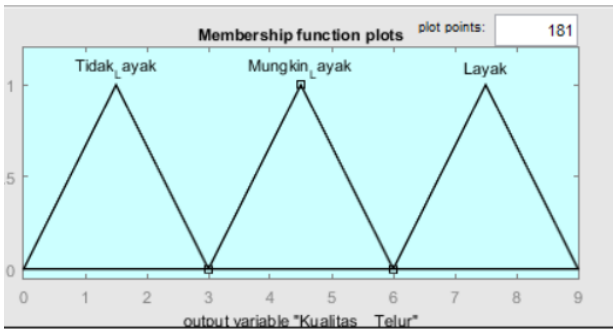

Figure 5. Graph of the Ouput value of Kualitas_Telur

In the picture above is a membership function graph of the output variable, namely Duck Egg Feasibility. This variable is created with Triangular and has a range from 0-9 with parameters Not Feasible, Probably Feasible and Feasible. It can be known that the Quality of Eggs is not feasible is with an index of 0-3, the Quality of Probably Decent is 3-6 and the Quality of Decent Eggs is 6-9.

CASE STUDY

As an illustration, in an egg distribution agent, 1 sample of duck eggs with a weight of 5.5 grams, a shell thickness of 7.5 grams and the viscosity of the contents of the egg can be given a value of 7. From these data, we can determine the quality of the duck egg's feasibility for consumption using the principle of fuzzy logic

Based on the interview results, there are 3 parameters of the weight level of a duck egg, namely Light, Standard and Weight with an index value in the table below. The ideal weight level for a duck egg is in the range of 6 - 6.5 grams. Because if the weight of an egg is too large, then there is a problem in the reproductive system of ducks when producing eggs that exceed their normal limits.

Table 1. Duck Egg Weight Input

Egg Weight Rate (gr)	Conditions
0 – 5,9	Light
6 – 6,5	Standard
6,6 - 10	Heavy

From the table, the following graph is obtained:

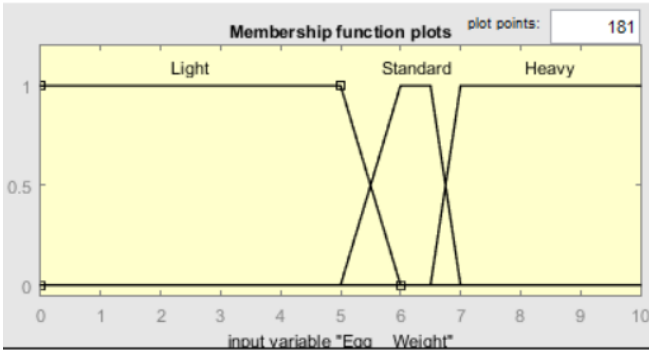

Figure 6. Egg Weight Membership Set

It can also be known that the membership set for egg weights is as follows:

$$\text{Fx (Egg Weight)} \begin{cases} Light(x) & \begin{cases} x < 0 & ;0 \\ 0 \le x \le 5 & ;1 \\ 5 \le x \le 6 & ;\frac{6-x}{6-5} \\ 0 \le x \le 5 & ;1 \\ x > 6 & ;0 \end{cases} \\ Standard(x) & \begin{cases} x < 5 & ;0 \\ 5 \le x \le 6 & ;\frac{x-5}{6-5} \\ 6 \le x \le 6.5 & ;1 \\ 6.5 \le x \le 7 & ;\frac{7-x}{7-6.5} \\ x > 7 & ;0 \end{cases} \\ Heavy(x) & \begin{cases} x < 6.5 & ;0 \\ 6.5 \le x \le 7 & ;\frac{x-6.5}{7-6.5} \\ 7 \le x \le 10 & ;1 \\ x > 10 & ;0 \end{cases} \end{cases}$$

In addition, eggs that can be said to be viable are those that have thick shells, because if thin or cracked shells can allow the entry of harmful microorganisms into the eggs, increasing the risk of contamination and poisoning. There are 2 parameters to identify the thickness of a duck eggshell, namely Thick and Thin. Here's the data:

Table 2. Shell Thickness Input

Egg Thickness Rate (mm)	Conditions
0 – 4,5	Thin
4,5- 10	Thick

The graph for the thickness of the egg shell is as follows:

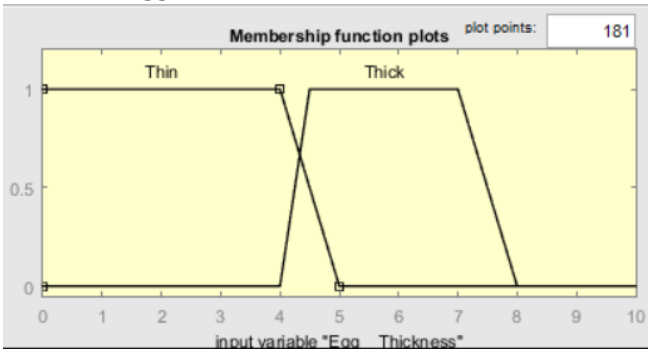

Figure 7. Shell Thickness Membership Set

It can also be known that the membership set for eggshell thickness is as follows:

$$\text{Fx (Egg Thickness)} \begin{cases} Thin(x) & \begin{cases} x < 0 & ;0 \\ 0 \le x \le 4 & ;1 \\ 4 \le x \le 5 & ;\frac{5-x}{5-4} \\ x > 5 & ;0 \end{cases} \\ Thick(x) & \begin{cases} x < 4 & ;0 \\ 4 \le x \le 4.5 & ;\frac{x-4.5}{4.5-4} \\ 4.5 \le x \le 7 & ;1 \\ 7 \le x \le 8 & ;\frac{8-x}{8-7} \\ x > 8 & ;0 \end{cases} \end{cases}$$

After that, a decent egg has an ideal viscosity of content. The viscosity of the egg filling is an important factor because it affects texture, consistency, and quality. The viscosity of the contents of the egg can also give an indication of the nutritional content of the egg. Eggs with thick contents may contain more nutrients than eggs with liquid contents. The consistency of egg contents can also affect food safety. Eggs that are too liquid may have a higher risk of being contaminated with harmful bacteria or microbes. The following is the data obtained to categorize the concentration of viscosity of egg contents.

Table 3. Duck Egg Content Viscosity Input

Viscosity level of duck egg contents	Conditions
0 – 5	Watery
5-10	Limpy

The graph for the viscosity of duck egg contents is as follows:

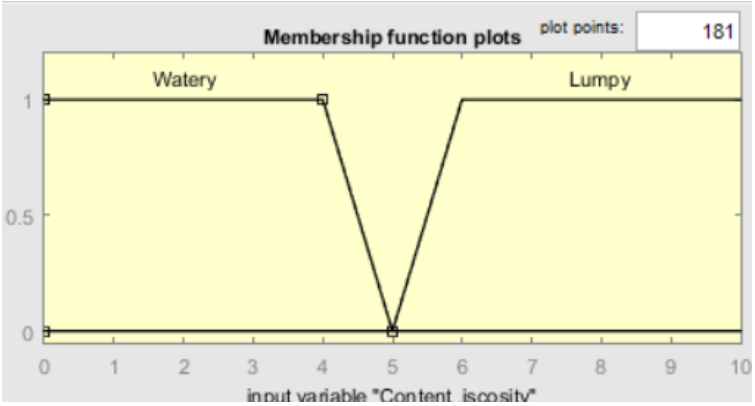

Figure 8. Egg Content Viscosity Membership Set

It can also be known that the membership set for the viscosity of egg contents is as follows:

$$\text{Fx (Content Viscosity)} \begin{cases} Watery(x) & \begin{cases} x < 0 & ;0 \\ 0 \le x \le 4 & ;1 \\ 4 \le x \le 5 & ;\frac{5-x}{5-4} \\ x > 5 & ;0 \end{cases} \\ Lumpy(x) & \begin{cases} x < 5 & ;0 \\ 5 \le x \le 6 & ;\frac{x-6}{6-54} \\ 6 \le x \le 10 & ;1 \\ x > 10 & ;0 \end{cases} \end{cases}$$

The Output Variables for categorizing an egg as Feasible , May Be Feasible and not Feasible are as follows:

Table 4. Duck Egg Feasible Output

.Egg Feasible Rate	Conditions
0-3	Feasible
3-6	May be Feasible
6-9	Not Feasible

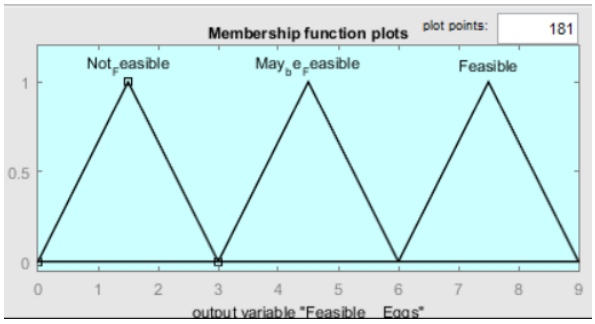

Figure 9. Egg qualification output graphic

In the picture above is an output graph of Duck Egg Eligibility. After that, define fuzzy rules based on the required inputs and outputs. Here is the Fuzzy Rule to determine the feasibility of duck egg quality:

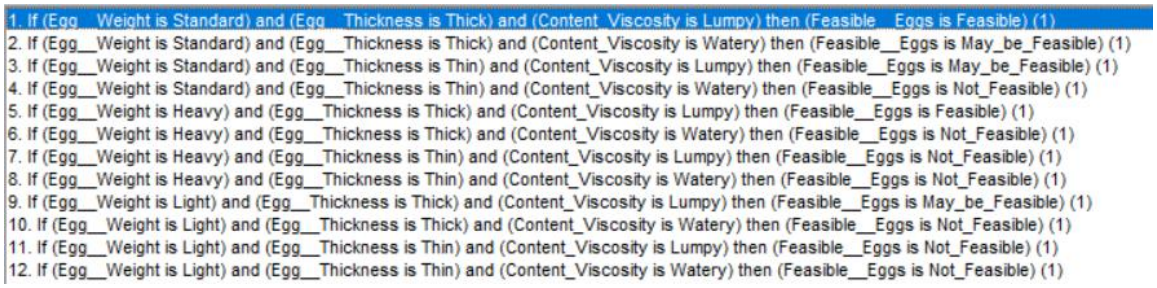

Figure 10. Fuzzy Rule Base feasibility of duck egg quality

For cases like the above, if it is known that a duck egg weighs 5.5 grams, the Shell Thickness is 7.5 grams and the Viscosity of the Contents of the egg can be given a value of 7. So here is a calculation using the Fuzzy logic method:

1. Determine the input value of Duck Egg Quality

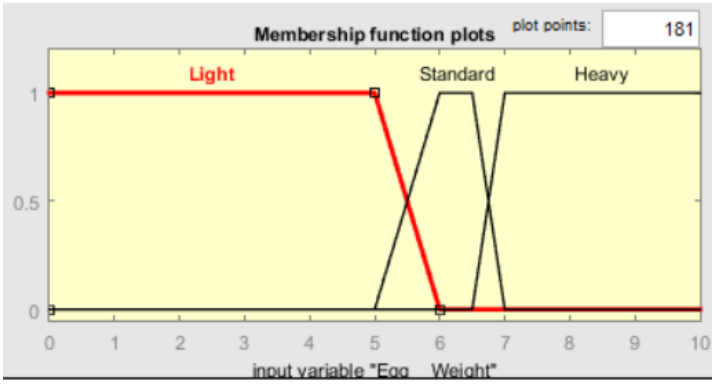

Figure 11. Egg Weight Membership Degree Graph

To determine the degree of membership of egg weight with an egg weight value of 5.5 grams. Then the equation obtained is:

$$\mu_{x\_Light[5.5gr]} = \frac{d-x}{d-c} = \frac{6-5.5}{6-5} = \frac{0.5}{1} = 0.5$$

2. Determine the input value of Duck Eggshell Quality

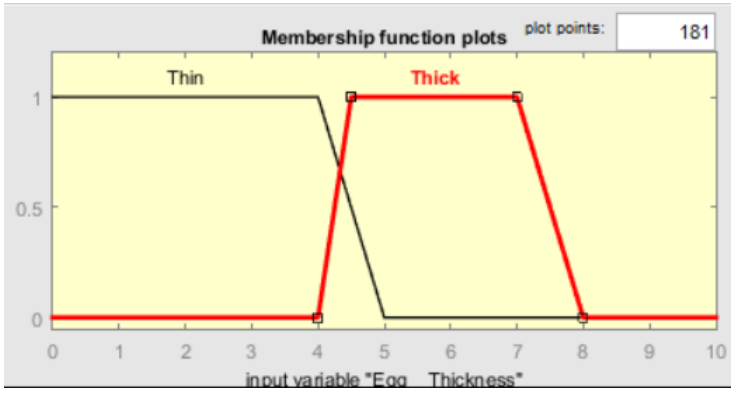

Figure 12. Shell Immunity Degree Graph

To determine the degree of membership of the eggshell with a value of eggshell thickness of 7.5 mm. Then the equation obtained is

$$\mu_{x\_Thick[7.5mm]} = \frac{d-x}{d-c} = \frac{8-7.5}{8-7} = \frac{0.5}{1} = 0.5$$

3. Determine the input value Feasibility Quality of Duck Egg Contents

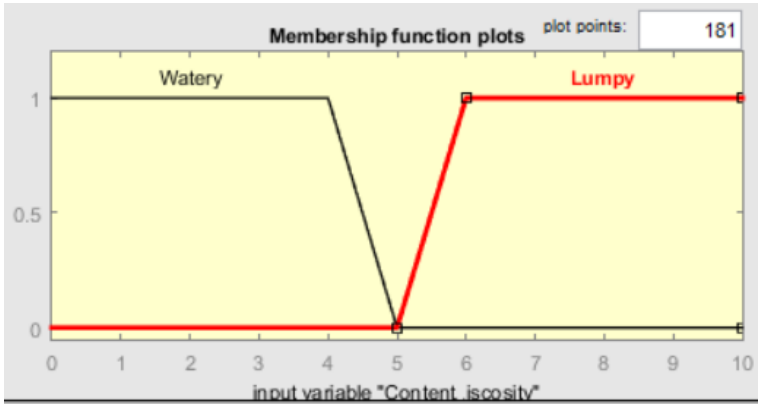

Figure 13. Graph of Degree of Membership Viscosity of Content

To determine the degree of membership of the eggshell with a value of eggshell thickness of 7.5 mm. Then the equation obtained is

$$\mu_{x_{Lumpy[7]}} = 1$$

4. After getting the input value, then adjust it to the fuzzy rules that have been created.

1. If (Egg__Weight is Standard) and (Egg__Thickness is Thick) and (Content_Viscosity is Lumpy) then (Feasible__Eggs is Feasible) (1)
2. If (Egg__Weight is Standard) and (Egg__Thickness is Thick) and (Content_Viscosity is Watery) then (Feasible__Eggs is May_be_Feasible) (1)
3. If (Egg__Weight is Standard) and (Egg__Thickness is Thin) and (Content_Viscosity is Lumpy) then (Feasible__Eggs is May_be_Feasible) (1)
4. If (Egg__Weight is Standard) and (Egg__Thickness is Thin) and (Content_Viscosity is Watery) then (Feasible__Eggs is Not_Feasible) (1)
5. If (Egg__Weight is Heavy) and (Egg__Thickness is Thick) and (Content_Viscosity is Lumpy) then (Feasible__Eggs is Feasible) (1)
6. If (Egg__Weight is Heavy) and (Egg__Thickness is Thick) and (Content_Viscosity is Watery) then (Feasible__Eggs is Not_Feasible) (1)
7. If (Egg__Weight is Heavy) and (Egg__Thickness is Thin) and (Content_Viscosity is Lumpy) then (Feasible__Eggs is Not_Feasible) (1)
8. If (Egg__Weight is Heavy) and (Egg__Thickness is Thin) and (Content_Viscosity is Watery) then (Feasible__Eggs is Not_Feasible) (1)
9. If (Egg__Weight is Light) and (Egg__Thickness is Thick) and (Content_Viscosity is Lumpy) then (Feasible__Eggs is May_be_Feasible) (1)
10. If (Egg__Weight is Light) and (Egg__Thickness is Thick) and (Content_Viscosity is Watery) then (Feasible__Eggs is Not_Feasible) (1)
11. If (Egg__Weight is Light) and (Egg__Thickness is Thin) and (Content_Viscosity is Lumpy) then (Feasible__Eggs is Not_Feasible) (1)
12. If (Egg__Weight is Light) and (Egg__Thickness is Thin) and (Content_Viscosity is Watery) then (Feasible__Eggs is Not_Feasible) (1)

Figure 14. Fuzzy Rules

The picture above is the fuzzy rule obtained from the case study above, namely ***If (Egg_Weight is Light) and (Egg _Thickness is Thick) and (Content_viscosity is Lumpy) THEN (Feasible_Egg is May Be Feasible)***. Then do the calculation of Defuzzyfication.

5. Defuzzyfication

- **Operator Fuzzy**

  After determining the fuzzy rule, then in this case it is subject to rule number 9. Because the rule used is *AND*, the fuzzy operator used is the minimum value of the input parameter.

  $\alpha 1 = Min\left(\mu x\_Weight_{Light_{(5.5\ gr)}} \cap \mu x\_Thickness\ _{Thick_{(7.5mm)}} \cap \mu x\_\text{Viscosity}\ _{Lumpyl_{(1)}}\right)$

  $\alpha 1 = Min\ (\ 0.5\ ;\ 0.5\ ;\ 1)$

  $\alpha 1 = 0.5$

- **Implication Function**

  Every rule on the fuzzy knowledge base will be associated with a relationship (Mentari, 2022). From the fuzzy operator obtained, the equation can be determined as below to determine the implication function. The following is a graph and calculation on the implication function:

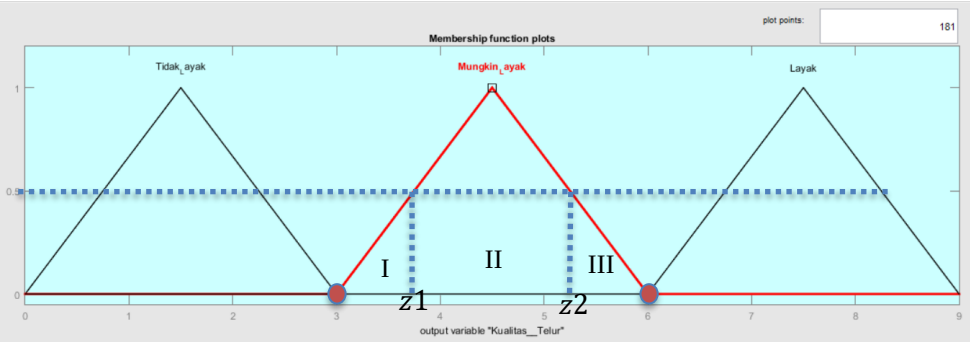

Figure 15. Implication Function

- Decent Left Side

  $$\alpha = \frac{z1 - a}{b - a}$$

  $$0.5 = \frac{z1 - 6}{7.5 - 6}$$

  $$0.75 = z - 6$$

  $$z1 = 6{,}75$$

- Decent Right Side

  $$\alpha = \frac{c - z2}{c - b}$$

  $$0.5 = \frac{9 - z2}{9 - 7.5}$$

  $$0.75 = \frac{9 - z2}{1.5}$$

  $$0.75 = 9 - z2$$

  $$z2 = 8.25$$

- Area Size

  $$AS1 = \frac{(z1 - 6\ ) \times (0.5)}{2} = \frac{(6{,}75 - 6)\ \times 0.5}{2} = \frac{0{,}75\ \times 0.5}{2} = 0.1875$$

  $$AS2 = (\ 8.25 - 6.75\ ) \times 0.5 = 1.5\ \times 0.5 = 0.75$$

$$AS3 = \frac{(z2 - 8.25\ ) \times (0.5)}{2} = \frac{(9 - 8.25)\ \times 0.5}{2} = \frac{0{,}75\ \times 0.5}{2} = 0.1875$$

- **Moment Calculation**
  Compile all outputs into sets as follows.

$$\text{F(x,a,b,c,d)} = \begin{cases} 0 & x < 6 \\ \frac{x-6}{7.5-6} & 6 \le x \le 6.75 \quad => \quad 0.67x - 4 \\ 0.5 & 6.75 \le x \le 8.25 \quad => \quad 0.5 \\ \frac{9-x}{9-7.5} & 8.25 \le x \le 9 \ => \quad 6 - 0.67x \\ 0 & x > 9 \end{cases}$$

- **Momen Set**

  Momen $\int_a^b F(x)\ x\ , dx$

  1. **Momen Set 1**

  $$\int_6^{6.75} (\ 0.67x - 4)x\ dx =$$

  $$\int_6^{6.75} (0.67x - \ 4)x\ dx \ \rightarrow \int_6^{6.75} 0.67x^2\ -\ 4x\ dx \ \rightarrow \int \frac{67x^2}{100}\ \ -\ 4xdx$$
  $$\rightarrow \int \frac{67x^2}{100} dx + \int -4xdx$$
  $$\rightarrow \frac{67\ \int x^2 dx}{100} - 4 \int xdx$$
  $$\rightarrow \frac{67x^3}{300}\ 2x^2 \rightarrow \frac{67}{300} \times 6.75^2 - \left(\frac{67}{100} \times 6^3 - 2 \times 6^2\right)$$
  $$\rightarrow \frac{8451}{6400} \rightarrow 1.3204$$

  2. **Momen Set 2**

  $$\int_{6.75}^{8.25} (\ 0.5)x\ dx = 5{,}625$$
  $$\rightarrow \int \frac{x}{2} dx \rightarrow \int \frac{xdx}{2} \ \rightarrow \frac{x^2}{4}$$
  $$\rightarrow \frac{8.25^2}{4} - \frac{6.75^2}{4} \ \rightarrow \frac{45}{8} \rightarrow 5.625$$

  3. **Momen Set 3**

  $$\int_{8.25}^{9} (\ 6 - 0.67x)x\ dx$$
  $$\rightarrow \int_{8.25}^{9} 6x - 0.67x^3\ dx$$
  $$\rightarrow \int 6x - \frac{67x^2}{100} \rightarrow 3x^2\ - \frac{67\ \int x^2 dx}{100} \rightarrow 3x^2 - \frac{67\ x^3}{300}$$
  $$\rightarrow 3\ \times\ 9^2 - \frac{67}{100}\ \times\ 9^3 - \left(3\ \times 8.25^2 - \frac{67}{300} \times 8.25^3\right)$$
  $$\rightarrow \frac{9009}{6400} \rightarrow 1.407$$

6. Results of Defuzzyfication

Defuzzyfication uses the Center Of Area (COA) Method with the operator used is "and". The results of Defuzzyfication are as follows

$$Z^* = \frac{\int_a^b F(x)x, dx}{\int_a^b F(x)dx} = \frac{Total\ Moments}{Total\ Area}$$

$$Z^* = \frac{M1 + M2 + M3}{AS1 + AS2 + AS3}$$

$$Z^* = \frac{1.3204 + 5.625 + 1.407}{0.1875 + 0.75 + 0.1875} = 7.42$$

From the description above, which is the result of the calculation of defuzzyfication with the Center of Area (COA) method, the best egg yield is 4.45 on a scale of 1 to 10. These results are obtained through calculations using the fuzzy Mamdani method. The results also show that the quality of the eggs can be said to be "May be Feasible", because it is on the output graph " May be Feasible" on a scale of 3 to 6. This is because a good egg is an egg that weighs standard, not too light and not too heavy. Then a good egg is an egg that has a thick shell and also a thick filling.

CONCLUSION

Based on the process of using *fuzzy logic* to determine the quality of duck eggs based on the input variables of egg weight, shell thickness, and viscosity of egg contents, it can be concluded that the use of *fuzzy* logic allows the assessment of duck egg quality more flexibly and nuancedly. Differences in the productivity and quality of duck eggs can be caused by intensive or extensive rearing systems as well as different nutritional compositions of feed (Sunarno, 2020). Taking into account various input variables such as egg weight, shell thickness, and viscosity of egg contents, egg quality assessment is not only based on exact values, but takes into account the degree of uncertainty. With significant input variables will later affect the quality of eggs. Each variable has a certain range of values that affect the category of egg quality. According to Widyantara, optimal seed and feed quality will contribute to the quality and ideal egg size (Widyantara et al., 2017).

Fuzzy Rule Base and Defuzzyfication become important steps in converting qualitative assessments into understandable quantitative values. This process allows for more measurable decision making based on uncertain information. The interpretation of duck egg quality can be classified into several grades based on the defuzzyfication value, such as "Not Feasible", "May be Feasible", and "Feasible". This allows recommendations on the use of eggs that are good for consumption, considering that eggs are one of the most popular animal products compared to other animal products (Darwanto et al., 2023). So that it can adjust to health standards and help in ensuring egg quality in accordance with health and food safety standards. Variables such as shell thickness and viscosity of egg contents can be potential indicators. But keep in mind that storage of duck eggs in different durations and temperatures can lead to changes in their physical properties and the occurrence of contamination or deterioration in egg quality. (Fanta et al., 2023)

Thus, the use of *fuzzy* logic in determining duck egg quality not only considers quantitative aspects, but also accommodates the degree of uncertainty, and complexity in egg quality assessment to ensure more informative and data-driven decisions

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