



DEVELOPMENT OF A FUZZY LOGIC CONTROLLER (FLC) FOR A CHICKEN FEATHER PLUCKING MACHINE

S. A. Alim^{1*}, I. A. Abdullateef² and K. O. Shobowale³

¹Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria

²Department of Electrical & Electronic Engineering, University of Ilorin, Ilorin, Nigeria

³Department of Mechatronics Engineering, Air Force Institute of Technology, Kaduna, Nigeria.

*Corresponding author's email address: moajlst@yahoo.com

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ABSTRACT

Feathers are epidermal growths or flat appendages that form a unique exterior covering, or plumage, on (avian) birds, some non-avian and possibly other archosauromorphs. They are regarded as the most complicated skin structures observed in vertebrates. The traditional method of manually plucking the feathers with the hand is still the common practice in Nigeria for both private and commercial use. For both manual and machine plucking, the chicken must have undergone scalding. In an attempt to add some form of intelligence to the design of the mechanical chicken feather plucking machines, a fuzzy logic controller (FLC) is developed for this system. Compared to conventional control techniques, FLC has been best applied in complex ill-defined problems, which can be controlled by an efficient human operator without knowledge of their underlying dynamics. In the design of the FLC, two input parameters were considered namely scalding temperature and weight of the chicken. While the output parameters considered were the rotating speed and rotating time of the plucker. Nine rules were developed to effect the control process. For a chicken of 2.0kg weight and temperature of 80°C, the rotating speed and plucking time are 402rpm and 20.3secs. It shows the proof of concept that the chicken feather plucking process can be automated.

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1.0 Introduction

Feathers are epidermal growths or flat appendages that form a unique exterior covering, or plumage, on dinosaurs, birds, some non-avian (non-bird) and possibly other archosauromorphs. They are regarded as the most complicated skin structures observed in vertebrates (Prum and Brush, 2002; Prum and Brush, 2003). They aid in thermal insulation, flight, and waterproofing. In addition, the associated coloration helps them look pretty, communicate and offer some form of protection (Pettingill, 1970; Smith, 2020).

After slaughtering the chickens, there is the need to remove the feathers from the skin so as to be able to cut the animal into smaller pieces. This would enable the removal of the inedible parts while preparing the edible parts for consumption. The traditional method of manually plucking the feathers is commonly practiced in Nigeria for domestic and commercial uses. Researchers have developed different types plucking machines which vary in dimensions and orientation. For both manual and machine plucking, the chicken must have undergone scalding. Scalding is done

to reduce the feather retention force (FRF) on the chicken. Local breed of chicken, cockrels, layers, broilers and noilers are the major categories of chickens that are reared and consumed in Nigeria. Of these four categories, broilers have the least feather retention force, while the local breed have the highest feather retention force.

Scalding is the process of immersing the birds in warm water to loosen the feathers. In a small plant, scalding (i.e., placing the carcass in and removing it from a scalding tank) is performed manually, but in large plants it is done in a continuous manner whereby the birds are subjected to a single or multistage scalding bath(s) while suspended from a moving shackle line (Berry, 2017; Barbut, 2004; Irshad and Arun, 2013; Barbut, 2016). The water can be heated by oil, gas, electricity, alternatively, vertical cabinets utilizing hot-water sprays or steam can also be used (Irshad and Arun, 2013).

Interestingly, there are various scalding schemes, where selection of one over the other depends on the following; the degree of difficulty in removing the feathers (FRF), the chilling method that is to follow (water or air), and the age of the bird (Barbut, 2004; Irshad and Arun, 2013; Barbut, 2016). Higher scalding temperatures are better for loosening feathers from their follicles, but hard scalding is also the harshest on the skin. The outer layer of the skin, epidermis, becomes loose and is removed during the plucking operation. The removal of the epidermis can result in discoloration of the skin if it is dehydrated during subsequent air chilling (Irshad and Arun, 2013). The objective of this study is to replace the manual and mechanical process of feather plucking with an intelligent based system through fuzzy logic controller.

The scald temperature and time profile depend mainly on the desired final market carcass/part skin color, the age and weight of the broilers, kill-line speed, and the number and type of scald tanks (Buhr, Walker, Bourassa, Caudill, Kiepper and Zhuang, 2016). Adequate agitation of the scald water and uniform application temperature are essential to ensure good feather removal (Barbut, 2004; Barbut, 2016). The methods of scalding are: -

I. Soft scalding/semi scalding/slack scalding method is a process that leaves the epidermal layer intact but still allows a relatively easy feather removal. It is commonly used for young broilers and young turkeys (Berry, 2017; Barbut, 2004; Energy Solution Centre, 2007; Irshad and Arun, 2013; Barbut, 2016). Birds slaughtered for display should be scalded in this way to improve their appearance, this is because water that is too hot will cause the outer layer of skin to loosen or be lost (Berry, 2017; Barbut, 2004; Irshad and Arun, 2013; Buhr, Walker, Bourassa, Caudill, Kiepper and Zhuang, 2014). The suggested temperature-time combinations for soft scalding are as seen in Table I.

Table 1: Suggested scalding parameters for soft scalding

S/N	Author(s)	Scalding temperature	Scalding time
1	Nunes, 2011	55°C	120 - 180 secs
2	Energy Solution Centre, 2007	51.1 – 54.4 °C	45 secs
3	Mountney and Parkhurst, 2001	50 – 51 °C	210 secs
4	Irshad and Arun, 2013	50 - 51 °C	60 – 180 secs
5	Barbut, 2004	50 - 53 °C	60 – 180 secs
6	Berry, 2017	51.7 – 54.4 °C	30 - 60 secs
7	Buhr et al. 2014	51 - 54 °C	120 - 210 secs
8	Barbut, 2016	50–53 °C	60 - 180 secs

2. Sub scalding/medium scalding method is used for mature birds. The epidermal layer is broken down by this time–temperature combination, and the feathers are usually much easier to remove (Berry, 2017; Energy Solution Centre, 2007; Irshad and Arun, 2013; Barbut, 2016). For home processing, this method of scalding is recommended (Berry, 2017). The suggested temperature-time combinations for medium scalding are as seen in Table 2.

Table 2: Suggested scalding parameters for medium scalding

S/N	Author(s)	Year	Scalding temperature	Scalding time
1	Irshad and Arun,	2013	54 - 58 °C	60 - 120 secs
2	Energy Solution Centre	2007	53.9 – 57.8 °C 60 – 62.8 °C	60 - 120 secs 15 - 30 secs
3	Barbut,	2004	54 - 58 °C	60 - 120 secs
4	Berry	2017	58.9 - 60 °C	30 - 75 secs
5	Buhr et al	2016	54 - 58°C 60 - 63°C	60 - 120 secs 15 - 30 secs
6	Barbut	2016	54 – 58 °C	60 – 120 secs

3. Hard scalding/full scalding method is the fastest and eliminates pinfeathers, but the carcasses tend to dry out and have a less desirable appearance. It is easier to remove the feathers from carcasses scalded at these temperature ranges than from those scalded at lower temperature, but the flesh of such poultry is doughy and lifeless, as such the skin becomes discolored soon after processing (Berry, 2017; Barbut, 2004; Energy Solution Centre, 2007; Irshad and Arun, 2013; Buhr et al., 2014). Because the skin removes, the use of hard scalding for chickens is limited in some markets (Energy Solution Centre, 2007). Hard scalding has been the most common scalding method in the US poultry industry and is desirable for products with retained skin that are to be batter coated (Irshad and Arun, 2013; Buhr et al., 2014).

Waterfowls such as geese, ducks and swans, may be scalded at this temperature (or higher temperature) because it is the only appropriate method of releasing their feathers (they have higher FRF). Also, the skin does not discolor as readily as do other species of poultry (Berry, 2017; Barbut, 2004; Energy Solution Centre, 2007; Irshad and Arun, 2013; Barbut, 2016). Hard

scalding raises the temperature of the bird's tissues and minimize the growth of bacteria and defeathering should be performed within 90 seconds of scalding (Energy Solution Centre, 2007). The suggested temperature-time combinations for hard scalding are as seen in Table 3.

Table 3: Suggested scalding parameters for hard scalding

S/N	Author(s)	Year	Scalding temperature	Scalding time
1	Irshad and Arun	2013	56 - 60°C	45 - 90 secs
2	Energy Solution Centre	2007	71.1 °C	10 secs
3	Nunes	2011	57°C	120 secs
4	Mountney and Parkhurst	2001	56 – 58 °C	120 - 150 secs
5	Barbut	2004	60 °C	45 - 90 secs
6	Berry	2017	60 – 65.6 °C	
7	Buhr et al	2014	60 – 66 °C	45 - 90 secs
8	Barbut	2016	60 – 63 °C	45 – 90 secs

Hotter or longer scalding may be better for defeathering and Salmonella control. This leads to over scalding which increases the toughness of cooked chicken and turkey breast meat. A too-high scald temperature also causes a potential carcass yield loss attributed to subcutaneous fat (lipid) liquefaction (Buhr et al., 2014).

2.1 Manual Scalding and Manual Defeathering

Manual scalding is the process of immersing of slaughtered bird in a hot water container and using fingers to pluck the feathers. Manual scalding is practiced at home and in some small facilities. The dead bird is immersed in 60-65.6°C (140-150°F) water for about one minute. In most cases, an open tank is used that can accommodate one to ten birds, and the water is kept hot by a burner located in the bottom of the tank. The water is replaced and the tank cleaned once every shift or day (Energy Solution Centre, 2007). Figure 1 shows the process of manual scalding and manual defeathering. The manual scalding process as can be seen, the water is heated with an electric cooker and the carcass to be scalded is immersed in the water that is still being heated.



Figure 1: Manual Scalding and manual defeathering

The chicken is removed from the scalding tank and the person can be seen plucking the feathers manually. This process takes between 2 and 5 minutes depending on how fast the plucker is. Birds should be plucked immediately after scalding. If mechanical pluckers are used, they should be adjusted for the size birds being plucked. Mechanical pluckers make the job much faster. Carcasses that are to be exhibited should be plucked by hand being sure that all pinfeathers are removed, and that there is no damage to the skin. This procedure requires a good deal of time if done correctly. Rubbing the feathers from the skin is frequently more effective than a picking motion (Berry, 2017). Figure 2 shows a fully feathered live chicken which is what is available before the slaughtering and scalding processes are done. And a fully defeathered carcass which is what is obtained after the series of processing.



Figure 2: A fully feathered live chicken/ fully defeathered bird

2.0 Methodology

In order to achieve the plucking process, the scalded chicken was lowered into the vertically assembled feather plucking machine (Figure 3). This is a galvanized steel drum lined internally with rubber fingers subjected into a rotary motion by the transmitted torque from an electric motor. The carcass was rubbed with the rubber fingers and the feathers were thereby plucked continuously until the bird is completely defeathered (Adetola et al., 2012). It also shows a summary of the defeathering process. It starts from scalding the carcass, the mechanical scalding is done and the chicken is picked out after the defeathering is done.



Figure 3: Mechanical Chicken Feather Plucking Machine (farmsquare, 2021)

In an attempt to add some form of intelligence to the design of the mechanical chicken feather plucking machines, a fuzzy logic controller (FLC) is developed for this system. Compared to conventional control techniques, FLC has been best applied in complex ill-defined problems, which can be controlled by an efficient human operator without knowledge of their underlying dynamics. In the design of the FLC, two input parameters were considered namely scalding temperature and weight of the chicken. While the output parameters considered were the rotating speed and rotating time of the plucker. The parameters are as discussed below.

Scalding Temperature: The scalding temperature plays the major role in the efficient plucking of chicken feathers whether manually or by a machine. In fact, the percentage reduction in feather retention force (FRF) ranges from 18% to 81% after about 2.5 minutes, 56°C scalding (Abubakar et al., 2019). As such, the system is designed to have a temperature range from 50 – 100°C, because most of the scalding done at home and by the local butchers in Nigeria who are the main target of this work is between 75 – 90°C usually at a lower retention time of less than 2 minutes. This position is also supported by the work of Adetola et al. 2012. The membership functions used are as seen in Figure 4.

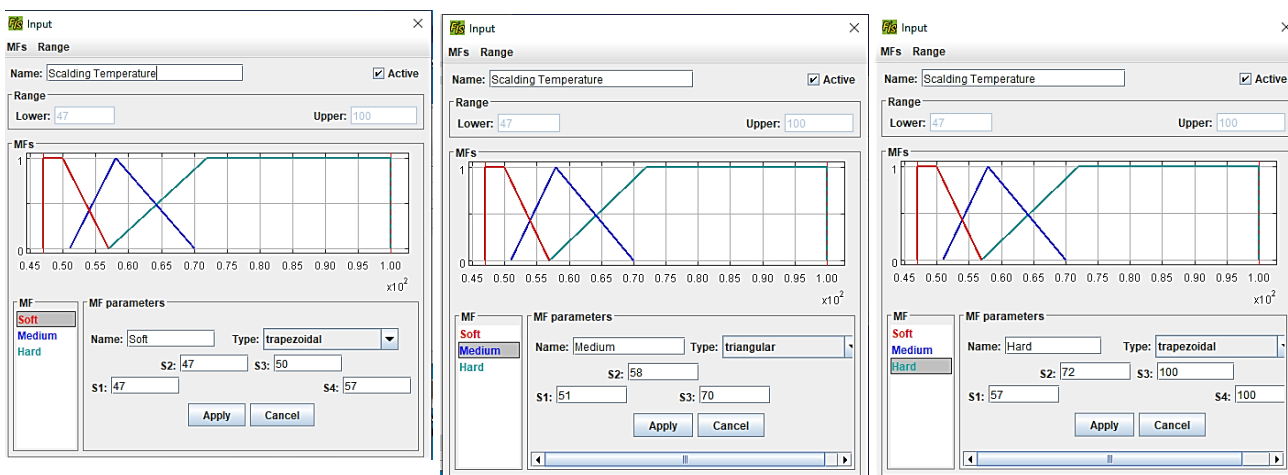


Figure 4: Membership Functions of the Scalding Temperature

Weight of the Chicken: The age of a chicken in weeks has a relation to its weight. Due to this, weight is taken as an input parameter. The weight of the chicken has relationship with the body size parameters such as neck length, back length, kneel length, wing length, breast width, thigh length and shank length. The weight usually requested for by eateries is between 1.5-2.0kg after plucking. This informed the selection of 1.2 – 4.7kg as the weight of the chicken. Some people usually prefer large bird having a weight of around 4kg. The membership function is as seen below in Figure 5.

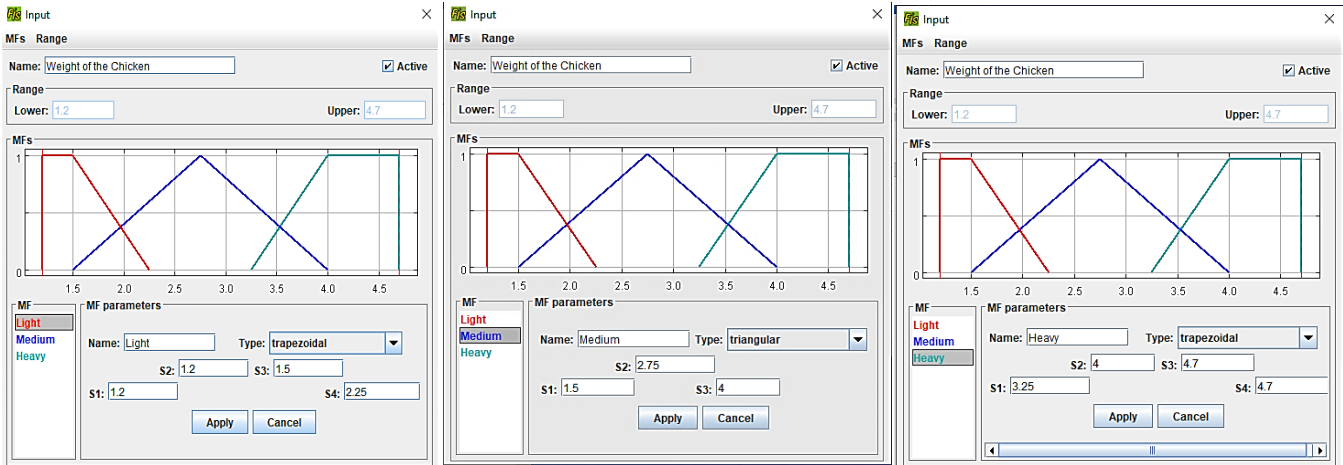


Figure 5: Membership Functions of the Weight of the Chicken

Drum Rotating Speed: One of the two output parameters of the plucker is the rotating speed of the rotating disc of the plucker/drum. The rotating disc is the only rotating part of the machine, mounted on the motor and has some plucking fingers (rubber studs) on it. Accordingly, the work of Mady and Obia (2018), the rotating speed ranging from 240-560rpm. This is the range adopted in this work for the universe of discourse of the rotating disc. The membership functions are as seen in Figure 6.

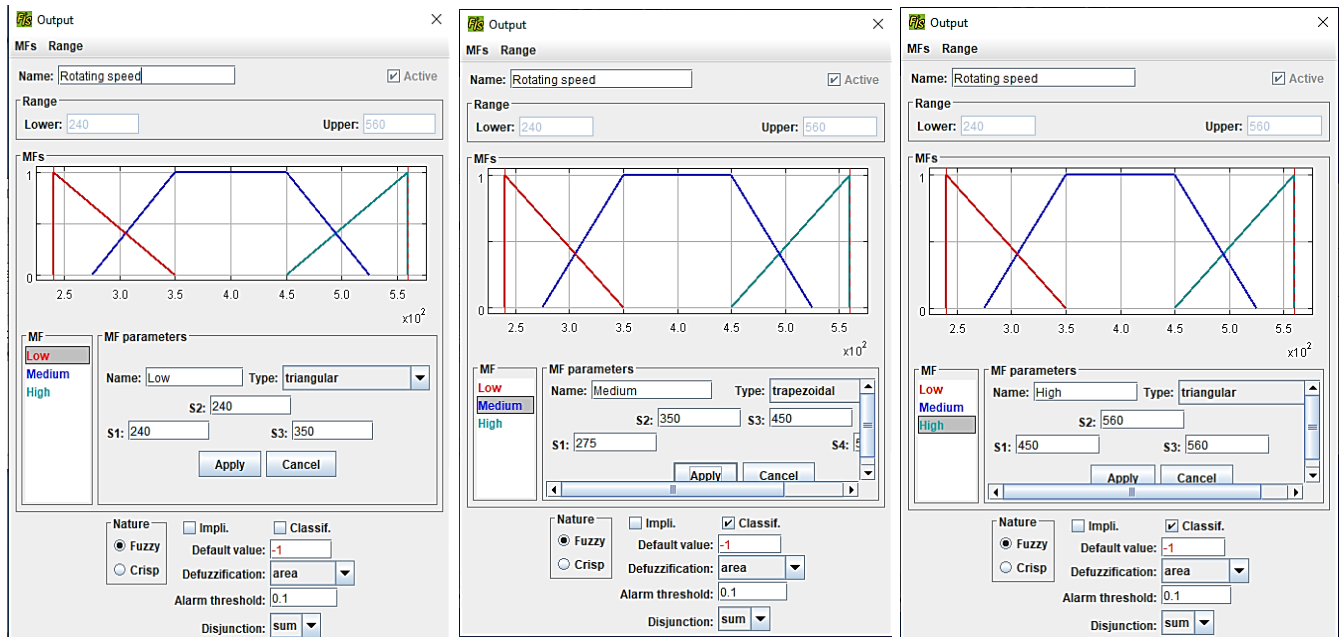


Figure 6: Membership Functions of the Drum Rotating Speed

Plucking Time: the second output parameters selected is plucking time. This was done in order to ensure that the machine does not work endlessly, the outer skin of the carcass does not peel off and that time is conserved as time is money in this regard. The more chickens that is processed translates into finance for the operator of the machine. Accordingly, the work of Mady and Obia

(2018), they used three different scalding times of 30, 60 and 90 seconds. As such, 7 – 90 secs were selected as the plucking time. The membership function of the plucking time is in Figure 7.

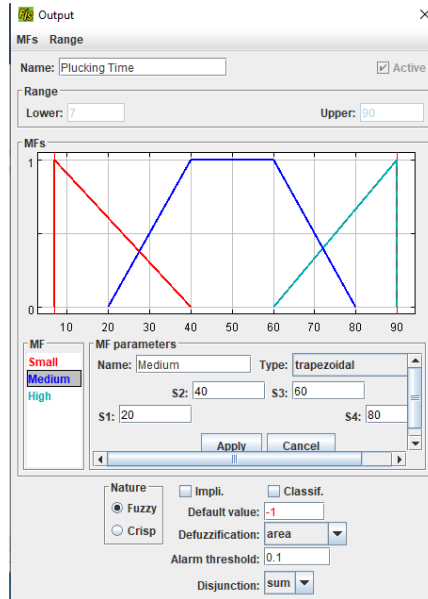


Figure 7: Membership Functions of the Plucking Time

3.1 Operating Principle of the proposed system

The chicken feather plucker would be designed to take two 2kg birds at a time. A pressure sensitive plate would be used at the bottom of the rotating drum. This would double as the weight sensor. A temperature sensor would be installed to measure the instantaneous temperature of the carcass. These two sensors would get the inputs for the microcontroller to process and send actuation message to the motor and the timer. The timer connected to the motor controls the time of operation of the motor. The motor controls the speed of rotation of the plucker. At the end of the rotation, the carcass(es) can be removed for further processing. The block diagram of the proposed FLC chicken defeathering machine is as seen in Figure 8.

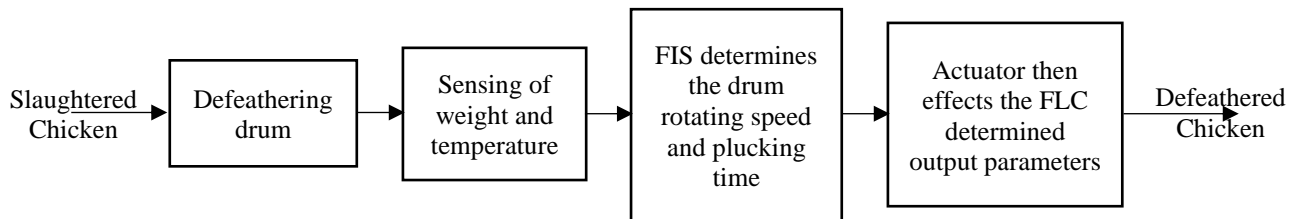


Figure 8: Block Diagram of the Proposed FLC Chicken Defeathering Machine

Rule Base

1. IF (Weight of the Chicken is Light) And (Temperature of the Chicken is Soft Scalding) THEN (Speed of the Plucker is High) And (Plucking Time is Long)
2. IF (Weight of the Chicken is Medium) And (Temperature of the Chicken is Soft Scalding) THEN (Speed of the Plucker is Medium) And (Plucking Time is Long)
3. IF (Weight of the Chicken is Heavy) And (Temperature of the Chicken is Soft Scalding) THEN (Speed of the Plucker is High) And (Plucking time is Medium)
4. IF (Weight of the Chicken is Light) And (Temperature of the Chicken is Medium Scalding) THEN (Speed of the Plucker is Low) And (Plucking Time is Medium)
5. IF (Weight of the Chicken is Light) And (Temperature of the Chicken is Hard Scalding) THEN (Speed of the Plucker is Low) And (Plucking Time is Small)
6. IF (Weight of the Chicken is Medium) And (Temperature of the Chicken is Medium Scalding) THEN (Speed of the Plucker is Medium) And (Plucking Time is Small)
7. IF (Weight of the Chicken is Medium) And (Temperature of the Chicken is Hard Scalding) THEN (Speed of the Plucker is High) And (Plucking Time is Small)
8. IF (Weight of the Chicken is Heavy) And (Temperature of the Chicken is Medium Scalding) THEN (Speed of the Plucker is Medium) And (Plucking Time is Long)
9. IF (Weight of the Chicken is Heavy) And (Temperature of the Chicken is Hard Scalding) THEN (Speed of the Plucker is Low) And (Plucking is Medium)

3.0 Results and Discussion

The developed FLC system was simulated using FisPro and the results are as presented. Figures 9 and 10 show the interaction between Weight of chicken vs Rotating speed and Weight of chicken vs Plucking time respectively. It can be seen that as the weight increases, the plucking speed increases up to about 520rpm for a chicken with weight of about 2.25kg. The plucking speed remain relatively up to a weight of about 2.25kg. After this, the rotating speed drops gradually until it gets to zero. Similarly, as the weight of the chicken increases, the plucking time rises up to about 1.3kg weight, then remains relatively constant at about 19sec up to about 3.2kg weight. The rule base used is based on expert knowledge obtained from literature and this basically affected the output obtained from the simulation results. However, the validation of these results guides to know whether to modify the rule base as the performance of the FLC in giving desired output is tied to the rule base.

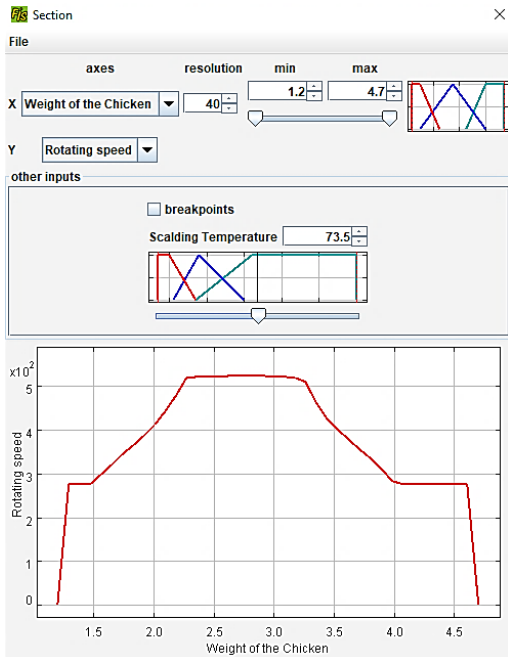


Figure 9: Weight of chicken vs Rotating speed

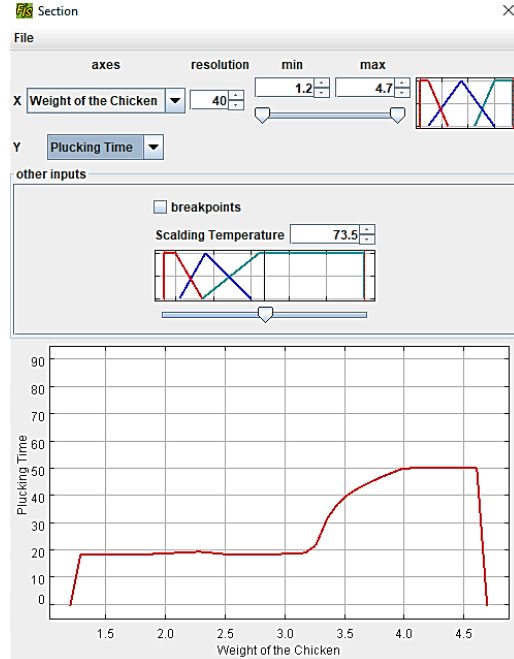


Figure 10: Weight of chicken vs Plucking time

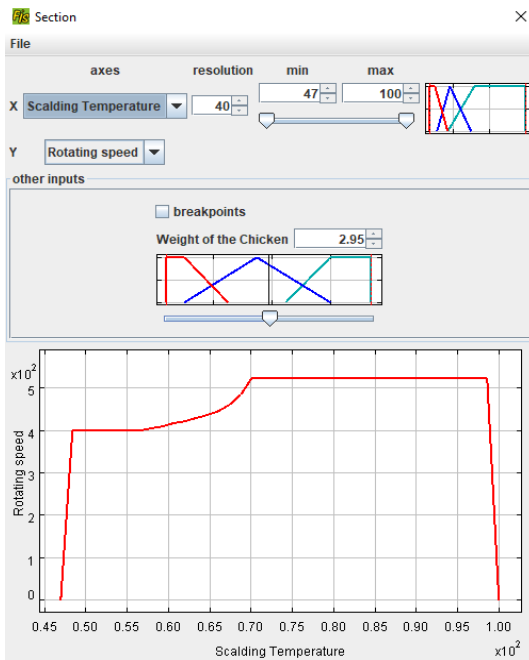


Figure 11: Scalding temperature vs Rotating speed

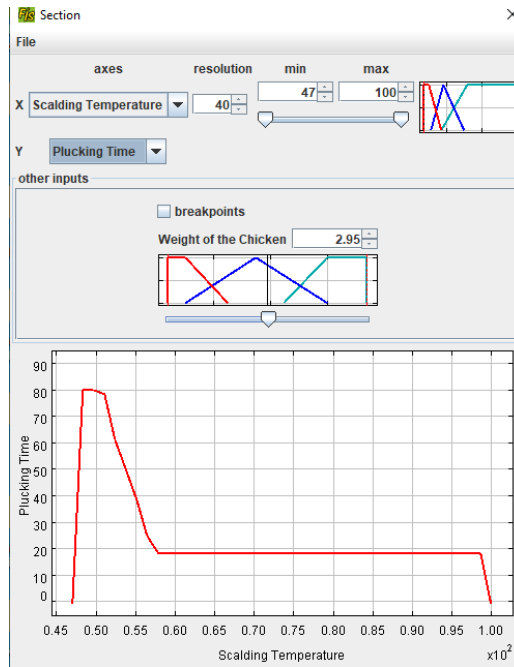


Figure 12: Scalding temperature vs Plucking time

Figures 11 and 12 show the interaction between Scalding temperature vs Rotating speed and Scalding temperature vs Plucking time respectively. As the Scalding temperature increases, the rotating speed experiences a sharp rise to about 400rpm. Then rises until the speed is at about 520rpm for 70°C scalding temperature. The speed stays relatively stable at this point till it fall back to zero. Furthermore, the plucking time has a rapid rise to about 80secs, before falling to about 19secs. The information obtained from the literature with regards to the range of rotating speed was not much, however assumptions were made to get the linguistic hedges (Low, Medium and High) which eventually formed out universe of discourse. When a validation of the simulation results is conducted, proper modifications can be made to the rule base.

For a two input two output system that is designed, assuming that the weight of the chicken is 1.5kg and the scalding temperature is 80°C then the Rotating speed and the Plucking time are 278rpm and 18.6sec. The input (1.5kg and 80°C are crisp input, the fuzzified by the FLC and the fuzzy output is computed. The fuzzy output is then defuzzified using centre of area method to obtain the output (278rpm and 18.6 seconds). 1.5kg weight of chicken would have a 1.0 membership function on light weight, while 80°C would also have 1.0 membership function on high temperature. These fuzzified input would then trigger some of the rules in the rule base and the corresponding output are computed. The implication of this is that if a chicken weighing 1.5kg scalded at a temperature of 80°C, the plucking machine would rotate at a speed of 278rpm for 18.6 seconds.

Conclusion

The simulation studies were clear indicating that the chicken feather plucking process could be automated. As a result of cost, most of the consumers go for chicken usually not more than 2.0kg and the scalding temperature is usually very hot water assumed to be around 80°C. As such, for a chicken of 1.5kg weight and the scalding temperature is 80°C then the rotating speed and the plucking time are 278rpm and 18.6sec. It is evident that the system has a potential to be integrated into a small-scale slaughterhouse to reduce the plucking time, reduce waiting time of customers and increase the earning of the owners of the slaughter houses.

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