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doi:10.15199/48.2024.02.18

Design of A Beef Freshness Detector based on Color and Scent with the Mamdani Fuzzy Method

Abstract. *Currently, the identification of beef is still done manually either through observation or press the meat to know the beef texture. This method has many disadvantages if the consumers are not thorough in differentiating the beef freshness quality. The design of a system that can identify beef quality by utilizing the characteristic of the meat rotting process is proposed. The beef's freshness can be detected through the smell or the scent of the beef. It is also can be detected through color. The fresh beef scent will have a different smell from the rotting beef scent, so the changing color. The proposed design is the beef freshness detector system using two kinds of sensor which is a Gas Sensor, MQ-136 and MQ-137 to detect the beef scent and a color sensor (TCS3200) to detect beef color change. It is also used a microcontroller as the main unit of data acquisition and uses Mamdani Fuzzy Method as to decision-making system for the acquisition of data from the sensors. The overall test result in the system has an 86,67% probability of success with an error rate of 13,3% from 15 trials.*

Streszczenthe ie. Obecnie identyfikacja wołowiny nadal odbywa się ręcznie, poprzez obserwację lub wyciskanie mięsa w celu poznania tekstury wołowiny. Metoda *ta ma wiele wad, jeśli konsumenci nie są wnikliwi w różnicowaniu jakości świeżości wołowiny. Zaproponowano projekt systemu umożliwiającego identyfikację jakości wołowiny na podstawie charakterystyki procesu gnicia mięsa. Świeżość wołowiny można rozpoznać po zapachu lub zapachu wołowiny. Można to również wykryć poprzez kolor. Zapach świeżej wołowiny będzie miał inny zapach niż zapach gnijącej wołowiny, a więc zmienia kolor. Proponowany projekt to system wykrywania świeżości wołowiny wykorzystujący dwa rodzaje czujników: czujnik gazu, MQ-136 i MQ-137 do wykrywania zapachu wołowiny oraz czujnik koloru (TCS3200) do wykrywania zmiany koloru wołowiny. Wykorzystywany jest również mikrokontroler jako główna jednostka gromadzenia danych i wykorzystuje metodę Mamdani Fuzzy Method jako system podejmowania decyzji w zakresie pozyskiwania danych z czujników. Ogólny wynik testu w systemie ma 86,67% prawdopodobieństwa powodzenia przy poziomie błędu 13,3% z 15 pró*b. (***Projekt detektora świeżości wołowiny na podstawie koloru i zapachu metodą rozmytą Mamdani***)

Keywords: Beef Freshness Detection Results, Mamdani Fuzzy Method, Beef Scent and Color Detection
Słowa kluczowe: Wyniki wykrywania świeżości wołowiny, metoda rozmyta Mamdani, wykrywanie zapachu i koloru wołowiny

Introduction

Beef is an example of a basic food ingredient that is used extensively widespread. Therefore, certain quality standards are needed so that consumers do not feel disadvantaged. These standards include purity and freshness with certain standards. Process distribution from breeders to consumers has a very long procedure, which caused the price of beef sold in the market to soar. This kind of price causes unscrupulous elements to use various methods to get benefits, one of which is mixing fresh meat with not a fresh meat[1].

With that kind of fraud, ordinary consumers will suffer from the problems of meat. Presently, determining the quality of beef is carried out manually, namely by pressing the beef so that it can see the texture of the meat. This manual method has disadvantages for consumers who are not careful in choosing qualified meat. This is why a system design to utilize the characteristic of decaying meat is proposed[2].

The freshness of the meat can be detected from the smell or aroma that is released by the meat. It can also be detected by its color. The smell of fresh meat, of course, will be different from the smell of rotting meat, so will the color also change. It is less precise if the detection relies on the human sense of smell and vision. For this reason, a meat aroma detection sensor is needed and sensors that can accurately detect changes in meat color. The combination of these two sensors results in a meat freshness detection system. The main difference in the quality of local beef and imported beef lies in the aroma, taste, and smell. Local beef has aroma, taste, smell, and a distinctive red color. One of the marks of whether the beef is good is from the texture that if pressed will return to its original state. Otherwise, the meat is no longer good or damaged. Good quality beef has a special taste and aroma as well as yellowish white fat (vein). When it is processed or cooked, the meat veal will get more delicious and have the taste of tender meat[3-15.]

For that reason, a system design to detect meat freshness is proposed using two kinds of sensors, which is Gas Sensors (MQ-136 and MQ-137) for performing meat aroma detection and Color Sensor (TCS3200) to detect the change in meat color. In addition, a microcontroller is used as the main unit for data acquisition and use the Mamdani Fuzzy Method for the system taking test samples from the data that has been acquired from the sensor[16].

MQ-136 and MQ-137 Sensor

SnO2 is a sensitive material in sensors with the MQ type. When exposed to clean air, the level of its conductivity tends to have a low rate. The conductivity value will increase when exposed to detected gas according to the gas concentration in the air. Sensor conductivity changes can be used as an output signal that has the relationship between gas and air detected by using a simple circuit.

Two MQ-type sensors have similar principles and characteristics. The difference lies in the results of the gas types detection. The MQ-136 sensor is used specifically to detect the concentration of H2S gas in the air, whereas the MQ-137 sensor is used specifically to detect the presence of NH3 gas in the air

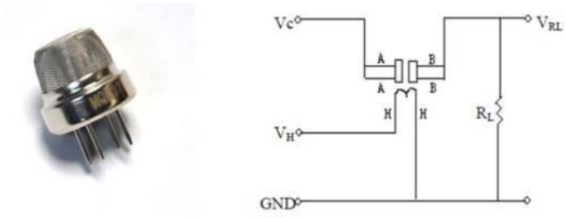


Fig 1. MQ Sensor Form and Schematic [2]

TCS 3200

The color sensor is used to detect the color of the meat's freshness. Light-to-frequency converter on the TCS 3200 reads the array from the photodiode with an 8x size. This photodiode has 16 green filters, 16 blue filters, 16 red filters as well as 16 colorless filters. The output frequency produced by the sensor is 2 Hz – 500 kHz.

Fig 2. TCS3200 Color Sensor [2]

Table 1. Beef with Fresh Condition

Red Filter	Green Filter	Blue Filter
38	19	16
38	15	16
45	20	20
17	7	6
22	10	8

Table 2. Beef with Decayed Condition

Red Filter	Green Filter	Blue Filter
15	5	5
48	26	23
36	17	14
50	31	25
36	18	16

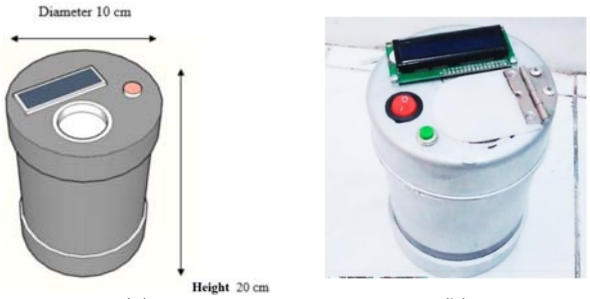
Mamdani Fuzzy Method

The Mamdani Fuzzy Method is useful before drawing the best formula or decision in an uncertain situation. This method utilized linguistic rules and stored fuzzy algorithms that can be analyzed mathematically so that it is easier to understand [16].

The process of decision gathering using the Fuzzy Mamdani Method to get the best statement is being done through many stages, namely the fuzzy sets preparation, implication benefit application, rules composition, and defuzzification. The advantage of the method is specifically more listening to what will be produced in every fuzzy environment, so it will result in more accurate statements. Besides, the method is compatible if the input is received from the human. The disadvantage of the method is it can only be used in the quantitative information composition, not in qualitative information.

Research Method

Mechanical Design



(a) (b)

Fig 3. Beef Freshness Detector Hardware with (a) 3D design, (b) Tools Design

Figure 3 above shows the mechanical design of the Beef Freshness Detector. The Device has a dimension of 20 cm in height and 10 cm in diameter. MQ sensors are located on the side of the device and the TCS sensor is located on the bottom side of the device.

Electrical Design

Figure 4 above shows the electrical wiring of the device. The input of the system consists of MQ-137, MQ-136, TCS3200, and a button. The output of the system is a Buzzer and an LCD to display the status data. The electrical wiring is supplied by the 9V DC Battery.

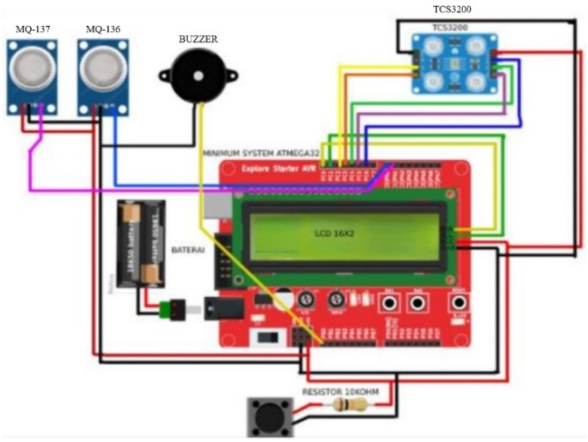


Fig 4. Beef Freshness Detector Electrical Wiring

Software Design

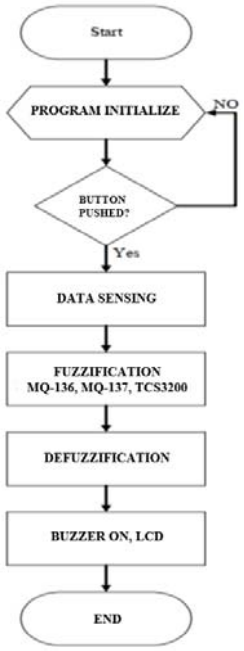


Fig 5. The Detector's Fuzzy System Flowchart

Figure 5 above shows the flowchart of the Detector's Fuzzy System Flowchart. When the button is pushed, the main controller will gather data from the sensor's sensing and then process it to the Fuzzy Input. From then, the defuzzification applied to classify the beef and the status of the beef will be displayed at the buzzer three times and text on LCD. The Fuzzifications membership of the sensors is using ppm data as Table 3 below to determine the quality of beef through data processing.

Table 3. The System's Fuzzy Membership

Sensor	Low (ppm)	High (ppm)
MQ-136	19,397	34,414
MQ-137	9,144	21,154
TCS3200	42	74

MQ-136 Membership Function

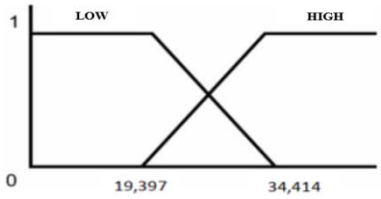


Fig 6. MQ-136 Fuzzy Membership Function

$$\mu\ low[x] = \begin{cases} 1 & x \geq 34{,}141 \\ \dfrac{34{,}141 - x}{15{,}017} & 19{,}397 \leq x \leq 34{,}141 \\ 0 & x \leq 19{,}397 \end{cases}$$

$$\mu\ high[x] = \begin{cases} 1 & x \leq 19{,}397 \\ \dfrac{x - 19{,}397}{15{,}017} & 19{,}397 \leq x \leq 34{,}141 \\ 0 & x \geq 34{,}141 \end{cases}$$

MQ-137 Membership Function

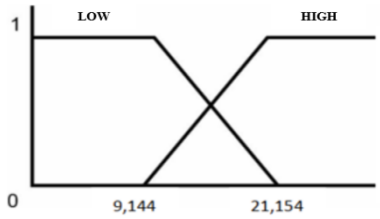


Fig 7. MQ-137 Fuzzy Membership Function

$$\mu\ low[x] = \begin{cases} 1 & x \leq 21{,}154 \\ \dfrac{21{,}154 - x}{12{,}01} & 9{,}144 \leq x \leq 21{,}154 \\ 0 & x \geq 9{,}144 \end{cases}$$

$$\mu\ high[x] = \begin{cases} 1 & x \leq 9{,}144 \\ \dfrac{x - 9{,}144}{12{,}01} & 9{,}144 \leq x \leq 21{,}154 \\ 0 & x \geq 21{,}154 \end{cases}$$

TCS3200 Membership Function

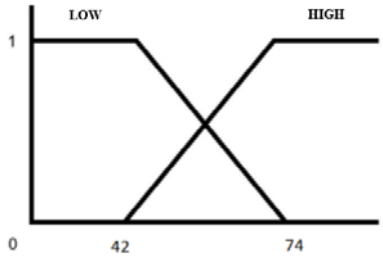


Fig 8. TCS3200 Fuzzy Membership Function

$$\mu\ low[x] = \begin{cases} 1 & x \leq 74 \\ \dfrac{74 - x}{32} & 42 \leq x \leq 74 \\ 0 & x \geq 74 \end{cases}$$

$$\mu\ high[x] = \begin{cases} 1 & x \leq 42 \\ \dfrac{x - 42}{32} & 42 \leq x \leq 74 \\ 0 & x \geq 42 \end{cases}$$

Fuzzy Rule Base

Table 4. System's Fuzzy Rule Base

MQ-136	MQ-137	TCS3200	Beef Condition
Low	Low	Low	Fresh
Low	Low	High	Fresh
Low	High	Low	Bad
Low	High	High	Medium
High	Low	Low	Bad
High	Low	High	Medium
High	High	Low	Bad
High	High	High	Bad

Defuzzification

The system selected three outputs to determine the condition of beef freshness represented in the following membership function. The Defuzzification method applied is the Mean Of Maximum (MOM) method. The method solves the crisp by gathering the crisp which has the largest membership degree from the domain of maximum membership value. Figure 9 below shows the Membership Function curve for the system's defuzzification.

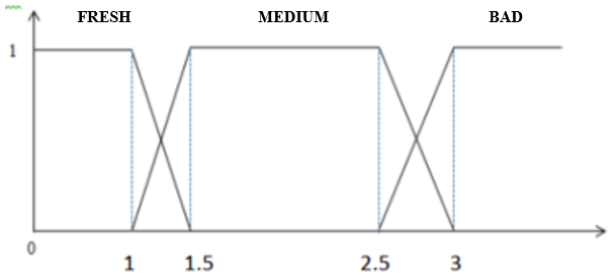


Fig 9. System's Defuzzification Membership Function

$$\mu\ Fresh[x] = \begin{cases} 1 & x \leq 1 \\ \dfrac{1{,}5 - x}{0{,}5} & 1{,}5 \leq x \leq 1 \\ 0 & x \geq 1{,}5 \end{cases}$$

$$\mu\ Medium[x] = \begin{cases} 0 & x \leq 1\ or\ x \geq 3 \\ \dfrac{x - 1}{0{,}5} & 1{,}5 \leq x \leq 1 \\ \dfrac{3 - x}{0{,}5} & 3 \leq x \leq 2{,}5 \\ 1 & 2{,}5 \leq x \leq 1{,}5 \end{cases}$$

$$\mu\ Bad[x] = \begin{cases} 0 & x \leq 2{,}5 \\ \dfrac{x - 2{,}5}{0{,}5} & 3 \leq x \leq 2{,}5 \\ 1 & x \geq 3 \end{cases}$$

Result and Discussions

MQ-136 Test Result

The sensor test is applied to determine the sulfide (H2S), the main factor of meat decaying by aerobic bacteria on meat causing mucus production, changes in meat color, fat, phosphorescent, and odor. To determine the meat quality is to get the fresh one and then let it stand for 6 hours to change into medium and another 6 hours to change into bad result. Table 5 below shows the classification of the Sulfide (H2S).

Table 5. Sulfide (H2S) Parameter of Classification

Output Range (ppm)	Classification
0 – 25	Fresh
25 – 35	Medium
35 – 45	Bad

Table 6. MQ-136 Test Result of The Beef Quality in ppm

Fresh	Medium	Bad	No Beef
23,631	34,414	43,115	0,156
18,627	35,042	35,216	0,303
19,553	32,616	34,414	0,156
18,028	32,634	34,151	0
17,880	30,917	33,374	0,156
21,176	31,876	33,631	0,230
20,030	31,634	32,368	0,156
18,627	29,531	35,216	0,080
18,325	32,867	32,121	0,156
18,627	33,119	33,119	0,156

Table 6 above shows the reading result of the MQ-136 test on the beef quality of 10 passing through the sensor in 10 trials. From the data, it is calculated the average value of each quality of beef. The fresh quality has an average value of **19,4504**, the medium quality has an average value of **32,665**, the bad quality has an average value of **34,672** and **0,1549** for no beef situation.

MQ-137 Test Result

The sensor test is applied to determine the ammonia (NH3) level of organic matter pollution in the meat. Table 7

and Table 8 below show the Ammonia parameter and MQ-137 test result of the beef.

Table 7. Ammonia (NH3) Parameter of Classification

Output Range (ppm)	Classification
0 – 10	Fresh
11 – 19	Medium
20 – 25	Bad

Table 8. MQ-137 Test Result of The Beef Quality in ppm

Fresh	Medium	Bad	No Beef
9,513	12,666	20,319	0,069
9,291	11,465	21,154	0,134
9,513	12,569	22,032	0,069
9,144	11,913	20,648	0
9,144	11,117	22,032	0,069
8,787	12,190	21,853	0,102
9,072	12,474	21,474	0,069
9,072	12,763	21,675	0,035
9,291	12,666	20,648	0,069
9,217	12,284	21,326	0,069

Table 8 above shows the reading result of the MQ-137 test on the beef quality of 10 passing through the sensor in 10 trials. From the data, it is calculated the average value of each quality of beef. The fresh quality has an average value of **9,2044**, the medium quality has an average value of **12,2107**, the bad quality has an average value of **20,4161,** and **0,0685** for no beef situation.

TCS3200 Test Result

The sensor is utilized to detect the color change of the beef. The test is being done by taking data starting from the no meat test, then with the fresh quality, medium, and lastly bad quality meat. The output parameter of this sensor is RGB color categories known as Red, Green, and Blue. Table 9 below shows the data for each quality of the meat.

Table 9. TCS3200 Test Result of The Beef Quality

Fresh			Medium			Bad			No Beef		
R	G	B	R	G	B	R	G	B	R	G	B
77	33	28	52	24	21	33	19	17	255	253	255
68	22	19	50	27	24	47	29	27	252	254	255
74	28	23	54	20	17	44	27	25	251	253	255
71	25	21	58	28	25	44	26	24	255	253	255
83	35	30	48	25	23	43	26	24	253	255	255
71	26	22	51	24	22	35	21	17	255	255	254
82	34	31	53	28	25	46	29	28	255	254	255
76	31	26	56	21	18	45	27	26	255	255	255
77	32	28	58	27	22	46	27	25	254	253	255
70	24	22	49	26	24	42	26	25	253	255	254

Mamdani Fuzzy Test Result

To test the Fuzzy system, each data from the sensors will be applied as an input reference. The fuzzy system will determine the decision for the output value based on sensor data references. Table 10 below shows the test result on each quality of the beef.

Table 10. Mamdani Fuzzy Test Result

MQ-136	MQ-137	TCS3200	Fuzzy	State
23,631	9,513	77	1,128	Fresh
18,627	9,291	68	1,094	Fresh
19,553	9,513	74	1,015	Fresh
18,028	9,144	71	1,047	Fresh
17,880	9,144	83	1,000	Fresh
34,414	12,666	59	2,633	Medium
38,042	11,465	61	2,648	Medium
32,616	12,569	64	2,672	Medium
31,634	11,913	60	2,641	Medium
30,917	11,117	63	2,664	Medium
43,115	20,319	33	2,965	Bad
35,216	21,154	47	2,922	Bad
34,414	22,032	44	2,969	Bad
34,151	20,648	44	2,969	Bad
33,374	22,032	43	2,964	Bad

Overall System Test Result

Table 11. Overall System's Test Result

Beef Quality	MQ-136	MQ-137	TCS3200	Fuzzy	Device Result	Status
Fresh	18,434	9,276	72	1,031	Fresh	Match
Fresh	24,654	9,103	69	1,163	Fresh	Match
Bad	33,245	15,748	40	2,775	Bad	Match
Fresh	26,360	9,224	63	1,222	Fresh	Match
Medium	30,762	11,560	59	2,633	Medium	Match
Medium	34,849	11,956	67	2,691	Medium	Match
Bad	32,674	14,672	48	2,770	Bad	Match
Fresh	19,235	10,344	66	1,125	Fresh	Match
Fresh	23,541	9,582	75	1,124	Fresh	Match
Medium	28,176	12,152	73	2,642	Medium	Match
Bad	40,679	20,763	38	2.984	Bad	Match
Bad	35,602	18,421	39	2.886	Bad	Match
Medium	28,194	11,982	58	2,750	Bad	Not Match
Bad	37,512	21,852	31	3.000	Bad	Match
Medium	34,313	12,666	58	2,750	Bad	Not Match

Table 11 above shows the overall system test result. From the data, the system has a success rate of 86,67% with 13,3% error from 15 trials since there are 2 of the beef that does not match in the system's detection. This is caused by a voltage drop in the device which causes instability in data acquisition.

Conclusions

From the overall test, MQ-136 and MQ-137 can be applied to determine the freshness degree of the beef. The MQ-136 test result on beef qualities shows an average value of 19,4504 on fresh quality, 32,665 on medium, and 34,6725 on bad quality. The MQ-137 test result on beef qualities shows an average value of 9,2044 on fresh quality, 12,2107 on medium, and 20,4161 on bad quality. The designed system has a success rate of 86,67% with an error degree of 13,3%, with 2 mismatches from 15 trials.

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