INNOVATIVE JOURNAL
OF INTELLIGENT CONTROL AND OPTIMIZATION FOR ELECTRICAL SYSTEM
Vol. 3 (2026) No. 1

Publisher by AITEKS : Aliansi ahlI TEKnologi dan Sains
https://ijcioes.org/index.php/ijcioes

Design of a Chayote Jelly Candy Stirring System Based on Color Sensors and Artificial Neural Networks

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Abstract*— The utilization of chayote (Sechium edule) as a raw material for jelly candy production has potential to increase agricultural value. However, the production process still faces challenges during the stirring stage and in determining the dough maturity level, which are commonly performed manually. This manual approach is subjective, inconsistent, and reduces process efficiency and product quality. This study aims to design and implement an intelligent control based chayote jelly candy stirring device using an artificial neural network to determine the dough maturity level automatically. The system was developed using a TCS3200 color sensor to detect changes in dough color in RGB components, a MAX6675 thermocouple sensor to monitor cooking temperature, and an Arduino Uno microcontroller as the main for data processing and actuator control. The RGB color data were processed using a backpropagation artificial neural network method to classify the dough condition. Network training was conducted using 170 training datasets with 10,000 epochs. Experimental results show that the system can identify the dough maturity level with 95.25% accuracy. The mature dough condition was detected at average color values of R = 154.2, G = 167, and B = 86.5 within a cooking temperature range of 70-80 °C. The system also displays information on temperature, color values, and dough maturity status, while automatically controlling the stirring motor. Therefore, the developed device improves consistency, efficiency, and reliability in chayote jelly candy manufacturing.

Keywords: Artificial neural network, Automatic stirring device, Control system, MAX6675 thermocouple, TCS3200 color sensor.

Manuscript received 22 Jan. 2026; revised 31 May. 2026; accepted 25 June. 2026. Date of publication 30 June. 2026.

I. INTRODUCTION

As an alternative to increasing the added value of chayote (*Sechium edule*), this agricultural commodity can be processed into semi moist products such as jelly candy, which offer superior characteristics including a chewy texture, adaptable flavor profiles, and longer shelf life compared to the fresh raw material [1]. However, at both household and small-scale industrial levels, the production process of chayote jelly candy is still predominantly carried out using manual methods, particularly during the stirring process and the determination of batter maturity [2]. The assessment of batter maturity is generally based on the operator's visual observation of color changes and viscosity during the cooking process, making it highly dependent on experience and subjective perception [3]. This condition results in inconsistent production processes, potentially reducing product quality and increasing the risk of misjudgment due to operator fatigue during prolonged operations [4].

Several previous studies have shown that color characteristics can be used as an important indicator for determining the maturity level of food products during thermal processing [5]. RGB-based color sensors have been applied to objectively and repeatedly detect color changes in food materials [6]. In addition, the application of artificial intelligence methods, particularly artificial neural networks (ANN) using the backpropagation algorithm, has proven effective in recognizing nonlinear data patterns and is widely employed in classification systems within engineering and food industry applications [7].

Several studies on automated food processing systems indicate that the integration of sensors with machine learning methods can improve the consistency and reliability of production processes [8]. However, the application of color sensors combined with artificial neural networks to determine the maturity level of jelly candy batter, especially those made from chayote, remains relatively limited [9]. This indicates a research opportunity to develop a more adaptive and accurate system by directly utilizing visual information from the batter.

Based on the problems described above, this study aims to design and analyze a chayote jelly candy stirring device that is adaptive to changes in batter conditions during the cooking process. The system is based on a microcontroller and is equipped with color and temperature sensors, and applies a backpropagation-based artificial neural network method to classify batter maturity levels based on changes in RGB values [10]. The novelty of this research lies in the use of batter color data as the primary parameter for determining maturity, processed using ANN, so that the system does not rely solely on temperature or heating duration [11]. Through this approach, the proposed system is expected to produce a more controlled, consistent, and efficient stirring process, while supporting improvements in the quality of chayote jelly candy products [12].

II. METHOD

The methodology section describes the stages of the research implementation in a systematic and detailed manner to ensure that the study can be replicated by other researchers. The methods employed include system design, hardware assembly, software development, data acquisition, artificial neural network model training, and system performance evaluation.

A. *Research Implementation Flow*

The research implementation flow is illustrated in Figure 1. The study begins with a literature review related to food processing automation, the utilization of color sensors, and the application of artificial neural networks in control systems. This stage aims to establish the theoretical and methodological foundations that support the system design.

The next stage involves the design of a chayote jelly candy stirring system, which includes both hardware and software design. The hardware design covers the selection and integration of main components such as a microcontroller, a color sensor, a temperature sensor, and a stirring motor. Meanwhile, the software design focuses on the development of sensor data acquisition algorithms, color data processing, and the implementation of artificial neural networks.

After the system is assembled and operates properly, color data of the jelly batter are collected under various conditions during the heating and stirring processes. The collected data are used as training data to develop a backpropagation-based artificial neural network model for classifying the batter maturity level.

The final stage of the research is system testing, which aims to evaluate sensor performance, the accuracy of batter maturity classification results, and the overall reliability of the system.

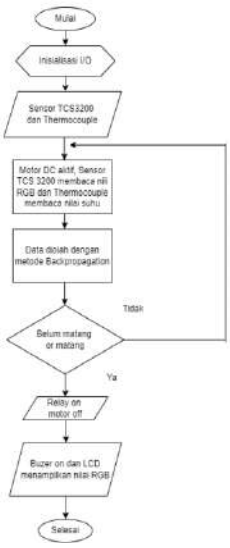


FIGURE 1. Research Implementation Flowchart

B. *System Design and Configuration*

The configuration of the chayote jelly candy stirring system is shown in Figure 2. The system is designed as an integrated unit operating in real time. An Arduino Uno is used as the main controller responsible for reading sensor data, processing th e data, and controlling the actuators. A TCS3200 color sensor is employed to detect changes in the batter color, while a MAX6675 thermocouple temperature sensor is used to monitor the cooking temperature during the heating process [13]. A DC motor is utilized as the stirring actuator and is controlled via a relay. System status information is displayed on an LCD, while a buzzer functions as an indicator when the batter has reached the mature condition [14].

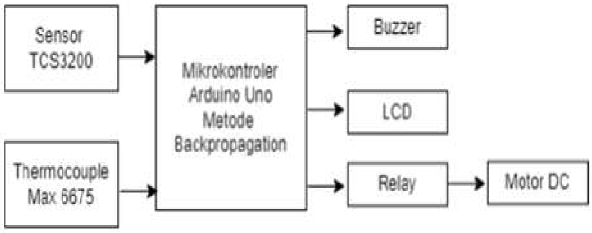


FIGURE 2. Block Diagram of the Chayote Jelly Candy Stirring System

C. Equipment and Materials

In this study, an Arduino Uno microcontroller (ATmega328) is used as the main control unit of the system. A TCS3200 color sensor is employed to detect changes in the batter color, while a K-type thermocouple temperature sensor with a MAX6675 module is used to monitor the temperature during the stirring and heating processes [15]. A 12 V DC motor functions as the stirring actuator and is controlled via a 5 V relay. The system is equipped with a 20×4 I2C-based LCD to display temperature data, RGB values, and batter maturity status, as well as a buzzer serving as an indicator for process completion [16]. System programming is carried out using the Arduino IDE, and MATLAB is utilized for training the backpropagation-based artificial neural network model.

The materials used include chayote (*Sechium edule*) as the main raw material for jelly candy, granulated sugar as a sweetener, agar or gelatin as a texturizing agent, and water as a solvent in the cooking process.

D. Research Location and Duration

This research was conducted in a processing and instrumentation laboratory. The research duration covered the stages of system design, data acquisition, artificial neural network model training, as well as system testing and result analysis.

E. Working Principle of the TCS3200 Color Sensor

The TCS3200 color sensor operates by converting the intensity of light reflected from the batter surface into a frequency signal. The sensor is equipped with an array of photodiodes, each fitted with red (R), green (G), and blue (B) color filters that can be selected through the configuration of selector pins.

When the batter is positioned for measurement, the reflected light from its surface is captured by the photodiodes and processed to produce frequency values for each RGB color component [17]. These frequency values are then read by the microcontroller and converted into calibrated RGB values, which are subsequently used as input parameters in the batter maturity classification system [18], [19].

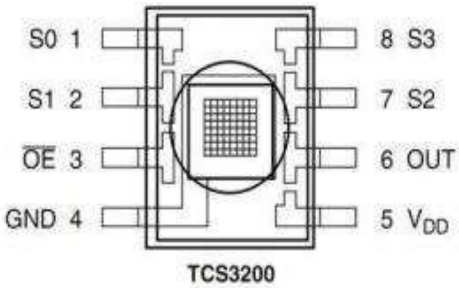


FIGURE 3. Pins of the TCS3200 Color Sensor

F. *Data Collection and Artificial Neural Network Model Training*

The data collection stage was conducted by recording the RGB values of the jelly candy batter under various conditions during the heating and stirring processes. Data acquisition was performed periodically until a range of color variations representing both immature and mature batter conditions was obtained. The determination of maturity classes was based on visual observation and the texture characteristics of the final product.

The collected data were then used as training data for an artificial neural network employing the backpropagation algorithm. The architecture of the artificial neural consisting of three neurons in the input layer (R, G, and B), one hidden layer, and one neuron in the output layer representing the batter maturity class. The training process was carried out by adjusting the netwo rk weights until a minimum error value and optimal classification accuracy were achieved.

The approach to classifying dough maturity levels based on RGB values and artificial neural networks refers to methods that have been widely used in color-based food quality assessment, in which color features are extracted and processed using the backpropagation algorithm to recognize nonlinear visual pattern changes [20].

G. System Testing

System testing was conducted to evaluate the performance and reliability of the developed device. The tests included evaluations of the color sensor and temperature sensor readings, assessment of the stirring motor response to the artificial neural network classification results, and measurement of the system's accuracy in determining the batter maturity level. The testing results were compared with the actual batter conditions to assess the overall success rate and stability of the system. The identification of labu siam cracker dough color using an IoT-based color sensor can help improve product quality consistency and minimize errors caused by visual observation [21]. This study uses a backpropagation neural network to determine the evenness of the chayote chip dough. The Tcs3200 Color Sensor mounted on the stirrer is used as a sensor to determine the color of the chayote emping dough. A regression score of 1 indicates that the input and target data match in the test results of the artificial neural network, which has an objective error (MSE) value of 0.0096306 achieved in the 313th epoch [22].

III. RESULT AND DISCUSSION

A. Results of TCS3200 Color Sensor Voltage Measurements

Testing of the TCS3200 sensor was conducted to ensure proper sensor operation and to determine the voltage values at the measurement points of the circuit. Measurements were performed at the output pin of the TCS3200 sensor with an input voltage of 5 V DC. The measurement points of the TCS3200 sensor circuit are shown in Figure 4.

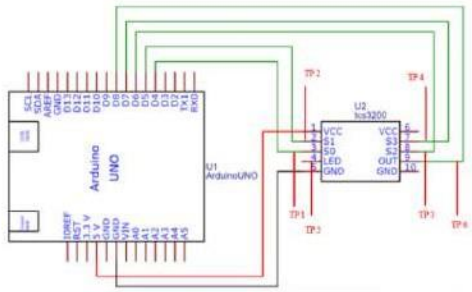


FIGURE 4. Measurement Points of the TCS3200 Sensor Circuit

Based on the measurement results of the TCS3200 sensor with an input voltage of 5 V DC, the voltage values obtained were 4.8 V at pin S0, 4.6 V at pin S1, 4.8 V at pin S2, 4.8 V at pin S3, 4.7 V at the LED pin, and 2.7 V at the output pin. The measurement results are presented in Table I.

TABLE I
Voltage Measurement Results of the TCS3200 Sensor

Measurement Point	Measurement Results (VDC)
S0	4,5
S1	4,6
S2	4,8
S3	4,6
Led	4,7
Out	2,7

B. Analysis of the TCS3200 Sensor Calibration System

Calibration was performed to ensure the accuracy of the sensor in detecting various colors. The calibration of the TCS3200 sensor aims to obtain reference RGB (Red, Green, Blue) values that correspond to standard colors, enabling the sensor to accurately recognize and distinguish the color of the dough in the developed device. The calibration results of the TCS3200 sensor using colored paper are presented in Table II.

Table II
TCS3200 Sensor Calibration Results

No	Figure	Color	TCS3200 (0-255)		
			R	G	B
1		Green	154	152	144
2		Red	225	118	136
3		Blue	95	171	207
4		Black	16	15	14
5		White	255	255	255

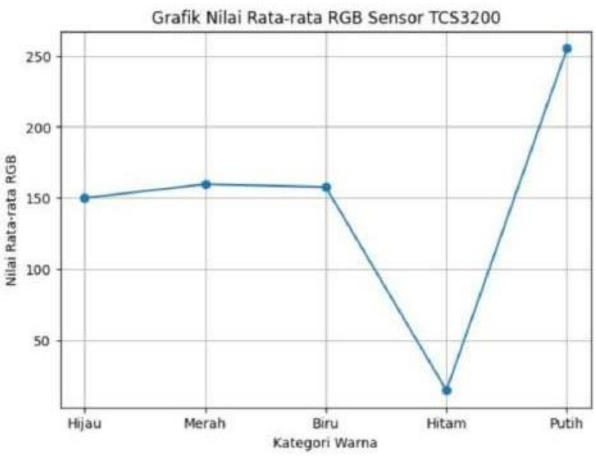


FIGURE 5. Calibration Results of the TCS3200 Color Sensor

Based on the sensor calibration results presented in Table II, it can be observed that the RGB values measured for white color are consistently higher than those for black color. For the white color, the measured RGB values are R = 255, G = 255, and B = 255, whereas for the black color, the measured RGB values are R = 16, G = 14, and B = 15. These results indicate that the TCS3200 sensor is capable of accurately distinguishing differences in color intensity.

C. Results of Dough Testing

In this sensor response test, the system was evaluated by detecting color changes during the stirring process of chayote (Sechium edule) jelly candy dough. The expected outcome of the sensor readings was to obtain color data for each detected condition until an appropriate average value representing the dough characteristics was achieved.

The measurements were conducted during the stirring process using a formulation consisting of 2 kg of chayote, 2 kg of granulated sugar, and two sachets of agar powder. The results of the first experimental measurement of the chayote jelly candy dough are presented in Table III.

Table III.
Dough Testing Results

Sensor Reading Values			Dough Description	Dough Condition
R	G	B		
215	235	145	Initial stage of ingredient mixing	Uncooked
196	216	126	Dough evenly mixed	Uncooked
172	194	105	Soft and sticky dough	Uncooked
148	172	83	Thick and sticky dough	Uncooked
133	150	70	Cooked and sticky dough	Cooked

Based on the results of Experiment 1, it can be concluded that the color change indicating the mature dough condition occurred at RGB values of R = 133, G = 150, and B = 70. The RGB measurement results of the dough in Experiment 2 are presented in Table IV.

Table IV.
RGB Value Readings in Experiment

Sensor Reading Values			Dough Description	Dough Condition
R	G	B		
220	240	150	Initial stage of ingredient	Uncooked
206	225	139	Dough evenly mixed	Uncooked
176	189	112	Soft and sticky dough	Uncooked
161	171	98	Thick and sticky dough	Uncooked
145	150	83	Cooked and sticky dough	Cooked

Based on the results of Experiment 2, it can be concluded that the color change indicating the mature dough condition occurred at RGB values of R = 145, G = 150, and B = 83. The RGB measurement results of the dough in Experiment 3 are presented in Table V.

Table V.
RGB Value Readings in Experiment 3

Sensor Reading Values			Dough Description	Dough Condition
R	G	B		
225	245	155	Initial stage of ingredient mixing	Uncooked
214	233	143	Dough evenly mixed	Uncooked
201	217	130	Soft and sticky dough	Uncooked
188	201	118	Thick and sticky dough	Uncooked
171	180	101	Cooked and sticky dough	Cooked

Based on the results of Experiment 3, it can be concluded that the color change indicating the mature dough condition occurred at RGB values of R = 171, G = 180, and B = 101. The RGB measurement results of the dough in Experiment 4 are presented in Table VI.

Table VI.
RGB Value Readings in Experiment 4

Sensor Reading Values			Dough Description	Dough Condition
R	G	B		
230	250	160	Initial stage of ingredient mixing	Uncooked
220	240	150	Dough evenly mixed	Uncooked
208	228	138	Soft and sticky dough	Uncooked
196	216	126	Thick and sticky dough	Uncooked
168	188	92	Cooked and sticky dough	Cooked

Based on the results of Experiment 4, it can be concluded that the color change indicating the mature dough condition occurred at RGB values of R = 168, G = 188, and B = 92. Based on the results of Experiments 1 to 4, the average RGB values obtained for the mature dough condition are as follows:

Table VII.
Average RGB Values from the Experiments

Experiment	Sensor Reading Values		
	R	G	B
Experiment 1	133	150	70
Experiment 2	145	150	83
Experiment 3	171	180	101
Experiment 4	168	188	92
Average Value	154,2	167	86,5

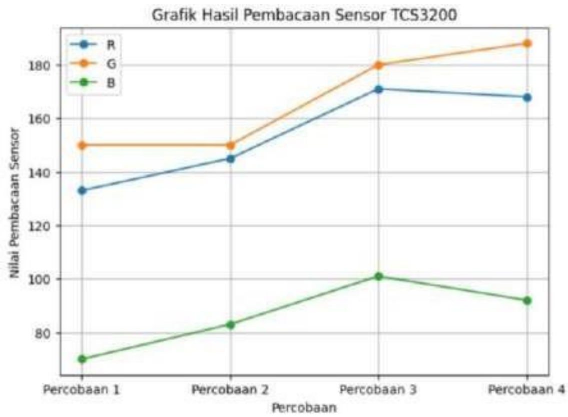


FIGURE 6. Results of the Average Values of the Experiment

Therefore, based on the experimental data presented in the tables and graphs above, it can be concluded that the detection of dough color changes until reaching the mature condition requires the RGB values measured by the TCS3200 color sensor to reach an average of R = 258.2, G = 167, and B = 86.5.

D. Testing and Analysis of the MAX6675 Thermocouple Circuit

The thermocouple sensor testing was conducted to evaluate whether the thermocouple sensor operates properly and to determine the voltage at the measurement points of the thermocouple circuit. The measurement point of the MAX6675 thermocouple sensor is located at the output terminal of the MAX6675 module, with an input voltage of 5 V DC. The measurement point of the MAX6675 thermocouple circuit is illustrated in Figure 7.

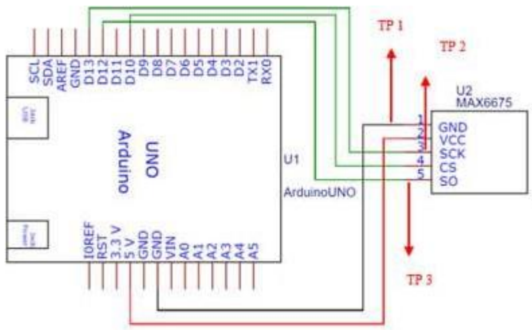


FIGURE 7. Measurement Points of the Max6675 Thermocouple

Based on the measurements conducted on the thermocouple, data were obtained when the MAX6675 thermocouple was supplied with an input voltage of 5 V. The measured values using a multimeter were 4.7 V at the SCK pin, 4.8 V at the CS pin, 4.8 V at the S2 pin, and 4.7 V at the S0 pin. The results are presented in Table VIII below.

Table VIII.
Voltage Measurement Results of the Max6675 Thermocouple

Measurement Point	Measurement Results (VDC)
SCK	4,7
SC	4,8
S0	4,7

E. Testing and Analysis of the LCD & I2C Circuit

The testing of the LCD & I2C module was carried out using a multimeter. The test was performed on the SCL and SDA pins of the I2C module to measure the voltage supplied to these pins with an input voltage of 5 VDC. The testing points on the LCD & I2C module are shown in Figure 9, and the measurement results of the LCD & I2C module are presented in Table 7 below.

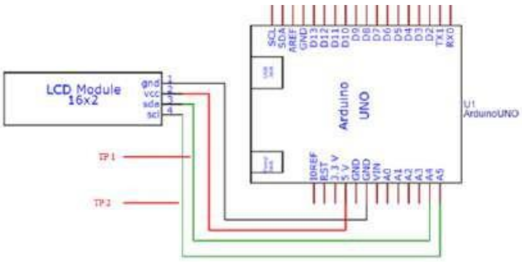
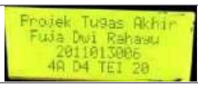
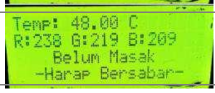


FIGURE 8. Measurement Points of the LCD & I2C Module

Table IX.
Measurement Results of the LCD & I2C Circuit

LCD Display	Voltage on the LCD I2C Module	
	Pin SDA (A5)	Pin SCL (A4)
	4,2	**4,2**
	4,2	**4,2**
	4,2	**4,2**

Based on Table IX, the measurement results of the LCD indicate that when the LCD has a VCC-GND voltage of 5 V, with SCL and SDA values of 4.2 V each, the LCD is able to display information such as temperature, RGB values, name, student ID number, and the status of the dough.

IV. CONCLUSION

Based on the design and testing results, this study successfully developed and implemented a chayote (Sechium edule) jelly candy stirring device using a microcontroller, with an artificial neural network (ANN) applied as the decision-making method for determining the dough's ripeness. Overall, the developed system functions as intended, automatically detecting the dough's condition based on color and temperature parameters during stirring and heating processes.

Testing results showed that the ripeness of the jelly dough can be consistently identified at average color component values of red (R) = 154.2, green (G) = 167, and blue (B) = 86.5, with a cooking temperature range of 70-80 °C. These parameters serve as an objective reference for determining dough ripeness, eliminating the need for subjective visual observation by operators.

The implementation of the backpropagation ANN with three input parameters (R, G, and B values) demonstrated good performance in classification. From a total of 170 training data points with 10,000 epochs, the system correctly recognized 160 data points, achieving an accuracy of 95.25%. This indicates that the ANN method is effective in recognizing patterns of color changes in the dough during the jelly cooking process.

All data obtained from the TCS3200 color sensor and MAX6675 thermocouple sensor were successfully processed by the microcontroller and displayed in real-time on the LCD, allowing users to monitor temperature, color, and dough ripeness status during stirring. Consequently, this system improves product quality consistency and enhances the efficiency of chayote jelly candy production.

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