THE 1ST LEWIS
The 1st Lawang Sewu International Symposium
Volume 1, November 2022

E-ISSN : 2987-2685
page 11 - 20

Development of Electronic Sensing Devices of Artificial Neural Network Programming Application for Borax in Food Detection

Agus Suyanto[1*], Achmad Solichan[2]
[1]Faculty of Nursing and Health Sciences, Universitas Muhammadiyah Semarang, Indonesia
[2]Faculty of Engineering, Universitas Muhammadiyah Semarang, Indonesia
*Corresponding author : agussuyanto.kh@unimus.ac.id

ABSTRACT

The use of Food Additives is regulated in BPOM regulation number 11 of 2019. In practice, there are food entrepreneurs who use prohibited BTP, one of which is borax to thicken meatballs, noodles, and rice cakes. The prohibition on the use of borax in food is stated in the Regulation of the Minister of Health No. 722/MenKes/Per/IX/88 where borax is a hazardous material. The development of electronic sensing equipment to detect borax can be used for rapid identification in the field as early detection for food safety monitoring. The research phase consists of the design of the E-sensing device followed by the programming of the Artificial Terms Network method using Matlab software. Meatball samples with the addition of 0%, 1%, 2%, and 3% borax were measured for RGB color image values using E sensing as input for Matlab programming. The design of E Sensing uses an NCU ESP8266 node microcontroller, TCS 3200 color sensor, and LCD can be used to measure the color image of meatballs with RGB value output. Matlab ANN programming results are less sensitive for borax detection at 1% and 2% borax content, as seen from the low test accuracy value (<75%), while the 3% borax content is quite sensitive with a test accuracy value of 90.9091%. Display graphical user interface (GUI) on a computer screen can be used easily by users.

Keywords: Borax, NCU ESP 8266 microcontroller, Artificial neural network, TCS 3200 sensor, Electronic sensing

1. INTRODUCTION

In the practice of food processing, the use of Food Additives (BTP) is commonly used to improve food quality, both physically, chemically, and sensory. The use of BTP is regulated in BPOM regulation number 11 of 2019 [1]. In practice, there are food entrepreneurs who use prohibited BTP, one of which is borax to thicken meatballs and noodles. The prohibition on the use of borax in food is stated in the Regulation of the Minister of Health No. 722/MenKes/Per/IX/88 borax as a hazardous material [2].

Research on meatballs in the city of X from 10 samples of meatballs showed that 80% of the samples examined contained borax (eight samples out of ten samples) and the borax content found in meatballs was between 0.08% - 0.29% [3]. Rumanta stated that the quality test of market snacks in the form of meatballs, and wet noodles in market X had shown the presence of borax in the sample [4].

E-ISSN : 2987-2685
page 11 - 20

According to the Regulation of the Minister of Health of the Republic of Indonesia Number 03 of 2012 concerning Food Additives, borax is one type of food additive that is prohibited from being used in food products [5]. The bad effects of consuming borax are irritating the gastrointestinal tract, which is characterized by headaches, dizziness, vomiting, nausea, and diarrhea. Further symptoms are marked by the body becoming weak, kidney damage, even shock, and death if swallowed 5-10 g/kg body weight.

Borax is a white crystalline compound that is odorless and stable at room temperature. Borax is a chemical compound with the name Sodium tetraborate ($NaB_4O_7.10H_2O$). If it dissolves in water it will become hydroxide and boric acid (H_3BO_3). Consuming foods that contain borax does not directly cause harm, but the borax will accumulate little by little because it is absorbed cumulatively in the consumer's body [6].

The development of an instrument to detect borax can be done based on the indication of the color of the meatballs. The color sensor used in E Sensing is required to detect color as an electrical quantity in the form of frequency. One of the manufacturers that have successfully developed these sensors is Figaro with its TGS series and Quartz crystal microbalance (QCM). A data acquisition system is needed to get sensor output values for characterization. The sensor in the E Sensing system is connected to the transducer which changes the physical data from the food color image containing borax which will enter as input from the transducer to be converted into electrical energy in digital form. The control element or controller in the data acquisition system is an electronic circuit consisting of 4 modules namely CPU, memory, input, and output supported by programming software.

Perceptron multi-layer is the most widely used architecture for practical applications of Neural Networks. In most cases, the network consists of two layers of adaptive weights with full connectivity between the input and hidden units, and between hidden and output units. The network can learn complex non-linear regression by adjusting the w weights in the network using the appropriate optimization algorithm.

The multivariate data processing technique used and the simplest is the back-propagation (BP) technique [7]. Identification uses the artificial neural network method by learning using the backpropagation algorithm from the output signal pattern of the sensor array used. ANN is an artificial representation of the human brain which always tries to simulate the learning process of the human brain [8] 2010). ANN is a generalization of a mathematical model of human cognition based on the assumption that information processing occurs in simple elements called neurons. Signals flow between nerve cells through a connecting junction, each connecting junction has a corresponding weight and each nerve cell will be an activation function of the weighted sum of the incoming signals to determine the output signal [9].

AI applications in the food sector can help product quality control, starting from the selection of raw materials (quality selection), control of processing processes, and the desired final quality criteria. In the selection of raw materials, AI can be used to select fruit maturity criteria. Process control can adjust heat sufficiency. AI in the food sector application is made in a programmable logic controller (PLC) electronic circuit system.

E-ISSN : 2987-2685
page 11 - 20

Identification of borax can be carried out by chemical analysis both qualitatively and quantitatively, but it is constrained by limited equipment and analysis time. The development of electronic sensing equipment design is expected to overcome this problem, where the resulting output is in the form of qualitative and quantitative data. The research objective of E-sensing design consists of a microcontroller and color sensor and artificial neural network architecture for the identification of borax in food.

2. METHOD

1.1. Design of Electronic Sensing Devices

The design of electronic sensing includes E Sensing which is divided into three stages, namely: 1) Design of electronic sensing systems, 2) Data analysis using artificial neural network architecture based on the smallest MSE (Mean Square Error) in training followed by statistical analysis of principal component analysis (principal component analysis/PCA), and 3) measurement data validation.

The software on the PC uses the Matlab 2014a software functions to read the output of the sensor array, acquire the data in a computer unit, process the data for neural network training, and display the results. The Artificial Neural Network that will be used is a Multi-Layer Perceptron with Backpropagation training which is a supervised learning algorithm. The Multi-Layer Perceptron (MLP) design uses n layers (input, hidden, and output layers) as shown in Figure 1. The determination of the ANN architecture, namely the number of hidden layers, is carried out by trial and error using the developed program. The number of hidden layers selected is based on the smallest MSE value and the optimum number of hidden layers.

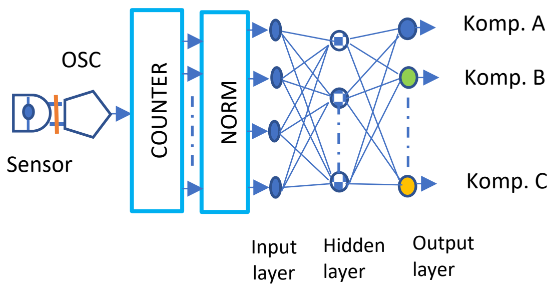


Figure 1 *Electronic gas sensor data processing with artificial neural network pattern recognition [10]*

1.2. Manufacturing Procedure of Meatballs for Training Samples and Test Samples

The steps for making the meatballs for the training sample and the test sample were making the meatball dough, adding different levels of borax, weighing the mass of the meatballs, and cooking the meatballs. The treatment for sensor readings with the addition of sample borax was divided into 4 types of treatment, namely without borax, with the addition of 1%, 2%, and 3% borax.

E-ISSN : 2987-2685
page 11 - 20

1.3. Sensor Readings and Data Capture

When given additional borax, the food will change color so that it affects the change in light intensity from the reflected light that hits it (Syah et al. 2005). The color change in the food is not so significant that it would be very difficult to tell the difference with the naked eye. The TCS3200 sensor can distinguish colors based on the intensity of the Red-Green-Blue (RGB) values reflected by objects [11].

3. DISCUSSION

3.1. Manufacture of electronic sensing devices

The software was created using the Processing Programming Language on the Node NCU ESP 8266 microcontroller in the Arduino IDE platform module. The NCU ESP 8266 converts the digital signal frequency of the TCS3200 sensor and the gas sensor analog signal into digital values. The digital color value uses an 8-bit resolution value that represents the sensor's reading range of color in RGB form. Furthermore, the digital sensor value is processed using Backpropagation and the results are displayed on the LCD.

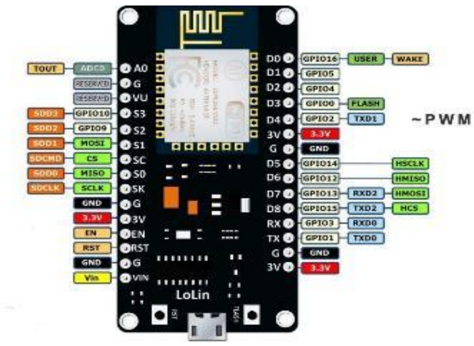


Figure 2 *NodeNCU ESP8266 [12]*

The NodeNCU v3 specification consists of a Tensilica microcontroller 32-bit, Flash Memory 4 KB, Operating voltage 3.3 V, Input Voltage 7 – 12 V, Digital I/O 16, Analog Input 1 (10 Bit), UART Interface 1, SPI Interface 1, and I2C interfaces 1.

A B

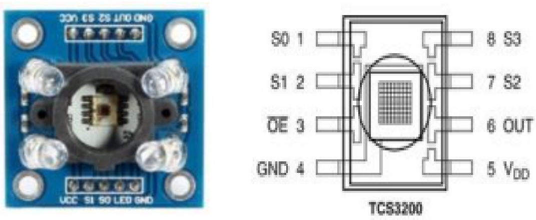


Figure 3 *TCS3200 color sensor (A), pins on the TCS 32000 sensor (B) [13]*

The microcontroller circuit uses the NodeNCU ESP8266 which is connected to the TCS 3200 color sensor. NodeNCU is an electronic board based on the ESP8266 chip with the ability to run microcontroller functions and also an internet connection (WiFi). There are several I/O pins so that they can be developed into an IoT monitoring and controlling application. NodeNCU ESP8266 can be programmed using the Arduino IDE which is connected to a PC via the USB port.

E-ISSN : 2987-2685
page 11 - 20

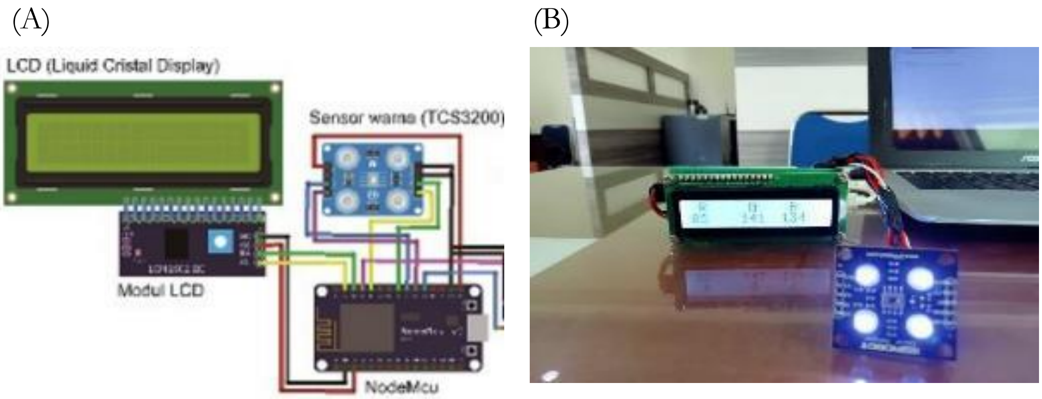


Figure 4 *Design of the E sensing tool (A) and physical photos of the E sensing tool using the TCS 3200 color sensor (B)*

The detection of borax cannot use a gas sensor because borax does not produce gas or aroma in the meatballs. The sensor used in the microcontroller circuit for detecting borax in meatballs uses a color sensor, based on the change in color of the meatballs. The name of borax detection microcontroller circuit does not use an olfactory system but uses color image reading so it is named an electronic sensing device (electronic sensing or e-sensing). In previous studies, the TCS3200 sensor was able to detect the color of leaves and stems to monitor plant growth [14], as an indicator of plant health status.

The TCS3200 Color Sensor uses the TAOS TCS3200 RGB chip which has been integrated with 4 white LEDs. This sensor can detect and measure the intensity of the visible color from the reflection of light on objects originating from 4 LEDs. The TAOS TCS3200 RGB chip is composed of two integrated main components, namely the photodiode and the converter of the electric current generated by the photodiode into frequency. The photodiodes are arranged in the form of an 8x8 array with a configuration of 16 photodiodes for each red filter (R), green filter (G), blue filter (B), and no filter (clear). The photodiode configuration used is set using selectors S2 and S3 to determine the type of filter. Meanwhile, on the output frequency scale of the photodiode, selectors S0 and S1 are used with a maximum frequency scale of 20% (100 kHz) [15].

The photodiode will produce a digital signal with a frequency proportional to the basic color of the light hitting it. The digital signal is then sent to the NCU ESP 8266 using serial communication with a single cable. The TCS3200 sensor sends a digital signal to the NCU ESP 8266 per RGB color packet for each reading data. RGB color packets are sent alternately starting from R, G, and B colors with a delay of 10 ms. The process of calculating the frequency of a digital signal originating from the TCS3200 Sensor is to make a 1-second period timer and then count it according to the number of waves in the signal. The correlation of the signal frequency value is directly proportional to the detected color digital value. The greater the frequency of the signal generated, the greater the digital color value which indicates the color of the detected object is getting brighter or brighter.

The calibration process needs to be done before the sensor is used to detect borax in meatballs. This aims for accurate measurement results. The TCS3200 sensor calibration process is carried out by monitoring the RGB values on white and black objects using the

E-ISSN : 2987-2685
page 11 - 20

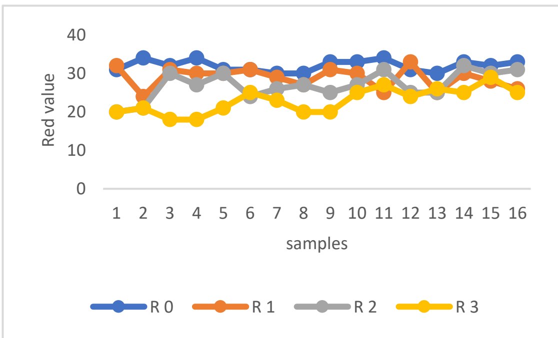
Arduino serial monitor. An accurate white reading is when the RGB value shows a value close to or equal to 255. Meanwhile, an accurate black reading when the RGB value shows a value close to or equal to 0.

3.2. Measurement of meatball color using E sensing

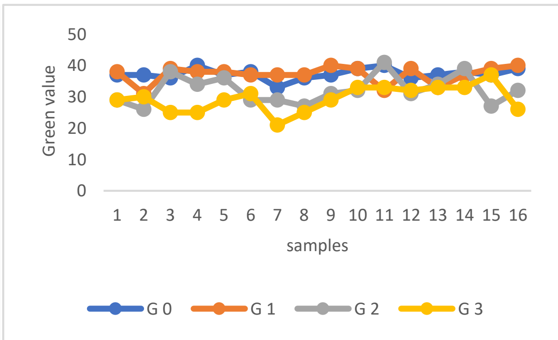
Data collection for the number of samples used was 16 meatball samples from each treatment. On the detection of samples containing borax, the meatballs were split into two parts and then placed in a borax test chamber perpendicular to the TCS3200 sensor. In addition, it is necessary to know the stability of sensor readings so that it helps in calibrating the sensor output.

The e-sensing tool that has been calibrated can then be used to perform color readings on the sample. The figure shows the Red Green Blue (RGB) values in the meatball samples in 16 samples with 0%, 1%, 2%, and 3% borax (R0, R1, R2, R3; G0, G1, G2, G3, and B0, B1, B2, B3). The color of the blue line is the meatball sample without borax, adjacent to the brown color is the sample with 1% borax, and the farthest from the orange color is the meatball sample with 3% borax content. This shows that the reading results of the e-sensing tool are quite valid where each meatball with a different borax content produces a different RGB color image.

(A)



(B)



(C)

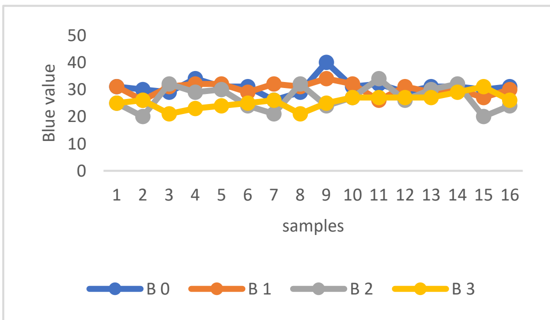


Figure 5 *Results of reading the values of Red (A), Green (B), and Blue (C) in the meatball sample using the e-sensing tool*

3.3. Matlab Programming Artificial Neural Networks (ANN)

The ANN Backpropagation Algorithm consists of 3 stages, namely feed-forwardfeed-forward input pattern training, back propagation of a collection of errors

E-ISSN : 2987-2685
page 11 - 20

(errors), and weight adjustment or the stage of changing weights. The training process is carried out to find a model that can classify unknown data classes. The backpropagation architecture that will be used is limited to one input layer, one hidden layer, and one output layer (Figure 9). In the input layer, the data used is the reading output from each sensor while in the hidden layer, the calculation process is carried out. The output layer generates data that determines whether the meatball contains borax with the symbol 0 or does not contain borax with the symbol 1. The Backpropagation Algorithm is described in detail as follows [16].

1) Initialize all weights with small random numbers.
2) Determine the number of iterations, the target error, and the learning rate value
3) Repeat the following process during (iteration < maximum iteration) and (MSE > target error)

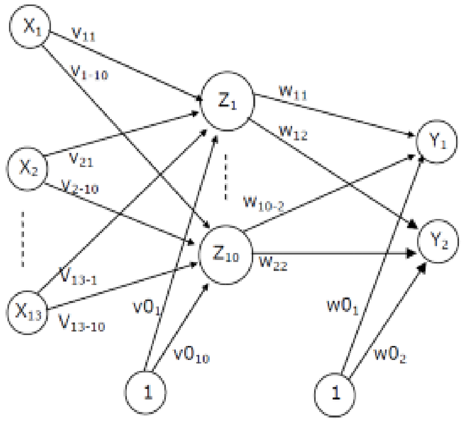


Figure 6 *Back propagation architecture [15]*

3.4. Learning Stages on the Training Sample

The learning process begins with taking sample data several times. The digital value of the sensor reading on the sample is then changed in the range between 0.1 to 0.9 with the normalization method. After the data has been normalized, NCU ESP 8266 processes the data with Backpropagation. This process produces a weight that corresponds to the reading data of each sensor. The weight is then stored and used in the process of testing meatball samples.

3.5. Tool Testing on Test Samples

The testing process begins with sensor readings on one sample to be tested. The digital value of the sensor reading results is then normalized and processed using Backpropagation with the weights that have been obtained in the learning process. This process determines whether the test sample contains borax. After obtaining the results of this testing process, the information will be displayed on the graphical user interface (GUI) display in the Matlab program.

E-ISSN : 2987-2685
page 11 - 20

3.6. Learning stage

The learning phase is carried out using a training sample. Determination of the best network parameters seen from the MSE. The smaller the MSE, the greater the recognition success rate. This stage is carried out by finding the number of neurons in the hidden layer, the learning rate, and the appropriate momentum. The target error value used in this network is 0.2. With this target value, it is hoped that the network will be stable enough when it reaches the error value. Based on experiments, the target error value is below 0.2.

3.7. Testing process

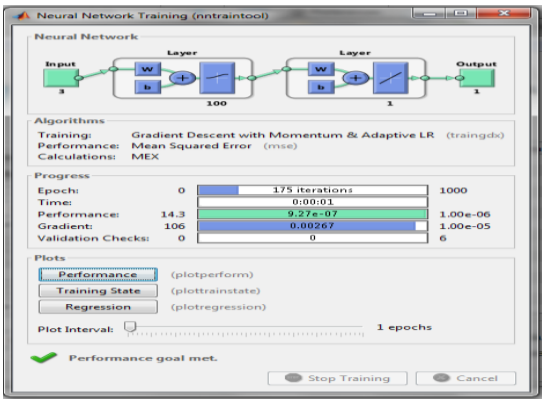
The testing process is carried out using a test sample. This process begins by reading the output of the TCS3200 sensor or gas sensor and then the reading data is normalized before being processed using backpropagation. The stages in the testing process are the same as the learning process. The difference between the testing process and the learning process is that the testing process only involves a feedforward phase without a backpropagation phase.

The results of the Matlab JST training with a 1% borax meatball sample obtained a minimum MSE value of 0.0015 with 175 iterations and a regression value of 0.99753 or a validation level of 99.753%. The training results obtained an error of 0 and an accuracy of 100%, while the test results obtained an error of 1 and an accuracy of 36.3636%.

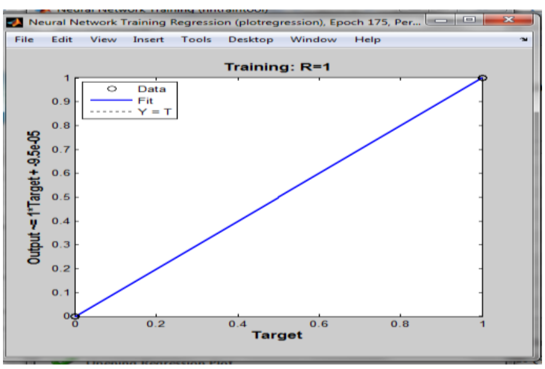
The results of Matlab JST training with a 2% borax meatball sample obtained a minimum MSE value of 0.000863 with 1000 iterations and a regression value of 0.99842 or a validation level of 99.842%. The training results obtained 0 errors and 100% accuracy, while the test results obtained 4 errors and 63.6364% accuracy.

The results of Matlab JST training with a 3% borax meatball sample obtained a minimum MSE value of 9.27 x 10-7 with 175 iterations and a regression value of 1 or a 100% validation level. The training results obtained an error of 0 and an accuracy of 100%, while the test results obtained an error of 1 and an accuracy of 90.9091%.

(A)



(B)



E-ISSN : 2987-2685
page 11 - 20

(C) (D)

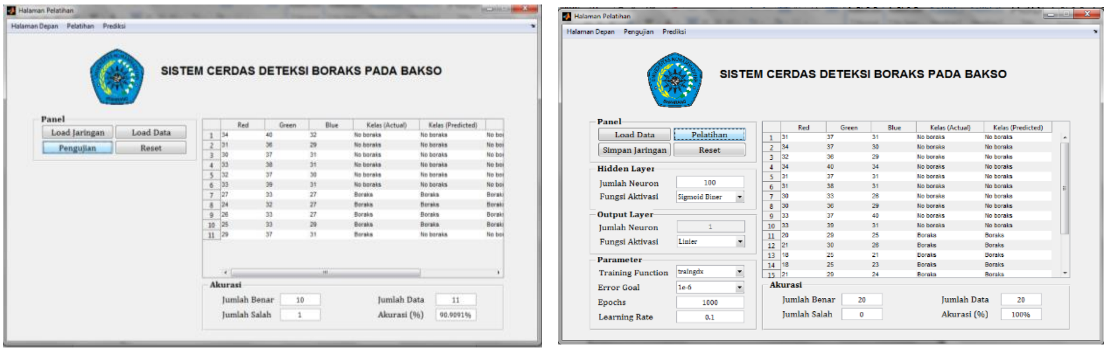


Figure 7 *Training stages (A), regression values (B), training results (C), and test results (D) for a sample of 3% borax meatballs*

The benefit of programming ANN using Matlab is that it can estimate or predict 'there' or 'no' borax in meatballs by entering the RGB value from the color sensor reading. The system is less sensitive to the 1% and 2% borax content seen from the low test accuracy value (<75%), while the 3% borax content is quite sensitive with a test accuracy value of 90.9091%. The graphical user interface (GUI) display can be seen in the figure, with the results of testing the values R 33, G 39, and B 31 not containing borax, while the values R 25, G 33, and B 29 contain borax.

(A) (B)

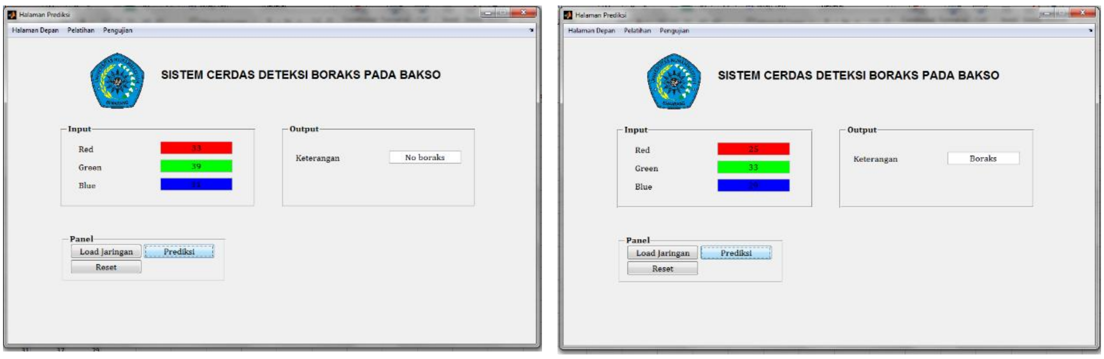


Figure 8*. GUI display of intelligent meatball detection system using ANN training results at 3% borax content, not containing borax (A), containing borax (B)*

4. CONCLUSION

The E Sensing design uses the NCU ESP8266 microcontroller node, the TCS 3200 color sensor, and LCD can be used to measure meatball color images with RGB value output. NodeNCU ESP8266 can be programmed using the Arduino IDE which is connected to a PC via the USB port.

ANN programming using Matlab programming can be used to detect borax in meatballs using RGB color image input from meatballs. The system is less sensitive to the 1% and 2% borax content seen from the lowtest accuracy value (<75%), while the 3% borax content is quite sensitive with a test accuracy value of 90.9091%. The graphical user interface (GUI) display on a computer screen can be used easily by users.

E-ISSN : 2987-2685
page 11 - 20

REFERENCES

[1] BPOM. 2019. Peraturan Badan Pengawas Obat dan Makanan Nomor 11 Tahun 2019 Tentang Bahan Tambahan Pangan https://peraturanpedia.id/ (Diunduh 28 Nopember 2022)

[2] Permenkes. 1988. Peraturan Menteri Kesehatan Nomor 722/MENKES/PER/IX/1988 Tahun 1988 tentang Bahan Tambahan Makanan. https://www.hukumonline.com/ (Diunduh 28 Nopember 2022)

[3] Panjaitan L. 2010. Pemeriksaan dan Penetapan Kadar Boraks dalam Bakso di Kotamadya Medan. http://Repository.usu.ac.id/bitstream/123456789 /17273/ 7/

[4] Rumanta M, Ratnaningsih A, Iryani K. 2014. Analisis Kandungan Boraks Pada Jajanan Pasar di Wilayah Kecamatan Pamulang, Tangerang Selatan. Laporan penelitian Fundamental UT Lanjut.

[5] Permenkes. 2012. Peraturan Menteri Kesehatan Nomor 33 Tahun 2012 Tentang Bahan Tambahan Pangan. www.Peraturanpedia.id (Diunduh 15 Desember 2021)

[6] Subiyakto, M.G. 1991. Bakso, Boraks dan Bleng. Jakarta : PT.Gramedia

[7] Gardner, J.W., Yinon, J., 2004, Electronic Sensing and Sensors for the Detection of Explosives*, Kluwer Academic Publisher, New York*.

[8] Andrijasa, M.F, & Mistianingsih. 2010. Jumlah Pengangguran di ProvinsiKalimantan Timur DenganMenggunakan Algoritma PembelajaranBackpropagation. Jurnal InformatikaMulawarman, 5(1) *(Diunduh 20 Desember 2022*].

[9] Puspitaningrum D., 2016. Pengantar Jaringan Syaraf Tiruan, Penerbit Andi Yogyakarta,

[10] Muhammad Rivai, Djoko Purwanto, Hendro Juwono, Hari Agus Sujono. 2010. Electronic Sensing using Gas Chromatography Column and Quartz Crystal Microbalance. *TELKOMNIKA, Vol.9, No.2, August 2011, pp. 319-326*

[11] Atistell, G. Zhang, V.C. Sturm, J. 2014. Color Recognition sensor in standard CMOS technology. Solid-State Electronics; Sciencedirect.

[12] [Istiqomah Sumadikarta, Muhammad Machfi Isro'i. 2020. Perancangan Smarthome Berbasis Arduino Nodemcu Esp8266 (Studi Kasus: Griya Setu Permai). Jurnal Ilmiah Fakultas Teknik LIMIT'S Vol.16 No 1 Maret 2020.

[13] Anomim. 2021. Pin-pin pada sensor TCS 3200. http:// Elektronikadasar.web.id (Diunduh 25 November 2021)

[14] Seelye M, Gupta GS, Bailey D, Seelye J. 2011. Low Cost Colour Sensors for monitoring plant growth in a laboratory. New Zealand Institute for Plant & Food Research Limited; New Zealand

[15] Taos. 2011. TCS3200, TCS3210 programmable color light-to-frequency converter [internet]. [Diunduh 21 november 2021]. Tersedia pada:http:// www.taosinc.com.

[16] Devi, C. J., Reddy, B. S. P., Kumar, K.V., Reddy, B. M., Nayak, N.R. (2012). "ANN Approach forWeather Prediction using Back Propagation". International Journal of Engineering Trends andTechnology. Vol. 3. Issue 1.