Journal of Natural Sciences and Applications
Vol. 1, No. 1, February 2026, pp. 42-53
https://doi.org/10.58421/jnsa.v1i1.1285

Prototype of Tape Fermentation Tool with Temperature and Humidity Control and Gas Monitoring

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Article Info

Article history:

Received 2026-01-16
Revised 2026-02-20
Accepted 2026-02-22

Keywords:

Tape fermentation
Arduino Uno
DHT22 sensor
MQ-2 gas sensor
Automatic control system

ABSTRACT

The traditional tape fermentation process is still carried out manually without adequate temperature control and gas monitoring, resulting in inconsistent fermentation quality. To address these issues, a prototype tape fermentation device based on an Arduino Uno was developed, equipped with an automatic temperature and humidity control system and a gas sensor. The Arduino Uno functions as a control center that processes data from the DHT22 temperature and humidity sensor and the MQ-2 gas sensor. When the temperature or humidity drops below the specified limit, the system automatically activates the heater and humidifier, indicated by the indicator LED lights. Fermentation activity is detected by the MQ-2 sensor, which recognizes the fermentation gases, namely ethanol and carbon dioxide (CO_2). When these gases are detected at certain concentrations, the RGB LED lights up as a visual indicator that fermentation is active. The sensor data is processed by the Arduino and displayed in real time through a digital interface, allowing users to monitor the fermentation directly. Test results show that this device is able to maintain a stable fermentation environment and provide accurate information regarding fermentation activity. This prototype is expected to improve the efficiency, safety, and quality of modern tape production and provide a practical solution for home producers and small industries..

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1. INTRODUCTION

Tape is a traditional Indonesian food made through the fermentation of carbohydrate- or starch-containing foodstuffs using yeast as a fermentation agent [1]. This fermentation process is highly influenced by environmental conditions, particularly temperature and humidity. Incorrect settings for these parameters can lead to a decrease in

https://doi.org/10.58421/jnsa.v1i1.1285

the quality and quantity of the resulting tape, thus impacting the productivity of the tape industry.

Fermentation temperature plays a crucial role in the activity of microorganisms responsible for converting carbohydrates in cassava into compounds that play a role in the tape fermentation process. The correct temperature ensures optimal yeast growth and prevents the growth of unwanted pathogenic microorganisms. The temperature range generally considered ideal for cassava tape fermentation is between 25°C and 30°C. This range provides optimal conditions for the growth and activity of desirable microorganisms [2]. In addition to temperature, environmental humidity also plays a crucial role in the cassava tape fermentation process. Based on findings from previous research, environmental humidity during the tape fermentation process can increase naturally over time. One study noted that an initial humidity of 56% can increase to 95% after 24 hours of fermentation. This increase is caused by the increase in temperature due to the activity of microorganisms, which triggers the formation of water vapor and dew in the fermentation vessel. This condition creates an increasingly humid environment and supports optimal tape fermentation [3].

The fermentation process of cassava tape involves the activity of microorganisms in yeast that convert carbohydrates into ethanol and carbon dioxide (CO_2). The CO_2 gas produced during fermentation plays an important role in forming the soft and hollow texture of the tape, as well as providing a distinctive aroma to the final product. [4]. Based on the results of the study, the alcohol content produced from cassava tape fermentation is influenced by the dosage of yeast used. At a yeast dosage of 1.5%, the alcohol content produced reaches 0.55%, followed by a dosage of 1.0% at 0.41%, and the lowest at a dosage of 0.5% at 0.38%. These data show that the higher the yeast dosage, the higher the alcohol content formed. This is due to the increasing number of yeast (Saccharomyces cerevisiae) involved in the fermentation process, where the yeast converts sugar into alcohol and CO_2 gas. Based on theoretical estimates of the fermentation reaction, cassava tape produces an average of 4.28 grams/L of CO_2 gas. This process involves enzymes such as amylase and maltase, which hydrolyze starch into glucose, which is then converted into ethanol and CO_2 by the enzyme zymase [5].

With the advancement of technology, sensor-based monitoring systems have been widely used to control the fermentation process in various food products. Temperature, humidity, and gas sensors allow for real-time monitoring of environmental conditions and provide rapid response to deviations during the fermentation process. However, the application of practical and affordable automated monitoring systems for cassava tape fermentation is still limited.

Based on this, this research aims to design and implement a prototype cassava tape fermentation device equipped with a sensor-based temperature, humidity, and gas monitoring system. A sensor is a device used to detect or respond to changes in the physical, chemical, or biological conditions of the surrounding environment and convert them into signals that can be measured or processed by an electronic system. In modern electronic systems, sensors function as a key component that collects information from the

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environment, such as temperature, light, pressure, or gas concentration, then converts it into an electrical signal in the form of a voltage or current that can be further processed by a control system or microcontroller. With these capabilities, sensors are widely used in various fields, such as environmental monitoring systems, industrial automation, healthcare devices, and Internet of Things (IoT) technology [6]. Sensors can be combined with various other devices, such as microcontrollers [7] and electrochemical instruments [8, 9].

This prototype is equipped with a visual indicator in the form of an RGB LED to simulate the system's automatic response to changes in environmental temperature. This approach is expected to allow for more efficient monitoring of the fermentation process and provide an initial overview of the control system for further development.

2. METHOD

This research used an engineering experimental approach to design and test a prototype tape fermentation device equipped with temperature and humidity controls, and fermentation gas monitoring. The research was conducted experimentally in a laboratory. The research stages included a literature review to determine equipment requirements, the creation of a design sketch as a preliminary design, the design and assembly of the device, functional testing of the device during the tape fermentation process, and functional analysis based on the test results.

In this study, the tape fermentation device was designed with several key components to support the control and monitoring of the fermentation process. The main components include a DHT22 temperature and humidity sensor to measure environmental conditions in real time, an MQ-2 gas sensor to detect the presence of fermentation gas, a microcontroller as the control center, and actuators in the form of a heater and a humidifier, indicated by the flashing LEDs in the circuit. Furthermore, the device is equipped with an RGB LED connected to the gas sensor, which serves as a simple visual indicator to identify the presence of CO2 and ethanol during the fermentation process.

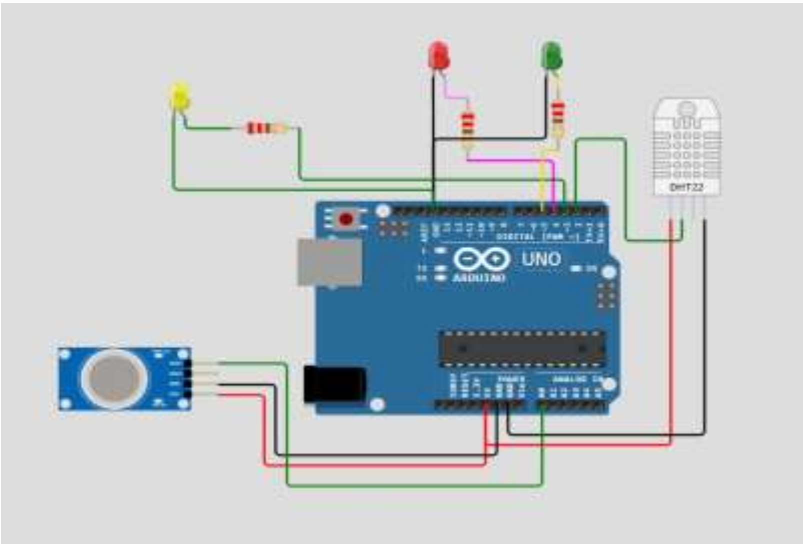

Figure 1. Electronic circuit design for a tape fermentation tool based on Arduino Uno

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Figure 1 shows the design of an Arduino Uno-based tape fermentation device. This device uses a DHT22 sensor to measure the temperature and humidity of the fermentation chamber in real time. Data from the sensor is processed by the Arduino Uno to control fermentation conditions according to set parameters. The heater activates when the temperature drops below 25°C, and when the heater is operating, a red LED lights up to indicate that the heater is operating. The humidifier activates when the humidity drops below 56%, indicated by a green LED when the humidifier is operating. An MQ-2 gas sensor is used to detect the presence of gas during fermentation, with a yellow LED lighting up when gas is detected. The combined concentration of ethanol and carbon dioxide (CO_2) gas detected during the fermentation process is estimated to be 4000–5000 ppm, indicating successful fermentation. Therefore, this study uses DHT22 and MQ-2 sensors, along with an Arduino Uno microcontroller, to build a tape fermentation system based on temperature, humidity, and gas detection monitoring. The component selection was based on literature review and references from previous studies demonstrating the performance and accuracy of the sensors used. The tape fermentation monitoring and control system is designed using several key, integrated components. An Arduino Uno microcontroller serves as the control center, processing data from sensors and automatically regulating actuators. A DHT22 sensor measures the temperature and humidity of the fermentation chamber in real time to maintain ideal environmental conditions throughout the fermentation process. An MQ-2 gas sensor detects the presence of fermentation gases, specifically ethanol and carbon dioxide (CO_2), which are indicators of tape fermentation activity. Data from these sensors is processed by the Arduino Uno to control the heater and humidifier, and provides visual indicators via LEDs to indicate the condition of the equipment and fermentation activity. These components were selected based on the accuracy, stability, and rapid response required to ensure optimal tape fermentation with effective, real-time monitoring.

How the device works

1. System components such as the Arduino Uno, DHT22 sensor, MQ-2 sensor, and indicator LEDs are assembled on a breadboard according to the device's design schematic.
2. The DHT22 sensor is tested by bringing it close to the tape's environment to ensure that temperature and humidity readings can trigger the LED activation according to the system logic, which is stated as an actuator.
3. The MQ-2 sensor is tested by bringing it close to the tape to simulate the presence of fermentation gas. The yellow indicator LED is observed to detect the sensor's response.
4. The system output is observed to determine whether the LED indicator lights up according to the parameters of temperature <25°C, humidity <56%, and the presence of gas.
5. The test results are recorded, and the system is assessed based on the device's success in detecting simulated conditions and responding automatically as designed.

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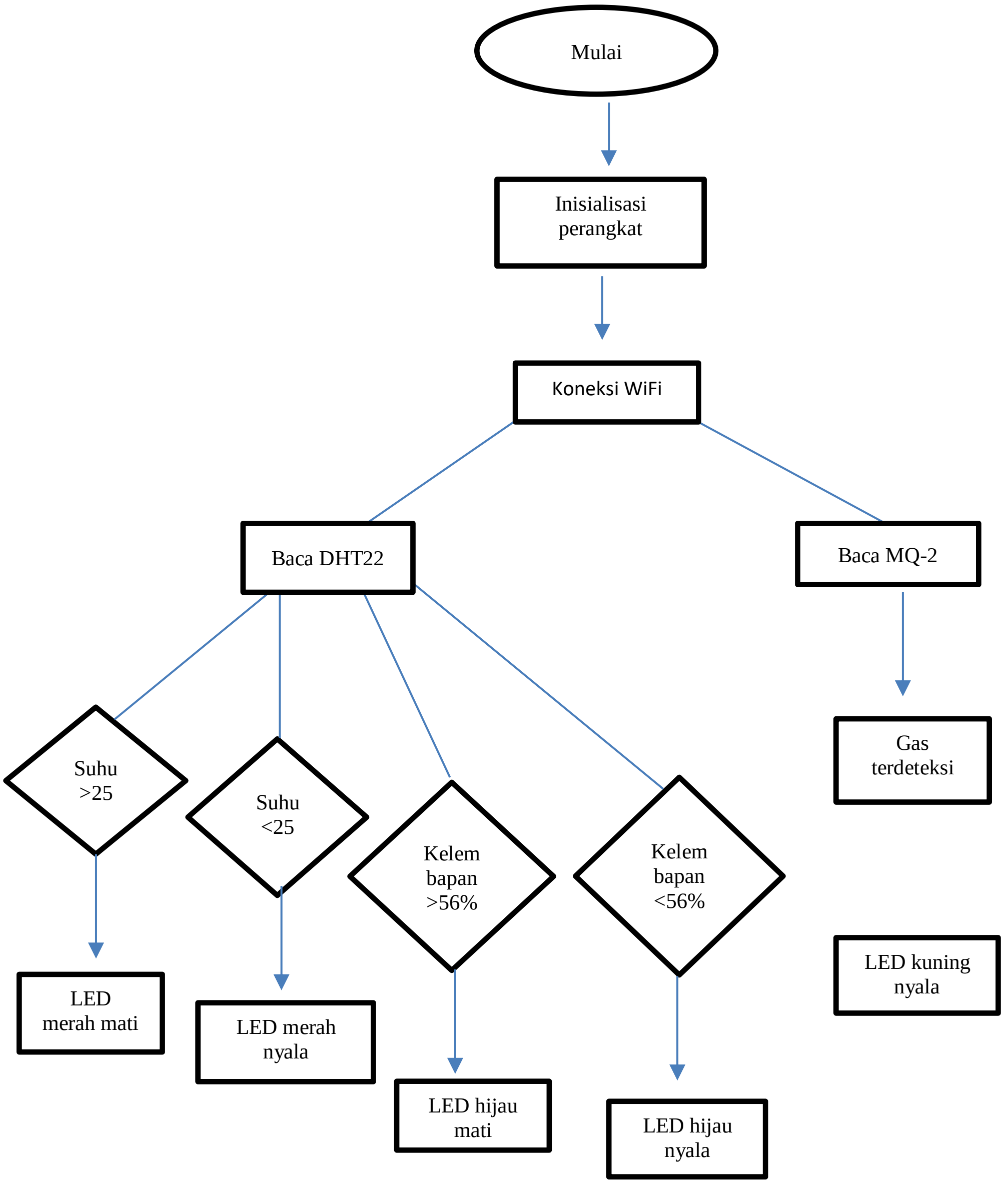

Figure 2. Flow diagram of the tempeh fermentation prototype tool

This flowchart forms the basis for the overall system implementation. After the design and implementation stages of the method are complete, testing is conducted to evaluate the system's performance, which will be discussed in the next section.

3. RESULTS AND DISCUSSION

3.1. Monitoring System Functionality Evaluation

System testing was conducted to evaluate the functionality of the Arduino Uno-based tape fermentation tool prototype equipped with a temperature and humidity sensor (DHT22) and a gas sensor (MQ-2). Although testing was conducted after the tape fermentation process was complete, the tool was still able to respond to actual environmental conditions.

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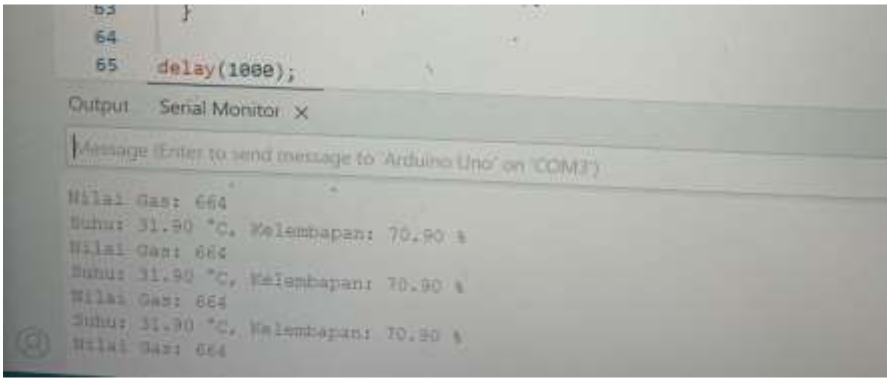

Figure 3. Arduino Serial Monitor

Based on the data displayed on the serial monitor (Figure 2), the DHT22 sensor recorded an ambient temperature of 31.90°C and a humidity of 70.90%. These values reflect the warm and humid conditions in the room where the device was tested. Because the temperature and humidity readings exceeded the system activation thresholds (25°C and 56%, respectively), the heater and humidifier were deactivated, in accordance with the programmed system logic. This is indicated by the red and green LEDs that function as heater and humidifier operation indicators not being lit.

(a) (b)

Figure 4. Prototype of Arduino Uno-Based Tape Fermentation Tool (a) Top view (b) Side view

The DHT22 is a digital sensor designed to measure temperature and humidity, with a calibrated digital signal output. This sensor combines digital data acquisition technology with temperature and humidity sensing technology, resulting in reliable performance and good long-term stability. Its ability to provide accurate data makes the DHT22 one of the sensors widely used in environmental monitoring systems [10]. The DHT22 is a temperature and humidity sensor that combines an NTC-based temperature measurement element and a capacitive humidity sensor integrated with a high-performance 8-bit microcontroller. This sensor boasts advantages in terms of fast response time, high resistance to interference, and cost efficiency. Compared with other sensors such as the SHT10, the DHT22 offers good accuracy at a more affordable price, making it a popular choice for temperature and humidity monitoring applications requiring medium to high precision. Furthermore, the use of the DHT22 in conjunction with Arduino and expansion

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modules allows for interactive system integration and the ability to represent the correlative relationship between temperature and humidity in real time [11].

3.2. Gas Detection by the MQ-2 Sensor

The MQ-2 gas sensor recorded a gas concentration of 664, indicating that there was still residual gas from the tape fermentation process, but in relatively low amounts. This value did not exceed the threshold set in the system to activate the yellow LED as an indicator of increasing gas concentration, so the indicator did not light up. This indicates that the Arduino-based control system works according to the designed logic, which is to only activate the LED when the gas concentration exceeds a certain threshold indicated as an abnormal condition or an active fermentation phase. Based on the results of previous research, the highest alcohol content produced from cassava tape fermentation with a yeast dose of 1.5% was 0.55% (v/v), which when converted into gas concentration units is equivalent to approximately 5,500 ppm [12]. Therefore, if the detected gas is only around 664 analog values, it can be concluded that the fermentation process has passed the active phase and the cassava tape is in a mature condition. This low gas concentration indicates that microorganism activity has decreased significantly, so that gas production from fermentation also decreases. Thus, the system does not activate the yellow LED because there is no gas potential corresponding to the gas concentration in the fermentation process, and the tape can be said to have reached the final stability of its fermentation process [13].

The MQ-2 gas sensor is a type of metal oxide semiconductor (MOS) sensor that is sensitive to various gases such as LPG, smoke, alcohol, propane, hydrogen, methane, and carbon monoxide. This sensor is widely used in air quality monitoring systems, breathalyzers, and early fire detection [14]. The MQ-2 sensor itself is a device capable of detecting the concentration of flammable gases and smoke in the air. This device converts the concentration reading into an analog voltage as its output. The MQ-2 sensor is very effective for measuring flammable gases with a concentration range from 300 to 10,000 ppm, and can operate in a fairly wide temperature range, namely between -20 and 50°C. Furthermore, this sensor is also quite power efficient, consuming only less than 150 mA at a voltage of 5V [15].

This system demonstrated stable and responsive performance to the measured environmental parameters. Data displayed via the serial monitor was read in real-time and consistently (Figure 2), and the indicator LEDs turned on or off according to the sensor conditions (Figure 1), proving that the integration between the sensors, microcontroller, and actuators in the system was functioning properly. Testing conducted after the fermentation process was completed resulted in the device not yet showing a response to extreme conditions such as low temperature (<25°C), low humidity (<56%), or high gas levels (>4000 ppm or more). Therefore, further testing is highly recommended during the active fermentation phase so that all system features can be tested optimally and validation against real fermentation conditions can be carried out more comprehensively [16].

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Input to Arduino

```
#include <DHT.h>

#define DHTPIN 2        // DHT22 ke pin digital 2
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);

// LED
const int ledMerah = 4;
const int ledHijau = 5;
const int ledKuning = 3;

// Sensor gas MQ-2
const int gasPin = A0;          // AOUT ke A0
const int ambangGas =4000;      // ambang batas nilai gas (bisa
disesuaikan)

void setup() {

 Serial.print("Suhu: ");
   Serial.print(suhu);
   Serial.print(" °C, Kelembapan: ");
   Serial.print(kelembapan);
   Serial.println(" %");
```

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```
  // Kontrol LED suhu
  if (suhu < 25) {
    digitalWrite(ledMerah, HIGH);
  } else {
    digitalWrite(ledMerah, LOW);
  }
// kontrol LED kelembaban
 if (kelembapan < 56) {
    digitalWrite(ledHijau, HIGH);
  } else {
    digitalWrite(ledHijau, LOW);
```

3.3. Test Results

Testing was conducted by placing the sensor in a chamber filled with tape. The parameters tested were temperature, humidity, and gas. The sensor placement is shown in Figure 5, while the test results are presented in Table 1.

Figure 5. MQ-2 Sensor in the Tape Fermentation Chamber

Table 1. Test Results of the Tape Fermentation Tool Prototype

Parameter	Value	Result	Interpretation
Temperature	31,90 °C	Red LED is off	The temperature is warm enough for the tape fermentation process..
Humidity	70,90 %	Green LED is off	The environment is humid enough for the fermentation process.
Gas	664	Yellow LED is off	The tape fermentation process has passed the active phase

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From the results presented in Table 1, it is clear that the cassava tape placed in the chamber was mature, having passed the active fermentation phase. This is indicated by a relatively warm temperature and high humidity. This indicates that the sensor used is functioning properly and is capable of detecting the maturity of the cassava tape fermentation process.

Based on the measurements obtained, the fermentation temperature was recorded at 31.90°C. This temperature is within the optimal temperature range for the tape fermentation process, which is around 28–32°C, thus supporting the activity of microorganisms involved in the fermentation process. At this temperature, the enzymes produced by the microorganisms in the yeast are able to work effectively in breaking down starch into simple sugars, which are then fermented into alcohol and other metabolites. Several studies have reported that fermentation temperatures within this range can increase the activity of microorganisms such as Saccharomyces cerevisiae and Amylomyces rouxii, which are commonly found in tape yeast [17].

In addition to temperature, environmental humidity is also an important factor in the fermentation process. Measurements showed a humidity value of 70.90%, indicating that the environment is sufficiently humid to support the activity of fermentation microorganisms. Adequate humidity can help maintain the stability of the fermentation environment and maintain enzymatic activity throughout the process. Appropriate humidity conditions are known to enhance the growth of fermentation microorganisms and accelerate the conversion of starch into sugars and other metabolites [18].

The gas parameter showed a value of 664, indicating the presence of gaseous compounds produced during the fermentation process. This gas is generally a result of the metabolism of microorganisms during the conversion of sugar into alcohol and carbon dioxide. Carbon dioxide production is one indicator that the fermentation process is underway. However, based on system indicators, this condition indicates that the fermentation process has likely passed the maximum activity phase. This indicates that the tape fermentation process is proceeding well and has likely entered the final stage or product maturation phase [19].

Overall, the combination of temperature, humidity, and gas parameters indicates that the fermentation environment is within the range that supports optimal tape fermentation, indicating that the fermentation process is underway and has likely passed the active phase.

4. CONCLUSION

The fermentation monitoring prototype, which utilizes temperature, humidity, and gas sensors, has successfully performed according to the objectives outlined in the introduction. The system automatically detects temperatures below 25°C and humidity below 56%, indicating that the heating and humidifier systems are activated by red and green LEDs. Furthermore, the presence of fermentation gases, such as carbon dioxide (CO_2) and ethanol, at concentrations of 4000-5000 ppm, can be detected, indicated by a yellow LED.

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With this sensor-based monitoring, the fermentation process can be monitored in real time and more efficiently, helping maintain optimal environmental conditions. This prototype has the potential for further development, such as the addition of app-based remote monitoring features or an automatic notification system, enabling implementation on an industrial scale or further research.

REFERENCES

[1] L. Masdarini, "Manfaat dan Keamanan Makanan Fermentasi untuk Kesehatan (Tinjauan dari Aspek Ilmu Pangan)," J. Pendidik. Teknol. dan Kejuruan, vol. 8, no. 1, 2011.
[2] Fauziyah, S. A. H., Haniifah, A. A., Ramadhan, B. N., Suwito, E. B., Aurelia, N. P., Tobing, P. N. B., & Mutmainnah, T. (2025). Implementation of Fuzzy Logic in Temperature and Fermentation Time Control System on Alcohol Content of Cassava Tape Product. Journal of Applied Science, Technology & Humanities, 2(1), 119–135. DOI: https://doi.org/10.62535/2mzdar32
[3] K. Djuneidi, H. Jatnika, R. Ningrum, and W. S. Cahoyo, "Alat Pendeteksi dan Monitoring Kematangan Tape," Petir, vol. 12, no. 2, pp. 222–230, 2019, doi: 10.33322/petir.v12i2.531.
[4] S. P. Jayanti, H. Husain, and N. M. G. Oktaviani, "Analisis Proses Fermentasi Tape dengan Variasi Ragi-Ragi Tape (Aspergillus oryzae), Bread Yeast (Saccharomyces cerevisiae), dan Ragi Tempe (Rhizopus oligosporus)," J. Gizi dan Pangan, vol. 9, no. 3, pp. 64–71, 2014.
[5] K. Y. A. Utama, "Perbandingan Kualitas Antar Sensor Suhu dengan Menggunakan Arduino Pro Mini," e-NARODROID, vol. 2, no. 2, pp. 145–150, 2016.
[6] Zeng, F., Pang, C., & Tang, H. (2024). Sensors on Internet of Things Systems for the Sustainable Development of Smart Cities: A Systematic Literature Review. Sensors, 24(7), 2074. DOI: https://doi.org/10.3390/s24072074
[7] Setiawan, Z., Hiswara, A., & Muthmainah, H. N. (2023). Mengoptimalkan Jaringan Sensor Nirkabel dalam Aplikasi Monitor Lingkungan dengan Teknologi IoT di Indonesia. Jurnal Multidisiplin West Science, 2(10), 858–867. DOI: https://doi.org/10.58812/jmws.v2i10.704
[8] Hayat, M., Saepudin, E., Einaga, Y., & Ivandini, T. A. (2019). CdS Nanoparticle-based Biosensor Development for Aflatoxin Determination. International Journal of Technology, 10(4), 787–797. DOI: https://doi.org/10.14716/ijtech.v10i4.2407.
[9] Hayat, M., Ivandini, T. A., Saepudin, E., & Einaga, Y. (2016). Anodic Stripping Voltammetry of Synthesized CdS Nanoparticles at Boron-Doped Diamond Electrodes. AIP Conference Proceedings, 1729. DOI: https://doi.org/10.1063/1.4946955.
[10] S. A. H. Saptadi, "Perbandingan Akurasi Pengukuran Suhu dan Kelembaban Antara Sensor DHT11 dan DHT22," J. INFOTEL, vol. 6, no. 2, pp. 49–56, 2014.
[11] S. I. Jumaila and S. Maulida, "Pemantauan Suhu dan Kelembaban di Laboratorium Kalibrasi Tekanan dan Volume Berbasis Web Secara Real Time," J. Otomasi Kontrol dan Instrum., vol. 9, no. 1, pp. 9–19, 2017.
[12] S. A. H. Saptadi and D. Kurnianto, "Rancang Bangun Thermohygrometer Digital Menggunakan Sistem Mikropengendali Arduino dan Sensor DHT22," in Proc. SNST ke-6 Tahun 2015, pp. 84–88.
[13] A. Adriansyah and O. Hidayatama, "Rancang Bangun Prototipe Elevator Menggunakan Mikrokontroler Arduino ATMEGA 328P," J. Teknol. Elektro, Univ. Mercu Buana, vol. 5, no. 3, pp. 100–108, 2013.
[14] T. Suryana, "Implementasi Modul Sensor MQ2 untuk Mendeteksi Adanya Polutan Gas di Udara," J. Komputika, vol. 10, no. 2, pp. 112–114, 2021.
[15] A. Khairuman and Martina, "Perancangan Alat Pendeteksi CO_2 Menggunakan Sensor MQ-2 Berbasis Internet of Things," METHOMIKA: J. Manaj. Inf. & Komp. Akuntansi, vol. 4, no. 1, pp. 73–79, 2020.
[16] D. Kanipa, "Pengaruh Konsentrasi Ragi pada Pembuatan Tape Ketan," J. Ilmu dan Teknol. Pangan, Univ. Hasanuddin, vol. 1, no. 2, pp. 54–58, 2013.
[17] Nuraida, L. (2023). Microorganisms of fermented foods and beverages in Indonesia. Food Research, 7(1), 1–10. https://doi.org/10.26656/fr.2017.7(1).001

https://doi.org/10.58421/jnsa.v1i1.1285

[18] Widodo, W., Handayani, M. N., & Nurhadi, B. (2022). Effect of environmental conditions on traditional fermented cassava (tape) quality. Journal of Food Science and Technology. https://doi.org/10.1007/s13197-022-05436-0

[19] Putra, R., & Rahayu, E. S. (2024). Microbial dynamics during cassava tape fermentation and its impact on product quality. Foods, 13(4), 612. https://doi.org/10.3390/foods13040612.