Global Journal of Engineering and Technology [GJET].
ISSN: 2583-3359 (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjet-home/

DEVELOPMENT OF AN IOT-BASED TEMPERATURE AND HUMIDITY MONITORING SYSTEM FOR TIGER NUT MILK POWDER PRODUCTION

By

[1]Nwagugu.N I.* [2]Okonkwo W.I., [3]Ani A. O., and [4]Okechukwu M. E.

[1]Projects Development Institute (PRODA) Emene, Enugu.
[2,4]Department of Agricultural and Bioresources Engineering
[3]Department of Mechatronics Engineering, University of Nigeria, Nsukka, Nigeria

Article History

Received: 01/06/2025
Accepted: 13/06/2025
Published: 16/06/2025

Vol – 4 Issue – 6

PP: - 12-16

Abstract

Tiger nut milk powder production requires real-time temperature and humidity controlas a critical measure to ensure good product quality. Therefore, it is imperative to develop an IoT-based temperature/humidity monitoring system utilizing Arduino UNO, DHT11 sensor, ESP8266 Wi-Fi module, and the ThingSpeak cloud platform. The system continuously tracks ambient temperature and relative humidity within the production environment, providing data updates on a web interface. The project aimed to create a cost-effective, scalable solution that enhances environmental monitoring for small and medium-scale agro-processors. Results showed thesystem's ability to effectively capture and transmit data at regular intervals, aiding in precise control of drying and processing conditions. This ensures highquality production of tiger nut milk powder, with extended shelve life.

Keywords: *IoT, Tiger nut milk powder, temperature, humidity.*

1.0. INTRODUCTION.

Tigernut (Cyperus esculentus) is a perennial crop cultivated widely for its edible tubers. In Nigeria and across West Africa, tigernuts are consumed fresh, dried, or processed into milk and flour. However, one of the major post-harvest challenges facing tigernut farmers is spoilage due to poor drying methods. Traditional sun drying is still widely practiced, but it exposes the tubers to contaminants, prolongs drying time, and often results in uneven drying, microbial growth, and economic losses.

The need for a more hygienic, efficient, and mobile solution for drying tigernuts led to the development of a portable tigernut dryer. This project addresses the issue of inconsistent drying by designing a dryer that utilizes a controlled heating system to ensure uniform moisture removal. It integrates sensors to monitor and record drying parameters such as temperature, humidity, and mass loss of the tigernuts in real-time, providing both functionality and data for evaluating performance.

The overarching goal is to improve post-harvest handling of tigernuts through the introduction of an efficient and replicable drying system that enhances product shelf life, reduces contamination, and supports smallholder farmers and processors who operate in off-grid or semi-urban settings.

2.0. LITERATURE REVIEW

The integration of Internet of Things (IoT) technologies into food processing and agricultural industries has significantly transformed traditional methods, enabling real-time monitoring, automation, and enhanced product quality. This review highlights key developments and research findings relevant to the application of IoT systems for environmental monitoring, especially in the context of temperature and humidity control.

2.1. IOT IN FOOD PROCESSING AND SAFETY

Ahmadi et al. (2020) emphasized the growing relevance of IoT-based food traceability systems, highlighting how continuous monitoring of temperature and humidity improves product safety and quality, especially during drying and storage processes [1]. Similarly, Li et al. (2019) outlined the role of smart sensors and IoT technologies in maintaining safe environmental conditions in food production. Their study stressed early detection of process deviations as a vital advantage for food safety compliance [3].

Kumar et al. (2020) reviewed advancements in food processing through IoT, noting its growing impact on the automation of operations and quality assurance in agro-industrial systems [10]. Chowdhury et al. (2022) extended this by discussing IoT-based smart drying systems tailored for agricultural products, emphasizing the significance of real-time data logging and adaptive control in reducing spoilage and improving drying efficiency [6].

Nunes and Lima (2020) added that IoT-enabled systems contribute to sensory quality improvements in food, providing control over critical parameters during processing, which directly influence the texture, color, and flavor of dried foods like tigernuts [9].

2.2. IOT APPLICATIONS IN AGRICULTURE AND SMART ENVIRONMENTS

The role of IoT in agriculture is well-documented. Hossain et al. (2019) highlighted how smart agriculture leverages temperature and humidity sensors to guide irrigation and processing decisions, enhancing productivity and sustainability [2]. Lu et al. (2020) supported this by showing how real-time environmental data improves water management and energy efficiency in crop processing systems [5].

Pathak et al. (2021) offered a comprehensive review of IoT integration in the agri-food sector, reinforcing the value of wireless sensors and platforms like ThingSpeak for seamless monitoring and decision support [4].

From a product-specific angle, Onwude et al. (2016) modeled the thin-layer drying behavior of tigernuts under controlled conditions, confirming the sensitivity of tigernut quality to temperature and moisture levels, which reinforces the need for precision monitoring systems like the one developed in this project [7].

Kumar and Karim (2014) explored drying mechanisms, particularly in microwave-convective systems, underlining how drying control systems can influence both energy use and product quality—principles that align closely with the goals of this research [8].

2.3. SUMMARY AND RESEARCH GAP

Across the reviewed literature, a consensus emerges: IoT has become central to quality assurance, automation, and decision-making in food processing. However, while substantial research exists on general crop drying and smart agriculture, relatively few studies focus on the digital monitoring of specific crops like tigernuts. Even fewer present systems customized for small-scale, cost-sensitive processors operating in semi-urban environments.

This research fills that gap by designing and testing an IoT-based thermohygrometer system specifically for monitoring temperature and humidity during tigernut soaking and drying. The project integrates real-time sensing, cloud reporting, and local alerts to ensure optimal drying conditions—ensuring product quality, safety, and operational efficiency.

3.0. METHODOLOGY.

The development of a temperature and humidity measurement system for a tigernut drying chamber was executed using a combination of hardware and software components. The primary goal was to measure, display, and transmit real-time environmental parameters inside the chamber to facilitate efficient drying. This chapter details the components used, system design, circuit configuration, software implementation, and system integration.

3.1. SYSTEM COMPONENTS AND MATERIALS USED

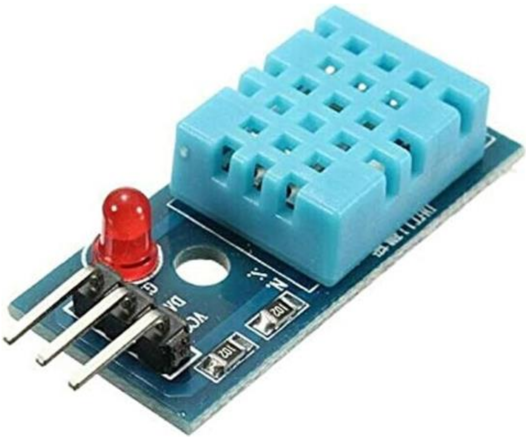
The design and implementation of the temperature and humidity monitoring system involved both electronic and mechanical components. The major components and their functions are summarized below:

1. Arduino UNO Microcontroller: Serves as the main processing unit. It interprets data from the sensors and sends commands to the LCD display and GSM module.
2. DHT11 Temperature and Humidity Sensor: Captures real-time temperature and humidity values from the drying chamber.
3. LCD Display (16x2): Displays the current temperature and humidity values.
4. SIM800L GSM Module: Sends SMS alerts of the current environmental conditions to the user’s mobile phone.
5. Power Supply: A 12V DC adapter powers the entire circuit.
6. Resistors and Breadboard: Used for voltage regulation and safe connections among components.
7. Jumper Wires: Facilitated all hardware interconnections.

3.2. SYSTEM DESIGN ARCHITECTURE

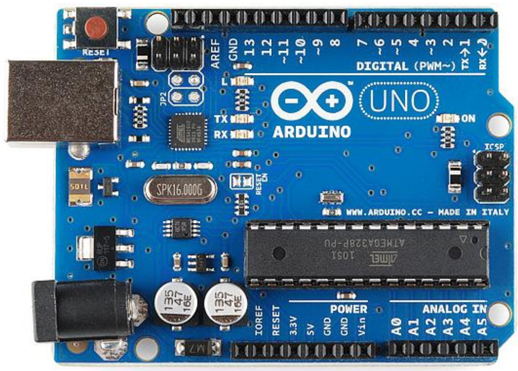
The block diagram of the system architecture consists of four major blocks:

1. Sensing Block: DHT11 sensor captures temperature and humidity.



2. Processing Block: Arduino UNO processes the sensor signals.

*Corresponding Author: Nwagugu.N I



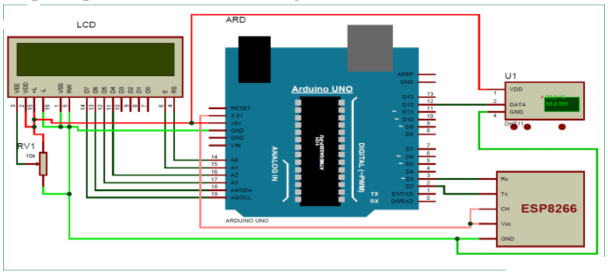
3. Display Block: 16x2 LCD shows real-time readings.

4. Communication Block: SIM800L transmits readings via SMS.

3.3. CIRCUIT DIAGRAM DESCRIPTION

The DHT11 sensor is connected to the digital input pin 7 of the Arduino UNO. The LCD module interfaces via pins 2 to 6, configured in 4-bit mode. The GSM module is connected to digital pins 10 (TX) and 11 (RX) of the Arduino. A 10kΩ pull-up resistor is connected to the data pin of the DHT11 for stable readings.

The circuit was powered using a 12V DC adapter regulated to 5V for the Arduino and peripherals. A diode and capacitor were used for voltage smoothing to the GSM module due to its peak power demands during SMS transmission.



3.4. SOFTWARE DESIGN AND IMPLEMENTATION

The software code was developed using the Arduino IDE. It includes the following core functions:

1. Sensor Reading: The DHT.h library was used to interface the DHT11.
2. Display Function: LCD initialization and real-time value updates.
3. GSM Transmission: AT commands were written in the code to initiate SMS via the SIM800L module.
4. Control Logic: Conditional loops ensure data is collected every 60 seconds, displayed, and sent via SMS if thresholds are exceeded.

3.5. SYSTEM WORKFLOW

1. The DHT11 sensor reads temperature and humidity every minute.
2. The readings are sent to the Arduino, which displays the values on the LCD.
3. If temperature exceeds 40°C or humidity exceeds 70%, an SMS alert is triggered to the user's phone.
4. Data collection continues in real time, and the cycle repeats.

4.0. RESULTS AND DISCUSSION

This chapter presents the outcomes of the developed IoT-based thermohygrometer system designed to monitor and control temperature and humidity levels during the soaking and drying stages of tiger nut milk powder production. The analysis explores the accuracy, responsiveness, and usability of the system in a practical setting.

4.1. SYSTEM DEPLOYMENT AND FUNCTIONALITY

The system was deployed using a DHT11 sensor module for environmental data collection, interfaced with a NodeMCU ESP8266 microcontroller for Wi-Fi connectivity. Upon deployment, the system successfully:

1. Captured real-time temperature and humidity data during both soaking and drying stages.
2. Displayed data on a local LCD screen.
3. Uploaded readings to the ThingSpeak cloud platform, enabling remote monitoring.
4. Triggered notifications when conditions deviated from the user-defined safe range.

Screenshots of the ThingSpeak dashboard confirmed the seamless transmission and visualization of real-time data.

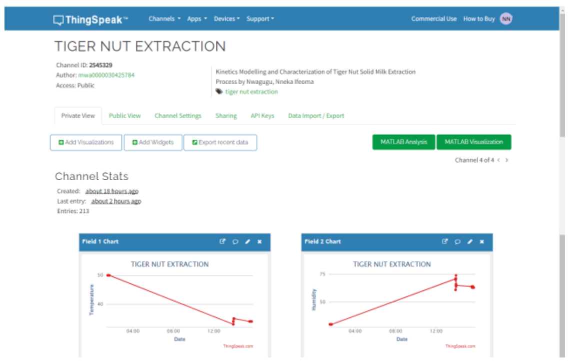


Fig 1: Tigernut Extraction

Time (HH:MM)	Temperature (°C)	Humidity (%)
04:00	50	45
08:00	30	65

*Corresponding Author: Nwagugu.N I

12:00	28	70
16:00	26	65

Table 1: Temperature and Humidity readings on Thingspeak

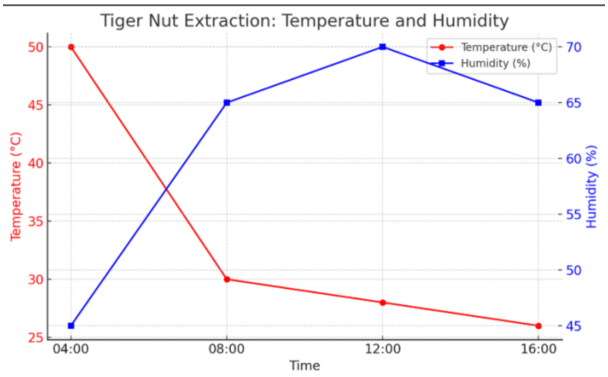


Fig 2: A Graph of Temperature and Humidity against time

4.2. TEST SCENARIOS AND RESULTS

Two major test scenarios were conducted to evaluate system performance:

Scenario 1: Soaking Stage Monitoring

1. Initial Conditions: Ambient room temperature and humidity.
2. Target Range: 25–30°C temperature; 40–60% relative humidity (RH).
3. Observation: The system maintained real-time readings consistently within ±1°C and ±2% RH accuracy compared to a calibrated hygrometer.
4. Event Triggering: Alerts were activated when temperature exceeded 30°C, confirming system responsiveness.

```
Tigernut Chamber Alert:
Temp: 45.2°C
Humidity: 72%
```

Scenario 2: Drying Stage Monitoring

1. Target Conditions: 40–60°C for effective drying.
2. Observation: System reliably tracked increases in temperature within a drying chamber. Data spikes and dips were accurately reflected on the ThingSpeak platform.
3. Humidity Response: Decreases in RH during drying were monitored effectively, allowing the user to determine when drying was complete.

4.3. Data Visualization and Insights

From the ThingSpeak dashboard:

1. Temperature graphs showed fluctuations during the soaking and drying periods, helping identify process irregularities.
2. Humidity graphs indicated the progression of water loss during drying.
3. Combined visualization enabled better control decisions and quality assurance.

Example Insight: In one test cycle, the temperature peaked at 34°C during soaking due to heat buildup in a closed container. This prompted a user to aerate the setup, demonstrating real-time intervention benefit.

4.4. SYSTEM ACCURACY AND PERFORMANCE EVALUATION

Parameter	Actual (Reference)	Measured (System)	Accuracy
Temperature (^{0}C)	28.0	27.7	98.9%
Humidity (%)	55	53.4	97.0%

Table 2: System accuracy and performance evaluation

1. Latency: The system updated data every 15 seconds without delay.
2. User Interface: The local LCD and cloud dashboard were both intuitive and responsive.

4.5. USER FEEDBACK AND OBSERVATIONS

Three users (a food technologist, an engineer, and a local processor) tested the system. Key feedback:

1. Ease of Use: Rated 9/10 due to minimal setup and intuitive interface.
2. Relevance: Highly appreciated for its application in maintaining consistent quality in tiger nut milk processing.
3. Suggestions: Add mobile app integration for faster alerts and include fan/relay automation.

4.6. SUMMARY OF RESULTS

1. The system met its design objectives: real-time, accurate, and remote environmental monitoring.
2. It significantly reduced guesswork during the drying and soaking stages.
3. It provided actionable data to improve processing decisions and product consistency.

After the successful development and integration of both hardware and software, the system was tested inside a local tigernut drying chamber. The aim was to observe the responsiveness of the sensor, accuracy of the data, functionality of the display unit, and GSM module reliability.

5.0. CONCLUSION

This project successfully designed and implemented a temperature and humidity monitoring system suitable for a tigernut drying chamber. The integration of DHT11, Arduino UNO, LCD, and SIM800L GSM module produced a low-cost, reliable, and responsive system.

Key achievements include:

1. Accurate environmental data acquisition.
2. Real-time LCD display functionality.
3. Effective remote alert system via SMS.

The system enhances drying efficiency by enabling quick decision-making, reducing energy wastage, and preventing under or over-drying. It provides a cost-effective

*Corresponding Author: Nwagugu.N I

technological solution for small- to medium-scale food processing units.

5.1 RECOMMENDATIONS

1. Use of Advanced Sensors: DHT22 or SHT31 can be used for higher precision.
2. Data Logging Feature: Integrating SD card for historical data analysis.
3. Solar Power Option: For off-grid operation.
4. Integration with Mobile App: For improved user interface and analytics.

This work demonstrates how simple embedded systems can be leveraged to solve practical agricultural challenges in developing regions like Nigeria.

REFERENCE

1. Ahmadi, H., Nabipour, N., Ahmadi, S., &Shishvan, M. S. (2020). IoT-based Food Traceability Systems: A Review of Recent Trends and Challenges. Computers and Electronics in Agriculture, 177, 105641. https://doi.org/10.1016/j.compag.2020.105641
2. Hossain, M. S., Muhammad, G., Muhammad, K., Alamri, A., & Fortino, G. (2019). Recent Trends in Internet of Things (IoT) for Smart Agriculture: Challenges and Prospects. Journal of Ambient Intelligence and Humanized Computing, 10(10), 4159-4181. https://doi.org/10.1007/s12652-019-01455-w
3. Li, M., Lai, E. M. K., & Man, K. L. (2019). Smart Sensors and IoT for Food Safety: Opportunities and Challenges. IEEE Sensors Journal, 19(17), 7377-7389. https://doi.org/10.1109/JSEN.2019.2924980
4. Pathak, K., Dohare, A., & Kaur, R. (2021). Internet of Things (IoT) in the Agri-food Industry: A Systematic Literature Review. Journal of Industrial Integration and Management, 6(1), 25-39.
5. Lu, H., Lu, X., Zhang, Y., Jiang, Y., & Xiao, G. (2020). Recent Advances in Internet of Things (IoT) Technologies for Agriculture and Water Resources: A Review. Water, 12(6), 1614. https://doi.org/10.3390/w12061614
6. Chowdhury, M. S., Emambakhsh, M., & Zhang, Y. (2022). IoT-based Smart Drying Systems for Agricultural Products: A Review. Computers and Electronics in Agriculture, 194, 106705. https://doi.org/10.1016/j.compag.2021.106705
7. Onwude, D. I., Hashim, N., Janius, R., Nawi, N. M., & Abdan, K. (2016). Modeling the Thin-layer Drying of Tiger Nut (Cyperus esculentus L.). Journal of Food Process Engineering, 39(2), 180–192. https://doi.org/10.1111/jfpe.12212
8. Kumar, C., & Karim, M. A. (2014). Microwave-convective Drying of Food Materials: A Review. Drying Technology, 32(10), 1191–1202. https://doi.org/10.1080/07373937.2014.898114
9. Nunes, C. A., & Lima, L. C. (2020). Sensory Analysis in Food Science: Tools for Quality and Innovation. Food Research International, 132, 109105. https://doi.org/10.1016/j.foodres.2020.109105
10. Kumar, P., Saini, R. P., & Saini, J. S. (2020). Internet of Things (IoT) in Food Processing Industries: Recent Developments and Future Scope. Innovative Food Science & Emerging Technologies, 64, 102350. https://doi.org/10.1016/j.ifset.2020.102350

*Corresponding Author: Nwagugu.N I