SITEKIN: Jurnal Sains, Teknologi dan Industri, Vol. 23, No. 1, December 20205, pp.179 - 186
ISSN 2407-0939 print/ISSN 2721-2041 online

Application of the Internet of Things in Controlling the Water Content Quality of Honey

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ABSTRACT

Agriculture is one of the key aspects of a nation's survival. In support of the Astacita *Program of the President and Vice President of the Republic of Indonesia, which aims for food self-sufficiency, this research focuses on the topic of food security. In practice, food security faces several challenges, such as production that does not meet quality standards and very low productivity levels. One example is the cultivation of Kalimantan honey bees. Honey is one of Kalimantan's natural resources that is highly beneficial for enhancing the human immune system. According to the Indonesian National Standard (SNI) 8664:2018, the acceptable water content in honey should be less than 22%. However, in reality, the water content in honey often exceeds 22%, reaching up to 27%. The purpose of this research is to reduce the water content in honey so that its shelf life can be extended to six months, making it suitable for export. This study employs an Internet of Things (IoT) approach, involving the stages of planning, analysis, design, implementation, testing, and evaluation. The research produced a device capable of reducing the water content of Trigona honey (27%) to meet SNI standards within 5 hours,* Cerana *honey (43%) within 7 hours, and* Dorsata *honey (30%) within 9 hours. The use of this device proved effective in lowering honey's water content to below 22%, in compliance with SNI standards, which means the honey becomes more durable, marketable, and exportable. This research is expected to contribute to strengthening food security in the city of Balikpapan.*

Keywords : Quality Control, Food Security, Honey, Internet of Things .

Introduction

The vision and mission of President Prabowo Subianto in achieving Golden Indonesia (Indonesia Emas) emphasize the strengthening of micro, small, and medium enterprises (MSMEs), industrial downstreaming, and food security as key national development strategies. MSMEs play a crucial role in driving economic growth through job creation and the generation of added value from local products. However, the sustainability of MSMEs' contributions largely depends on their ability to maintain product quality, enhance productivity, and comply with national and international quality standards.

Indonesia's food security sector continues to face significant challenges, particularly in terms of production quality and efficiency. Low productivity and non-compliance with established quality standards remain persistent issues across various food subsectors. One relevant example is the production of Kalimantan honey, a flagship commodity of Balikpapan City, which holds substantial potential to be developed as a high-value export product.

Honey is a natural liquid produced by honeybees from floral nectar or other plant parts, including extrafloral nectar [1]. Kalimantan honey is widely recognized for its bioactive compounds that contribute to enhancing the human immune system, resulting in increasing demand in both domestic and international markets. Therefore, efforts to preserve and improve honey quality are essential to ensure product competitiveness and sustainability.

According to the Indonesian National Standard (SNI) 8664:2018, the acceptable moisture content of honey must be below 22%. However, field observations indicate that honey produced by local farmers often exceeds this threshold, with moisture levels reaching up to 27%. Elevated moisture content is closely associated with fermentation processes caused by osmophilic yeasts, which can significantly reduce honey quality and shorten its shelf life [2].

High moisture content not only deteriorates the physicochemical properties of honey but also directly affects its market value and consumer acceptance. This condition may lead to reduced income for honey producers and hinder the contribution of the honey sector to regional food security and economic development. Consequently, effective and efficient solutions are required to control honey moisture content in accordance with established quality standards.

Although previous studies have investigated the physicochemical characteristics of honey, factors influencing moisture content, and conventional post-harvest treatments, most approaches remain static and rely heavily on manual supervision. Meanwhile, the application of Internet of Things (IoT) technology in the food sector has expanded rapidly; however, research specifically integrating IoT-based systems for controlling the moisture content of locally produced Indonesian honey, particularly at the MSME scale, remains limited. Therefore, this study aims to address this research gap by designing and implementing an IoT-based system capable of automatically and real-time monitoring and controlling honey moisture content, thereby ensuring compliance with SNI standards, increasing product value, and supporting MSME development and regional food security.

Research Methods

This study is a research and development (R&D) project aimed at producing a prototype of an Internet of Things (IoT)-based device for reducing the moisture content of honey. The approach used is a systems approach, in which the device is developed through structured and integrated stages.

Tools and Materials

1. Hardware : honey moisture sensor), microcontroller (Arduino Uno), Heater, support component, an insulated box/chamber as a container for the dehydration process, cable, and power supply.
2. Software : platform IoT Arduino, programming language.

Test Material

1. Trigona Honey (first moisture content ±27%)
2. Cerana Honey (first moisture content ±43%)
3. Dorsata Honey (first moisture content ±30%)

- The stages in developing the honey moisture reduction system begin with a planning phase. This phase includes identifying the problem of excessive moisture content in honey and determining the need for a device capable of reducing moisture levels. Subsequently, a literature review is conducted to examine honey moisture standards, honey physicochemical characteristics, and relevant Internet of Things (IoT) technologies. Based on this review, the functional and technical specifications of the device, including required components and materials, are formulated.
- The next stage involves analyzing the operational principles of the honey moisture reduction system. This analysis focuses on understanding the interaction between temperature, airflow, and moisture evaporation processes within the honey treatment chamber, as well as defining the control mechanisms required to achieve stable and uniform moisture reduction.
- Following the system analysis, the hardware design phase is carried out, which includes the selection and integration of key components such as sensors, wiring, fans, heaters, and a microcontroller. In parallel, an efficient chamber model is designed to optimize heat distribution and air circulation, thereby enhancing the moisture reduction process while maintaining honey quality.
- The software design phase involves developing control logic for automatic temperature regulation and implementing data processing algorithms. This phase also includes programming the microcontroller to manage sensor inputs and actuator outputs in real time. Finally, the IoT architecture is designed to enable real-time data visualization and monitoring. Sensor data are transmitted to an IoT platform, allowing users to observe temperature and moisture conditions remotely and to evaluate system performance effectively.

Research Flowchart

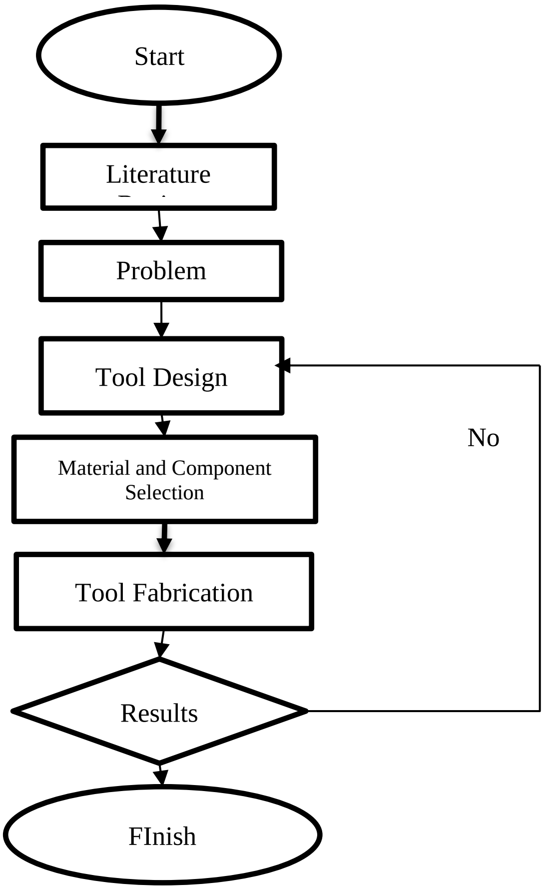

Figure 1. Research Flowchart

Results and Discussion

The result of this research is the design of a honey neutralizing device used to improve the quality of honey by utilizing the Internet of Things (IoT). The following are the results from each stage of the research using the Internet of Things with the Arduino program. Below is the flow of the Arduino process. The program flow is divided into two main parts: setup (Initialization) and loop (Main Loop)**.**

A. **Initialization Phase (setup)**

When the Arduino is powered on for the first time, the setup function runs once:

- Start Communication: Initialize Serial Monitor communication (9600 baud) and set up the I2C connection for the LCD.
- LCD Initialization: Turn on the LCD backlight.
- SHTC3 Initialization: Attempt to start the SHTC3 sensor.
- If Failed: The program displays "SHTC3 ERROR" on the LCD and stops completely (enters an infinite loop).
- If Successful**:** The program proceeds to the next step.
- DS18B20 Initialization: Start the DS18B20 temperature sensor.
- Status Message: Display "SHTC3 & DS18B20" and "Ready" on the LCD for 2 seconds.
- Relay Initialization: Set pinRelay (Pin 8) as OUTPUT and set it to LOW (turn off the relay/heater initially).

B. Main Loop Phase (loop)

After the setup is complete, the loop function runs continuously:

SITEKIN: Jurnal Sains, Teknologi dan Industri, Vol. 23, No. 1, December 20205, pp.179 – 186
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1. Read NTC: Read the analog value from pinNTC (A0).
2. NTC Temperature Calculation: Convert the analog value to voltage, then to resistance, and finally calculate the temperature in Celsius (using the Steinhart-Hart equation). The temperature value is rounded to the nearest integer.
3. Relay Control (Hysteresis):
    - Check NTC temperature: If the temperature falls below tempMin (45°C), set the relay pin to LOW (turn on the heater).
    - Check NTC temperature: If the temperature rises above tempMax (55°C), set the relay pin to HIGH (turn off the heater).
    - **Note:** If the temperature is between 45°C and 55°C, the relay status remains unchanged from its previous state.
4. Read SHTC3: Attempt to obtain temperature and humidity data from the SHTC3 sensor.
    - If Successful: Round and store the temperature and humidity values. Print the data to the Serial Monitor.
    - If Failed: Print an error message to the Serial Monitor.
5. Read DS18B20: Request a temperature reading from the DS18B20 sensor.
    - If Successful (not -127): Round, store, and print the temperature value to the Serial Monitor.
    - If Failed: Print an error message to the Serial Monitor.
6. Update LCD Display:
    - **Row 0:** Display SHTC3 temperature (or "SHT:Err") and SHTC3 humidity (or "H:Err").
    - **Row 1:** Display DS18B20 temperature (or "DS:Err") and NTC temperature.
7. Delay: Pause the program for 2000 milliseconds (2 seconds) before repeating the entire loop from the beginning.

Figure 2. Arduino Uno-based temperature control

The figure shows an Arduino Uno-based temperature control system that integrates three types of sensors: SHTC3 for temperature and humidity measurement, DS18B20 for probe-based temperature measurement, and NTC thermistor as the main sensor for controlling the heater (heating pad). Data from the NTC is used by the Arduino to control a relay based on minimum and maximum temperature limits, so that the heater turns on or off automatically. Meanwhile, the temperature and humidity values from SHTC3 and the temperature from the DS18B20 are displayed in real-time on a 16×2 I2C LCD, making it easy to monitor system conditions. This diagram also shows the system workflow from sensor readings, data processing by the Arduino, to output in the form of heater control and information display, which makes the system suitable for incubator, dryer, or simple temperature controller applications.

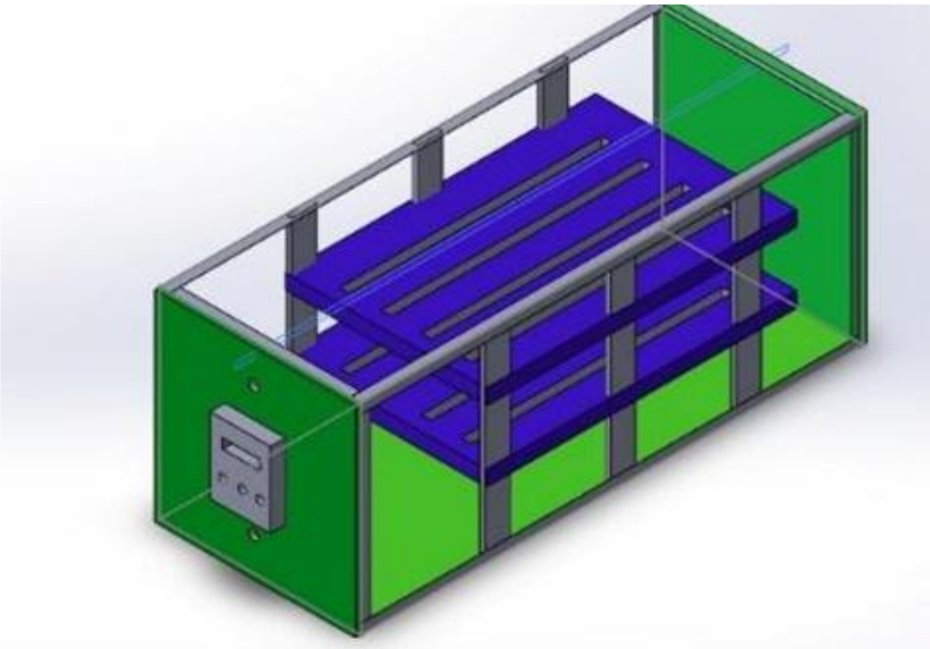

Figure 3. Design of the Honey Neutralizing Device Prototype

The box design in the image is a mechanical realization of the Arduino-based temperature control system implemented in the program. The transparent space functions as a heating chamber, where objects are placed on blue tiered shelves that have gaps to help circulate hot air for even temperature. A heating pad is placed at the bottom of the chamber as a heat source, while an NTC sensor is installed near the heat source because in the program the NTC is used as the main sensor controlling the relay to turn the heater on and off at a temperature range of 45–55 °C. The SHTC3 sensor is placed in the center of the chamber to measure air temperature and humidity representatively, while the DS18B20 sensor is positioned near the shelf or object to monitor the actual temperature at the measurement point. All electronic circuits such as Arduino, relays, and power supplies are placed on the left side panel separate from the heating chamber to maintain safety from heat and humidity, while the 16×2 LCD on the panel displays NTC temperature data, DS18B20 temperature, and temperature and humidity from SHTC3 in real-time, so users can monitor the condition of the chamber without opening the box.

Figure 4. Honey Moisture Content Quality Control Device

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After designing the Honey Moisture Neutralizing Device, the next step is to conduct moisture content tests on the honey samples. The following are the results of the moisture content testing on the honey.

Table 1. Results of Honey Moisture Content Testing

Use Necta Dray					
	Honey and Moisture Content Testing				
Time/Hour	**Trigona (%)**	**Cerana (%)**	**Dorsata (%)**	**SNI**	**Keterangan**
0	27	43	30	22	
1	26.2	40	29	22	
2	25.5	38	28	22	
3	24.8	36	27	22	
4	24.2	34	26.2	22	
5	23.7	32	25.5	22	
6	23.2	30	24.8	22	
7	22.7	28.5	24.2	22	
8	22.3	27.2	23.6	22	
9	21.9	26	23.1	22	Trigona meets the standards
10	21.5	25	22.6	22	
11	21.2	24.2	22.2	22	
12	20.9	23.5	21.9	22	Dorsata meets the standards
13	20.6	22.8	21.6	22	
14	20.3	22.2	21.3	22	
15	20	21.7	21	22	Cerana meets the standards

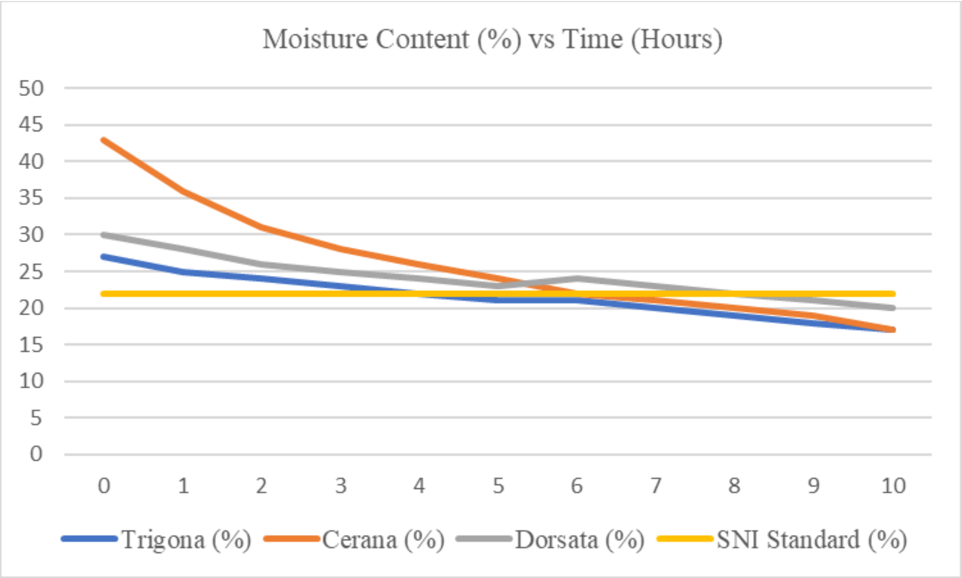

Figure 5. Honey Moisture Content Test Results

Table 1 and Figure 5 presents the results of moisture content testing for three types of honey Trigona, Cerana, and Dorsata using the Necta Dray device over a drying period of 0–15 hours. The Indonesian National Standard (SNI) for honey moisture content is 22%, which is used as the reference limit.

Moisture Reduction Trend

All honey types exhibited a progressive decrease in moisture content as drying time increased. This confirms that the Necta Dray device is effective in reducing honey moisture through controlled drying.

- Cerana honey showed the highest initial moisture content (43%), followed by Dorsata (30%) and Trigona (27%).

- Despite the different starting values, all honey types experienced a relatively consistent downward trend throughout the drying process.

Compliance with SNI Standard

The time required for each honey type to meet the SNI moisture standard differed significantly:

- Trigona honey reached the SNI standard at hour 9, with a moisture content of 21.9%. This indicates that Trigona honey requires the shortest drying time, likely due to its lower initial moisture content.
- Dorsata honey met the SNI standard at hour 12, when its moisture content decreased to 21.9%. The longer drying time reflects its moderately high initial moisture.
- Cerana honey reached the SNI standard last, at hour 15, with a moisture content of 21.7%, due to its significantly higher initial water content.

Discussion

The results of the present study demonstrate that an IoT-based honey moisture reduction system with controlled temperature and humidity is effective in reducing honey water content to meet national quality standards. This finding is consistent with previous studies reporting that controlled thermal processing significantly accelerates water evaporation in honey while maintaining process stability [1].

The application of moderate and regulated heating in this study aligns with prior reviews indicating that low-to-medium temperature treatment is optimal for reducing honey moisture without inducing excessive quality degradation [3]. Furthermore, literature emphasizes that maintaining a balance between temperature, processing time, and air circulation is essential to preserve sensory and physicochemical properties of honey[4]. The automated control mechanism implemented through microcontroller-based systems in this research corroborates findings from studies on automated honey dehydrators, which reported improved consistency and repeatability compared to manual drying methods [5]. Similarly, Arduino-based honey dehydration systems have been shown to effectively regulate environmental variables, resulting in faster and more reliable moisture reduction [6] [7]. The operating temperature range used in this study corresponds with pilot-scale dehydration research that employed temperatures between 36°C and 52°C to achieve export-grade moisture levels [8], [9]. However, such studies also highlight the trade-off between drying rate and energy consumption, which remains an important consideration for system scalability. Advanced dehydration technologies such as heat pump-assisted systems and falling film evaporators have been proposed to improve energy efficiency in honey dehydration processes[10], [11].

Although the present study utilizes conventional heating, these advanced approaches provide valuable insights for future system optimization. The observed relationship between drying duration and moisture reduction in this study is in agreement with kinetic models describing moisture loss behavior during honey dehumidification [2], [12], [13]. Such models are useful for predicting optimal processing times and could be integrated into future control algorithms. Previous studies have reported that prolonged dehumidification can negatively affect honey pH and acidity levels [14]. Therefore, the ability of the proposed system to achieve target moisture content within a relatively short processing time represents a significant advantage in terms of quality preservation. From a thermal design perspective, uneven heat distribution has been identified as a major cause of inconsistent moisture reduction in honey dehydrators [15], [16], [17].

Conclusion

This study successfully developed and implemented an Internet of Things (IoT)-based honey moisture reduction device that effectively improves the quality of Kalimantan honey. The system enables real-time monitoring and control of temperature and humidity, ensuring a stable and controlled moisture reduction process. Experimental results demonstrate that the device is capable of reducing the moisture content of three types of honey—Trigona, Cerana, and Dorsata—to comply with the Indonesian National Standard (SNI) 8664:2018, which requires a maximum moisture content of 22%.

The effectiveness of the developed device is further evidenced by its relatively short processing time. Trigona honey exhibited a reduction in moisture content from 27% to 21.5% within 5 hours, Cerana honey from 43% to 21% within 7 hours, and Dorsata honey from 30% to 20.8% within 9 hours. Variations in processing time among the honey types are primarily attributed to differences in their initial moisture content and physicochemical characteristics. Based on these findings, it can be concluded that the application of IoT technology in honey moisture reduction devices represents an effective and promising solution for improving honey quality, extending shelf life, and supporting local honey producers in meeting national quality standards. With further development and optimization, this system has strong potential for wider implementation at the small-scale and small-to-medium enterprise levels to enhance the competitiveness of local honey products in both national and international markets.

Acknowledge

We would like to thank the entire research team for their assistance, and all parties who have contributed to the smooth implementation of this study.

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