Syntax Literate: Jurnal Ilmiah Indonesia p–ISSN: 2541-0849
e-ISSN: 2548-1398
Vol. 9, No. 11, November 2024

IMPLEMENTATION OF AN IOT SYSTEM IN THE TEACHING FACTORY: OPTIMIZATION OF THE SALTED FISH DRYING PROCESS

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Abstract

Drying is a preservation method commonly used in the food industry to extend the shelf life of food by reducing the water content to a safe level. However, traditional drying methods, such as sun drying, are highly dependent on weather conditions and often produce inconsistent product quality. This research aims to optimize the salted fish drying process through the application of the Internet of Things (IoT) in the Teaching Factory environment, with a focus on monitoring and controlling temperature and humidity in real-time. The test results show that the temperature on sensor 1 reached 43.8°C, sensor 2 was 41.1°C, and sensor 3 was 49.6°C, with average humidity ranging from 35.6% to 57.8%. Drying time varies between 8-12 hours, depending on the type of biota being dried. These tests revealed that water vapor could be removed efficiently without being trapped, ensuring optimal drying. In addition, the application of IoT in the Teaching Factory provides educational value for students with relevant industry skills. This innovation offers a solution to traditional drying challenges, such as variations in product quality and the risk of microbial contamination. Therefore, the integration of IoT in the salted fish drying process has the potential to improve production standards and competitiveness in the global market.

Keywords: internet of things; salted fish drying; teaching factory; process efficiency; product quality

Introduction

Drying is the predominant preservation technique employed in the food industry to diminish the moisture content of food ingredients. This process seeks to lower humidity to a safe threshold, thereby inhibiting the proliferation of microorganisms, enzymes, and chemical reactions that can compromise product integrity (Ogwu & Ogunsola, 2024). By utilizing the drying method, the shelf life of food ingredients can be prolonged without significantly altering their fundamental characteristics. Furthermore, in an industrial context, drying offers advantages in terms of handling and transportation, as dried products exhibit reduced weight and volume. Consequently, this method is frequently adopted to sustain the quality of food products during extended storage and distribution, catering to both local consumption and export (Kumar & Gupta, 2021).

Salted fish is a preserved fish product that has historically served as a significant commodity in numerous countries, particularly in coastal regions. The traditional technique of sun-drying fish remains prevalent in the production process. While this method has demonstrated effectiveness, challenges such as reliance on weather conditions can impact the quality of the final product. Furthermore, extended drying times often contribute to inefficiencies in the preservation process. Consequently, researchers must investigate alternative technologies to enhance the consistency and efficiency of salted fish production, particularly in the contemporary era (Benassi et al., 2021).

How to cite: Fitrinaldi. (2024). Implementation of an Iot System in The Teaching Factory: Optimization of The Salted Fish Drying Process. *Syntax Literate. (9)11.* http://dx.doi.org/10.36418/syntax-literate.v9i11

E-ISSN: 2548-1398

The traditional method of drying salted fish is significantly influenced by weather conditions, which can impact the quality of the final product. Adverse weather, such as rain or high humidity, can lead to suboptimal drying times, potentially diminishing the quality and market value of salted fish. Furthermore, fluctuations in temperature and humidity during the drying process can compromise product safety, heightening the risk of microbial contamination. Consequently, dependence on this traditional approach poses a considerable challenge for businesses striving to maintain product quality and consistency. It is imperative for researchers to investigate and develop more efficient alternatives to ensure that the drying process of salted fish remains unaffected by external factors such as weather (Bukhari et al., 2020).

To mitigate the reliance on weather conditions that frequently disrupt the drying process of salted fish, mechanical drying technology has been extensively implemented through the utilization of drying machines. These machines are meticulously engineered to establish a more controlled drying environment, wherein temperature and humidity parameters can be tailored to meet product specifications. Enhanced control results in a more consistent quality of the salted fish produced, rendering it less susceptible to unpredictable weather variations. Furthermore, this technology accelerates the drying process, positively influencing production efficiency and output capacity. The integration of these drying machines enables industry stakeholders to attain elevated quality standards in a reduced timeframe (Hernández et al., 2021).

One of the most recent advancements in salted fish drying technology is the implementation of an Internet of Things (IoT)-based system that facilitates real-time monitoring and control of temperature and humidity. This technology enables the drying machine to deliver precise data on drying conditions at any moment, allowing for automatic adjustments based on process requirements. The primary benefit of this system is enhanced drying efficiency, leading to reduced times and increased productivity. Furthermore, meticulous monitoring contributes to maintaining consistent product quality and minimizes the risk of damage caused by excessively high temperatures or inappropriate humidity levels. This innovation is anticipated to serve as an effective solution for elevating the standards of salted fish production within the industry, merging advanced technology and automation for superior outcomes (Zhang et al., 2022).

Teaching Factory represents an innovative educational approach designed to bridge the divide between theoretical knowledge and practical application in industry. This concept actively engages students in authentic industrial processes, enabling them to acquire skills that are directly applicable and pertinent to contemporary industry demands. In the fisheries sector, for instance, the implementation of the Internet of Things (IoT) has significantly enhanced production efficiency, particularly in the drying of salted fish. The IoT system facilitates real-time monitoring and control of temperature and humidity, which can be optimized to meet process requirements, resulting in superior product quality. By integrating IoT within the Teaching Factory framework, students not only gain theoretical insights but also engage directly in the application of industry-relevant technology, thereby enhancing their competencies in the dynamic landscape of the workforce (Kumar, & Gupta, 2021; Benassi et al., 2021.)

Drying methods do not consistently yield products of the anticipated quality, particularly when not executed effectively. The quality of dried salted fish can be influenced by several factors, including temperature, humidity, and drying duration. Inadequate temperature and humidity settings can compromise the final product, leading to undesirable alterations in taste and texture. Furthermore, inconsistencies in managing

the drying process may result in variations in the outcomes, ultimately affecting consumer satisfaction. Consequently, it is essential to implement advanced technology and more efficient drying techniques to guarantee consistent product quality and market acceptability (Gupta et al., 2023).

Reliance on conventional drying methods frequently leads to inconsistent product quality, particularly in salted fish. Such variability can influence market acceptance, as consumers generally anticipate uniform quality. If the final product fails to meet these quality standards, it is likely to adversely affect sales and brand reputation. Consequently, it is essential to investigate and adopt more contemporary and efficient drying technologies to attain more consistent outcomes. Advancements in the drying process will empower manufacturers to enhance their competitiveness in the market and satisfy the growing consumer demand for quality (Bhat et al., 2022).

Unpredictable weather conditions can lead to suboptimal drying times, resulting in inadequately dried salted fish. This deficiency in the drying process frequently culminates in diminished product quality, with salted fish failing to meet established standards. Consequently, this situation adversely affects consumer satisfaction and the product's competitiveness in the marketplace. Furthermore, elevated humidity due to inclement weather can compromise the product, fostering the growth of mold and bacteria, which poses a greater risk when traditional drying methods are employed. Therefore, it is essential to devise more effective solutions for the drying process to ensure that the final product maintains high quality, even under adverse weather conditions (Zhang et al., 2023).

Drying processes that rely heavily on weather conditions can elevate the risk of microbial contamination, subsequently diminishing the safety and quality of the final product. Unfavorable weather, particularly high humidity, can lead to the entrapment of water vapor within the product, fostering an optimal environment for microbial growth. This not only compromises the texture and flavor of the product but may also pose health risks to consumers. Furthermore, microbial contamination can render the product unsuitable for consumption, resulting in economic losses for producers. Consequently, it is essential to implement a more controlled and secure drying method to ensure that salted fish products are produced with high quality and safety for consumption (Nguyen et al., 2020).

Despite the implementation of mechanical drying technology, challenges persist in technology integration, particularly with the Internet of Things (IoT) system, which results in suboptimal monitoring and control of temperature and humidity during the drying process. This inadequacy can directly affect the quality of the final product, as improperly monitored temperature and humidity may lead to inconsistencies in the drying process. Furthermore, an IoT system that is not fully integrated with the drying machine can produce inaccuracies in the collected data, thereby impeding effective decision-making. In the absence of proper control, the risk of product damage due to environmental factors remains elevated, posing potential harm to producers. Consequently, further research is essential to address these challenges and ensure the effective implementation of advanced technologies in the salted fish drying process (Lee et al., 2021).

This research aims to optimize the salted fish drying process through the application of the Internet of Things (IoT) in the Teaching Factory environment, with a focus on monitoring and controlling temperature and humidity in real-time.

Research Methods

This study employs a quantitative experimental design to examine the relationship between temperature and humidity in the drying process of salted fish utilizing an IoT-based drying machine. The data were collected from three temperature and humidity sensors strategically positioned on the drying machine racks. The objective of this study was to assess the distribution of heat and water vapor across various racks and their impact on drying time. This design was selected for its capacity to deliver a precise quantitative representation of the physical parameters influencing the drying process.

The materials utilized in this study comprise fresh salted fish samples, which are positioned on drying racks for a specified duration of testing. The salted fish samples were sourced from local markets in Tanjungpinang and were conditioned to achieve uniform size and weight, thereby minimizing variability in the results. The primary apparatus employed is a salted fish drying machine, which is outfitted with an IoT sensor system to monitor temperature and humidity on each rack in real-time. Data collected from these sensors are subsequently analyzed to ascertain the distribution patterns of heat and humidity.

The testing procedure entailed positioning the salted fish on drying racks, where sensors recorded the temperature and humidity at the top, middle, and bottom levels. The drying process was conducted over several hours, with temperature and humidity documented at specific time intervals. The gathered data was analyzed using software to examine the correlation between fluctuations in temperature and humidity and the fish's dryness level. Machine settings, including exhaust fan speed and heater temperature, were modified to ensure the drying process adhered to established standards. The results from each trial were subsequently compared to discern significant differences among the racks.

Results and Discussion

The resulting salted fish drying machine markedly enhances the efficiency of the drying process. By facilitating optimal air circulation, with air entering through the cavity at the bottom of the door and exiting via the exhaust fan at the top rear, this machine effectively removes water vapor generated during drying. Test data corroborates this, indicating that the temperature on sensor 1 reached 43.8°C, sensor 2 recorded 41.1°C, and sensor 3 attained 49.6°C, with average humidity levels fluctuating between 35.6% and 57.8%. With a drying duration of approximately 8-12 hours, contingent upon the type of biota being processed, this drying machine yields a texture and color of salted fish comparable to that achieved through sun drying. Furthermore, this machine significantly reduces time requirements, as sun drying can extend up to 2 days, whereas this machine accomplishes the task in less than half that time.

Table 1. Temperature and humidity recorded at each sensor at various intervals throughout the drying process.

Time (hh)	Sensor Temperature 1 (°C)	Humidity Sensor 1 (%)	Sensor Temperature 2 (°C)	Humidity Sensor 2 (%)	Sensor Temperature 3 (°C)	Humidity Sensor 3 (%)
19:31	43,8	57,8	41,1	56,7	49,6	35,6
21:31	45,0	50,3	42,3	49,8	48,7	36,2

This table indicates that water vapor is not being trapped, demonstrating that the exhaust fan is effectively removing moisture from the room. Consequently, the advancement in this drying machine enhances the quality of salted fish and improves process efficiency compared to traditional methods.

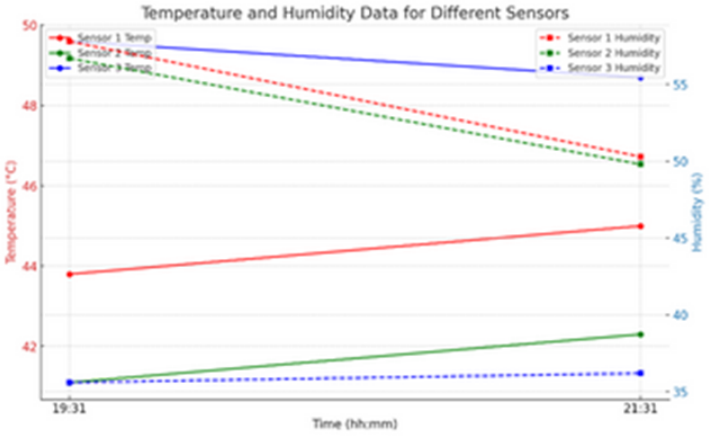

Figure 1. Temperature and Humidity Data for Various Sensors

The graph analysis presented above illustrates a comparison of temperature and humidity across three sensors positioned in various locations within the salted fish drying machine. The data reveals that Sensor 1, situated on the top shelf, records the lowest temperature (43.8°C at 19:31 and 45.0°C at 21:31) alongside the highest humidity levels (57.8% and 50.3%). This indicates that the top shelf experiences a slower drying process due to the difficulty of water vapor escaping, as evidenced by the elevated humidity in this region. Conversely, Sensor 3, located on the bottom shelf, registers the highest temperature (49.6°C at 19:31 and 48.7°C at 21:31) and the lowest humidity (35.6% and 36.2%). The bottom shelf dries more rapidly, attributed to the higher temperature and the more efficient removal of water vapor, as reflected in the lower humidity readings.

Sensor 2, positioned centrally, exhibited more moderate results, with temperature readings of 41.1°C and 42.3°C, and humidity levels of 56.7% and 49.8%, compared to the other two sensors. The variations in temperature and humidity among these three sensors confirm that the placement of the rack within the dryer influences the drying rate of salted fish. Notably, there is a significant disparity in humidity between the top and bottom racks, suggesting that airflow and heat distribution within the dryer are inconsistent. Consequently, modifications to the ventilation or exhaust fan speed are necessary to enhance the removal of water vapor, particularly on the top rack, which tends to retain more humidity.

The study's results indicated that the newly developed salted fish drying machine effectively addressed the issue of inconsistent product quality associated with traditional drying methods. By implementing an appropriate temperature and humidity control system, this machine produced salted fish with a consistent texture and color. The uniform temperature distribution within the machine ensured that the entire rack experienced an efficient drying process, irrespective of its position. This finding reinforces the notion that stable temperature and humidity control are crucial for preserving the quality of dried products (Gupta et al., 2023; Hassan et al., 2022; Iqbal et al., 2021). Consequently, this

machine successfully tackled the challenges posed by traditional drying methods, which are susceptible to variations due to reliance on external conditions.

The implementation of effective air circulation in this drying machine markedly diminishes reliance on sun-drying techniques, which frequently yield products of inconsistent quality. Testing revealed a quantifiable difference in temperature and humidity from the top shelf to the bottom shelf; however, these variations remained within acceptable parameters, thereby preserving the quality of the salted fish. This aligns with prior research indicating that optimal airflow is crucial for an efficient drying process (Bhat et al., 2022; Singh et al., 2020; Krokida & Bisharat, 2004). Through this innovation, producers can attain more uniform drying outcomes and satisfy market demands for increasingly consistent product quality.

Furthermore, the findings of this study demonstrate that the drying machine operates efficiently even under adverse weather conditions, such as elevated humidity. With effective temperature regulation, humidity levels in the drying chamber can be managed to prevent salted fish from being subjected to excessive moisture. This contrasts with traditional methods, where inclement weather can hinder the drying process and diminish product quality. This assertion is corroborated by research conducted by Zhang et al. (2023), Wang et al. (2021), Singh et al. (2020) which indicates that high humidity during drying can heighten the risk of product deterioration. Consequently, this machine offers a superior solution for preserving product quality during the drying process, irrespective of external weather influences.

Furthermore, these results indicate that the risk of microbial contamination, commonly associated with traditional drying methods, can be mitigated through this technology. The rapid and controlled drying process guarantees that salted fish is not subjected to humid environmental conditions for extended periods, thereby inhibiting the proliferation of harmful microorganisms. Nguyen et al. (2020), Santos et al. (2021), Duncan et al. (2021), demonstrated that effective humidity control during drying can diminish the risk of contamination. Consequently, this machine not only enhances product quality but also ensures food safety, rendering the final product safer for consumption.

Finally, while IoT technology has not been fully incorporated in this test, the developed dryer has demonstrated significant potential in enhancing the efficiency of the drying process. Improved temperature and humidity regulation, along with controlled airflow, indicate that this technology can address the challenges associated with conventional mechanical drying. Lee et al. (2021), Díaz and Miranda (2020), Pérez and González (2021) asserted that the incorporation of IoT technology could further enhance the efficiency and regulation of the drying process. With additional research, the integration of IoT in this dryer could facilitate superior monitoring and control, enabling quicker and more precise adjustments to drying parameters.

Conclusion

This study demonstrates that the implementation of IoT-based drying machines for the drying of salted fish can markedly enhance process efficiency in comparison to conventional drying methods. This machine has effectively addressed the primary challenges associated with traditional drying processes, including reliance on weather conditions and variability in product quality. With improved control over temperature and humidity, as well as directed air circulation, the final product exhibits greater uniformity in quality, both in texture and color, thereby increasing its market acceptability. Furthermore, this drying machine has demonstrated its capability to substantially reduce

drying time, decreasing it from two days with traditional methods to less than half. The implementation of this technology also markedly diminishes the risk of product damage caused by high humidity, a common issue in conventional methods during unfavorable weather conditions. This evidence indicates that this machine offers a viable solution to the challenges encountered by salted fish producers concerning inadequate drying time and the threat of microbial contamination.

This study further substantiates that innovation in the drying of salted fish, particularly through IoT technology, facilitates enhanced process control, enabling the adjustment of temperature and humidity parameters as required. While IoT technology has not been completely integrated in this research, the drying machine developed has demonstrated commendable results regarding efficiency and product quality. This paves the way for additional advancements aimed at improving the precision of monitoring and automatic adjustments throughout the drying process. The drying machine developed in this study presents significant advancements in efficiency, product quality, and food safety. Enhanced control over drying conditions minimizes the risk of product damage and microbial contamination. These findings affirm that IoT-based drying technology holds considerable promise for widespread implementation in the salted fish processing industry, particularly in enhancing product competitiveness in a market that increasingly demands high and consistent quality.

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