Brilliance
Research of Artificial Intelligence

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

Usability-Driven Development of an IoT-Based Salted Fish Quality Detection Application Using the QUIM Model

Muhammad Ikhwani[1]*, Lidya Rosnita[2], Nanda Sitti Nurfebruary[3], Asih Makarti Muktitama[4], Fidyatunnisa[5], Muhammad Zuhdi[6]
[1, 3, 5, 6]Information System, Universitas Malikussaleh, Indonesia, [2]Informatic Engineering, Universitas Malikussaleh, Indonesia, [4]Aquaculture, Universitas Malikussaleh. Indonesia
[1]muhammad.ikhwani@unimal.ac.id , [2]lidyarosnita@unimal.ac.id, [3]nandasitti.nur@unimal.ac.id, [4]makartiasih@unimal.ac.id, [5]fidyatun.nisa@unimal.ac.id, [6]muhammad.210180117@mhs.unimal.ac.id

open access

***Corresponding Author**

Article History:
Submitted: 08-12-2025
Accepted: 21-12-2025
Published: 29-12-2025

Keywords:
Food MSMEs; Internet of Things; QUIM; Salted Fish; Usability.

ABSTRACT

Salted fish is a vital component of Indonesia's coastal economy, supporting numerous fishing households and local micro, small, and medium enterprises (MSMEs). However, maintaining product quality during household freezer storage remains a significant challenge. Temperature and humidity fluctuations in shared freezers often lead to quality degradation, discoloration, and the risk of microbial contamination by pathogens such as *Salmonella* and *Staphylococcus aureus*. To address these issues, this study developed an Internet of Things (IoT)–based monitoring system that integrates temperature and humidity sensors with an Android application to provide real-time data visualization and automated risk notifications. Recognizing that usability is critical for technology adoption among food-related MSMEs, the Quality in Use Integrated Measurement (QUIM) framework was applied to evaluate system performance across ten dimensions: effectiveness, productivity, satisfaction, efficiency, learnability, flexibility, error tolerance, safety, accessibility, and sustainability. The system was designed using human-centered principles and implemented with an ESP32 microcontroller and DHT22 sensors. A 14-day pilot trial demonstrated that the application could reliably detect environmental fluctuations, with usability scores reflecting high effectiveness (4.1/5) and user satisfaction (4.3/5). Although minor issues with internet connectivity and error message clarity were noted, iterative improvements were successfully incorporated. These findings demonstrate the feasibility of combining IoT technology with QUIM-based evaluation to enhance food storage practices and support quality management in salted fish processing among MSMEs.

INTRODUCTION

Salted fish represents a traditional processed fishery product with substantial cultural and historical relevance in Indonesia, particularly within coastal communities. As a maritime country with substantial capture fisheries and aquaculture resources, Indonesia widely relies on salting as an effective preservation method to extend shelf life, reduce post-harvest losses, expand market access, and provide an affordable source of animal protein for lower- and middle-income communities (Abdullah et al., 2024; Yusnidar et al., 2024).

The processing of salted fish is predominantly conducted by micro, small, and medium enterprises (MSMEs), which play a strategic role in local economic development by generating employment, especially for women in coastal areas, increasing household income, and sustaining economic activities in production centres (Sari et al., 2024). One example of such a community-based MSME is the Kase Teuplah fish-drying group in Pusong Baru Village, Lhokseumawe. The group consists primarily of women and youth who have discontinued formal education and functions as a key economic pillar within the village (Sari et al., 2024). Initially operating as individual household businesses, the group has evolved into a collective enterprise aimed at strengthening the local economy through employment creation. Its core activities include producing various types of salted fish, such as talang fish, kadra fish, and other marine species, while attempting to maintain consistent product quality. Despite participation in formal training programs, quality control remains a persistent challenge (Abdullah et al., 2024).

A major source of quality degradation occurs during the storage stage. To extend shelf life, salted fish is commonly stored in household freezers. However, frequent opening and closing of freezers results in fluctuations in internal temperature and humidity, creating conditions favourable for the proliferation of pathogenic microorganisms such as *Salmonella* and *Staphylococcus aureus* (Abdullah et al., 2024; Nurmalasari & Febrianto, 2025). These fluctuations accelerate product deterioration, compromise food safety, and increase health risks for consumers. Moreover, declining product quality leads to economic losses due to reduced selling prices, higher operational costs, and a shortened lifespan of storage equipment (Nurmalasari & Febrianto, 2025).

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

Recent developments in Internet of Things (IoT) technologies provide new opportunities to address these storage-related challenges. IoT-based monitoring systems equipped with temperature and humidity sensors enable continuous and real-time observation of storage conditions without requiring physical interaction with the freezer (Putra & Hidayat, 2024; Al-Fuqaha et al., 2015). Such systems allow early detection of unfavourable conditions, thereby reducing contamination risks and improving storage efficiency (Badia-Melis & Barragán, 2018; Protopappas et al., 2025). Several studies have demonstrated the effectiveness of IoT-based solutions in food storage and cold chain monitoring, including applications in fisheries and aquaculture systems (Ula et al., 2022; Rezeki, 2024; Iqbal, 2025; Tailor, 2025; Dash, 2022).

Nevertheless, the successful implementation of IoT solutions in food-related MSMEs is not solely dependent on technical performance. Usability has been identified as a critical determinant of technology adoption, particularly in community-based enterprises where users have diverse educational backgrounds and varying levels of digital literacy (Puspitasari & Arifin, 2024; Wulandari & Susanto, 2024). Previous studies report that many IoT applications in MSMEs fail due to complex interfaces, unclear feedback, and misalignment with users' capabilities and daily operational practices (Puspitasari & Arifin, 2024; Wulandari & Susanto, 2024). These limitations highlight the need for systematic usability evaluation frameworks in the design and development of IoT-based applications.

In this context, the Quality in Use Integrated Measurement (QUIM) framework offers a comprehensive approach to evaluating application quality in real-world usage environments. QUIM assesses multiple dimensions, including effectiveness, efficiency, productivity, satisfaction, safety, learnability, flexibility, error tolerance, accessibility, and sustainability. The framework is aligned with international usability standards such as ISO 9241-11 and foundational usability principles proposed by Nielsen (ISO, 1998; Nielsen, 1993). Furthermore, prior studies have demonstrated the effectiveness of QUIM in improving technology adoption among users with limited digital literacy, particularly in mobile and agricultural applications (Rahman et al., 2025; Heo & Seo, 2009).

Therefore, this study adopts the QUIM framework as the foundation for designing an IoT-based Android application to monitor the quality of salted fish for the Kase Teuplah group. The primary contribution of this study lies in integrating QUIM into the early design phase of an IoT application tailored for food-related MSMEs, with the aim of delivering a technically reliable, user-centered, and sustainably adoptable solution.

LITERATURE REVIEW

The sustainability, safety, and quality of fishery products have become central concerns in recent global and national development agendas. Recent reports from the Food and Agriculture Organization emphasize that post-harvest losses in fisheries remain significant, particularly in developing countries where inadequate storage systems and traditional handling practices persist (FAO, 2022; FAO, 2023). These challenges are strongly linked to recent progress evaluations of the United Nations Sustainable Development Goals, especially SDG 2 Zero Hunger and SDG 12 Responsible Consumption and Production, which highlight the urgency of improving food preservation, reducing losses, and ensuring sustainable production systems (UN, 2022; UN, 2023). In the Indonesian context, recent policy implementations and derivative regulations continue to reinforce earlier national laws on food safety and fisheries by emphasizing digital transformation, quality assurance, and MSME empowerment in the fisheries sector (Ministry of Marine Affairs and Fisheries, 2023). Empirical studies further confirm that traditional fish processing MSMEs continue to experience challenges related to inconsistent storage conditions, microbial contamination risks, and limited access to modern preservation technologies, which ultimately affect both product safety and economic outcomes (Abdullah et al., 2024; Nurmalasari & Febrianto, 2025).

Recent advancements in digital technologies, particularly Internet of Things (IoT)-based monitoring systems, have demonstrated significant potential in addressing these challenges. Contemporary Scopus-indexed studies indicate that IoT-enabled solutions can provide real-time monitoring of temperature, humidity, and environmental conditions, thereby reducing spoilage, improving cold chain efficiency, and enhancing food safety in fisheries supply chains (Protopappas et al., 2025; Dash, 2022). Furthermore, the integration of low-cost sensors and mobile-based platforms has made these technologies increasingly accessible for small-scale enterprises, including MSMEs in coastal communities (Iqbal, 2025; Ula et al., 2022). However, despite these technological benefits, recent literature highlights that adoption remains constrained by usability issues, limited digital literacy, and socio-technical barriers (Puspitasari & Arifin, 2024; Wulandari & Susanto, 2024). Studies published within the last five years emphasize that user-centered design and usability evaluation frameworks are essential to ensure effective implementation and long-term adoption of IoT solutions in low-resource environments (Rahman et al., 2025). Therefore, integrating usability-focused frameworks such as QUIM into IoT system development is increasingly recognized as a critical approach to bridging the gap between technological innovation and practical usability in community-based MSMEs.

METHOD

This research employs a quantitative-dominant mixed-methods approach to comprehensively evaluate both technical performance and user experience. Integrating usability questionnaires (QUIM), system performance testing, structured observation, and semi-structured interviews enables both objective measurement and subjective evaluation,

Brilliance
Research of Artificial Intelligence

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

an approach recommended for IoT usability studies that involve real-time environmental systems and end users (Costa et al., 2023; Protopappas, Pallis, et. al, 2025). The developed IoT device was deployed inside a household freezer at the salted fish production facility, while the Android application visualized real-time sensor data for production workers over a defined evaluation period.

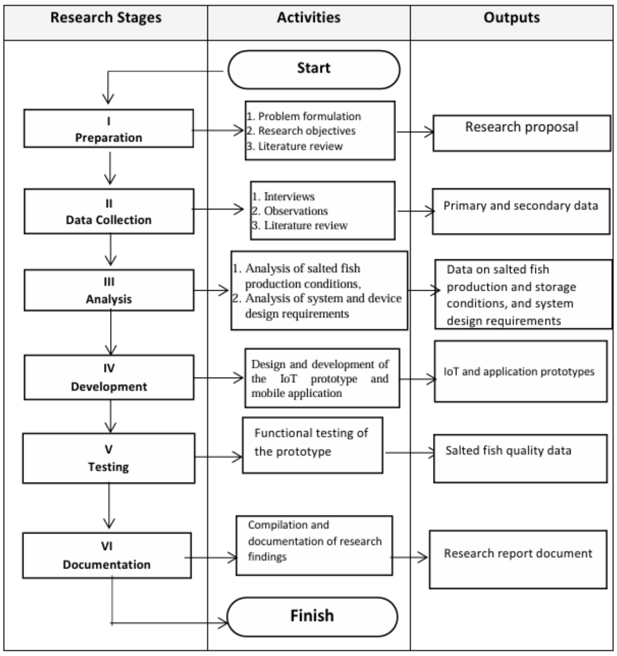

Fig 1. Research Stages

The study was conducted through structured research stages to ensure systematic implementation and reliable outcomes (Costa et al., 2023). Initially, problem formulation and literature review activities were undertaken to collect relevant references on IoT design, sensor technologies for real-time monitoring, and usability evaluation frameworks. Literature on sensor-based monitoring systems highlights the critical need to track parameters such as temperature and humidity to reduce food quality degradation and spoilage in food supply chains (Costa et al., 2023; Protopappas et al., 2025). This foundational stage produced a documented problem definition and guided subsequent instrument preparation.

Data collection involved members of the Kase Teuplah fish dryers in Pusong Baru Village, Lhokseumawe. Interviews and direct observations identified contextual user needs and handling practices, including freezer access patterns that affect environmental stability. Observed processes included initial processing, drying, salting, and storage of salted fish. The collected primary and secondary data were analysed using the QUIM usability model to align user requirements with application and hardware design. Recent IoT research emphasises combining technical metrics with user-centred evaluations to support adoption in low-literacy user groups (Protopappas et al., 2025).

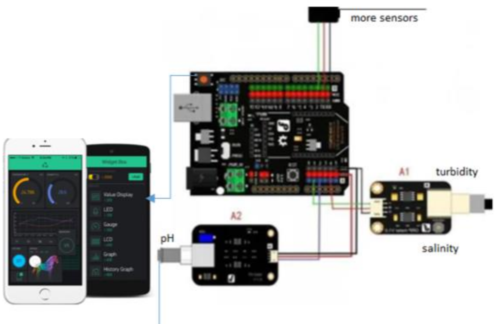

Fig 2. Prototype Design of the Salted Fish Quality Detection Application

Based on this analysis and experimental testing using sensors within a freezer environment, an IoT hardware prototype was developed and iteratively refined through functional testing. This iterative Research and Development (R&D) model ensured that data collection and testing contributed to improving the accuracy and reliability of the IoT device, consistent with engineering best practices in IoT development (Costa et al., 2023). The QUIM model was

Brilliance
Research of Artificial Intelligence

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

applied to accommodate usability factors such as effectiveness, efficiency, satisfaction, error tolerance, and learnability, which were evaluated through direct observation of users interacting with the application, QUIM-based interviews, and objective measures of task performance. Quantitative findings were supplemented by qualitative user feedback, enabling a comprehensive evaluation of the user experience and guiding iterative system improvements.

RESULT

The field survey revealed that the Kase Teuplah group utilizes shared household freezers with capacities ranging from 350 to 900 liters for storing salted fish. Frequent opening and closing of the freezer doors were identified as a primary factor contributing to instability in temperature and humidity conditions.

Observational results showed that the freezer temperature remained stable at approximately −20 °C when the door was closed but increased to around −14 °C when opened more than ten times within one hour. Humidity levels ranged between 65% and 80%, with higher values observed near the door. Interview results indicated that all participants used Android smartphones but had no prior experience with monitoring applications. Users preferred simple visual indicators such as colors and symbols rather than text-based information. The main quality issues reported were discoloration and rancid odor after more than two weeks of storage, along with occasional spoilage due to fly contamination. Documentation data confirmed that approximately 15–20% of stored salted fish experienced quality degradation after two weeks.

Based on these findings, the system requirements included high-accuracy temperature and humidity sensors (±0.5 °C tolerance), a Wi-Fi-enabled microcontroller, and an Android application capable of real-time monitoring and automated notifications. The ESP32 microcontroller was selected due to its efficiency and connectivity features. The application interface was designed using color-coded indicators (green, yellow, red) with a simplified interaction flow and user-friendly error messages.

The developed prototype consisted of an ESP32 microcontroller integrated with a DHT22 sensor for environmental monitoring. Data were transmitted via Wi-Fi and stored in a Firebase Realtime Database. The Android application, developed using Flutter, successfully displayed real-time temperature and humidity data, graphical trends, and color-based notifications. Audible alerts were triggered when temperature exceeded −16 °C or humidity surpassed 75%, demonstrating the system's capability to provide real-time monitoring and early warning functionality.

Fig 3. IoT Device for Salted Fish Quality Detection

In addition, the Android application for visualizing data from the IoT device was successfully developed. Below is the android application that presents the user interface and user experience (UI/UX):

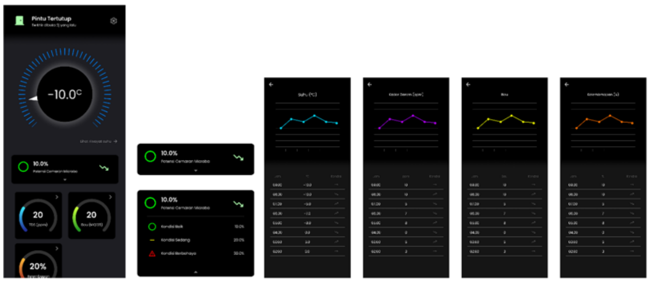

Fig 4. Android Application Interface for Salted Fish Quality Detection

The system was subsequently tested over a 14-day period by placing the IoT device inside the freezer used by the Kase Teuplah group. The visualization of the monitoring results over this testing period is presented in Figure 5. The results showed that the freezer temperature fluctuated between −16 °C and −20 °C, while humidity ranged from 65% to 74%. Initial conditions were relatively stable, but fluctuations became more pronounced on certain days, particularly

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

when the freezer door was opened frequently. For example, the temperature increased to −16 °C with a corresponding rise in humidity to 70%, indicating a direct relationship between door activity and environmental instability. Over time, humidity levels showed a tendency to increase, reaching a peak of 74%, while temperature remained within a fluctuating but controlled range. Toward the end of the testing period, the conditions became relatively more stable, although minor variations persisted. These findings indicate that while the freezer can maintain freezing temperatures, operational practices significantly influence internal conditions and may create an environment conducive to microbial growth if not properly monitored.

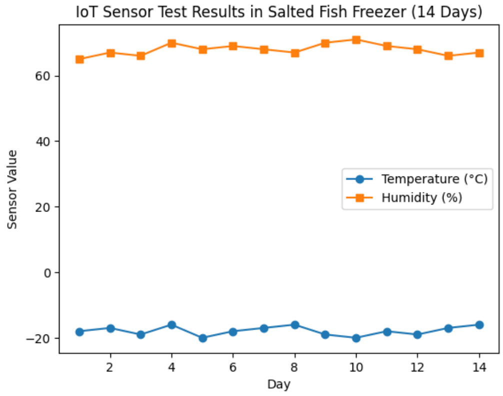

Fig 5. IoT Testing Results in the Freezer over a 14-Day Period

Further analysis demonstrated that the system effectively detected environmental changes and provided timely notifications. The average temperature under low door-opening frequency was approximately −19.5 °C, whereas frequent opening resulted in an increase to −14.8 °C. Humidity levels ranged from 62% to 78%, with noticeable increases when the freezer door remained open for extended periods. The application achieved a notification accuracy of approximately 95% when predefined thresholds were exceeded, and users were able to quickly interpret alerts due to the use of intuitive color indicators. However, some users reported confusion when error messages appeared, particularly in cases of unstable internet connectivity, indicating a need for further refinement in system feedback mechanisms.

Usability evaluation using the QUIM framework was conducted with ten respondents, and the overall results are illustrated in Figure 6. The findings revealed generally positive performance across multiple usability dimensions. Satisfaction and flexibility received the highest ratings, indicating that users found the application both acceptable and adaptable to their needs. Other dimensions, including effectiveness, productivity, learnability, accessibility, and security, also demonstrated favorable results, suggesting that the system was functionally reliable and relatively easy to use. However, the lowest score was observed in the error tolerance dimension, reflecting challenges in user understanding of system errors, particularly those related to connectivity issues.

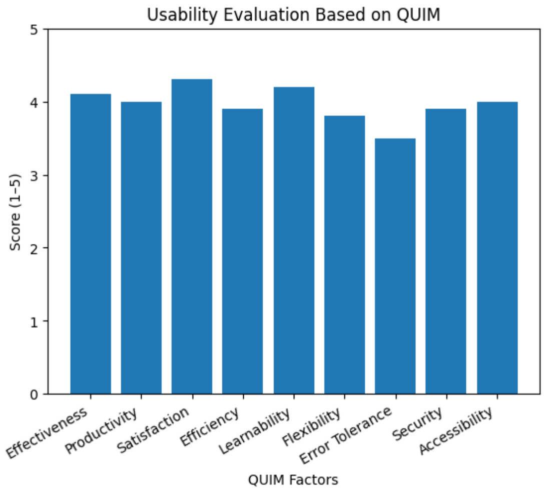

Fig 6. QUIM Scores During the Testing Period

The proportional distribution of QUIM factors is further illustrated in Figure 7. The results show that satisfaction contributed the highest proportion, indicating strong user acceptance, while error tolerance contributed the lowest proportion, highlighting the need for improvement in error handling and feedback clarity. Additionally, the sustainability aspect could not be fully evaluated within the limited duration of the study.

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

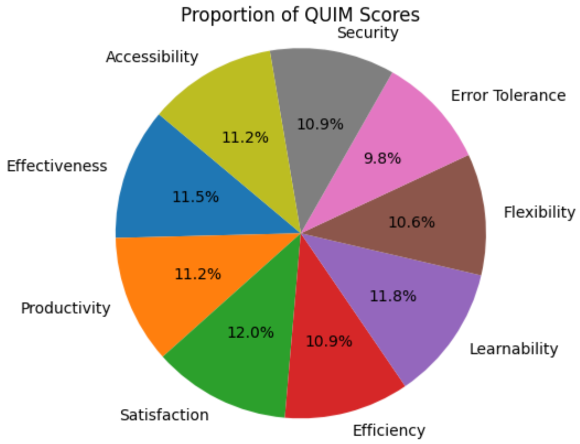

Fig 7. Proportion of QUIM Factors

It is shown based on the context that the study successfully completed all major stages, including preparation, data collection, requirements analysis, prototype development, and system testing. The developed IoT-based solution demonstrated its capability to monitor temperature and humidity fluctuations in real time and provide actionable feedback to users. The usability evaluation indicated that the application was effective and well-received, particularly due to its simple interface and intuitive design. Nevertheless, limitations related to error messaging and internet stability were identified, providing important directions for future improvements. These results confirm the potential of integrating IoT and usability-focused design frameworks to support quality management in salted fish processing within MSME environments.

DISCUSSION

The results demonstrate that temperature and humidity instability inside the freezer is primarily driven by operational practices, particularly the frequency of door opening. The observed increase in temperature from −20 °C to approximately −14 °C under frequent access conditions indicates a substantial deviation from optimal freezing standards. This finding confirms that, although the storage system is technically capable of maintaining low temperatures, human interaction introduces variability that can compromise storage stability. The simultaneous increase in humidity further strengthens the assumption that thermal fluctuations directly influence moisture dynamics, creating conditions that may accelerate microbial activity and product degradation.

The implementation of the IoT-based monitoring system proved effective in capturing these environmental fluctuations and translating them into actionable information. The system's ability to detect changes in real time and generate notifications with approximately 95% accuracy indicates strong performance in addressing the identified problem. Compared to conventional manual monitoring practices, which are often inconsistent and reactive, the proposed system offers a proactive approach to maintaining storage quality. The integration of temperature and humidity thresholds also demonstrates the system's capability to function as an early warning mechanism, thereby supporting preventive decision-making in food storage management.

From a usability perspective, the findings highlight the importance of aligning system design with user characteristics, particularly in MSME contexts with limited digital literacy. The high scores in satisfaction, flexibility, and learnability suggest that the use of simple visual indicators and minimal interaction steps effectively reduced user complexity. This result is consistent with user-centered design principles, where intuitive interfaces significantly improve technology adoption. However, the relatively low score in error tolerance indicates that system feedback, especially during connectivity disruptions, remains a critical limitation. This suggests that even well-designed interfaces require robust and easily interpretable error-handling mechanisms to ensure consistent user experience.

Overall, the study demonstrates that the integration of IoT technology with usability-focused design provides a practical solution for improving the quality management of salted fish storage. The findings contribute to addressing a real-world problem by linking environmental monitoring with user-friendly interaction, thereby bridging the gap between technical capability and practical adoption. Nevertheless, the system's dependency on stable internet connectivity and the limited evaluation period represent constraints that should be addressed in future research. Further development is recommended to enhance system robustness, improve error communication, and evaluate long-term sustainability under broader operational conditions.

CONCLUSION

The development of an IoT-based salted fish quality monitoring system integrating the Quality in Use Integrated Measurement (QUIM) usability model was successfully completed. This study systematically executed all research

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

stages, including preparation, data collection, requirements analysis, and prototype design, ensuring a robust development process. The ESP32-based IoT prototype, equipped with a DHT22 sensor, together with the Android application, enabled real-time visualization of temperature and humidity and provided automated notifications, demonstrating reliable functionality under experimental conditions.

A 14-day field trial confirmed that the system effectively detected temperature fluctuations ranging from −16 °C to −20 °C and humidity variations between 65% and 74%, with notification accuracy reaching 95%. Usability evaluation using the QUIM framework indicated that the application is user-friendly and accessible for individuals with limited digital literacy, with overall scores exceeding 4.0. Satisfaction was rated highest, while error tolerance received the lowest score, highlighting areas for improvement in system feedback and error messaging.

Despite the positive outcomes, the study identified limitations, including dependency on stable internet connectivity and occasional user confusion in interpreting error messages. Addressing these limitations in future iterations could enhance system reliability and adoption. Moreover, extended testing over longer periods and under varied operational conditions would provide further validation of the system's performance and durability.

The proposed system has significant practical implications for MSMEs involved in salted fish processing. By enabling continuous monitoring and early detection of storage-related quality issues, the application has the potential to reduce product losses, improve food safety, and enhance economic outcomes, with estimated reductions in losses of up to 25% upon full implementation. Future research should focus on improving connectivity robustness, refining error communication, and expanding the system for broader application in small-scale food enterprises.

ACKNOWLEDGMENT

We would like to express our gratitude to LPPM for providing us with a research grant sourced from PNBP Universitas Malikussaleh in 2025.

REFERENCES

Abdullah, M., et al. (2024). Analisis risiko kontaminasi mikroba pada ikan asin akibat praktik penyimpanan di freezer UMKM pesisir Aceh. *Jurnal Teknologi dan Keamanan Pangan, 15*(2), 123–135.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., & Aledhari, M. (2015). Internet of Things: A survey on enabling technologies, protocols and applications. *IEEE Communications Surveys & Tutorials, 17*(4), 2347–2376. https://doi.org/10.1109/COMST.2015.2444095

Badia-Melis, R., McCarthy, U., Ruiz-Garcia, L., & Garcia Hierro, J. (2022). New trends in cold chain monitoring applications: A review. *Food Control, 86*, 170–182. https://doi.org/10.1016/j.foodcont.2017.11.022

Costa, T. P. d., Gillespie, J., Cama-Moncunill, X., Ward, S., & Condell, J. (2023). A systematic review of real-time monitoring technologies and its potential application to reduce food loss and waste: Key elements of food supply chains and IoT technologies. *Sustainability, 15*(1), 614. https://doi.org/10.3390/su15010614

Food and Agriculture Organization. (2022). *The state of world fisheries and aquaculture 2022: Towards blue transformation.* Rome: FAO.

Food and Agriculture Organization. (2023). *Blue transformation roadmap: Implementation update.* Rome: FAO.

Ghosh, T., Raj, G. V. S. B., & Dash, K. K. (2022). A comprehensive review on nanotechnology-based sensors for monitoring quality and shelf life of food products. *Measurement: Food, 7*, 100049. https://doi.org/10.1016/j.meafoo.2022.100049

Heo, J., Ham, D.-H., Park, S., & Song, C. (2009). A framework for evaluating the usability of mobile phones based on multi-level, hierarchical model of usability factors. *Interacting with Computers, 21*(4), 263–275. https://doi.org/10.1016/j.intcom.2009.05.006

Islam, M. N., Khan, N. I., & Inan, T. T. (2023). Designing user interfaces for illiterate and semi-literate users: A systematic review and future research agenda. *SAGE Open, 13*(2). https://doi.org/10.1177/21582440231172741

Iqbal, M., Yousaf, J., Khan, A., & Muhammad, T. (2025). IoT-enabled food freshness detection using multi-sensor data fusion and mobile sensing interface. *ICCK Transactions on Sensing, Communication, and Control, 2*(2), 122–131. https://doi.org/10.62762/TSCC.2025.401245

Ministry of Marine Affairs and Fisheries Republic of Indonesia. (2023). *Strategic plan for marine and fisheries sector development 2020–2024 (updated implementation report).* Jakarta: MMAF.

M. Nosheen, M. M. S. Missen, and M. A. Fahiem, "A Quality Assessment Model Based on Usability Metrics for M-Health Applications User Interfaces", jictra, pp. 1–8, Jun. 2018, Accessed: Apr. 09, 2026. [Online]. Available: https://www.jictra.com.pk/index.php/jictra/article/view/76

Nielsen, J. (1993). *Usability engineering.* San Francisco, CA: Morgan Kaufmann.

Nurmalasari, R., & Febrianto, A. (2025). Dampak fluktuasi suhu freezer terhadap pertumbuhan bakteri patogen dan kerusakan ikan asin: Studi kasus di Lhokseumawe. *Prosiding Seminar Nasional Teknologi Pangan Terapan.*

Protopappas, L., Bechtsis, D., & Tsotsolas, N. (2025). IoT services for monitoring food supply chains: Design and implementation considerations. *Applied Sciences, 15*(13), 7602. https://doi.org/10.3390/app15137602

E-ISSN : 2807-9035
Volume 5, **Number** 2, November 2025
https://doi.org/10.47709/brilliance.v5i2.6209

Puspitasari, L., & Arifin, B. (2024). Tantangan adopsi aplikasi pertanian berbasis IoT pada kelompok tani perempuan dengan literasi digital rendah di Indonesia. *Jurnal Sosiologi Pedesaan, 8*(3), 210–225.

Putra, D. S., & Hidayat, R. (2024). Sistem pemantauan kondisi penyimpanan ikan berbasis IoT menggunakan sensor suhu, kelembaban, dan gas amonia. *Jurnal Teknologi Informasi dan Komunikasi, 11*(1), 45–58.

Rahman, F., et al. (2025). Improving the adoption of agricultural mobile applications: A framework integrating quality in use measurement (QUIM) for low-literate users. *International Journal of Human-Computer Interaction, 41*(5), 567–580.

Rezeki, S., Novriyenni, N., & Syari, M. A. (2024). Prototype of fish drying device for the production of salted fish based on IoT. *Journal of Artificial Intelligence and Engineering Applications (JAIEA), 4*(1), 386–390. https://doi.org/10.59934/jaiea.v4i1.641

Sari, R. K., Rahayu, W., & Fitriani, D. (2024). Peran kelompok perempuan pengolah ikan dalam peningkatan ekonomi keluarga dan tantangan teknologi di desa pesisir Lhokseumawe. *Jurnal Pemberdayaan Masyarakat: Media Pemikiran dan Dakwah Pembangunan, 10*(1), 77–94.

Tailor, R., Parikh, S., Kumar, K., Collins, T., & El-Ocla, H. (2025). IoT-based food quality monitoring system. *IET Wireless Sensor Systems, 15*(1), e70008. https://doi.org/10.1049/wss2.70008

Ula, M., Adek, R. T., Bustami, B., Mulaesyi, S., & Juhri, M. B. (2022, December). A monitoring system for aquaponics based on Internet of Things. In *Proceedings of Malikussaleh International Conference on Multidisciplinary Studies (MICoMS)* (Vol. 3, Article 49). Universitas Malikussaleh. https://doi.org/10.29103/micoms.v3i.49

United Nations. (2022). *The sustainable development goals report 2022.* New York: United Nations.

United Nations. (2023). *The sustainable development goals report 2023.* New York: United Nations.

Yusnidar, Y., Aminah, S., Anora, A., & Sari, C. P. M. (2024). Pengolahan ikan menjadi ikan kering melalui fermentasi untuk meningkatkan pendapatan masyarakat desa Jambo Mesjid. *Jurnal Pengabdian Kreativitas (JPeK), 3*(1), 17–24.